CHAPTER 1: OPERATIONS AND PRODUCTIVITY

TRUE/FALSE

1. Some of the operations-related activities of Hard Rock Café include designing meals and analyzing them for ingredient cost and labor requirements.
True (Global company profile, easy)

2. The production process at Hard Rock Café is limited to meal preparation and serving customers.
False (Global company profile, easy)

3. All organizations, including service firms such as banks and hospitals, have a production function.
True (What is operations management? moderate)

4. Operations management is the set of activities that create value in the form of goods and services by transforming inputs into outputs.
True (What is operations management? easy)

5. An example of a "hidden" production function is money transfers at banks.
True (What is operations management? moderate)

6. One reason to study operations management is to learn how people organize themselves for productive enterprise.
True (Why study OM, easy)

7. The operations manager performs the management activities of planning, organizing, staffing, leading, and controlling of the OM function.
True (What operations managers do, easy)

8. "How much inventory of this item should we have?" is within the critical decision area of managing quality.
False (What operations managers do, easy)

9. In order to have a career in operations management, one must have a degree in statistics or quantitative methods.
False (What operations managers do, easy)

10. Henry Ford is known as the Father of Scientific Management.
False (The heritage of operations management, easy)

11. Shewhart's contributions to operations management came during the Scientific Management Era.
False (The heritage of operations management, easy)

12. Students wanting to pursue a career in operations management will find multidisciplinary knowledge beneficial.
True (Where are the OM jobs? easy)

13. Customer interaction is often high for manufacturing processes, but low for services.
False (Operations in the service sector, moderate)

14. Productivity is more difficult to improve in the service sector.
True (The productivity challenge, moderate)

15. Manufacturing now constitutes the largest economic sector in postindustrial societies.
False (Operations in the service sector, moderate)

16. In the past half-century, the number of people employed in manufacturing has more or less held steady, but each manufacturing employee is manufacturing about 20 times as much.
True (Operations in the service sector, easy)

17. A knowledge society is one that has migrated from work based on knowledge to one based on manual work.
False (The productivity challenge, easy)

18. Productivity is the total value of all inputs to the transformation process divided by the total value of the outputs produced.
False (The productivity challenge, easy)

19. Measuring the impact of a capital acquisition on productivity is an example of multi-factor productivity.
False (The productivity challenge, moderate)

20. Ethical and social dilemmas arise because stakeholders of a business have conflicting perspectives.
True (Ethics and social responsibility, easy) {AACSB: Ethical Reasoning}

MULTIPLE CHOICE

21. At Hard Rock Café, tasks that reflect operations or operations management include
    a. designing meals
    b. testing meals (recipes)
    c. analyzing meals for the cost of ingredients
    d. preparing employee schedules
    e. all of the above
    e (Global company profile, easy)

22. An operations task performed at Hard Rock Café is
    a. borrowing funds to build a new restaurant
    b. advertising changes in the restaurant menu
    c. calculating restaurant profit and loss
    d. preparing employee schedules
    e. all of the above
    d (Global company profile, moderate)

23. Operations management is applicable
    a. mostly to the service sector
    b. to services exclusively
    c. mostly to the manufacturing sector
    d. to all firms, whether manufacturing and service
    e. to the manufacturing sector exclusively
    d (What is operations management? moderate)

24. Which of the following are the primary functions of **all** organizations?
    a. operations, marketing, and human resources
    b. marketing, human resources, and finance/accounting
    c. sales, quality control, and operations
    d. marketing, operations, and finance/accounting
    e. research and development, finance/accounting, and purchasing
    d (Organizing to produce goods and services, moderate)

25. Budgeting, paying the bills, and collection of funds are activities associated with the
    a. management function
    b. control function
    c. finance/accounting function
    d. production/operations function
    e. staffing function
    c (Organizing to produce goods and services, moderate)

26. Which of the following would **not** be an operations function in a fast-food restaurant?
    a. advertising and promotion
    b. designing the layout of the facility
    c. maintaining equipment
    d. making hamburgers and fries
    e. purchasing ingredients
    a (Organizing to produce goods and services, moderate)

27. The marketing function's main concern is with
    a. producing goods or providing services
    b. procuring materials, supplies, and equipment
    c. building and maintaining a positive image
    d. generating the demand for the organization's products or services
    e. securing monetary resources
    d (Organizing to produce goods and services, moderate)

28. Reasons to study Operations Management include
    a. studying why people organize themselves for free enterprise
    b. knowing how goods and services are consumed
    c. understanding what human resource managers do
    d. learning about a costly part of the enterprise
    e. all of the above
    d (Why study OM? moderate)

29. Reasons to study Operations Management include learning about
    a. why people organize themselves for productive enterprise
    b. how goods and services are produced
    c. what operations managers do
    d. a costly part of the enterprise
    e. all of the above
    e (Why study OM? easy)

30. The five elements in the management process are
    a. plan, direct, update, lead, and supervise
    b. accounting/finance, marketing, operations, and management
    c. organize, plan, control, staff, and manage
    d. plan, organize, staff, lead, and control
    e. plan, lead, organize, manage, and control
    d (What do operations managers do? easy)

31. Illiteracy and poor diets have been known to cost countries up to what percent of their productivity?
    a. 2%
    b. 5%
    c. 10%
    d. 20%
    e. 50%
    d (Productivity variables, moderate) {AACSB: Multiculture and Diversity}

32. Which of the following is **not** an element of the management process?
    a. controlling
    b. leading
    c. planning
    d. pricing
    e. staffing
    d (What do operations managers do? easy)

33. An operations manager is **not** likely to be involved in
    a. the design of goods and services to satisfy customers' wants and needs
    b. the quality of goods and services to satisfy customers' wants and needs
    c. the identification of customers' wants and needs
    d. work scheduling to meet the due dates promised to customers
    e. maintenance schedules
    c (What do operations managers do? easy)

34. All of the following decisions fall within the scope of operations management **except** for
    a. financial analysis
    b. design of goods and processes
    c. location of facilities
    d. managing quality
    e. All of the above fall within the scope of operations management.
    a (What do operations managers do? easy)

35. The Ten Critical Decisions of Operations Management include
    a. Layout strategy
    b. Maintenance
    c. Process and capacity design
    d. Managing quality
    e. all of the above
    e (Why study OM? easy)

36. Which of the following is **not** one of The Ten Critical Decisions of Operations Management?
    a. Layout strategy
    b. Maintenance
    c. Process and capacity design
    d. Mass customization
    e. Supply chain management
    d (Why study OM? moderate)

37. The Ten Critical Decisions of Operations Management include
    a. Finance/accounting
    b. Advertising
    c. Process and capacity design
    d. Pricing
    e. all of the above
    c (Why study OM? moderate)

38. Walter Shewhart is listed among the important people of operations management because of his contributions to
    a. assembly line production
    b. measuring the productivity in the service sector
    c. just-in-time inventory methods
    d. statistical quality control
    e. all of the above
    d (The heritage of operations management, moderate)

39. Walter Shewhart, in the _____, provided the foundations for _____ in operations management.
    a. 1920s; statistical sampling
    b. United Kingdom; mass production
    c. U.S. Army; logistics
    d. nineteenth century; interchangeable parts
    e. none of the above
    a (The heritage of operations management, moderate)

40. Eli Whitney, in the _____, provided the foundations for _____ in operations management.
    a. 1920s; statistical sampling
    b. United Kingdom; mass production
    c. U.S. Army; logistics
    d. nineteenth century; interchangeable parts
    e. none of the above
    d (The heritage of operations management, moderate)

41. The person most responsible for popularizing interchangeable parts in manufacturing was
    a. Frederick Winslow Taylor
    b. Henry Ford
    c. Eli Whitney
    d. Whitney Houston
    e. Lillian Gilbreth
    c (The heritage of operations management, moderate)

42. The "Father of Scientific Management" is
    a. Henry Ford
    b. Frederick W. Taylor
    c. W. Edwards Deming
    d. Frank Gilbreth
    e. just a figure of speech, not a reference to a person
    b (The heritage of operations management, easy)

43. Henry Ford is noted for his contributions to
    a. standardization of parts
    b. statistical quality control
    c. assembly line operations
    d. scientific management
    e. time and motion studies
    c (The heritage of operations management, easy)

44. Who among the following is associated with contributions to quality control in operations management?
    a. Charles Babbage
    b. Henry Ford
    c. Frank Gilbreth
    d. W. Edwards Deming
    e. Henri Fayol
    d (The heritage of operations management, moderate)

45. The field of operations management is shaped by advances in which of the following fields?
    a. chemistry and physics
    b. industrial engineering and management science
    c. biology and anatomy
    d. information technology
    e. all of the above
    e (The heritage of operations management, moderate)

46. Which of the following statements is **true**?
    a. Almost all services and almost all goods are a mixture of a service and a tangible product.
    b. A **pure good** has no tangible product component.
    c. A **pure service** has only a tangible product component.
    d. There is no such thing as a **pure good**.
    e. None of the above is a true statement.
    a (Operations in the service sector, difficult)

47. Which of the following statements is **true**?
    a. The person most responsible for initiating use of interchangeable parts in manufacturing was Eli Whitney.
    b. The origins of management by exception are generally credited to Frederick W. Taylor.
    c. The person most responsible for initiating use of interchangeable parts in manufacturing was Walter Shewhart.
    d. The origins of the scientific management movement are generally credited to Henry Ford.
    e. The person most responsible for initiating use of interchangeable parts in manufacturing was Henry Ford.

    a (The heritage of operations management, moderate)

48. The service industry makes up approximately what percentage of all jobs in the United States?
    a. 12%
    b. 40%
    c. 66%
    d. 79%
    e. 90%

    d (Operations in the service sector, moderate)

49. Typical differences between goods and services do **not** include
    a. cost per unit
    b. ability to inventory items
    c. timing of production and consumption
    d. customer interaction
    e. knowledge content

    a (Operations in the service sector, moderate)

50. Which is **not** true regarding differences between goods and services?
    a. Services are generally produced and consumed simultaneously; tangible goods are not.
    b. Services tend to be more knowledge-based than products.
    c. Services tend to have a more inconsistent product definition than goods.
    d. Goods tend to have higher customer interaction than services.
    e. None of the above is true.

    d (Operations in the service sector, moderate)

51. Which of the following is **not** a typical attribute of goods?
    a. output can be inventoried
    b. often easy to automate
    c. aspects of quality difficult to measure
    d. output can be resold
    e. production and consumption are separate

    c (Operations in the service sector, moderate)

52. Which of the following services is **least likely to be** unique, i.e., customized to a particular individual's needs?
    a. dental care
    b. hairdressing
    c. legal services
    d. elementary education
    e. computer consulting
    d (Operations in the service sector, moderate)

53. Which of the following is **not** a typical service attribute?
    a. intangible product
    b. easy to store
    c. customer interaction is high
    d. simultaneous production and consumption
    e. difficult to resell
    b (Operations in the service sector, moderate)

54. Which of the following statements concerning growth of services is **true**?
    a. Services now constitute the largest economic sector in postindustrial societies.
    b. The number of people employed in manufacturing has more or less held steady since 1950.
    c. Each manufacturing employee now produces about 20 times more than in 1950
    d. All of the above are true.
    e. None of the above is true.
    d (Operations in the service sector, moderate)

55. Current trends in operations management include all of the following **except**
    a. just-in-time performance
    b. rapid product development
    c. mass customization
    d. empowered employees
    e. All of the above are current trends.
    e (Exciting new trends in operations management, moderate)

56. Which of the following is **not** a current trend in operations management?
    a. just-in-time performance
    b. global focus
    c. supply chain partnering
    d. mass customization
    e. All of the above are current trends.
    e (Exciting new trends in operations management, moderate)

57. One new trend in operations management is
    a. global focus
    b. mass customization
    c. empowered employees
    d. rapid product development
    e. All of the above are new trends in operations management.
    e (Exciting new trends in operations management, moderate)

58. Which of the following statements about trends in operations management is **false**?
    a. Job specialization is giving way to empowered employees.
    b. Local or national focus is giving way to global focus.
    c. Environmentally-sensitive production is giving way to low-cost focus.
    d. Rapid product development is partly the result of shorter product cycles.
    e. All of the above statements are true.
    c (Exciting new trends in operations management, moderate)

59. A foundry produces circular utility access hatches (manhole covers). If 120 covers are produced in a 10-hour shift, the productivity of the line is
    a. 1.2 covers/hr
    b. 2 covers/hr
    c. 12 covers/hr
    d. 1200 covers/hr
    e. none of the above
    c (The productivity challenge, easy) {AACSB: Analytic Skills}

60. A foundry produces circular utility access hatches (manhole covers). Currently, 120 covers are produced in a 10-hour shift. If labor productivity can be increased by 20%, it would then be
    a. 14.4 covers/hr
    b. 24 covers/hr
    c. 240 valves/hr
    d. 1200 covers/hr
    e. none of the above
    a (The productivity challenge, moderate) {AACSB: Analytic Skills}

61. Gibson Valves produces cast bronze valves on an assembly line. If 1600 valves are produced in an 8-hour shift, the productivity of the line is
    a. 2 valves/hr
    b. 40 valves/hr
    c. 80 valves/hr
    d. 200 valves/hr
    e. 1600 valves/hr
    d (The productivity challenge, easy) {AACSB: Analytic Skills}

62. Gibson Valves produces cast bronze valves on an assembly line, currently producing 1600 valves each 8-hour shift. If the productivity is increased by 10%, it would then be
    a. 180 valves/hr
    b. 200 valves/hr
    c. 220 valves/hr
    d. 880 valves/hr
    e. 1760 valves/hr
    c (The productivity challenge, moderate) {AACSB: Analytic Skills}

63. Gibson Valves produces cast bronze valves on an assembly line, currently producing 1600 valves per shift. If the production is increased to 2000 valves per shift, labor productivity will increase by
    a. 10%
    b. 20%
    c. 25%
    d. 40%
    e. 50%
    c (The productivity challenge, moderate) {AACSB: Analytic Skills}

64. The Dulac Box plant produces 500 cypress packing boxes in two 10-hour shifts. What is the productivity of the plant?
    a. 25 boxes/hr
    b. 50 boxes/hr
    c. 5000 boxes/hr
    d. none of the above
    e. not enough data to determine productivity
    a (The productivity challenge, moderate) {AACSB: Analytic Skills}

65. The Dulac Box plant works two 8-hour shifts each day. In the past, 500 cypress packing boxes were produced by the end of each day. The use of new technology has enabled them to increase productivity by 30%. Productivity is now approximately
    a. 32.5 boxes/hr
    b. 40.6 boxes/hr
    c. 62.5 boxes/hr
    d. 81.25 boxes/hr
    e. 300 boxes/hr
    b (The productivity challenge, moderate) {AACSB: Analytic Skills}

66. The Dulac Box plant produces 500 cypress packing boxes in two 10-hour shifts. Due to higher demand, they have decided to operate three 8-hour shifts instead. They are now able to produce 600 boxes per day. What has happened to production?
    a. It has increased by 50 sets/shift.
    b. It has increased by 37.5 sets/hr.
    c. It has increased by 20%.
    d. It has decreased by 8.3%.
    e. It has decreased by 9.1%.
    c (The productivity challenge, moderate) {AACSB: Analytic Skills}

67. Productivity measurement is complicated by
    a. the competition's output
    b. the fact that precise units of measure are often unavailable
    c. stable quality
    d. the workforce size
    e. the type of equipment used
    b (The productivity challenge, moderate)

68. The total of all outputs produced by the transformation process divided by the total of the inputs is
    a. utilization
    b. greater in manufacturing than in services
    c. defined only for manufacturing firms
    d. multifactor productivity
    e. none of the above
    d (The productivity challenge, moderate)

69. Which of the following inputs has the greatest potential to increase productivity?
    a. labor
    b. globalization
    c. management
    d. capital
    e. none of the above
    c (The productivity challenge, moderate)

70. Productivity can be improved by
    a. increasing inputs while holding outputs steady
    b. decreasing outputs while holding inputs steady
    c. increasing inputs and outputs in the same proportion
    d. decreasing inputs while holding outputs steady
    e. none of the above
    d (The productivity challenge, moderate)

71. The largest contributor to productivity increases is _____, estimated to be responsible for _____ of the annual increase.
    a. management; over one-half
    b. Mr. Deming; one-half
    c. labor; two-thirds
    d. capital; 90%
    e. technology; over one-half
    a (The productivity challenge, moderate)

72. The factor responsible for the largest portion of productivity increase in the U.S. is
    a. labor
    b. management
    c. capital
    d. all three combined; it is impossible to determine the contribution of individual factors
    e. none of these; most productivity increases come from investment spending
    b (The productivity challenge, moderate)

73. Which of the following is **not** true when explaining why productivity tends to be lower in the service sector than in the manufacturing sector?
    a. Services are typically labor-intensive.
    b. Services are often difficult to evaluate for quality.
    c. Services are often an intellectual task performed by professionals.
    d. Services are difficult to automate.
    e. Service operations are typically capital intensive.
    e (The productivity challenge, moderate)

74. Three commonly used productivity variables are
    a. quality, external elements, and precise units of measure
    b. labor, capital, and management
    c. technology, raw materials, and labor
    d. education, diet, and social overhead
    e. quality, efficiency, and low cost
    b (The productivity challenge, moderate)

75. The service sector has lower productivity improvements than the manufacturing sector because
    a. the service sector uses less skilled labor than manufacturing
    b. the quality of output is lower in services than manufacturing
    c. services usually are labor-intensive
    d. service sector productivity is hard to measure
    e. none of the above
    c (The productivity challenge, moderate)

76. Productivity tends to be more difficult to improve in the service sector because the work is
    a. often difficult to automate
    b. typically labor-intensive
    c. frequently processed individually
    d. often an intellectual task performed by professionals
    e. all of the above
    e (The productivity challenge, moderate)

77. Among the ethical and social challenges facing operations managers are
    a. honoring community commitments
    b. maintaining a clean environment
    c. efficiently developing and producing safe quality products
    d. providing a safe workplace
    e. all of the above
    e (Ethics and social responsibility, easy) {AACSB: Ethical Reasoning}

78. Among the ethical and social challenges facing operations managers are
    a. honoring financial commitments
    b. maintaining a clean environment
    c. developing low-cost products
    d. providing an efficient workplace
    e. all of the above
    b (Ethics and social responsibility, moderate) {AACSB: Ethical Reasoning}

79. Which of the following is **not** among the ethical and social challenges facing operations managers?
    a. honoring community commitments
    b. maintaining a clean environment
    c. efficiently developing and producing safe quality products
    d. increasing executive pay
    e. providing a safe workplace
    d (Ethics and social responsibility, easy) {AACSB: Ethical Reasoning}

80. A business's stakeholders, whose conflicting perspectives cause ethical and social dilemmas, include
    a. lenders
    b. suppliers
    c. owners
    d. employees
    e. all of the above
    e (Ethics and social responsibility, easy) {AACSB: Ethical Reasoning}

FILL-IN-THE-BLANK

81. Starbuck's stopped requiring signatures on credit-card purchases under $25 in an attempt to reduce _____ .
    transaction time (or service time) (The productivity challenge, easy)

82. _____ is the set of activities that transforms inputs into goods and services.
    Operations management (What is operations management? easy)

83. Marketing, Production, and _____ are the three functions that all organizations must perform to create goods and services.
    finance/accounting (Organizing to produce goods and services, easy)

84. "Should we make or buy this component?" is an issue in the _____ critical decision area.
    supply chain management (What operations managers do, easy)

85. Henry Ford and _____ are credited with the development of the moving assembly line.
    Charles Sorensen (The heritage of operations management, easy)

86. When a tangible product is not included in a service, it is called a _____.
    pure service (Operations in the service sector, easy)

87. _____ is the ability of the organization to be flexible enough to cater to the individual whims of consumers.
    Mass customization (Exciting new trends in operations management, moderate)

88. _____ is the operations management trend that moves more decision making to the individual worker.
    Empowered employees (Exciting new trends in operations management, moderate)

89. _____ is the total of all outputs produced by the transformation process divided by the total of the inputs.
    Multifactor productivity (The productivity challenge, easy)

90. Productivity is the ratio of _____ to _____. Using this relationship, productivity can be improved by _____ or _____.
inputs, outputs; reducing inputs while holding outputs constant; increasing outputs while holding inputs constant. (The productivity challenge, moderate)

SHORT ANSWER

91. Identify three or more operations-related tasks carried out by Hard Rock Café.
Providing custom meals; designing, testing, and costing meals; acquiring, receiving , and storing supplies; recruiting and training employees; preparing employee schedules; designing efficient restaurant layouts. (Global company profile, easy)

92. Identify two operations-related tasks carried out by Hard Rock Café. Match each to its area of the Ten Critical Decisions.
Providing custom meals—design of goods and services; designing, testing, and costing meals—design of goods and services; acquiring, receiving , and storing supplies—supply chain management; recruiting and training employees—human resources and job design; preparing employee schedules—intermediate and short-term scheduling; designing efficient restaurant layouts—layout strategy. (Global company profile, moderate)

93. Define operations management. Will your definition accommodate both manufacturing and service operations?
Operations management can be defined as the management of all activities directly related to the creation of goods and/or services through the transformation of inputs into outputs. (What is operations management? easy)

94. Identify the items that Fredrick W. Taylor believed management should be more responsible for.
He believed that management should be more responsible for matching employees to the right job, providing the proper training, providing proper work methods and tools, and establishing legitimate incentives for work to be accomplished. (The heritage of operations management, moderate)

95. Operations managers should be well versed in what disciplines in order to make good decisions?
Management science, information technology, and often one of the biological or physical sciences. (The heritage of operations management, moderate)

96. Why are services typically more difficult to standardize, automate, and make efficient?
Services typically require customer interaction, which makes it difficult to standardize, automate, and make efficient. (Operations in the service sector, moderate)

97. How do services differ from goods? Identify five ways.
Pick from the following: a service is usually intangible; it is often produced and consumed simultaneously; often unique; it involves high customer interaction; product definition is inconsistent; often knowledge-based; and frequently dispersed. (Operations in the service sector, moderate)

98. Services are often knowledge-based. Provide two examples, and explain why they are knowledge-based.
Answer will vary, but the textbook used educational, medical, and legal services. (Operations in the service sector, moderate)

99. Why are organizations changing from batch (large) shipments to just-in-time (JIT) shipments?
Organizations are switching to JIT shipments because inventory requires a large financial investment, and impedes the responsiveness to changes in the marketplace. (Exciting new trends in operations management, moderate)

100. Why are organizations becoming more global?
Organizations are becoming more global with the decline in the cost of communication and transportation. Additionally, resources—capital, material, talent, and labor--are also becoming more global. (Exciting new trends in operations management)

101. Identify the three productivity variables used in the text.
The three common variables are labor, capital, and management.
(Productivity variables, moderate)

102. What is a knowledge society?
A knowledge society is one in which much of the labor force has migrated from manual work to work based on knowledge. (The productivity challenge, moderate)

103. Why are operations managers faced with ethical and social challenges?
Businesses have diverse stakeholders, which include owners, employees, lenders, and distributors. These stakeholders hold conflicting perspectives. (Ethics and social responsibility, easy) {AACSB: Ethical Reasoning}

104. What are some of the ethical and social challenges faced by operations managers?
Efficiently developing and producing safe quality products; maintaining a clean environment; providing a safe workplace; honoring community commitments. (Ethics and social responsibility, easy) {AACSB: Ethical Reasoning}

105. As the administrative manager in a law office, you have been asked to develop a system for evaluating the productivity of the 15 lawyers in the office. What difficulties are you going to have in doing this, and how are you going to overcome them?
Productivity measurers for a law office are difficult. Simple criteria, like number of cases processed, fail to consider complexity of the case. Even counting wins is difficult, as many cases are settled with some sort of compromise. External elements such as the quality of the opposing counsel and the tenacity of the opposition also make counting look rather silly.

Categories of cases can help—(i.e., uncontested divorce, no personal injury auto case, etc.) However, many firms end up counting hours billed. This in turns leads to other problems, as noted by the number of false billing cases. (The productivity challenge, moderate) {AACSB: Reflective Thinking}

PROBLEMS

106. Susan has a part-time "cottage industry" producing seasonal plywood yard ornaments for resale at local craft fairs and bazaars. She currently works 8 hours per day to produce 16 ornaments.
a. What is her productivity?
b. She thinks that by redesigning the ornaments and switching from use of a wood glue to a hot-glue gun she can increase her total production to 20 ornaments per day. What is her new productivity?
c. What is her percentage increase in productivity?
a. 16 ornaments/8 hours = 2 ornaments/hour
b. 20 ornaments/8 hours = 2.5 ornaments/hour
c. Change in productivity = 0.5 ornaments/hour; percent change = 0.5/2= 25%
(The productivity challenge, moderate) {AACSB: Analytic Skills}

107. A firm cleans chemical tank cars in the Bay St. Louis area. With standard equipment, the firm typically cleaned 70 chemical tank cars per month. They utilized 10 gallons of solvent, and two employees worked 20 days per month, 8 hours a day. The company decided to switch to a larger cleaning machine. Last April, they cleaned 60 tank cars in only 15 days. They utilized 12 gallons of solvent, and the two employees worked 6 hours a day.
1. What was their productivity with the standard equipment?
2. What is their productivity with the larger machine?
3. What is the change in productivity?

Resource	**Standard Equipment**	**Larger Machine**	**Percent Change**
Solvent	$\frac{70}{10} = 7$	$\frac{60}{12} = 5$	$\frac{5-7}{7} = -28.57\%$
Labor	$\frac{70}{320} = 0.22$	$\frac{60}{180} = .33$	$\frac{.33-.22}{.22} = 50\%$

(The productivity challenge, moderate) {AACSB: Analytic Skills}

108. The Dulac Box plant produces wooden packing boxes to be used in the local seafood industry. Current operations allow the company to make 500 boxes per day, in two 8-hour shifts (250 boxes per shift). The company has introduced some small changes in equipment, and conducted appropriate job training, so that production levels have risen to 300 boxes per shift. These changes did not require any change in the amount of capital spending or energy use. What is the firm's new labor productivity?

600 boxes per day / 16 hours = 37.5 boxes per hour
(The productivity challenge, moderate) {AACSB: Analytic Skills}

109. Mark's Ceramics spent $4000 on a new kiln last year, in the belief that it would cut energy usage 25% over the old kiln. This kiln is an oven that turns "greenware" into finished pottery. Mark is concerned that the new kiln requires extra labor hours for its operation. Mark wants to check the energy savings of the new oven, and also to look over other measures of their productivity to see if the change really was beneficial. Mark has the following data to work with:

	Last Year	This Year
Production (finished units)	4000	4000
Greenware (pounds)	5000	5000
Labor (hrs)	350	375
Capital ($)	15000	19000
Energy (kWh)	3000	2600

Were the modifications beneficial?
The energy modifications did not generate the expected savings; labor and capital productivity decreased. (The productivity challenge, moderate) {AACSB: Analytic Skills}

Resource	**Last Year**					**This Year**					**Change**	**Pct. Change**
Labor	**4000**	**/**	**350**	**=**	**11.43**	**4000**	**/**	**375**	**=**	**10.67**	**-0.76**	**-6.7%**
Capital	**4000**	**/**	**15000**	**=**	**0.27**	**4000**	**/**	**19000**	**=**	**.21**	**-0.06**	**-22.2%**
Energy	**4000**	**/**	**3000**	**=**	**1.33**	**4000**	**/**	**2600**	**=**	**1.54**	**0.21**	**15.4%**

110. Martin Manufacturing has implemented several programs to improve its productivity. They have asked you to evaluate the firm's productivity by comparing this year's performance with last year's. The following data are available:

	Last Year	This Year
Output	10,500 units	12,100 units
Labor Hours	12,000	13,200
Utilities	$7,600	$8,250
Capital	$83,000	$88,000

Has Martin Manufacturing improved its productivity during the past year?
Productivity improved in all three categories this year; utilities showed the greatest increase, and labor the least. (The productivity challenge, moderate) {AACSB: Analytic Skills}

Resource	**Last Year**					**This Year**					**Change**	**Pct. Change**
Labor	**10500**	**/**	**12000**	**=**	**0.88**	**12100**	**/**	**13200**	**=**	**0.92**	**0.04**	**4.8%**
Capital	**10500**	**/**	**7600**	**=**	**1.38**	**12100**	**/**	**8250**	**=**	**1.47**	**0.09**	**6.2%**
Energy	**10500**	**/**	**83000**	**=**	**0.13**	**12100**	**/**	**88000**	**=**	**0.14**	**0.01**	**8.7%**

111. Felicien grows mirlitons (that's Cajun for Chayote squash) in his 100 by 100 foot garden. He then sells the crop at the local farmers' market. Two summers ago, he was able to produce and sell 1200 pounds of mirlitons. Last summer, he tried a new fertilizer that promised a 50% increase in yield. He harvested 1900 pounds. Did the fertilizer live up to its promise?
Since the productivity gain was 58.3%, not 50%, the fertilizer was at least as good as advertised. (The productivity challenge, moderate) {AACSB: Analytic Skills}

Two summers ago	Last summer	Change
1200 ÷ 10,000 = .12 lbs/sq. ft	**1900 ÷ 10,000 = .19 lbs/sq. ft**	**(.19 - .12) ÷ .12 = 58.3%**

112. The Dulac Box plant produces wooden packing boxes to be used in the local seafood industry. Current operations allow the company to make 500 boxes per day, in two 8-hour shifts (250 boxes per shift). The company has introduced some moderate changes in equipment, and conducted appropriate job training, so that production levels have risen to 300 boxes per shift. Labor costs average $10 per hour for each of the 5 full-time workers on each shift. Capital costs were previously $3,000 per day, and rose to $3,200 per day with the equipment modifications. Energy costs were unchanged by the modifications, at $400 per day. What is the firm's multifactor productivity before and after the changes?

MFP before: 500 boxes / ($10x5x16 + $3000 + $400) = 500 / 4200 = 0.119 boxes/dollar
MFP after: 600 boxes / ($10x5x16 + $3200 + $400) = 600 / 4400 = 0.136 boxes/dollar
(The productivity challenge, moderate) {AACSB: Analytic Skills}

113. Gibson Products produces cast bronze valves for use in offshore oil platforms. Currently, Gibson produces 1600 valves per day. The 20 workers at Gibson work from 7 a.m. until 4 p.m., with 30 minutes off for lunch and a 15 minute break during the morning work session and another at the afternoon work session. Gibson is in a competitive industry, and needs to increase productivity to stay competitive. They feel that a 20 percent increase is needed.

Gibson's management believes that the 20 percent increase will not be possible without a change in working conditions, so they change work hours. The new schedule calls on workers to work from 7:30 a.m. until 4:30 p.m., during which workers can take one hour off at any time of their choosing. Obviously, the number of paid hours is the same as before, but production increases, perhaps because workers are given a bit more control over their workday. After this change, valve production increased to 1800 units per day.

a. Calculate labor productivity for the initial situation
b. Calculate labor productivity for the hypothetical 20 percent increase
c. What is the productivity after the change in work rules?
d. Write a short paragraph analyzing these results.

(a) Workers are active for eight hours per day; labor productivity is 10 valves/hour
(b) Productivity rises by 20 percent, to 12 valves/hour; output will be 12x8x20 = 1920
(c) New productivity is 1800 / (20 x 8) = 11.25 valves/hour
(d) Gibson did not gain the desired 20 percent increase in productivity, but they did gain over ten percent, without extra equipment or energy, and without increasing the wage bill.
(The productivity challenge, moderate) {AACSB: Analytic Skills}

CHAPTER 2: OPERATIONS STRATEGY IN A GLOBAL ENVIRONMENT

TRUE/FALSE

1. NAFTA seeks to phase out all trade and tariff barriers among Canada, Mexico, and the United States.
True (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

2. The World Trade Organization has helped to significantly reduce tariffs around the world.
True (Global company profile, moderate) {AACSB: Multiculture and Diversity}

3. Production processes are being dispersed to take advantage of national differences in labor costs.
True (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

4. NAFTA seeks to phase out all trade and tariff barriers between the United States and Asia.
False (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

5. One reason for global operations is to gain improvements in the supply chain.
True (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

6. One reason to globalize is to learn to improve operations.
True (A global view of operations, easy) {AACSB: Multiculture and Diversity}

7. To attract and retain global talent, and to expand a product's life cycle, are both reasons to globalize.
True (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

8. A product will always be in the same stage of its product life cycle regardless of the country.
False (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

9. The World Trade Organization helps provide governments and industries around the world with protection from firms that engage in unethical conduct.
True (A global view of operations, moderate) {AACSB: Ethical Reasoning}

10. Boeing’s development of the 787 Dreamliner is an example of a company obtaining a competitive advantage via product differentiation/innovation.
True (Global company profile, easy)

11. An organization's strategy is its purpose or rationale for an organization's existence.
False (Developing missions and strategies, easy)

12. Operations strategies are implemented in the same way in all types of organizations.
False (Developing missions and strategies, moderate)

13. Between 1980 and 2005, the amount of money (bank deposits, government and corporate debt securities, and equity securities) invested in global capital markets more than tripled.
True (Introduction, difficult) {AACSB: Multiculture and Diversity}

14. Experience differentiation is an extension of product differentiation, accomplished by using people's five senses to create an experience rather than simply providing a service.
True (Achieving competitive advantage through operations, moderate)

15. An organization's ability to generate unique advantages over competitors is central to a successful strategy implementation.
True (Achieving competitive advantage through operations, moderate)

16. Low-cost leadership is the ability to distinguish the offerings of the organization in any way that the customer perceives as adding value.
False (Ten strategic decision of OM, moderate)

17. Most services are tangible; this factor determines how the ten decisions of operations management are handled differently for goods than for services.
False (Ten strategic decisions of OM, moderate)

18. The relative importance of each of the ten operations decisions depends on the ratio of goods and services in an organization.
True (Ten strategic decisions of OM, moderate)

19. Decisions that involve what is to be made and what is to be purchased fall under the heading of supply chain management.
True (Ten strategic decision of OM, moderate)

20. Manufacturing organizations have ten strategic OM decisions, while service organizations have only eight.
False (Ten strategic decisions of OM, easy)

21. Errors made within the location decision area may overwhelm efficiencies in other areas.
True (Ten strategic decisions of OM, moderate)

22. The PIMS study indicated that high ROI firms tend to have high product quality.
True (Issues in operations strategy, easy)

23. Southwest Airlines' core competence is operations.
True (Strategy development and implementation, moderate)

24. *Critical success factors* and *core competencies* are synonyms.
False (Strategy development and implementation, moderate)

25. SWOT analysis identifies those activities that make a difference between having and not having a competitive advantage.
False (Strategy development and implementation, moderate)

26. For the greatest chance of success, an organization's operations management strategy must support the company's strategy.
True (Strategy development and implementation, moderate)

27. Critical Success Factors are those activities that are key to achieving competitive advantage.
True (Strategy development and implementation, moderate)

28. A multinational corporation has extensive international business involvements.
True (Global operations strategy options, easy) {AACSB: Multiculture and Diversity}

29. The multidomestic OM strategy maximizes local responsiveness while achieving a significant cost advantage.
False (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

30. Firms using the global strategy can be thought of as "world companies."
False (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

MULTIPLE CHOICE

31. Which of the following statements regarding the Dreamliner 787 is true?
    a. Boeing has found partners in over a dozen countries.
    b. The new aircraft incorporates a wide range of aerospace technologies.
    c. The new aircraft uses engines from not one, but two manufacturers.
    d. Boeing will add only 20 to 30 percent of the aircraft's value.
    e. All of the above are true.
    e (Global company profile, moderate)

32. Boeing's new 787 Dreamliner
    a. is assembled in Washington, D.C.
    b. uses engines from Japan
    c. has its fuselage sections built in Australia
    d. has increased efficiency from new engine technology
    e. results from a partnership of about a dozen companies
    d (Global company profile, moderate)

33. Examples of response to the global environment include
    a. Boeing's worldwide sales and production
    b. Benneton's flexibility in design, production, and distribution
    c. A Chinese manufacturer, Haier, opening plants in the United States
    d. Ford's partnerships with Volvo and Mazda
    e. All of the above are examples.
    e (Introduction, easy) {AACSB: Multiculture and Diversity}

34. Which of the following is an example of globalization of operations strategy?
    a. Boeing's Dreamliner has engines with higher fuel/payload efficiency.
    b. Ford's new auto models have dent-resistant panels.
    c. A Chinese manufacturer, Haier, now operates plants in the United States.
    d. Hard Rock Café provides an "experience differentiation" at its restaurants.
    e. All of the above are examples.
    c (Introduction, moderate) {AACSB: Multiculture and Diversity}

35. Cost cutting in international operations can take place because of
    a. lower taxes and tariffs
    b. lower wage scales
    c. lower indirect labor costs
    d. less stringent regulations
    e. all of the above
    e (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

36. Which of the following did the authors **not** suggest as a reason for globalizing operations?
    a. reduce costs
    b. improve the supply chain
    c. stockholder approval ratings
    d. attract new markets
    e. All of the above were suggested.
    c (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

37. Multinational organizations can shop from country to country and cut costs through
    a. lower wage scales
    b. lower indirect labor costs
    c. less stringent regulations
    d. lower taxes and tariffs
    e. all of the above
    e (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

38. The term **maquiladora** is most synonymous with
    a. free trade zones
    b. Chinese forced labor camps
    c. home-based or cottage industry
    d. areas that do not meet U.S. standards for workplace safety and pollution
    e. none of the above
    a (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

39. Which of the following represent reasons for globalizing operations?
    a. to gain improvements in the supply chain
    b. to improve operations
    c. to expand a product's life cycle
    d. to attract and retain global talent
    e. All of the above are valid.
    e (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

40. Which of the following does **not** represent reasons for globalizing operations?
    a. reduce costs
    b. improve supply chain
    c. reduce responsiveness
    d. attract and retain global talent
    e. All of the above are valid reasons for globalizing operations.
    c (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

41. NAFTA seeks to
    a. substitute cheap labor in Mexico for expensive labor in the United States
    b. curb illegal immigration from Mexico to the United States
    c. phase out all trade and tariff barriers between the United States and Mexico
    d. phase out all trade and tariff barriers between the United States, Canada, and Mexico
    e. All of the above are NAFTA goals.
    d (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

42. With reference to cultural and ethical issues, the World Trade Organization has
    a. succeeded in providing equal protection of intellectual property among nations
    b. made progress in providing equal protection of intellectual property among nations
    c. phased out all trade and tariff barriers between the United States and Mexico
    d. eliminated slave labor and child labor
    e. played little role in addressing cultural and ethical issues among nations
    b (A global view of operations, difficult) {AACSB: Ethical Reasoning}

43. Which of the following is **true** about business strategies?
    a. An organization should stick with its strategy for the life of the business.
    b. All firms within an industry will adopt the same strategy.
    c. Well defined missions make strategy development much easier.
    d. Strategies are formulated independently of SWOT analysis.
    e. Organizational strategies depend on operations strategies.
    c (Developing missions and strategies, moderate)

44. Which of the following activities takes place once the mission has been developed?
    a. The firm develops alternative or back-up missions in case the original mission fails.
    b. The functional areas develop their functional area strategies.
    c. The functional areas develop their supporting missions.
    d. The ten OM decision areas are prioritized.
    e. Operational tactics are developed.
    c (Developing missions and strategies, moderate)

45. Which of the following statements about organizational missions is **false**?
    a. They reflect a company's purpose.
    b. They indicate what a company intends to contribute to society.
    c. They are formulated after strategies are known.
    d. They define a company's reason for existence.
    e. They provide guidance for functional area missions.
    c (Developing missions and strategies, moderate)

46. The impact of strategies on the general direction and basic character of a company is
    a. short range
    b. medium range
    c. long range
    d. temporal
    e. minimal
    c (Developing missions and strategies, moderate)

47. The fundamental purpose of an organization's mission statement is to
    a. create a good human relations climate in the organization
    b. define the organization's purpose in society
    c. define the operational structure of the organization
    d. generate good public relations for the organization
    e. define the functional areas required by the organization
    b (Developing missions and strategies, moderate)

48. Which of the following is **true**?
    a. Corporate mission is shaped by functional strategies.
    b. Corporate strategy is shaped by functional strategies.
    c. Functional strategies are shaped by corporate strategy.
    d. External conditions are shaped by corporate mission.
    e. Functional area missions are merged to become the organizational mission.
    c (Developing missions and strategies, difficult)

49. According to the authors, which of the following strategic concepts allow firms to achieve their missions?
    a. productivity, efficiency, and quality leadership
    b. differentiation, cost leadership, and quick response
    c. differentiation, quality leadership, and quick response
    d. distinctive competency, cost leadership, and experience
    e. differentiation, distinctive competency, quality leadership, and capacity
    b (Achieving competitive advantage through operations, moderate)

50. A firm can effectively use its operations function to yield competitive advantage via all of the following **except**
    a. customization of the product
    b. setting equipment utilization goals below the industry average
    c. speed of delivery
    d. constant innovation of new products
    e. maintain a variety of product options
    b (Achieving competitive advantage through operations, moderate)

51. Which of the following has progressed the furthest along its product life cycle?
    a. drive-thru restaurants
    b. Internet search engines
    c. iPods
    d. LCD & plasma TVs
    e. Xbox 360
    a (Issues in operations strategy, moderate)

52. The ability of an organization to produce goods or services that have some uniqueness in their characteristics is
    a. mass production
    b. time-based competition
    c. competing on productivity
    d. competing on flexibility
    e. competing on differentiation
    e (Achieving competitive advantage through operations, moderate)

53. Which of the following has made the least progress along its product life cycle?
    a. drive-thru restaurants
    b. Internet search engines
    c. iPods
    d. LCD & plasma TVs
    e. Xbox 360
    e (Issues in operations strategy, moderate)

54. A strategy is a(n)
    a. set of opportunities in the marketplace
    b. broad statement of purpose
    c. simulation used to test various product line options
    d. plan for cost reduction
    e. action plan to achieve the mission
    e (Achieving competitive advantage through operations, moderate)

55. Which of the following statements best characterizes delivery **reliability**?
    a. a company that always delivers on the same day of the week
    b. a company that always delivers at the promised time
    c. a company that delivers more frequently than its competitors
    d. a company that delivers faster than its competitors
    e. a company that has a computerized delivery scheduling system
    b (Achieving competitive advantage through operations, difficult)

56. Which of the following is an example of competing on the basis of differentiation?
    a. A firm manufactures its product with less raw material waste than its competitors do.
    b. A firm's products are introduced into the market faster than its competitors' products are.
    c. A firm's distribution network routinely delivers its product on time.
    d. A firm offers more reliable products than its competitors do.
    e. A firm advertises more than its competitors do.
    d (Achieving competitive advantage through operations, moderate)

57. The ability of an organization to produce services that, by utilizing the consumer's five senses, have some uniqueness in their characteristics is
    a. mass production
    b. time-based competition
    c. differentiation
    d. flexible response
    e. experience differentiation
    e (Achieving competitive advantage through operations, moderate)

58. Which of the following best describes "experience differentiation"?
    a. immerses consumers in the delivery of a service
    b. uses people's five senses to enhance the service
    c. complements physical elements with visual and sound elements
    d. consumers may become active participants in the product or service
    e. All are elements of experience differentiation.
    e (Achieving competitive advantage through operations, easy)

59. Experience Differentiation
    a. isolates the consumer from the delivery of a service
    b. is an extension of product differentiation in the service sector
    c. uses only the consumer's senses of vision and sound
    d. keeps consumers from becoming active participants in the service
    e. is the same as product differentiation, but applied in the service sector
    b (Achieving competitive advantage through operations, easy)

60. Which of the following is the best example of competing on low-cost leadership?
    a. A firm produces its product with less raw material waste than its competitors.
    b. A firm offers more reliable products than its competitors.
    c. A firm's products are introduced into the market faster than its competitors' products.
    d. A firm's research and development department generates many ideas for new products.
    e. A firm advertises more than its competitors.
    a (Achieving competitive advantage through operations, difficult)

61. Franz Colruyt has achieved low-cost leadership through
    a. Spartan headquarters
    b. absence of voice mail
    c. low-cost facilities
    d. no background music
    e. all of the above
    e (Achieving competitive advantage through operations, easy)

62. Franz Colruyt has achieved low-cost leadership through
    a. effective use of voice mail
    b. plastic, not paper, shopping bags
    c. background music that subtly encourages shoppers to buy more
    d. converting factories, garages, and theaters into retail outlets
    e. use of the Euro, not the currency of each European country
    d (Achieving competitive advantage through operations, easy)

63. Which of the following is an example of competing on quick response?
    a. A firm produces its product with less raw material waste than its competitors.
    b. A firm offers more reliable products than its competitors.
    c. A firm's products are introduced into the market faster than its competitors' products.
    d. A firm's research and development department generates many ideas for new products.
    e. A firm advertises more than its competitors.
    c (Achieving competitive advantage through operations, difficult)

64. Costs, quality, and human resource decisions interact strongly with the _____ decision.
    a. layout design
    b. process and capacity design
    c. supply chain management
    d. goods and service design
    e. All of the above are correct.
    d (Ten strategic decisions of OM, moderate)

65. Which of the following influences layout design?
    a. inventory requirements
    b. capacity needs
    c. personnel levels
    d. technology decisions
    e. All of the above influence layout decisions.
    e (Ten strategic decisions of OM, moderate)

66. Response-based competitive advantage can be
    a. flexible response
    b. reliable response
    c. quick response
    d. all of the above
    e. none of the above
    d (Ten strategic decisions of OM, moderate)

67. Which of the following is **not** an operations strategic decision?
    a. maintenance
    b. price
    c. layout design
    d. quality
    e. inventory
    b (Ten strategic decisions of OM, moderate)

68. Which of the following OM strategic decisions pertains to sensible location of processes and materials in relation to each other?
    a. layout design
    b. goods and service design
    c. supply chain management
    d. inventory
    e. scheduling
    a (Ten strategic decisions of OM, moderate)

69. Which of these companies is most apt to have quality standards that are relatively subjective?
    a. Chrysler
    b. Dell Computer
    c. Sanyo Electronics
    d. Harvard University
    e. Whirlpool
    d (Ten strategic decision of OM, moderate)

70. Which of the following will more likely locate near their customers?
    a. an automobile manufacturer
    b. an aluminum manufacturer
    c. an insurance company headquarters
    d. a medical clinic
    e. All of the above will tend to locate near their customers.
    d (Ten strategic decisions of OM, moderate)

71. Which of the following statements concerning the operations management decision is relevant to services?
    a. There are many objective quality standards.
    b. The customer is not involved in most of the process.
    c. The work force's technical skills are very important.
    d. Labor standards vary depending on customer requirements.
    e. Ability to inventory may allow the leveling of the output rates.
    d (Ten strategic decisions of OM, moderate)

72. Which of these organizations is likely to have the most important inventory decisions?
    a. a marketing research firm
    b. a lobbying agency
    c. a management consulting firm
    d. an aluminum manufacturer
    e. a law firm
    d (Ten strategic decisions of OM, moderate)

73. The PIMS program has identified the
    a. operations decisions all organizations must make
    b. distinctive competencies any company needs
    c. characteristics of firms with high "ROI"
    d. corporate decisions any company needs to make
    e. all of the above
    c (Issues in operations strategy, moderate)

74. Which of these is **not** one of the PIMS characteristics of high return on investment organizations?
    a. high product quality
    b. high capacity utilization
    c. low investment intensity
    d. low direct cost per unit
    e. All of the above are PIMS characteristics.
    e (Issues in operations strategy, moderate)

75. Standardization is an appropriate strategy in which stage of the product life cycle?
    a. introduction
    b. growth
    c. maturity
    d. decline
    e. retirement
    c (Issues in operations strategy, moderate)

76. Cost minimization is an appropriate strategy in which stage of the product life cycle?
    a. introduction
    b. growth
    c. maturity
    d. decline
    e. retirement
    d (Issues in operations strategy, moderate)

77. Which of the following preconditions does **not** affect the formulation of an OM strategy?
    a. knowledge of each product's life cycle
    b. external economic and technological conditions
    c. the company's employment benefits
    d. competitors' strengths and weaknesses
    e. knowledge of the company's strategy
    c (Issues in operations strategy, moderate)

78. The stage in the product life cycle at which it is a poor time to change quality is
    a. introduction
    b. growth
    c. maturity
    d. decline
    e. incubation
    c (Issues in operations strategy, moderate)

79. Which of the following changes does **not** result in strategy changes?
    a. change in the company's financial situation
    b. a company's adoption of new technology
    c. change in the product life cycle
    d. change in the competitive environment
    e. change in job scheduling techniques
    e (Issues in operations strategy, moderate)

80. All of these preconditions affect an operations management strategy **except**
    a. external economic and technological conditions
    b. competitors' strengths and weaknesses
    c. maintenance policies
    d. knowledge of the company's strategy
    e. knowledge of each product's life cycle
    c (Issues in operations strategy, moderate)

81. Understanding competitors' strengths and weaknesses, understanding current and prospective technological issues, and understanding product life cycle are examples of
    a. what is important to the transnational strategy but not the multidomestic strategy
    b. SWOT analysis
    c. elements in the formulation of an organization's mission
    d. preconditions to establishing and implementing a strategy
    e. the critical decision area of supply chain analysis
    d (Issues in operations strategy, moderate)

82. Which of the following statements is most correct?
    a. CSFs are often necessary, but not sufficient for competitive advantage.
    b. CSFs are often sufficient, but not necessary for competitive advantage.
    c. CSFs are neither necessary nor sufficient for competitive advantage.
    d. CSFs are both necessary and sufficient for competitive advantage.
    e. None of the above statements is correct.
    a (Strategy development and implementation, difficult)

83. Given the position of the iPod in the growth stage of its life cycle, which of the following OM Strategy/Issues should the makers of iPods be least concerned with at the current time?
    a. forecasting
    b. cost cutting
    c. increasing capacity
    d. product and process reliability
    e. enhancing distribution
    b (Issues in operations strategy, moderate)

84. Which of these organizations is likely to have the most complex inventory decisions?
    a. a marketing research firm
    b. a stock brokerage firm
    c. a management consulting firm
    d. a computer manufacturing company
    e. a high school
    d (Strategy development and implementation, moderate)

85. The three steps of the operations manager's job, in order, are
    a. develop the strategy, establish the organizational structure, find the right staff
    b. develop the strategy, find the right staff, establish the organizational structure
    c. find the right staff, establish the organizational structure, develop the strategy
    d. find the right staff, develop the strategy, establish the organizational structure
    e. establish the organizational structure, find the right staff, develop the strategy
    a (Strategy development and implementation, moderate)

86. When developing the operations strategy for a new manufacturing organization, one of the most important considerations is that it
    a. requires minimal capital investment
    b. utilizes as much automation as possible
    c. utilizes an equal balance of labor and automation
    d. supports the overall competitive strategy of the company
    e. none of the above
    d (Strategy development and implementation, moderate)

87. Which of the international operations strategies involves high cost reductions and high local responsiveness?
    a. international strategy
    b. global strategy
    c. transnational strategy
    d. multidomestic strategy
    e. none of the above
    c (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

88. Which of the international operations strategies involves low cost reductions and low local responsiveness?
    a. international strategy
    b. global strategy
    c. transnational strategy
    d. multidomestic strategy
    e. none of the above
    a (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

89. Which of the international operations strategies uses import/export or licensing of existing products?
    a. international strategy
    b. global strategy
    c. transnational strategy
    d. multidomestic strategy
    e. none of the above
    a (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

90. Which of the international operations strategies uses the existing domestic model globally?
    a. international strategy
    b. global strategy
    c. transnational strategy
    d. multidomestic strategy
    e. none of the above
    d (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

91. The acronym **MNC** stands for
    a. Mexican National Committee (for international trade)
    b. Maquiladora Negates Competition
    c. Maytag- Nestlé Corporation
    d. Multinational Corporation
    e. none of the above
    d (Global operations strategy options, easy) {AACSB: Multiculture and Diversity}

92. Caterpillar and Texas Instruments are two firms that have benefited from the use of
    a. the multidomestic strategy option.
    b. the multinational corporation strategy.
    c. the transnational strategy option.
    d. the maquiladora system in Europe.
    e. the global strategy option.
    e (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

93. Which of the following are examples of transnational firms?
    a. Nestlé
    b. Asea Brown Boveri
    c. Reuters
    d. Citicorp
    e. All of the above are transnationals.
    e (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

FILL-IN-THE-BLANK

94. Boeing found its Dreamliner 787 partners in _____ countries.
    over a dozen (Global company profile, easy) {AACSB: Multiculture and Diversity}

95. _____ are Mexican factories located along the U.S.-Mexico border that receive preferential tariff treatment.
    Maquiladoras (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

96. _____ is a free trade agreement among Canada, Mexico, and the United States.
    NAFTA--North American Free Trade Agreement (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

97. _____ and _____ are two issues where significant cultural differences are large and progress toward global uniformity has been slow.
    Bribery, protection of intellectual property (Global company profile, easy) {AACSB: Ethical Reasoning}

98. An organization that has worked to achieve global uniformity in cultural and ethical issues such as bribery, child labor, and environmental regulations is _____.
    the World Trade Organization (Global company profile, easy) {AACSB: Ethical Reasoning}

99. In goods producing organizations, _____,_____, and _____ may be inventoried.
    raw materials, work-in-process, and finished goods (Ten strategic decisions of OM, moderate)

100. Strategy is not static, but dynamic because of changes in the _____ and _____.
     organization, environment (Issues in operations strategy, moderate)

101. _____ is the stage in product life cycle at which it is a poor time to change quality.
     Maturity (Issues in operations strategy, moderate)

102. The _____ is how an organization expects to achieve its missions and goals.
     strategy (Developing missions and strategies, moderate)

103. The creation of a unique advantage over competitors is called a _____.
competitive advantage (Achieving competitive advantage through operations, moderate)

104. Service organizations can immerse the consumer in the service, or have the consumer become a participant in the service, as they practice _____.
experience differentiation (Achieving competitive advantage through operations, moderate)

105. Competitive advantage in operations can be achieved by _____, _____, and/or _____.
differentiation, low cost, response (Achieving competitive advantage through operations, moderate)

106. A(n) _____ is a firm that has extensive involvement in international business, owning or controlling facilities in more than one country.
MNC--multinational corporation (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

107. The _____ strategy utilizes a standardized product across countries.
global (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

108. The _____ strategy uses exports and licenses to penetrate globally.
international (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

109. The _____ strategy uses subsidiaries, franchises, or joint ventures with substantial independence.
multidomestic (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

110. The _____ strategy describes a condition in which material, people, and ideas cross or transgress national boundaries.
transnational (Global operations strategy options, moderate) {AACSB: Multiculture and Diversity}

SHORT ANSWER

111. Identify five countries from which Boeing's 787 Dreamliner will get suppliers.
France, Germany, UK, Italy, Japan, China, South Korea, Sweden, U.S. (Global company profile, easy) {AACSB: Multiculture and Diversity}

112. Identify five parts which Boeing's 787 Dreamliner will get from global suppliers; match each part with the country that will supply it.
France—landing gear, Germany—interior lighting, UK—fuel pumps or electronics, Italy—part of fuselage or horizontal stabilizer, Japan—wing box or hydraulic actuators, China—rudder or general parts, South Korea—wingtips, Sweden—cargo and access doors, U.S.—GE engines (Global company profile, moderate) {AACSB: Multiculture and Diversity}

113. How can global operations improve the supply chain?
The supply chain can often be improved by locating facilities in countries where unique resources exist. (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

114. How do global operations attract new markets?
Since international operations require local interaction with customers, suppliers, and other competitive businesses, international firms inevitably learn about unique opportunities for new products and services. (A global view of operations, moderate) {AACSB: Multiculture and Diversity}

115. State two examples of cultural and ethical issues that face operations managers in a global environment.
Student responses will vary, but there are several issues on which there are wide differences from country to country, culture to culture. Among those listed in the text are bribery, child labor, slave labor, and intellectual property rights. Students may bring forward from an earlier chapter issues such as environmental regulation or safe work environment, and may raise issues such as product safety. (A global view of operations, moderate) {AACSB: Ethical Reasoning}

116. What is the difference between a firm's mission and its strategy?
A firm's mission is its purpose or rationale for an organization's existence, whereas a firm's strategy is how it expects to achieve its mission and goals. (Developing missions and strategies, moderate)

117. Since the early 1990s, residents in a number of developing countries have overcome culture, religious, ethnic, and political productivity barriers. These disappearing barriers coupled with simultaneous advances in technology, reliable shipping, and cheap communication have all led to the growth of what three things?
1. World trade.
2. Global capital markets.
3. International movement of people.
(Introduction, moderate) {AACSB: Multiculture and Diversity}

118. Provide an example of an organization that achieves competitive advantage through experience differentiation. Explain.
Answers will vary, but Disney and Hard Rock Café are illustrated in the text. Competing on experience differentiation implies providing uniqueness to your service offering through immersion of the consumer into the service, with visual or sound elements to turn the service into an experience. (Achieving competitive advantage through operations, moderate)

119. With regard to the scheduling decision, how are goods-producing organizations different from service companies? Discuss.
Goods-producing companies: the ability to inventory may allow leveling the output rates; service companies: primarily concerned with meeting the customer's immediate schedule. (Ten strategic OM decisions, difficult)

120. How do goods and services differ with regard to handling the quality decision?
There are many objective quality standards for goods, whereas there are many subjective quality standards for services. (Ten strategic OM decisions, moderate)

121. What is the difference between goods and services in terms of their location selection?
Manufacturers of goods may need to be located close to raw materials, or labor force. Services, on the other hand, typically are located close to the customer. (Ten Strategic OM decisions, moderate)

122. How has Franz Colruyt achieved low-cost leadership? List three specific examples and describe each briefly.
Several methods are listed in the text. Among these are no shopping bags, dim lighting, no voice mail, conversion of older buildings, Spartan offices. (Achieving competitive advantage through operations, moderate)

123. Define *core competencies.*
A set of skills, talents, and activities that a firm does particularly well. (Strategy development and implementation, moderate)

124. For what type of organization might the location decision area be the least important of its ten decision areas? For what type of organization might the location decision be the most important of the ten decision areas? Discuss, augment your response with examples.
The relationship between the organization and its suppliers or its customers is key. If that relationship is very weak (as in no transportation costs, or customers can reach the firm from any location), location diminishes in importance. If that relationship is strong (uniqueness of site, high transportation costs, customers will not travel far) location increases in importance. "Least" examples: Telemarketing firm, tax help-line, Internet sales. "Most" examples: gold mine, oil well, ski resort. (Ten strategic OM decisions, difficult) {AACSB: Reflective Thinking}

125. What is SWOT analysis? List its four elements and describe its purpose.
The four elements of SWOT are strengths, weaknesses, opportunities, and threats. Its purpose is to maximize opportunities and minimize threats in the environment, while maximizing the advantages of the organization's strengths and minimizing the weaknesses. (Strategy development and implementation, moderate)

126. Are strategies static or dynamic? What are the forces that lead to this result?
Strategies should be dynamic because of changes within the organization; and changes in the environment. (Strategy development and implementation, moderate)

127. Identify and explain the four basic global operations strategies. Give an example of each strategy.
The multidomestic strategy decentralizes operating decisions to each country to enhance local responsiveness. The primary example from the textbook is McDonald's. The global strategy centralizes operating decisions, with headquarters coordinating the standardization and learning between facilities. The textbook names Texas Instruments and Caterpillar. The international strategy uses exports and licenses to penetrate the global markets. Students may cite Pier One, World Market, or any wine store. The transnational strategy exploits the economies of scale and learning, as well as pressure for responsiveness, by recognizing that core competence does not reside in just the "home" country, but can exist anywhere in the organization. Examples from the textbook include Bertelsmann, Reuters and Nestlé. (Global operations strategy options, difficult) {AACSB: Multiculture and Diversity}

CHAPTER 3: PROJECT MANAGEMENT

TRUE/FALSE

1. The ES of an activity that has only one predecessor is simply the EF of that predecessor.
True (Determining the project schedule, moderate)

2. One phase of a large project is scheduling.
True (The importance of project management, easy)

3. A project organization works best for an organization when the project resides in only one of its functional areas.
False (Project planning, moderate)

4. By their very nature, projects have a limited lifetime, and that sets project management apart from the management of more traditional activities.
True (Project planning, moderate)

5. One responsibility of a project manager is to make sure that the project meets its quality goals.
True (Project planning, moderate)

6. Work Breakdown Structure is a useful tool in project management because it addresses the timing of individual work elements.
False (Project planning, moderate)

7. Project managers have their own code of ethics, established by the Project Management Institute.
True (Ethical issues faced in project management, moderate) {AACSB: Ethical Reasoning}

8. Ethical issues which can arise in projects include bid rigging, bribery, and "low balling."
True (Ethical issues faced in project management, easy) {AACSB: Ethical Reasoning}

9. Gantt charts give a timeline for each of a project's activities, but do not adequately show the interrelationships of activities.
True (Project scheduling, moderate)

10. PERT, but not CPM, has the ability to consider the precedence relationships in a project.
False (Project scheduling, moderate)

11. The shortest of all paths through the network is the critical path.
False (Project management techniques: PERT and CPM, moderate)

12. The fundamental difference between PERT and CPM is that PERT uses the beta distribution for crashing projects while CPM uses cost estimates.
False (Project management techniques: PERT and CPM, moderate)

13. Slack is the amount of time an activity can be delayed without delaying the entire project.
True (Project management techniques: PERT and CPM, moderate)

14. Every network has at least one critical path.
True (Project management techniques: PERT and CPM, moderate)

15. The critical path can be determined by use of either the "forward pass" or the "backward pass."
False (Project management techniques: PERT and CPM, moderate)

16. The PERT pessimistic time estimate is an estimate of the minimum time an activity will require.
False (Project management techniques: PERT and CPM, easy)

17. The standard deviation of project duration is the average of the standard deviation of all activities on the critical path.
False (Project management techniques: PERT and CPM, moderate)

18. In PERT analysis, the identification of the critical path can be incorrect if a noncritical activity takes substantially more than its expected time.
True (Project management techniques: PERT and CPM, difficult)

19. Shortening the project's duration by deleting unnecessary activities is called "project crashing."
False (Cost-time trade-offs and project crashing, moderate)

20. In project management, crashing an activity must consider the impact on all paths in the network.
True (Cost-time trade-offs and project crashing, moderate)

MULTIPLE CHOICE

21. Which of the following statements regarding Bechtel is **true**?
    a. Its competitive advantage is project management.
    b. Bechtel was the construction contractor for the Hoover Dam.
    c. While helping to rebuild Iraq, Bechtel’s crews had to travel under armed escort.
    d. Bechtel's procurement program is global in nature.
    e. All of the above are true.
    e (Global company profile, easy)

22. Which of the following statements about Bechtel is **true**?
    a. Even though Bechtel is over 100 years old, the Kuwaiti oil fields was its first "project."
    b. Bechtel is the world's premier manager of massive construction and engineering projects.
    c. Bechtel's competitive advantage is supply chain management.
    d. While its projects are worldwide, its network of suppliers is largely in the U.S.
    e. All of the above are true.
    b (Global company profile, moderate)

23. The phases of project management are
    a. planning, scheduling, and controlling
    b. planning, programming, and budgeting
    c. planning, organizing, staffing, leading, and controlling
    d. different for manufacturing projects than for service projects
    e. GANTT, CPM, and PERT
    a (The importance of project management, easy)

24. A **project organization**
    a. is effective for companies with multiple large projects
    b. is appropriate only in construction firms
    c. often fails when the project cuts across organizational lines
    d. is formed to ensure that programs (projects) get proper management and attention
    e. **a** and **d** are both true
    e (Project planning, moderate)

25. Which of the following statements regarding project management is **false**?
    a. Gantt charts give a timeline for each of a project's activities, but do not adequately show the interrelationships of activities.
    b. A project organization works best for a project that is temporary but critical to the organization.
    c. Project organization works well when the work contains simple, independent tasks.
    d. Gantt charts and PERT/CPM are never used together.
    e. None of the above is true.
    c (Project planning, moderate)

26. A code of ethics especially for project managers
    a. has been established by the Project Management Institute
    b. has been formulated by the Federal government
    c. has been formulated by the World Trade Organization
    d. is inappropriate, since everyone should use the same guidance on ethical issues
    e. does not exist at this time
    a (Project planning, moderate) {AACSB: Ethical Reasoning}

27. Divulging information to some bidders on a project to give them an unfair advantage
    a. is the same thing as altering a status report
    b. is bribery
    c. is permitted by NAFTA
    d. is known as bid rigging
    e. is acceptable for private corporations but not for government agencies
    d (Project planning, moderate) {AACSB: Ethical Reasoning}

28. Ethical issues that may arise in projects large and small include
    a. bid rigging
    b. expense account padding
    c. compromised safety or health standards
    d. bribery
    e. All of the above are true.
    e (Project planning, easy) {AACSB: Ethical Reasoning}

29. Which of the following statements regarding Gantt charts is **true**?
    a. Gantt charts give a timeline and precedence relationships for each activity of a project.
    b. Gantt charts use the four standard spines of Methods, Materials, Manpower, and Machinery.
    c. Gantt charts are visual devices that show the duration of activities in a project.
    d. Gantt charts are expensive.
    e. All of the above are true.
    c (Project scheduling, moderate)

30. Which of the following statements regarding critical paths is **true**?
    a. The shortest of all paths through the network is the critical path.
    b. Some activities on the critical path may have slack.
    c. Every network has exactly one critical path.
    d. On a specific project, there can be multiple critical paths, all with exactly the same duration.
    e. The duration of the critical path is the average duration of all paths in the project network.
    d (Project management techniques: PERT and CPM, moderate)

31. Which of the following statements regarding CPM is **true**?
    a. The critical path is the shortest of all paths through the network.
    b. The critical path is that set of activities that has positive slack.
    c. Some networks have no critical path.
    d. All activities on the critical path have their LS equal their predecessor's EF.
    e. All of the above are false.
    d (Project management techniques: PERT and CPM, moderate)

32. A simple CPM network has three activities, A, B, and C. A is an immediate predecessor of B and of C. B is an immediate predecessor of C. The activity durations are A=4, B=3, C=8.
    a. The critical path is A-B-C, duration 15.
    b. The critical path is A-C, duration 12.
    c. The critical path is A-B-C, duration 13.5
    d. The critical path cannot be determined without knowing PERT expected activity times.
    e. The network has no critical path.
    a (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

33. A simple CPM network has three activities, D, E, and F. D is an immediate predecessor of E and of F. E is an immediate predecessor of F. The activity durations are D=4, E=3, F=8.
    a. The critical path is D-E-F, duration 15.
    b. The critical path is D-F, duration 12.
    c. Slack at D is 3 units
    d. Slack at E is 3 units
    e. Both **a** and **c** are true
    a (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

34. A simple CPM network has five activities, A, B, C, D, and E. A is an immediate predecessor of C and of D. B is also an immediate predecessor of C and of D. C and D are both immediate predecessors of E.
    a. There are two paths in this network.
    b. There are four paths in this network.
    c. There are five paths in this network.
    d. There are 25 paths through this network.
    e. None of these statements is true.
    b (Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

35. Activity D on a CPM network has predecessors B and C, and has successor F. D has duration 6. B's earliest finish is 18, while C's is 20. F's late start is 26. Which of the following is **true**?
    a. B is a critical activity.
    b. C is completed before B.
    c. D has no slack but is not critical.
    d. D is critical, and has zero slack.
    e. All of the above are true.
    d (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

36. Which of the following statements regarding CPM networks is **true**?
    a. There can be multiple critical paths on the same project, all with different durations.
    b. The early finish of an activity is the latest early start of all preceding activities.
    c. The late start of an activity is its late finish plus its duration.
    d. If a specific project has multiple critical paths, all of them will have the same duration.
    e. All of the above are true.
    d (Project management techniques: PERT and CPM, moderate)

37. Activity M on a CPM network has predecessors N and R, and has successor S. M has duration 5. N's late finish is 18, while R's is 20. S's late start is 14. Which of the following is **true**?
    a. M is critical and has zero slack.
    b. M has no slack but is not critical.
    c. The last start time of S is impossible.
    d. N is a critical activity.
    e. S is a critical activity.
    c (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

38. Which of the following statements concerning CPM activities is **false**?
    a. The early finish of an activity is the early start of that activity plus its duration.
    b. The late finish is the earliest of the late start times of all successor activities.
    c. The late start of an activity is its late finish less its duration.
    d. The late finish of an activity is the earliest late start of all preceding activities.
    e. The early start of an activity is the latest early finish of all preceding activities.
    d (Project management techniques: PERT and CPM, difficult)

39. The time an activity will take assuming very unfavorable conditions is
    a. the optimistic time
    b. the pessimistic time
    c. the activity variance
    d. the minimum time
    e. exactly twice as long as the expected time
    b (Project management techniques: PERT and CPM, moderate)

40. The critical path for the network activities shown below is _____ with duration _____.

Activity	Duration	Immediate Predecessors
A	4	---
B	2	A
C	7	--
D	4	A
E	5	B,C,D

a. A-B-D; 10
b. A-B-E; 11
c. C-E; 12
d. A-D-E; 13
e. A-B-C-D-E; 22
d (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

41. The critical path for the network activities shown below is _____ with duration _____.

Activity	Duration	Immediate Predecessors
A	2	--
B	4	--
C	6	A,B
D	1	A,B
E	2	B,C,D

a. A-D-E; 5
b. B-E; 6
c. B-D-E; 7
d. A-C-E; 10
e. B-C-E; 12
e (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

42. The _____ distribution is used by PERT analysis to calculate expected activity times and variances.
a. Normal
b. Beta
c. Alpha
d. Gaussian
e. Binomial
b (Project management techniques: PERT and CPM, easy)

43. The expected activity time in PERT analysis is calculated as
    a. the simple average of the optimistic, pessimistic, and most likely times
    b. the weighted average of **a**, **m**, and **b**, with **m** weighted 4 times as heavily as **a** and **b**
    c. the sum of the optimistic, pessimistic, and most likely times
    d. the sum of the optimistic, pessimistic, and most likely times, divided by six
    e. the sum of the activity variances, divided by six
    b (Project management techniques: PERT and CPM, moderate)

44. The critical path for the network activities shown below is _____ with duration _____.

Activity	Duration	Immediate Predecessors
A	10	---
B	8	---
C	2	A
D	4	A
E	5	B,C, D

    a. A-C; 12
    b. A-D-E; 19
    c. B-E; 13
    d. A-B-C-D-E; 29
    e. none of the above
    b (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

45. Which of the following statements regarding PERT times is **true**?
    a. The optimistic time estimate is an estimate of the minimum time an activity will require.
    b. The optimistic time estimate is an estimate of the maximum time an activity will require.
    c. The probable time estimate is calculated as t = (a + 4m + b).
    d. Pessimistic time estimate is an estimate of the minimum time an activity will require.
    e. Most likely time estimate is an estimate of the maximum time an activity will require.
    a (**Project management techniques: PERT and CPM, moderate)**

46. Which of the following statements regarding PERT times is **true**?
    a. Expected time is an estimate of the time an activity will require if everything goes as planned.
    b. The optimistic time estimate is an estimate of the maximum time an activity will require.
    c. The probable time estimate is calculated as t = (a + 4m + b)/6.
    d. Pessimistic time estimate is an estimate of the minimum time an activity will require.
    e. Most likely time estimate is an estimate of the maximum time an activity will require.
    c (Project management techniques: PERT and CPM, moderate)

47. The Beta distribution is used in project management to
    a. calculate slack on activities not on the critical path
    b. calculate the probability that a project will be completed within its budget
    c. calculate pessimistic and optimistic activity times
    d. determine which activity should be crashed
    e. none of the above
    e (Project management techniques: PERT and CPM, moderate)

48. The Beta distribution is used in project management to
    a. determine which activity should be crashed
    b. calculate the probability that a project will be completed within its budget
    c. calculate expected activity times
    d. calculate slack for activities on the critical path
    e. none of the above
    c (Project management techniques: PERT and CPM, moderate)

49. In a PERT network, non-critical activities that have little slack need to be monitored closely
    a. because PERT treats all activities as equally important
    b. because near-critical paths could become critical paths with small delays in these activities
    c. because slack is undesirable and needs to be eliminated
    d. because they are causing the entire project to be delayed
    e. because they have a high risk of not being completed
    b (Project management techniques: PERT and CPM, moderate)

50. Which of the following statements regarding PERT analysis is **true**?
    a. Each activity has two estimates of its duration.
    b. Project variance is the sum of all activity variances.
    c. Project standard deviation is the sum of all critical activity standard deviations.
    d. Only critical activities contribute to the project variance.
    e. None of the above is true.
    d (Project management techniques: PERT and CPM, moderate)

51. A project being analyzed by PERT has 60 activities, 13 of which are on the critical path. If the estimated time along the critical path is 214 days with a project variance of 100, the probability that the project will take 224 days or more to complete is
    a. near zero
    b. 0.0126
    c. 0.1587
    d. 0.8413
    e. 2.14
    c (Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

52. An activity on a PERT network has these time estimates: optimistic = 2, most likely = 5, and pessimistic = 10. Its expected time is
    a. 5
    b. 5.33
    c. 5.67
    d. 17
    e. none of these
    b (Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

53. An activity on a PERT network has these time estimates: optimistic = 1, most likely = 2, and pessimistic = 5. Its expected time is
    a. 2
    b. 2.33
    c. 2.67
    d. 8
    e. none of these
    b (Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

54. An activity on a PERT network has these time estimates: optimistic = 2, most likely = 3, and pessimistic = 8. Its expected time and variance (if it is a critical activity) are
    a. 3.67; 1
    b. 3.67; 6
    c. 4.33; 1
    d. 4.33; 6
    e. none of these
    a (Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

55. A local project being analyzed by PERT has 42 activities, 13 of which are on the critical path. If the estimated time along the critical path is 105 days with a project variance of 25, the probability that the project will be completed in 95 days or less is
    a. -0.4
    b. 0.0228
    c. 0.3444
    d. 0.9772
    e. 4.2
    b (Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

56. A project being analyzed by PERT has 38 activities, 16 of which are on the critical path. If the estimated time along the critical path is 90 days with a project variance of 25, the probability that the project will be completed in 88 days or less is
    a. 0.0228
    b. 0.3446
    c. 0.6554
    d. 0.9772
    e. 18
    b (Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

57. A PERT project has 45 activities, 19 of which are on the critical path. The estimated time for the critical path is 120 days. The sum of all activity variances is 64, while the sum of variances along the critical path is 36. The probability that the project can be completed between days 108 and 120 is
    a. -2.00
    b. 0.0227
    c. 0.1058
    d. 0.4773
    e. 0.9773
    d (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

58. A contractor's project being analyzed by PERT has an estimated time for the critical path of 120 days. The sum of all activity variances is 81; the sum of variances along the critical path is 64. The probability that the project will take 130 or more days to complete is
    a. 0.1056
    b. 0.1335
    c. 0.8512
    d. 0.8943
    e. 1.29
    a (Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

59. Analysis of a PERT problem shows the estimated time for the critical path to be 108 days with a variance of 64. There is a .90 probability that the project will be completed before approximately day _____.
    a. 98
    b. 108
    c. 109
    d. 115
    e. 118
    e (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

60. A project whose critical path has an estimated time of 120 days with a variance of 100 has a 20% chance that the project will be completed before day _____ (rounded to nearest day).
    a. 98
    b. 112
    c. 120
    d. 124
    e. 220
    b (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

61. A project whose critical path has an estimated time of 820 days with a variance of 225 has a 20% chance that the project will be completed before day _____ (rounded to nearest day).
    a. 631
    b. 689
    c. 807
    d. 833
    e. 1009
    c (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

62. Contract requirements state that a project must be completed within 180 working days, or it will incur penalties for late completion. Analysis of the activity network reveals an estimated project time of 145 working days with a project variance of 400. What is the probability that the project will be completed before the late-payment deadline?
    a. 0.0401
    b. 0.4599
    c. 0.8056
    d. 0.9599
    e. near 1.0000, or almost certain
    d (Project management techniques: PERT and CPM, difficult) {AACSB: Analytic Skills}

63. Which of these statements regarding time-cost tradeoffs in CPM networks is **true**?
    a. Crashing is not possible unless there are multiple critical paths.
    b. Crashing a project often reduces the length of long-duration, but noncritical, activities.
    c. Activities not on the critical path can never be on the critical path, even after crashing.
    d. Crashing shortens the project duration by assigning more resources to one or more of the critical tasks.
    e. None of the above is true.
    d (Cost-time trade-offs and project crashing, moderate)

64. What was the name of the construction project to rebuild the Pentagon after the terrorist attacks on Sept. 11, 2001?
    a. Project Panther
    b. Project Pit Bull
    c. Project Python
    d. Project Piranha
    e. Project Phoenix
    e (Project management techniques: PERT and CPM, moderate)

65. Which of the following statements regarding time-cost tradeoffs in CPM networks is **false**?
    a. "Project Crashing" shortens project duration by assigning more resources to critical tasks.
    b. Crashing sometimes has the reverse result of lengthening the project duration.
    c. Crashing must consider the impact of crashing an activity on all paths in the network.
    d. Activities not on the critical path can become critical after crashing takes place.
    e. All of the above are true.
    b (Cost-time trade-offs and project crashing, moderate)

66. If an activity whose normal duration is 13 days can be shortened to 10 days for an added cost of $1,500, the crash cost per period is
    a. $500
    b. $750
    b. $1,500
    d. $13,000
    e. $15,000
    a (Cost-time trade-offs and project crashing, moderate) {AACSB: Analytic Skills}

67. Two activities are candidates for crashing on a CPM network. Activity details are in the table below. To cut one day from the project's duration, activity _____ should be crashed first, adding _____ to project cost.

Activity	Normal Time	Normal Cost	Crash Duration	Crash Cost
One	8 days	$6,000	6 days	$6,800
Two	10 days	$4,000	9 days	$5,000

a. One; $400
b. One; $6,800
c. Two; $1,000
d. Two; $5,000
e. One or two should be crashed; $1,400

a (Cost-time trade-offs and project crashing, moderate) {AACSB: Analytic Skills}

68. If an activity whose normal duration is 15 days can be shortened to 10 days for an added cost of $2,000, the crash cost per period is
a. $400
b. $2,000
c. $10,000
d. $20,000
e. $30,000

a (Cost-time trade-offs and project crashing, moderate) {AACSB: Analytic Skills}

69. A network has been crashed to the point where all activities are critical. Additional crashing
a. is unnecessary
b. is impossible
c. is prohibitively expensive
d. may require crashing multiple tasks simultaneously
e. can be done, but all critical tasks must be reduced in duration

d (Cost-time trade-offs and project crashing, moderate)

70. Two activities are candidates for crashing on a CPM network. Activity details are in the table below. To cut one day from the project's duration, activity _____ should be crashed first, adding _____ to project cost.

Activity	Normal Time	Normal Cost	Crash Duration	Crash Cost
B	4 days	$6,000	3 days	$8,000
C	6 days	$4,000	4 days	$6,000

a. B; $2,000
b. B; $8,000
c. C; $1,000
d. C; $2,000
e. C; $6,000
c (Cost-time trade-offs and project crashing, moderate) {AACSB: Analytic Skills}

FILL-IN-THE BLANK

71. _____ is an organization formed to ensure that programs (projects) receive the proper management and attention.
Project organization (Project planning, easy)

72. _____ divides a project into more and more detailed components.
Work breakdown structure or WBS (Project planning, moderate)

73. The _____ has established a code of ethics especially for project managers.
Project Management Institute, (Project planning, easy) {AACSB: Ethical Reasoning}

74. _____ is a network technique using only one time factor per activity that enables managers to schedule, monitor, and control large and complex projects.
Critical path method or CPM (Project management techniques: PERT and CPM, easy)

75. A diagram of all activities and the precedence relationships that exist between these activities in a project is a(n) _____.
network (Project management techniques: PERT and CPM, moderate)

76. The _____ is the computed longest time path(s) through a network.
critical path (Project management techniques: PERT and CPM, easy)

77. The network analysis method that allows activity times to vary is _____.
PERT or Program Evaluation and Review Technique (Project management techniques: PERT and CPM, moderate)

78. _____ is the amount of time an individual activity in a network can be delayed without delaying the entire project.
Slack time (Project management techniques: PERT and CPM, easy)

79. The _____ distribution is appropriate for calculating expected activity times and activity variances in PERT networks.
Beta (Project management techniques: PERT and CPM, easy)

80. _____ is decreasing activity time in a network to reduce time on the critical path so total completion time is reduced.
Crashing (Cost-time trade-offs and project crashing, easy)

SHORT ANSWER

81. What are the three phases of a project? Describe each in a sentence or two.
The three phases are planning, scheduling, and controlling. Planning includes goal setting, defining the project, and team organization. Scheduling relates people, money, and supplies to specific activities and relates activities to each other. Controlling is where the firm monitors resources, costs, quality, and budgets. It also revises or changes plans and shifts resources to meet time and cost demands. (Introduction, moderate)

82. Identify the responsibilities of project managers.
Project managers are directly responsible for making sure that (1) all necessary activities are finished in proper sequence and on time; (2) the project comes in within budget; (3) the project meets its quality goals; and (4) the people assigned to the project receive the motivation, direction, and information needed to do their jobs. (Project planning, moderate)

83. What is a project organization?
A project organization is a form of management so that people and other resources are pooled for a limited amount of time to complete a specific goal or project. (Project planning, moderate)

84. Describe some of the challenges faced in the construction of the new 11-story building at Arnold Palmer Hospital in Orlando, Florida.
Prior to beginning actual construction, regulatory and funding issues added, as they do with most projects, substantial time to the overall project. Cities have zoning and parking issues, the EPA has drainage and waste issues, and regulatory authorities have their own requirements, as do issuers of bonds. (Project controlling, moderate)

85. What are some of the ethical issues faced by project managers? Which of these are likely to occur before a project begins, which are likely to occur while the project is underway, and which may occur after a project is complete? Illustrate any one of these from recent news.
A project manager, trying to select firms to undertake a project, might be exposed to bid rigging, low balling, or bribery on the part of firms competing for business. Once a project is underway, expense account padding, use of substitute (substandard) materials, or ignoring regulatory requirements are possible. Those who report on completed projects might not be truthful about the project's success (consider the massive changes that took place at NASA after two shuttle disasters, and note the very recent failure of the FBI's Carnivore software) (Project planning and project scheduling, moderate) {AACSB: Ethical Reasoning}

86. Identify and describe briefly each of the purposes of project scheduling.
It shows the relationship of each activity to others and to the whole project. It identifies the precedence relationship among activities. It encourages the setting or realistic time and cost estimates for each activity. It helps make better use of people, money, and material resources by identifying critical bottlenecks in the project. (Project scheduling, moderate)

87. What is the objective of critical path analysis?
Critical path analysis determines the longest path through a network of activities. This longest path is the key to making the schedule that provides for completing all activities in the shortest time. Critical path analysis identifies those activities critical to timely completion of all activities so they can receive management focus. (Project management techniques: PERT and CPM, moderate)

88. Explain why the critical path is the longest, not the shortest, path through a network.
Critical path is that set of activities in a project network that controls the duration of the entire project. The controlling element to completion of all activities is the longest path; any shorter path will not allow for all activities to be completed. (Project management techniques: PERT and CPM, moderate)

89. Define **slack**.
Slack is the amount of time an activity can be delayed without delaying the entire project, assuming its preceding activities are completed as early as possible. (Project management techniques: PERT and CPM, moderate)

90. Identify, in order, the six steps basic to both PERT and CPM.
1. Define the project and prepare the WBS.
2. Develop the relationships among the activities.
3. Draw the network connecting all of the activities.
4. Assign the time and/or cost estimates to each activity.
5. Compute the critical path—the longest time path through the network.
6. Use the network to help plan, schedule, monitor, and control the project.
(Project management techniques: PERT and CPM, moderate)

91. What is the basic difference between PERT and CPM?
The basic difference between PERT and CPM is that PERT requires three time estimates of activity completion time, whereas CPM uses only a single estimate. (Project management techniques: PERT and CPM, moderate)

92. PERT calculations typically include the duration variance of each activity. What is the purpose of this calculation—what's the role of variances in PERT analysis?
The activity variances influence the probability of project completion. Specifically, the sum of the variances of the critical tasks equals the variance of the project. Further, large variances on noncritical tasks need to be monitored. Such an activity might have an actual completion time so large that the task becomes a critical task. (Project management techniques: PERT and CPM, moderate)

93. Describe the differences between a Gantt chart and a PERT/CPM network.
The differences between a Gantt chart and a PERT/CPM network are mainly that PERT/CPM has the ability to consider precedence relationships and interdependence of activities. (Project management techniques: PERT and CPM, moderate)

94. Briefly discuss what is meant by critical path analysis. What are critical path activities and why are they important?
The critical path consists of those tasks that determine the overall project completion time (or that will delay the completion of the project if they are delayed); these must be managed most closely to ensure timely completion of the project. Critical path analysis is the determination of which task elements are on, or likely to be on, the critical path (the longest path through the network). (Determining the project schedule, moderate)

95. What are the earliest activity start time and latest activity start time, and how are they computed?
The earliest start time is the earliest time at which an activity may start and still satisfy all precedence requirements. The latest start time is the latest time at which an activity may start and still satisfy both precedence requirements and the overall project completion time. (Determining the project schedule, moderate)

96. How is the expected completion time of a project activity, and of a PERT project, computed?
The expected completion time of a project activity uses the Beta distribution; expected time is the weighted average of optimistic, most likely, and pessimistic time estimates. Expected completion of a PERT project is the sum of the expected times for individual activities that are on the critical path. (Determining the project schedule, moderate)

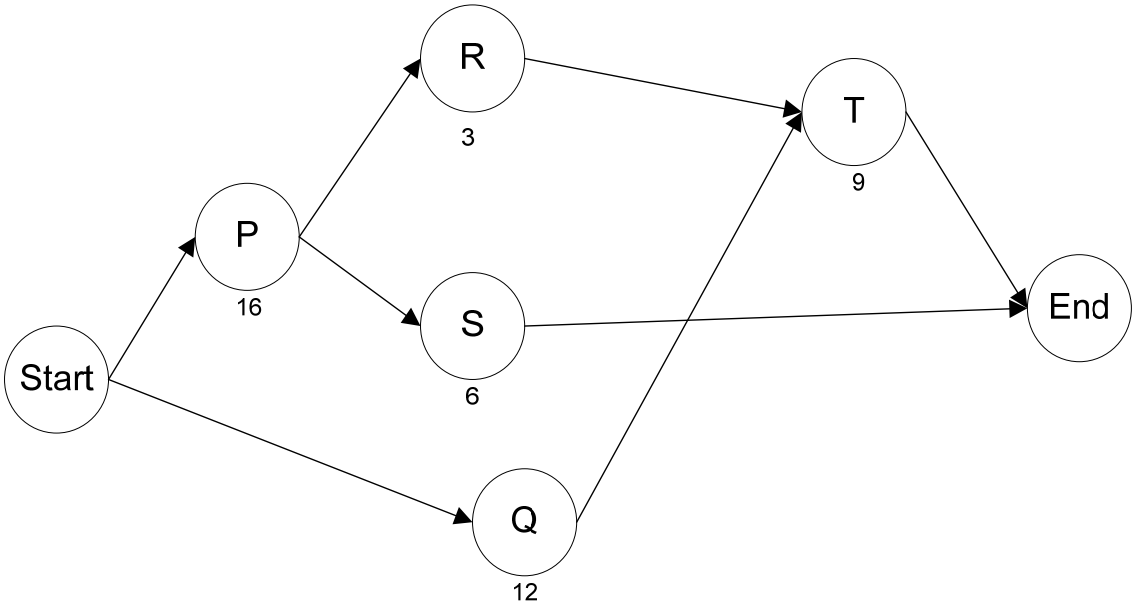
97. Describe in words how to calculate a project's standard deviation. What assumption allows that calculation to be accurate?
Add the variances of the activities on the critical path and then take the square root. We can do this because we assume that the activities are independent. (Variability in activity times, difficult)

98. Briefly describe the concept of cost/time trade-off and how it is used.
Cost/time trade-off is fundamentally PERT with additional information provided that enables one to monitor and control project cost and to study possible cost/time trade-offs. This can be done by making a budget for the entire project using the activity cost estimates and by monitoring the budget as the project takes place. Using this approach, we can determine the extent to which a project is incurring a cost overrun or a cost underrun. In addition, we can use the same technique to determine the extent to which a project is ahead of schedule or behind schedule. (Cost-time trade-offs and project crashing, moderate)

99. What are the advantages of using PERT and CPM?
The advantages include its usefulness for scheduling and controlling large projects, its straightforward concept, its graphical displays of relationships between activities, its critical path and slack time analysis, its ability to document processes, its wide range of applicability, and its usefulness in monitoring schedules and costs. (A critique of PERT and CPM, moderate)

PROBLEMS

100. Consider the network pictured below.
a. Enumerate all paths through this network.
b. Calculate the critical path for the network.
c. What is the minimum duration of the project?
d. How much slack exists at each activity?



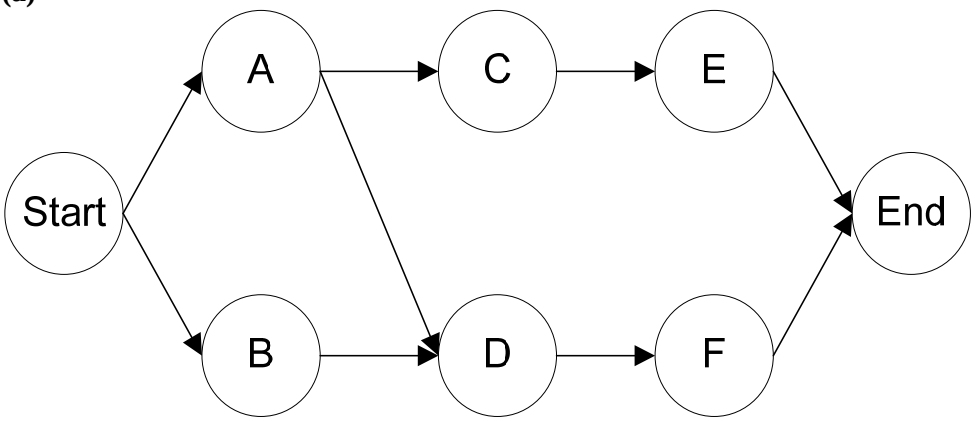
(a) Possible paths are P-S (length 22), P-R-T (length 28), and Q-T (length 21). (b) The longest of these, P-R-T, is the critical path, at 28 time units. (c) There is no slack at P, R, or T since these are critical tasks. S has 6 units slack, since the path it is on totals only 22 units, compared to the critical path length of 28. Q has 7 units of slack since it is on a 21 length path, 7 less than the maximum. (Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

101. A network consists of the activities in the following list. Times are given in weeks.

Activity	Preceding	Time
A	--	8
B	--	3
C	A	7
D	A, B	3
E	C	4
F	D	6

a. Draw the network diagram.
b. Calculate the ES, EF, LS, LF, and Slack for each activity.
c. What is project completion time?

(a)



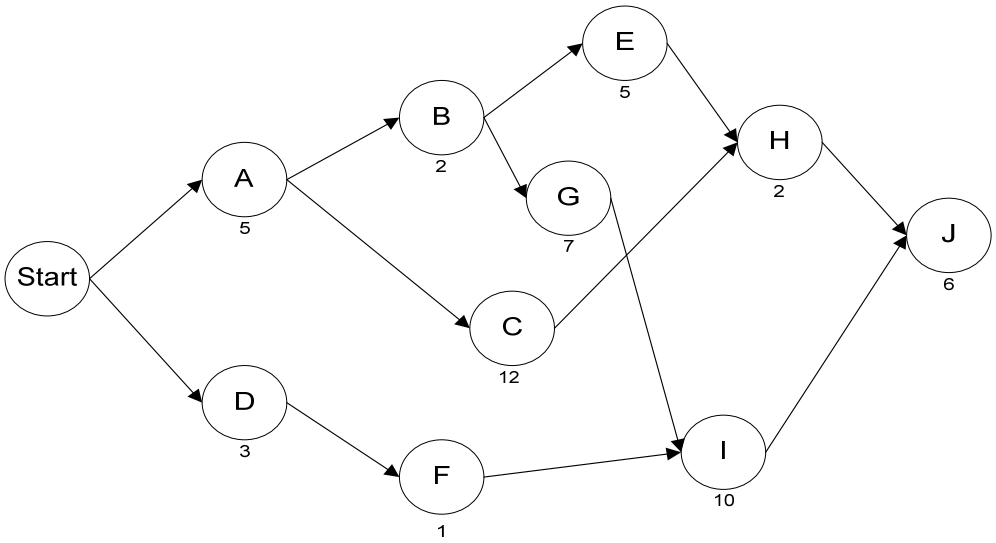
(b,c)

Results

Task	Early Start	Early Finish	Late Start	Late Finish	Slack
A	**0**	**8**	**0**	**8**	**0**
B	**0**	**3**	**7**	**10**	**7**
C	**8**	**15**	**8**	**15**	**0**
D	**8**	**11**	**10**	**13**	**2**
E	**15**	**19**	**15**	**19**	**0**
F	**11**	**17**	**13**	**19**	**2**
Project		**19**			

(Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

102. The network below represents a project being analyzed by Critical Path Methods. Activity durations are A=5, B=2, C=12, D=3, E=5, F=1, G=7, H=2, I=10, and J=6.



a. What task must be on the critical path, regardless of activity durations?
b. What is the duration of path A-B-E-H-J?
c. What is the critical path of this network?
d. What is the length of the critical path?
e. What is slack time at activity H?
f. What is the Late Finish of activity H?
g. If activity C were delayed by two time units, what would happen to the project duration?

(a) J; (b) 20; (c) A-B-G-I-J; (d) 30; (e) 5; (f) 24; (g) no impact.

Results

Task	Early Start	Early Finish	Late Start	Late Finish	Slack
A	**0**	**5**	**0**	**5**	**0**
B	**5**	**7**	**5**	**7**	**0**
C	**5**	**17**	**10**	**22**	**5**
D	**0**	**3**	**10**	**13**	**10**
E	**7**	**12**	**17**	**22**	**10**
F	**3**	**4**	**13**	**14**	**10**
G	**7**	**14**	**7**	**14**	**0**
H	**17**	**19**	**22**	**24**	**5**
I	**14**	**24**	**14**	**24**	**0**
J	**24**	**30**	**24**	**30**	**0**
	Project	**30**			

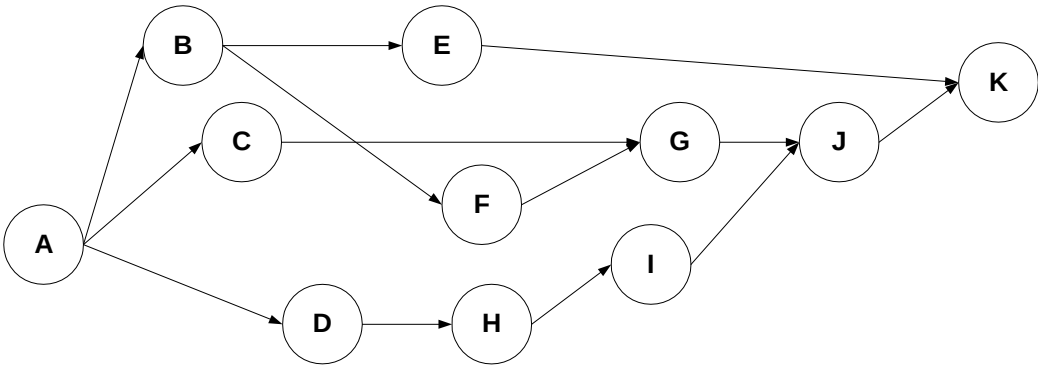
(Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

103. A network consists of the following list. Times are given in weeks.

Activity	Preceding	Duration
A	--	9
B	A	2
C	A	12
D	A	5
E	B	6
F	B	8
G	C, F	3
H	D	2
I	H	8
J	G, I	6
K	E, J	2

a. Draw the network diagram.
b. Which activities form the critical path?
c. How much slack exists at activities A and F?
d. What is the duration of the critical path?

(a) Network diagram



(b) paths A-D-H-I-J-K and A-C-G-J-K are critical; (c) A has no slack; F has 2 units (d) 32
(Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

104. A partially solved PERT problem is detailed in the table below. Times are given in weeks.

Activity	Preceding	Optimistic Time	Probable Time	Pessimistic Time	Expected Time	Variance
A	--	7	9	14		1.361
B	A	2	2	8		0
C	A	8	12	16		0
D	A	3	5	10		1.361
E	B	4	6	8		0
F	B	6	8	10		0
G	C, F	2	3	4		0
H	D	2	2	8		1.000
I	H	6	8	16		2.778
J	G, I	4	6	14		2.778
K	E, J	2	2	5		0.250

a. Calculate the expected time for each activity. Enter these values in the appropriate column in the table above.
b. Which activities form the critical path?
c. What is the estimated time of the critical path?
d. What are the project variance and the project standard deviation?
e. What is the probability of completion of the project after week 40?

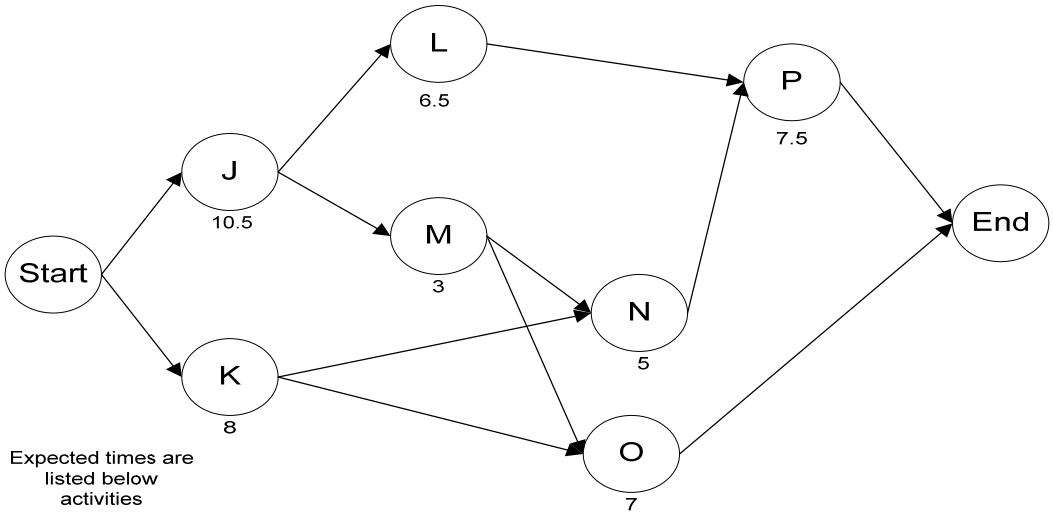
(a) A=9.5 B=3 C=12 D=5.5 E=6 F=8 G=3 H=3 I=9 J=7 K=2.5
(b) A-D-H-I-J-K; (c) 36.5; (d) 9.53, 3.09; (e) 0.13.
(Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

105. Consider the network described in the table below.

Activity	Immediate Predecessor(s)	Pessimistic	Probable	Optimistic
J	--	15	10	8
K	--	9	8	7
L	J	10	6	5
M	J	3	3	3
N	K,M	9	5	1
O	K,M	10	7	4
P	L,N	10	8	3

a. Calculate the expected duration of each activity.
b. Calculate the expected duration and variance of the critical path.
c. Calculate the probability that the project will be completed in fewer than 30 time units.

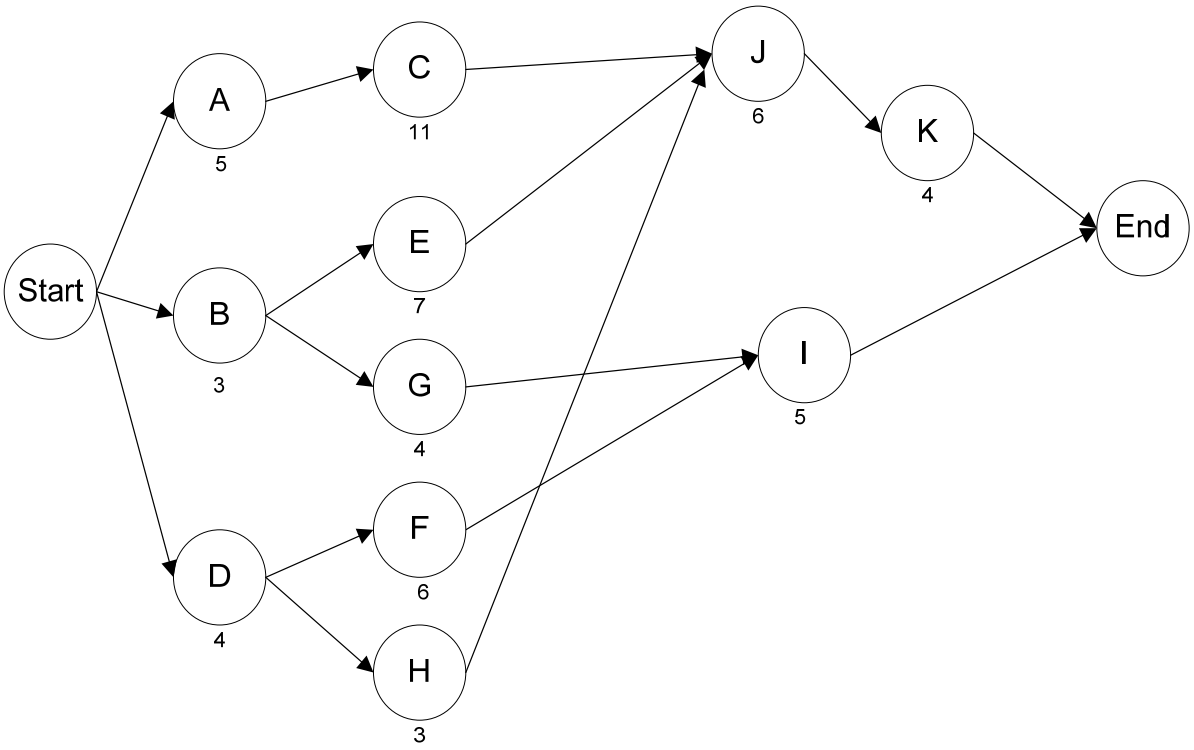
(a) See table below. (b) Tasks J-M-N-P are critical. The sum of their expected durations is 26.00; the sum of their variances is 4.50. (c) The standard deviation along the path is = 2.12; the probability that Duration < 30 is the probability that z < (30 - 26.00)/2.12 = 1.89. The associated normal curve area is 0.97062.



Task	Early Start	Early Finish	Late Start	Late Finish	Slack	Mean	Variance
J	0	10.5	0	10.5	0	10.5	1.361111
K	0	8	5.5	13.5	5.5	8	
L	10.5	17	19.5	26	9	6.5	
M	10.5	13.5	10.5	13.5	0	3	0
N	13.5	18.5	13.5	18.5	0	5	1.777778
O	13.5	20.5	19	26	5.5	7	
P	18.5	26	18.5	26	0	7.5	1.361111
Project		26				Project	4.5
						Std.dev	2.12132

(Project management techniques: PERT and CPM, mod.) {AACSB: Analytic Skills}

106. The network below represents a project being analyzed by Critical Path Methods. Activity durations are indicated on the network.



a. Identify the activities on the critical path.
b. What is the duration of the critical path?
c. Calculate the amount of slack time at activity H.
d. If activity I were delayed by ten time units, what would be the impact on the project duration?

(a) Critical activities are A-C-J-K; (b) The critical path is 26 time units; (c) Slack at H is 9 units; (d) I has 11 units slack--a ten unit delay would have no impact on the project.

Task	Early Start	Early Finish	Late Start	Late Finish	Slack
A	0	5	0	5	0
B	0	3	6	9	6
C	5	16	5	16	0
D	0	4	9	13	9
E	3	10	9	16	6
F	4	10	15	21	11
G	3	7	17	21	14
H	4	7	13	16	9
I	10	15	21	26	11
J	16	22	16	22	0
K	22	26	22	26	0
	Project	26			

(Project management techniques: PERT and CPM, mod.) {AACSB: Analytic Skills}

107. Three activities are candidates for crashing on a CPM network. Activity details are in the table below.

Activity	Normal Time	Normal Cost	Crash Duration	Crash Cost
X	8 days	$6,000	6 days	$8,000
Y	3 days	$1,800	2 days	$2,400
Z	12 days	$5,000	9 days	$7,700

a. What is the crash cost per unit time for each of the three activities?
b. Which activity should be crashed first to cut one day from the project's duration; how much is added to project cost?
c. Which activity should be the next activity crashed to cut a second day from the project's duration; how much is added to project cost?
(a) crash cost X = $1,000 per day; crash cost Y = $600 per day ; crash cost Z = $900 per day
(b) select Y, adding $600; (c) select Z, adding $900
(Cost-time trade-offs and project crashing, moderate) {AACSB: Analytic Skills}

108. Three activities are candidates for crashing on a CPM network. Activity details are in the table below.

Activity	Normal Time	Normal Cost	Crash Duration	Crash Cost
A	9 days	$8,000	7 days	$12,000
B	5 days	$2,000	3 days	$10,000
C	12 days	$9,000	11 days	$12,000

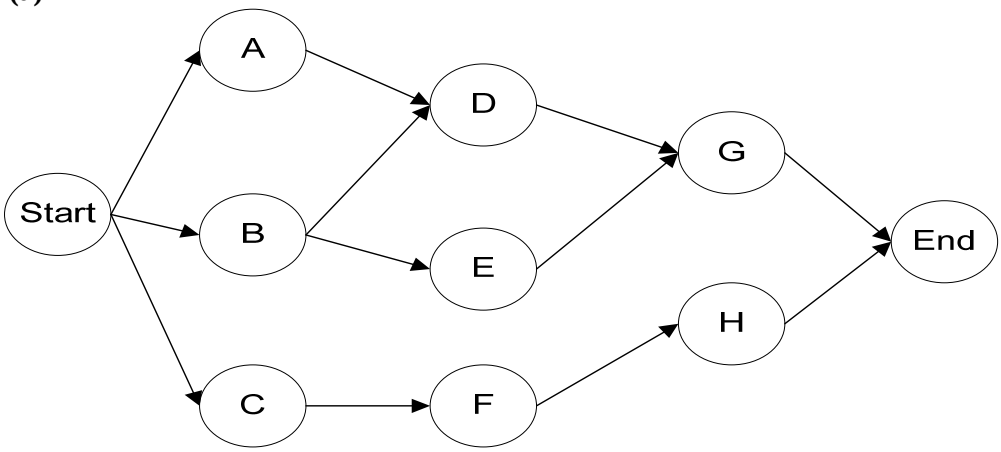
a. What is the crash cost per unit time for activity A?
b. What is the crash cost per unit time for activity B?
c. Which activity should be crashed first to cut one day from the project's duration; how much is added to project cost?
d. Which activity should be the next activity crashed to cut a second day from the project's duration; how much is added to project cost?
e. Assuming no other paths become critical, how much can this project be shortened at what total added cost?
(a) $2,000; (b) $4,000; (c) A, $2,000; (d) A again, $2,000 additional; (e) 5 days, $15,000.
(Cost-time trade-offs and project crashing, moderate) {AACSB: Analytic Skills}

109. A network consists of the following list. Times are given in weeks.

Activity	Preceding	Optimistic	Probable	Pessimistic
A	--	5	11	14
B	-	3	3	9
C	--	6	10	14
D	A, B	3	5	7
E	B	4	6	11
F	C	6	8	13
G	D, E	2	4	6
H	F	3	3	9

a. Draw the network diagram.
b. Calculate the expected duration and variance of each activity.
c. Calculate the expected duration and variance of the critical path.
d. Calculate the probability that the project will be completed in less than 28 weeks.

(a)



(b,c)

Task	Expected time	Variance	Std. dev.	Slack	Variance
A	**10.5**	**2.25**	**1.5**	**3**	
B	**4**	**1**	**1**	**8**	
C	**10**	**1.778**	**1.333**	**0**	**1.778**
D	**5**	**0.444**	**0.667**	**3**	
E	**6.5**	**1.361**	**1.167**	**8**	
F	**8.5**	**1.361**	**1.167**	**0**	**1.361**
G	**4**	**0.444**	**0.667**	**3**	
H	**4**	**1**	**1**	**0**	**1**
Project	**22.5**			**Project**	**4.139**
				Std. dev.	**2.034**

(d) z = (28-22.5)/2.03 = 2.71, (P<=28) = .997
(Project management techniques: PERT and CPM, moderate) {AACSB: Analytic Skills}

CHAPTER 4: FORECASTING

TRUE/FALSE

1. A naïve forecast for September sales of a product would be equal to the forecast for August.
False (Time-series forecasting, moderate)

2. The forecasting time horizon and the forecasting techniques used tend to vary over the life cycle of a product.
True (What is forecasting? moderate)

3. Demand (sales) forecasts serve as inputs to financial, marketing, and personnel planning.
True (Types of forecasts, moderate)

4. Forecasts of individual products tend to be more accurate than forecasts of product families.
False (Seven steps in the forecasting system, moderate)

5. Most forecasting techniques assume that there is some underlying stability in the system.
True (Seven steps in the forecasting system, moderate)

6. The sales force composite forecasting method relies on salespersons' estimates of expected sales.
True (Forecasting approaches, easy)

7. A time-series model uses a series of past data points to make the forecast.
True (Forecasting approaches, moderate)

8. The quarterly "make meeting" of Lexus dealers is an example of a sales force composite forecast.
True (Forecasting approaches, easy)

9. Cycles and random variations are both components of time series.
True (Time-series forecasting, easy)

10. A naive forecast for September sales of a product would be equal to the sales in August.
True (Time-series forecasting, easy)

11. One advantage of exponential smoothing is the limited amount of record keeping involved.
True (Time-series forecasting, moderate)

12. The larger the number of periods in the simple moving average forecasting method, the greater the method's responsiveness to changes in demand.
False (Time-series forecasting, moderate)

13. Forecast including trend is an exponential smoothing technique that utilizes two smoothing constants: one for the average level of the forecast and one for its trend.
True (Time-series forecasting, easy)

14. Mean Squared Error and Coefficient of Correlation are two measures of the overall error of a forecasting model.
False (Time-series forecasting, easy)

15. In trend projection, the trend component is the slope of the regression equation.
True (Time-series forecasting, easy)

16. In trend projection, a negative regression slope is mathematically impossible.
False (Time-series forecasting, moderate)

17. Seasonal indexes adjust raw data for patterns that repeat at regular time intervals.
True (Time-series forecasting, moderate)

18. If a quarterly seasonal index has been calculated at 1.55 for the October-December quarter, then raw data for that quarter must be multiplied by 1.55 so that the quarter can be fairly compared to other quarters.
False (Time-series forecasting: Seasonal variation in data, moderate)

19. The best way to forecast a business cycle is by finding a leading variable.
True (Time-series forecasting, moderate)

20. Linear-regression analysis is a straight-line mathematical model to describe the functional relationships between independent and dependent variables.
True (Associative forecasting methods: Regression and correlation analysis, easy)

21. The larger the standard error of the estimate, the more accurate the forecasting model.
False (Associative forecasting methods: Regression and correlation analysis, easy)

22. A trend projection equation with a slope of 0.78 means that there is a 0.78 unit rise in Y for every unit of time that passes.
True (Time-series forecasting: Trend projections, moderate)

23. In a regression equation where Y is demand and X is advertising, a coefficient of determination (R^2) of .70 means that 70% of the variance in advertising is explained by demand.
False (Associative forecasting methods: Regression and correlation analysis, moderate)

24. Demand cycles for individual products can be driven by product life cycles.
True (Time-series forecasting, moderate)

25. If a forecast is consistently greater than (or less than) actual values, the forecast is said to be biased.
True (Monitoring and controlling forecasts, moderate)

26. Focus forecasting tries a variety of computer models and selects the best one for a particular application.
True (Monitoring and controlling forecasts, moderate)

27. Many service firms use point-of-sale computers to collect detailed records needed for accurate short-term forecasts.
True (Forecasting in the service sector, moderate)

MULTIPLE CHOICE

28. What two numbers are contained in the daily report to the CEO of Walt Disney Parks & Resorts regarding the six Orlando parks?
    a. yesterday's forecasted attendance and yesterday's actual attendance
    b. yesterday's actual attendance and today's forecasted attendance
    c. yesterday's forecasted attendance and today's forecasted attendance
    d. yesterday's actual attendance and last year's actual attendance
    e. yesterday's forecasted attendance and the year-to-date average daily forecast error
    a (Global company profile, moderate)

29. Using an exponential smoothing model with smoothing constant $\alpha = .20$, how much weight would be assigned to the 2nd most recent period?
    a. .16
    b. .20
    c. .04
    d. .09
    e. .10
    a (Time-series forecasting, moderate) {AACSB: Analytic Skills}

30. Forecasts
    a. become more accurate with longer time horizons
    b. are rarely perfect
    c. are more accurate for individual items than for groups of items
    d. all of the above
    e. none of the above
    b (What is forecasting? moderate)

31. One use of short-range forecasts is to determine
    a. production planning
    b. inventory budgets
    c. research and development plans
    d. facility location
    e. job assignments
    e (What is forecasting? moderate)

32. Forecasts are usually classified by time horizon into three categories
    a. short-range, medium-range, and long-range
    b. finance/accounting, marketing, and operations
    c. strategic, tactical, and operational
    d. exponential smoothing, regression, and time series
    e. departmental, organizational, and industrial
    a (What is forecasting? easy)

33. A forecast with a time horizon of about 3 months to 3 years is typically called a
    a. long-range forecast
    b. medium-range forecast
    c. short-range forecast
    d. weather forecast
    e. strategic forecast
    b (What is forecasting? moderate)

34. Forecasts used for new product planning, capital expenditures, facility location or expansion, and R&D typically utilize a
    a. short-range time horizon
    b. medium-range time horizon
    c. long-range time horizon
    d. naive method, because there is no data history
    e. all of the above
    c (What is forecasting? moderate)

35. The three major types of forecasts used by business organizations are
    a. strategic, tactical, and operational
    b. economic, technological, and demand
    c. exponential smoothing, Delphi, and regression
    d. causal, time-series, and seasonal
    e. departmental, organizational, and territorial
    b (Types of forecasts, moderate)

36. Which of the following is **not** a step in the forecasting process?
    a. Determine the use of the forecast.
    b. Eliminate any assumptions.
    c. Determine the time horizon.
    d. Select forecasting model.
    e. Validate and implement the results.
    b (The strategic importance of forecasting, moderate)

37. The two general approaches to forecasting are
    a. qualitative and quantitative
    b. mathematical and statistical
    c. judgmental and qualitative
    d. historical and associative
    e. judgmental and associative
    a (Forecasting approaches, easy)

38. Which of the following uses three types of participants: decision makers, staff personnel, and respondents?
    a. executive opinions
    b. sales force composites
    c. the Delphi method
    d. consumer surveys
    e. time series analysis
    c (Forecasting approaches, moderate)

39. The forecasting model that pools the opinions of a group of experts or managers is known as the
    a. sales force composition model
    b. multiple regression
    c. jury of executive opinion model
    d. consumer market survey model
    e. management coefficients model
    c (Forecasting approaches, moderate)

40. Which of the following is **not** a type of qualitative forecasting?
    a. executive opinions
    b. sales force composites
    c. consumer surveys
    d. the Delphi method
    e. moving average
    e (Forecasting approaches, moderate)

41. Which of the following techniques uses variables such as price and promotional expenditures, which are related to product demand, to predict demand?
    a. associative models
    b. exponential smoothing
    c. weighted moving average
    d. simple moving average
    e. time series
    a (Forecasting approaches, moderate)

42. Which of the following statements about time series forecasting is **true**?
    a. It is based on the assumption that future demand will be the same as past demand.
    b. It makes extensive use of the data collected in the qualitative approach.
    c. The analysis of past demand helps predict future demand.
    d. Because it accounts for trends, cycles, and seasonal patterns, it is more powerful than causal forecasting.
    e. All of the above are true.
    c (Time-series forecasting, moderate)

43. Time series data may exhibit which of the following behaviors?
    a. trend
    b. random variations
    c. seasonality
    d. cycles
    e. They may exhibit all of the above.
    e (Time-series forecasting, moderate)

44. Gradual, long-term movement in time series data is called
    a. seasonal variation
    b. cycles
    c. trends
    d. exponential variation
    e. random variation
    c (Time-series forecasting, moderate)

45. Which of the following is **not** present in a time series?
    a. seasonality
    b. operational variations
    c. trend
    d. cycles
    e. random variations
    b (Time-series forecasting, moderate)

46. The fundamental difference between cycles and seasonality is the
    a. duration of the repeating patterns
    b. magnitude of the variation
    c. ability to attribute the pattern to a cause
    d. all of the above
    e. none of the above
    a (Time-series forecasting, moderate)

47. In time series, which of the following cannot be predicted?
    a. large increases in demand
    b. technological trends
    c. seasonal fluctuations
    d. random fluctuations
    e. large decreases in demand
    d (Time-series forecasting, moderate)

48. What is the approximate forecast for May using a four-month moving average?

Nov.	Dec.	Jan.	Feb.	Mar.	April
39	36	40	42	48	46

    a. 38
    b. 42
    c. 43
    d. 44
    e. 47
    d (Time-series forecasting, moderate) {AACSB: Analytic Skills}

49. Which time series model below assumes that demand in the next period will be equal to the most recent period's demand?
    a. naive approach
    b. moving average approach
    c. weighted moving average approach
    d. exponential smoothing approach
    e. none of the above
    a (Time-series forecasting, easy)

50. John's House of Pancakes uses a weighted moving average method to forecast pancake sales. It assigns a weight of 5 to the previous month's demand, 3 to demand two months ago, and 1 to demand three months ago. If sales amounted to 1000 pancakes in May, 2200 pancakes in June, and 3000 pancakes in July, what should be the forecast for August?
    a. 2400
    b. 2511
    c. 2067
    d. 3767
    e. 1622
    b (Time series forecasting, moderate) {AACSB: Analytic Skills}

51. A six-month moving average forecast is better than a three-month moving average forecast if demand
    a. is rather stable
    b. has been changing due to recent promotional efforts
    c. follows a downward trend
    d. follows a seasonal pattern that repeats itself twice a year
    e. follows an upward trend
    a (Time-series forecasting, moderate)

52. Increasing the number of periods in a moving average will accomplish greater smoothing, but at the expense of
    a. manager understanding
    b. accuracy
    c. stability
    d. responsiveness to changes
    e. All of the above are diminished when the number of periods increases.
    d (Time-series forecasting, moderate)

53. Which of the following statements comparing the weighted moving average technique and exponential smoothing is **true**?
    a. Exponential smoothing is more easily used in combination with the Delphi method.
    b. More emphasis can be placed on recent values using the weighted moving average.
    c. Exponential smoothing is considerably more difficult to implement on a computer.
    d. Exponential smoothing typically requires less record keeping of past data.
    e. Exponential smoothing allows one to develop forecasts for multiple periods, whereas weighted moving averages does not.
    d (Time-series forecasting, moderate)

54. Which time series model uses past forecasts and past demand data to generate a new forecast?
    a. naive
    b. moving average
    c. weighted moving average
    d. exponential smoothing
    e. regression analysis
    d (Time-series forecasting, moderate)

55. Which is **not** a characteristic of exponential smoothing?
    a. smoothes random variations in the data
    b. easily altered weighting scheme
    c. weights each historical value equally
    d. has minimal data storage requirements
    e. none of the above; they are all characteristics of exponential smoothing
    c (Time-series forecasting, moderate)

56. Which of the following smoothing constants would make an exponential smoothing forecast equivalent to a naive forecast?
    a. 0
    b. 1 divided by the number of periods
    c. 0.5
    d. 1.0
    e. cannot be determined
    d (Time-series forecasting, moderate)

57. Given an actual demand of 103, a previous forecast value of 99, and an alpha of .4, the exponential smoothing forecast for the next period would be
    a. 94.6
    b. 97.4
    c. 100.6
    d. 101.6
    e. 103.0
    c (Time-series forecasting, moderate) {AACSB: Analytic Skills}

58. A forecast based on the previous forecast plus a percentage of the forecast error is a(n)
    a. qualitative forecast
    b. naive forecast
    c. moving average forecast
    d. weighted moving average forecast
    e. exponentially smoothed forecast
    e (Time-series forecasting, moderate)

59. Given an actual demand of 61, a previous forecast of 58, and an α of .3, what would the forecast for the next period be using simple exponential smoothing?
    a. 45.5
    b. 57.1
    c. 58.9
    d. 61.0
    e. 65.5
    c (Time-series forecasting, moderate) {AACSB: Analytic Skills}

60. Which of the following values of alpha would cause exponential smoothing to respond the most slowly to forecast errors?
    a. 0.10
    b. 0.20
    c. 0.40
    d. 0.80
    e. cannot be determined
    a (Time-series forecasting, moderate)

61. A forecasting method has produced the following over the past five months. What is the mean absolute deviation?

Actual	Forecast	Error	|Error|
10	11	-1	1
8	10	-2	2
10	8	2	2
6	6	0	0
9	8	1	1

    a. -0.2
    b. -1.0
    c. 0.0
    d. 1.2
    e. 8.6
    d (Time-series forecasting, moderate) {AACSB: Analytic Skills}

62. The primary purpose of the mean absolute deviation (MAD) in forecasting is to
    a. estimate the trend line
    b. eliminate forecast errors
    c. measure forecast accuracy
    d. seasonally adjust the forecast
    e. all of the above
    c (Time-series forecasting, moderate)

63. Given forecast errors of -1, 4, 8, and -3, what is the mean absolute deviation?
    a. 2
    b. 3
    c. 4
    d. 8
    e. 16
    c (Time-series forecasting, moderate) {AACSB: Analytic Skills}

64. The last four months of sales were 8, 10, 15, and 9 units. The last four forecasts were 5, 6, 11, and 12 units. The Mean Absolute Deviation (MAD) is
    a. 2
    b. -10
    c. 3.5
    d. 9
    e. 10.5
    c (Time-series forecasting, moderate) {AACSB: Analytic Skills}

65. A time series trend equation is 25.3 + 2.1 X. What is your forecast for period 7?
    a. 23.2
    b. 25.3
    c. 27.4
    d. 40.0
    e. cannot be determined
    d (Time-series forecasting, moderate) {AACSB: Analytic Skills}

66. For a given product demand, the time series trend equation is 53 - 4 X. The negative sign on the slope of the equation
    a. is a mathematical impossibility
    b. is an indication that the forecast is biased, with forecast values lower than actual values
    c. is an indication that product demand is declining
    d. implies that the coefficient of determination will also be negative
    e. implies that the RSFE will be negative
    c (Time-series forecasting, moderate)

67. Yamaha manufacturers which set of products with complementary demands to address seasonal fluctuations?
    a. golf clubs and skis
    b. swimming suits and winter jackets
    c. jet skis and snowmobiles
    d. pianos and guitars
    e. ice skates and water skis
    c (Time-series forecasting, moderate)

68. Which of the following is **true** regarding the two smoothing constants of the Forecast Including Trend (FIT) model?
    a. One constant is positive, while the other is negative.
    b. They are called MAD and RSFE.
    c. Alpha is always smaller than beta.
    d. One constant smoothes the regression intercept, whereas the other smoothes the regression slope.
    e. Their values are determined independently.
    e (Time-series forecasting, moderate)

69. Demand for a certain product is forecast to be 800 units per month, averaged over all 12 months of the year. The product follows a seasonal pattern, for which the January monthly index is 1.25. What is the seasonally-adjusted sales forecast for January?
    a. 640 units
    b. 798.75 units
    c. 800 units
    d. 1000 units
    e. cannot be calculated with the information given
    d (Time-series forecasting, moderate) {AACSB: Analytic Skills}

70. A seasonal index for a monthly series is about to be calculated on the basis of three years' accumulation of data. The three previous July values were 110, 150, and 130. The average over all months is 190. The approximate seasonal index for July is
    a. 0.487
    b. 0.684
    c. 1.462
    d. 2.053
    e. cannot be calculated with the information given
    b (Time-series forecasting, moderate) {AACSB: Analytic Skills}

71. A fundamental distinction between trend projection and linear regression is that
    a. trend projection uses least squares while linear regression does not
    b. only linear regression can have a negative slope
    c. in trend projection the independent variable is time; in linear regression the independent variable need not be time, but can be any variable with explanatory power
    d. linear regression tends to work better on data that lack trends
    e. trend projection uses two smoothing constants, not just one
    c (Associative forecasting methods: Regression and correlation analysis, moderate)

72. The percent of variation in the dependent variable that is explained by the regression equation is measured by the
    a. mean absolute deviation
    b. slope
    c. coefficient of determination
    d. correlation coefficient
    e. intercept
    c (Associative forecasting methods: Regression and correlation analysis, moderate)

73. The degree or strength of a linear relationship is shown by the
    a. alpha
    b. mean
    c. mean absolute deviation
    d. correlation coefficient
    e. RSFE
    d (Associative forecasting methods: Regression and correlation analysis, moderate)

74. If two variables were perfectly correlated, the correlation coefficient r would equal
    a. 0
    b. -1
    c. 1
    d. b or c
    e. none of the above
    d (Associative forecasting methods: Regression and correlation analysis, moderate)

75. The last four weekly values of sales were 80, 100, 105, and 90 units. The last four forecasts were 60, 80, 95, and 75 units. These forecasts illustrate
    a. qualitative methods
    b. adaptive smoothing
    c. slope
    d. bias
    e. trend projection
    d (Monitoring and controlling forecasts, easy)

76. The tracking signal is the
    a. standard error of the estimate
    b. running sum of forecast errors (RSFE)
    c. mean absolute deviation (MAD)
    d. ratio RSFE/MAD
    e. mean absolute percentage error (MAPE)
    d (Monitoring and controlling forecasts, moderate)

77. Computer monitoring of tracking signals and self-adjustment if a signal passes a preset limit is characteristic of
    a. exponential smoothing including trend
    b. adaptive smoothing
    c. trend projection
    d. focus forecasting
    e. multiple regression analysis
    b (Monitoring and controlling forecasts, moderate)

78. Many services maintain records of sales noting
    a. the day of the week
    b. unusual events
    c. weather
    d. holidays
    e. all of the above
    e (Forecasting in the service sector, moderate)

79. Taco Bell's unique employee scheduling practices are partly the result of using
    a. point-of-sale computers to track food sales in 15 minute intervals
    b. focus forecasting
    c. a six-week moving average forecasting technique
    d. multiple regression
    e. a and c are both correct
    e (Forecasting in the service sector, moderate)

FILL-IN-THE-BLANK

80. _____ forecasts are concerned with rates of technological progress, which can result in the birth of exciting new products, requiring new plants and equipment.
Technological (Types of forecasts, easy)

81. _____ forecasts address the business cycle by predicting inflation rates, money supplies, housing starts, and other planning indicators.
Economic (Types of forecasts, moderate)

82. Demand forecasts, also called _____ forecasts, are projections of demand for a company's products or services.
sales (Types of forecasts, moderate)

83. _____ forecasts employ one or more mathematical models that rely on historical data and/or causal variables to forecast demand.
Quantitative (Forecasting approaches, moderate)

84. _____ is a forecasting technique based upon salespersons' estimates of expected sales.
Sales force composite (Forecasting approaches, moderate)

85. _____ forecasts use a series of past data points to make a forecast.
Time-series (Forecasting approaches, moderate)

86. A(n) _____ forecast uses an average of the most recent periods of data to forecast the next period.
moving average (Forecasting approaches, moderate)

87. The smoothing constant is a weighting factor used in _____.
exponential smoothing (Forecasting approaches, moderate)

88. Linear regression is known as a(n) _____ because it incorporates variables or factors that might influence the quantity being forecast.
associative model (Forecasting approaches, easy)

89. A measure of forecast error that does not depend on the magnitude of the item being forecast is the _____.
mean absolute percent error or MAPE (Forecasting approaches, easy)

90. _____ is a measure of overall forecast error for a model.
MAD or Mean Absolute Deviation (Forecasting approaches, moderate)

91. When one constant is used to smooth the forecast average and a second constant is used to smooth the trend, the forecasting method is _____.
exponential smoothing with trend adjustment or trend-adjusted smoothing or second-order smoothing or double smoothing (Forecasting approaches, moderate)

92. _____ is a time-series forecasting method that fits a trend line to a series of historical data points and then projects the line into the future for forecasts.
Trend projection (Forecasting approaches, moderate)

93. The _____ measures the strength of the relationship between two variables.
coefficient of correlation (Associative forecasting methods: Regression and correlation analysis, moderate)

94. If a barbershop operator noted that Tuesday's business was typically twice as heavy as Wednesday's, and that Friday's business was typically the busiest of the week, business at the barbershop is subject to _____.
seasonal variations (Forecasting approaches: seasonal variations in data, moderate)

95. _____ forecasting tries a variety of computer models and selects the best one for a particular application.
Focus (Monitoring and controlling forecasts, moderate)

SHORT ANSWER

96. A skeptical manager asks what short-range forecasts can be used for. Give her three possible uses/purposes.
Any three of: planning purchasing, job scheduling, work force levels, job assignments, production levels. (What is forecasting? moderate)

97. A skeptical manager asks what long-range forecasts can be used for. Give her three possible uses/purposes.
Any three of: planning new products, capital expenditures, facility location or expansion, research and development. (What is forecasting? moderate)

98. Describe the three forecasting time horizons and their use.
Forecasting time horizons **are: short range—generally less than three months, used for purchasing, job scheduling, work force levels, production levels; medium range—usually from three months up to three years, used for sales planning, production planning and budgeting, cash budgeting, analyzing operating plans; long range—usually three years or more, used for new product development, capital expenditures, facility planning, and R&D. (What is forecasting? moderate)**

99. List and briefly describe the three major types of forecasts.
The three types are economic, technological, and demand; economic refers to macroeconomic, growth and financial variables; technological refers to forecasting amount of technological advance, or futurism; demand refers to product demand. (Types of forecasts, moderate)

100. Identify the seven steps involved in forecasting.
1. Determine the use of the forecast.
2. Select the items that are to be forecast.
3. Determine the time horizon of the forecast.
4. Select the forecasting model(s).
5. Gather the data needed to make the forecast.
6. Make the forecast.
7. Validate the forecasting mode and implement the results.
(Seven steps in the forecasting process, moderate)

101. What are the realities of forecasting that companies face?
First, forecasts are seldom perfect. Second, most forecasting techniques assume that there is some underlying stability in the system. Finally, both product family and aggregated forecasts are more accurate than individual product forecasts. (Seven steps in the forecasting system, moderate)

102. What are the differences between quantitative and qualitative forecasting methods?
Quantitative methods use mathematical models to analyze historical data. Qualitative methods incorporate such factors as the decision maker's intuition, emotions, personal experiences, and value systems in determining the forecast. (Forecasting approaches, moderate)

103. Identify four quantitative forecasting methods.
The list includes naive, moving averages, exponential smoothing, trend projection, and linear regression. (Forecasting approaches, moderate)

104. What is a time-series forecasting model?
A *time series* forecasting model is any mathematical model that uses historical values of the quantity of interest to predict future values of that quantity. (Forecasting approaches, easy)

105. What is the difference between an associative model and a time-series model?
A *time series* model uses only historical values of the quantity of interest to predict future values of that quantity. The *associative* model, on the other hand, attempts to identify underlying causes or factors that control the variation of the quantity of interest, predict future values of these factors, and use these predictions in a model to predict future values of the specific quantity of interest. (Forecasting approaches, moderate)

106. Name and discuss three qualitative forecasting methods.
***Qualitative forecasting methods* include: jury of executive opinion, where high-level managers arrive at a group estimate of demand; sales force composite, where salespersons' estimates are aggregated; Delphi method, where respondents provide inputs to a group of decision makers; the group of decision makers, often experts, then make the actual forecast; consumer market survey, where consumers are queried about their future purchase plans. (Forecasting approaches, moderate)**

107. Identify four components of a time series. Which one of these is rarely forecast? Why is this so?
Trend, seasonality, cycles, and random variation. Since random variations follow no discernible pattern, they cannot be predicted, and thus are not forecast. (Time-series forecasting, moderate)

108. Compare seasonal effects and cyclical effects.
A cycle is longer (typically several years) than a season (typically days, weeks, months, or quarters). A cycle has variable duration, while a season has fixed duration and regular repetition. (Time-series forecasting, moderate)

109. Distinguish between a **moving average** model and an **exponential smoothing** model.
Exponential smoothing is a weighted moving average model wherein previous values are weighted in a specific manner--in particular, <u>all</u> previous values are weighted with a set of weights that decline exponentially. (Time-series forecasting, moderate)

110. Describe three popular measures of forecast accuracy.
***Measures of forecast accuracy* include: (a) *MAD* (mean absolute deviation). This is a sum of the absolute values of individual errors divided by the number of periods of data. (b) *MSE* (mean squared error). This is the average of the squared differences between the forecast and observed values. (c) *MAPE* (mean absolute percent error) is independent of the magnitude of the variable being forecast. (Forecasting approaches: Measuring forecast error, moderate)**

111. Give an example—other than a restaurant or other food-service firm—of an organization that experiences an hourly seasonal pattern. (That is, each hour of the day has a pattern that tends to repeat day after day.) Explain.
Answer will vary. However, two non-food examples would be banks and movie theaters. (Time-series forecasting, moderate) {AACSB: Reflective Thinking}

112. Explain the role of regression models (time series and otherwise) in forecasting. That is, how is trend projection able to forecast? How is regression used for causal forecasting?
For trend projection, the independent variable is time. The trend projection equation has a slope that is the change in demand per period. To forecast the demand for period t, perform the calculation a + bt. For causal forecasting, the independent variables are predictors of the forecast value or dependent variable. The slope of the regression equation is the change in the Y variable per unit change in the X variable. (Time-series forecasting, difficult)

113. Identify three advantages of the moving average forecasting model. Identify three disadvantages of the moving average forecasting model.
Three advantages of the model are that it uses simple calculations, it smoothes out sudden fluctuations, and it is easy for users to understand. The disadvantages are that the averages always stay within past ranges, that they require extensive record keeping of past data, and that they do not pick up on trends very well. (Time-series forecasting, moderate)

114. What does it mean to "decompose" a time series?
To *decompose a time series* means to break past data down into components of trends, seasonality, cycles, and random blips, and to project them forward. (Time-series forecasting, easy)

115. Distinguish a dependent variable from an independent variable.
The independent variable causes some behavior in the dependent variable; the dependent variable shows the effect of changes in the independent variable. (Associative forecasting methods: Regression and correlation, moderate)

116. Explain, in your own words, the meaning of the coefficient of determination.
The coefficient of determination measures the amount (percent) of total variation in the data that is explained by the model. (Associative forecasting methods: Regression and correlation, moderate)

117. What is a tracking signal? How is it calculated? Explain the connection between adaptive smoothing and tracking signals.
A tracking signal is a measure of how well the forecast actually predicts. Its calculation is the ratio of RSFE to MAD. The larger the absolute tracking signal, the worse the forecast is performing. Adaptive smoothing sets limits to the tracking signal, and makes changes to its forecasting models when the tracking signal goes beyond those limits. (Monitoring and controlling forecasts, moderate)

118. What is focus forecasting?
It is a forecasting method that tries a variety of computer models, and selects the one that is best for a particular application. (Monitoring and controlling forecasts, easy)

PROBLEMS

119. Weekly sales of ten-grain bread at the local organic food market are in the table below. Based on this data, forecast week 9 using a five-week moving average.

Week	Sales
1	415
2	389
3	420
4	382
5	410
6	432
7	405
8	421

(382+410+432+405+421)/5 = 410.0 (Time-series forecasting, easy) {AACSB: Analytic Skills}

120. Given the following data, calculate the three-year moving averages for years 4 through 10.

Year	Demand
1	74
2	90
3	59
4	91
5	140
6	98
7	110
8	123
9	99

Year	**Demand**	**3-Year Moving Ave.**
1	**74**	
2	**90**	
3	**59**	
4	**91**	**74.33**
5	**140**	**80.00**
6	**98**	**96.67**
7	**110**	**109.67**
8	**123**	**116.00**
9	**99**	**110.33**
		110.67

(Time-series forecasting, moderate) {AACSB: Analytic Skills}

121. What is the forecast for May based on a weighted moving average applied to the following past demand data and using the weights: 4, 3, 2 (largest weight is for most recent data)?

Nov.	Dec.	Jan.	Feb.	Mar.	April
37	36	40	42	47	43

2x42 + 3x47 + 4x43 = 84+141+172 = 397; 397/9 = 44.1 (Time-series forecasting, easy) {AACSB: Analytic Skills}

122. Weekly sales of copy paper at Cubicle Suppliers are in the table below. Compute a three-period moving average and a four-period moving average for weeks 5, 6, and 7. Compute MAD for each forecast. Which model is more accurate? Forecast week 8 with the more accurate method.

Week	Sales (cases)
1	17
2	21
3	27
4	31
5	19
6	17
7	21

Week	**Sales (cases)**	**3MA**	**|error|**	**4MA**	**|error|**
1	**17**				
2	**21**				
3	**27**				
4	**31**	**21.7**	**9.3**		
5	**19**	**26.3**	**7.3**	**24.0**	**5.0**
6	**17**	**25.7**	**8.7**	**24.5**	**7.5**
7	**21**	**22.3**	**1.3**	**23.5**	**2.5**
8		**19.0**		**22.0**	
		MAD =	**6.7**		**5.0**

The four-week moving average is more accurate. The forecast with the 4-moving average is 22.0. (Time-series forecasting, moderate) {AACSB: Analytic Skills}

123. The last four weekly values of sales were 80, 100, 105, and 90 units. The last four forecasts (for the same four weeks) were 60, 80, 95, and 75 units. Calculate MAD, MSE, and MAPE for these four weeks.

Sales	Forecast	Error	Error squared	Pct. error
80	**60**	**20**	**400**	**.25**
100	**80**	**20**	**400**	**.20**
105	**95**	**10**	**100**	**.095**
90	**75**	**15**	**225**	**.167**

MAD = 65/4 = 16.25; MSE = 1125/4 = 281.25; MAPE = 0.712/4 = .178 or 17.8%
(Time series forecasting: Measuring forecast error, moderate) {AACSB: Analytic Skills}

124. A management analyst is using exponential smoothing to predict merchandise returns at an upscale branch of a department store chain. Given an actual number of returns of 154 items in the most recent period completed, a forecast of 172 items for that period, and a smoothing constant of 0.3, what is the forecast for the next period? How would the forecast be changed if the smoothing constant were 0.6? Explain the difference in terms of alpha and responsiveness.
166.6; 161.2 The larger the smoothing constant in an exponentially smoothed forecast, the more responsive the forecast. (Time-series forecasting, easy) {AACSB: Analytic Skills}

125. Use exponential smoothing with $\alpha = 0.2$ to calculate smoothed averages and a forecast for period 7 from the data below. Assume the forecast for the initial period is 7.

Period	Demand
1	10
2	8
3	7
4	10
5	12
6	9

Period	**Demand**	**Forecast**
1	**10**	**7.0**
2	**8**	**7.6**
3	**7**	**7.7**
4	**10**	**7.5**
5	**12**	**8.0**
6	**9**	**8.8**

(Time-series forecasting, moderate) {AACSB: Analytic Skills}

126. The following trend projection is used to predict quarterly demand: Y = 250 - 2.5t, where t = 1 in the first quarter of 2004. Seasonal (quarterly) relatives are Quarter 1 = 1.5; Quarter 2 = 0.8; Quarter 3 = 1.1; and Quarter 4 = 0.6. What is the seasonally adjusted forecast for the four quarters of 2006?

Period	**Projection**	**Adjusted**
9	**227.5**	**341.25**
10	**225**	**180.00**
11	**222.5**	**244.75**
12	**220**	**132.00**

(Time-series forecasting, moderate) {AACSB: Analytic Skills}

127. Jim's department at a local department store has tracked the sales of a product over the last ten weeks. Forecast demand using exponential smoothing with an alpha of 0.4, and an initial forecast of 28.0. Calculate MAD and the tracking signal. What do you recommend?

Period	Demand
1	24
2	23
3	26
4	36
5	26
6	30
7	32
8	26
9	25
10	28

Period	Demand	Forecast	Error	RSFE	Absolute
1	**24**	**28.00**			
2	**23**	**26.40**	**-3.40**	**-3.40**	**3.40**
3	**26**	**25.04**	**0.96**	**-2.44**	**0.96**
4	**36**	**25.42**	**10.58**	**8.14**	**10.58**
5	**26**	**29.65**	**-3.65**	**4.48**	**3.65**
6	**30**	**28.19**	**1.81**	**6.29**	**1.81**
7	**32**	**28.92**	**3.08**	**9.37**	**3.08**
8	**26**	**30.15**	**-4.15**	**5.22**	**4.15**
9	**25**	**28.49**	**-3.49**	**1.73**	**3.49**
10	**28**	**27.09**	**0.91**	**2.64**	**0.91**
		Total	**2.64**		**32.03**
		Average	**0.29**	**0.74**	**3.56**
			Bias	**TS**	**MAD**

The tracking signal is acceptable; therefore, keep using the forecasting method. (Time-series forecasting, and Monitoring and controlling forecasts, moderate) {AACSB: Analytic Skills}

128. Favors Distribution Company purchases small imported trinkets in bulk, packages them, and sells them to retail stores. They are conducting an inventory control study of all their items. The following data are for one such item, which is not seasonal.

a. Use trend projection to estimate the relationship between time and sales (state the equation).
b. Calculate forecasts for the first four months of the next year.

	1	2	3	4	5	6	7	8	9	10	11	12
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sales	51	55	54	57	50	68	66	59	67	69	75	73

The trend projection equation is Y = 48.32 + 2.105 T. The next four months are forecast to be 75.68, 77.79, 79.89, and 82.00. (Time-series forecasting, moderate) {AACSB: Analytic Skills}

129. Use exponential smoothing with trend adjustment to forecast deliveries for period 10. Let alpha = 0.4, beta = 0.2, and let the initial trend value be 4 and the initial forecast be 200.

Period	Actual Demand
1	200
2	212
3	214
4	222
5	236
6	221
7	240
8	244
9	250
10	266

	Actual	Forecast	Trend	FIT
1	**200**	**200.00**	**4.00**	
2	**212**	**202.40**	**3.68**	**206.08**
3	**214**	**208.45**	**4.15**	**212.60**
4	**222**	**213.16**	**4.27**	**217.43**
5	**236**	**219.26**	**4.63**	**223.89**
6	**221**	**228.73**	**5.60**	**234.33**
7	**240**	**229.00**	**4.53**	**233.53**
8	**244**	**236.12**	**5.05**	**241.17**
9	**250**	**242.30**	**5.28**	**247.58**
10	**266**	**248.55**	**5.47**	**254.02**

(Time-series forecasting, moderate) {AACSB: Analytic Skills}

130. A small family-owned restaurant uses a seven-day moving average model to determine manpower requirements. These forecasts need to be seasonalized because each day of the week has its own demand pattern. The seasonal relatives for each day of the week are: Monday, 0.445; Tuesday, 0.791; Wednesday, 0.927; Thursday, 1.033; Friday, 1.422; Saturday, 1.478; and Sunday 0.903. Average daily demand based on the most recent moving average is 194 patrons. What is the seasonalized forecast for each day of next week?

The average value multiplied by each day's seasonal index. Monday: 194 x .445 = 86; Tuesday: 194 x .791 = 153; Wednesday: 194 x .927 = 180; Thursday: 194 x 1.033 = 200; Friday: 194 x 1.422 = 276; Saturday: 194 x 1.478 = 287; and Sunday: 194 x .903 = 175.
(Associative forecasting methods: Regression and correlation, moderate) {AACSB: Analytic Skills}

131. A restaurant has tracked the number of meals served at lunch over the last four weeks. The data shows little in terms of trends, but does display substantial variation by day of the week. Use the following information to determine the seasonal (daily) index for this restaurant.

	Week			
Day	1	2	3	4
Sunday	40	35	39	43
Monday	54	55	51	59
Tuesday	61	60	65	64
Wednesday	72	77	78	69
Thursday	89	80	81	79
Friday	91	90	99	95
Saturday	80	82	81	83

Day	**Index**
Sunday	**0.5627**
Monday	**0.7855**
Tuesday	**0.8963**
Wednesday	**1.0618**
Thursday	**1.1800**
Friday	**1.3444**
Saturday	**1.1692**

(Time-series forecasting, moderate) {AACSB: Analytic Skills}

132. A firm has modeled its experience with industrial accidents and found that the number of accidents per year (Y) is related to the number of employees (X) by the regression equation Y = 3.3 + 0.049*X. R-Square is 0.68. The regression is based on 20 annual observations. The firm intends to employ 480 workers next year. How many accidents do you project? How much confidence do you have in that forecast?
Y = 3.3 + 0.049 * 480 = 3.3 + 23.52 = 26.82 accidents. This is not a time series, so next year = year 21 is of no relevance. Confidence comes from the coefficient of determination; the model explains 68% of the variation in number of accidents, which seems respectable.
(Associative forecasting methods: Regression and correlation, moderate) {AACSB: Analytic Skills}

133. Demand for a certain product is forecast to be 8,000 units per month, averaged over all 12 months of the year. The product follows a seasonal pattern, for which the January monthly index is 1.25. What is the seasonally-adjusted sales forecast for January?
8,000 x 1.25 = 10,000 (Time-series forecasting, easy) {AACSB: Analytic Skills}

134. A seasonal index for a monthly series is about to be calculated on the basis of three years' accumulation of data. The three previous July values were 110, 135, and 130. The average over all months is 160. The approximate seasonal index for July is
(110 + 135 + 130)/3 = 125; 125/160 = 0.781 (Time-series forecasting, moderate) {AACSB: Analytic Skills}

135. Marie Bain is the production manager at a company that manufactures hot water heaters. Marie needs a demand forecast for the next few years to help decide whether to add new production capacity. The company's sales history (in thousands of units) is shown in the table below. Use exponential smoothing with trend adjustment, to forecast demand for period 6. The initial forecast for period 1 was 11 units; the initial estimate of trend was 0. The smoothing constants are $\alpha = .3$ and $\beta = .3$

Period	Actual
1	**12**
2	**15**
3	**16**
4	**16**
5	**18**
6	**20**

Period	Actual	Forecast	Trend	FIT
1	**12**	**11.00**	**0.00**	
2	**15**	**11.30**	**0.09**	**11.39**
3	**16**	**12.47**	**0.41**	**12.89**
4	**16**	**13.82**	**0.69**	**14.52**
5	**18**	**14.96**	**0.83**	**15.79**
6	**20**	**16.45**	**1.03**	**17.48**

(Time-series forecasting, moderate) {AACSB: Analytic Skills}

136. The quarterly sales for specific educational software over the past three years are given in the following table. Compute the four seasonal factors.

	YEAR 1	YEAR 2	YEAR 3
Quarter 1	1710	1820	1830
Quarter 2	960	910	1090
Quarter 3	2720	2840	2900
Quarter 4	2430	2200	2590

	Avg.	Sea. Fact.
Quarter 1	**1786.67**	**0.8933**
Quarter 2	**986.67**	**0.4933**
Quarter 3	**2820.00**	**1.4100**
Quarter 4	**2406.67**	**1.2033**
Grand Average	**2000.00**	

(Time-series forecasting, moderate) {AACSB: Analytic Skills}

137. An innovative restaurateur owns and operates a dozen "Ultimate Low-Carb" restaurants in northern Arkansas. His signature item is a cheese-encrusted beef medallion wrapped in lettuce. Sales (X, in millions of dollars) is related to Profits (Y, in hundreds of thousands of dollars) by the regression equation Y = 8.21 + 0.76 X. What is your forecast of profit for a store with sales of $40 million? $50 million?

Students must recognize that sales is the independent variable and profits is dependent; the problem is not a time series. A store with $40 million in sales: 40 x 0.76 = 30.4; 30.4 + 8.21 = 38.61, or $3,861,000 in profit; $50 million in sales is estimated to profit 46.21 or $4,621,000. (Associative forecasting methods: Regression and correlation, moderate) {AACSB: Analytic Skills}

138. Arnold Tofu owns and operates a chain of 12 vegetable protein "hamburger" restaurants in northern Louisiana. Sales figures and profits for the stores are in the table below. Sales are given in millions of dollars; profits are in hundreds of thousands of dollars. Calculate a regression line for the data. What is your forecast of profit for a store with sales of $24 million? $30 million?

Store	Profits	Sales
1	14	6
2	11	3
3	15	5
4	16	5
5	24	15
6	28	18
7	22	17
8	21	12
9	26	15
10	43	20
11	34	14
12	9	5

Students must recognize that "sales" is the independent variable and profits is dependent. Store number is not a variable, and the problem is not a time series. The regression equation is Y = 5.936 + 1.421 X (Y = profit, X = sales). A store with $24 million in sales is estimated to profit 40.04 or $4,004,000; $30 million in sales should yield 48.566 or $4,856,600 in profit. (Associative forecasting methods: Regression and correlation, moderate)

139. The department manager using a combination of methods has forecast sales of toasters at a local department store. Calculate the MAD for the manager's forecast. Compare the manager's forecast against a naive forecast. Which is better?

Month	Unit Sales	Manager's Forecast
January	52	
February	61	
March	73	
April	79	
May	66	
June	51	
July	47	50
August	44	55
September	30	52
October	55	42
November	74	60
December	125	75

Month	**Actual**	**Manager's**	**Abs. Error**	**Naive**	**Abs. Error**
January	**52**				
February	**61**				
March	**73**				
April	**79**				
May	**66**				
June	**51**				
July	**47**	**50**	**3**	**51**	**4**
August	**44**	**55**	**11**	**47**	**3**
September	**30**	**52**	**22**	**44**	**14**
October	**55**	**42**	**13**	**30**	**25**
November	**74**	**60**	**14**	**55**	**19**
December	**125**	**75**	**50**	**74**	**51**
		MAD	**18.83**		**19.33**

The manager's forecast has a MAD of 18.83, while the naive is 19.33. Therefore, the manager's forecast is slightly better than the naive.
(Monitoring and controlling forecasts, moderate) {AACSB: Analytic Skills}

CHAPTER 5: DESIGN OF GOODS AND SERVICES

TRUE/FALSE

1. Regal Marine's attempts to keep in touch with customers and respond to the marketplace are made impossible because consumer tastes change and maritime engineering improves.
False (Introduction, easy)

2. A product strategy may focus on differentiation, low-cost, or rapid response.
True (Introduction, easy)

3. The goal of the product decision is to develop and implement a product strategy that meets the needs of the marketplace with a competitive advantage.
True (Introduction, moderate)

4. Political/legal change and economic change are both factors influencing market opportunities for new products.
True (Goods and services selection, easy)

5. The four phases of the product life cycle are incubation, introduction, growth, and decline.
False (Goods and services selection, moderate)

6. In the maturity stage of the product life cycle, operations managers will be concerned with keeping sufficient capacity available for the product.
False (Goods and services selection, moderate)

7. Relatively few new product ideas, perhaps only 1 in 250, become successfully marketed products.
True (Goods and services selection, moderate)

8. 3M’s goal is to produce 30% of its profit from products introduced in the last 4 years.
True (Introduction, difficult)

9. Computer-aided design (CAD) refers to the use of specialized computer programs to direct and control manufacturing equipment.
False (Generating new products, moderate) {AACSB: Use of IT}

10. Virtual reality technology can improve designs less expensively than the use of physical models or prototypes.
True (Generating new products, moderate) {AACSB: Use of IT}

11. Quality function deployment refers to first, determining what will satisfy the customer, and second, translating the customers’ desires into a target design.
True (Product development, moderate)

12. Robust design is a method that ensures that small variation in production or assembly does not adversely affect the product.
True (Issues for product design, moderate)

13. Modular design exists only in tangible products; it makes no sense in services.
False (Issues for product design, moderate)

14. One environmentally friendly approach to product design is to use lighter components.
True (Issues for product design, moderate) {AACSB: Ethical Reasoning}

15. An operations manager's most ethical activity is to enhance productivity while delivering desired goods and services. Unfortunately, this activity is not environmentally sound.
False (Issues for product design, moderate) {AACSB: Ethical Reasoning}

16. Two issues—viewing a product in terms of its impact on the entire economy and considering the life cycle of a product—combine to increase the likelihood of ethical decisions by managers.
True (Issues for product design, moderate) {AACSB: Ethical Reasoning}

17. Rapidly developing products and moving them to the market is part of time-based competition.
True (Time-based competition, moderate)

18. The enhancement of existing products is an external product development strategy.
False (Time-based competition, easy)

19. The "make-or-buy" decision distinguishes between what an organization chooses to produce and what it chooses to purchase from suppliers.
True (Defining the product, moderate)

20. Group technology enables the grouping of parts into families based on similar processing requirements.
True (Defining the product, easy)

21. A work order is a listing of the components, their description, and the quantity of each required to make one unit of the product.
False (Documents for production, moderate)

22. An assembly drawing lists the operations necessary to produce the component.
False (Documents for production, moderate)

23. An assembly chart shows an exploded view of the product, usually via a three-dimensional or isometric drawing.
False (Documents for production, moderate)

24. The customer may participate in the design of, and in the delivery of, services.
True (Service design, moderate)

25. The moment-of-truth is the crucial moment between the service provider and the customer that exemplifies, enhances, or detracts from the customer's expectation.
True (Service design, moderate)

26. The expected value of each course of action in a decision tree is determined by starting at the beginning of the tree (the left-hand side) and working toward the end of the tree (the right).
False (Application of decision trees to product design, moderate)

MULTIPLE CHOICE

27. Which of these statements regarding Regal Marine is **true**?
    a. Product design is a critical decision for the firm.
    b. Regal uses a three-dimensional CAD system to shorten product development time.
    c. Regal still uses some wooden parts and hand-produces some components.
    d. Regal's use of CAD has resulted in a superior product.
    e. All of the above are true.
    e (Global company profile, moderate)

28. Regal Marine
    a. no longer builds boats with any wooden parts
    b. designs and builds boat hulls by hand
    c. treats the product design decision as critical to its success
    d. gets its competitive advantage by being the low-cost producer of boats designed by others
    e. designs several new boats each year, but contracts other firms for their manufacture
    c (Global company profile, moderate)

29. The three major subdivisions of the product decision are
    a. selection, definition, and design
    b. goods, services, and hybrids
    c. strategy, tactics, and operations
    d. cost, differentiation, and speed of response
    e. legislative, judicial, and executive
    a (Goods and services selection, moderate)

30. Which of the following statements is not true?
    a. Virtually all of Honda’s sales (autos, motorcycles, generators, lawn mowers) are based on its outstanding engine technology.
    b. Intel focuses on microprocessors and chips.
    c. Microsoft focuses on PC software.
    d. Firms such as 3M establish goals for profitability from new products.
    e. Dell Computers provides fast delivery to customers, but, in return, customers may only select from a limited choice of hardware configurations.
    e (Introduction, moderate)

31. Operations managers must be able to anticipate changes in which of the following?
    a. product mix
    b. product opportunities
    c. the products themselves
    d. product volume
    e. all of the above
    e (Goods and services selection, moderate)

32. In which stage of the product life cycle should product strategy focus on process modifications?
    a. introduction
    b. growth
    c. maturity
    d. decline
    e. none of the above
    a (Goods and services selection, moderate)

33. Which of the following would likely cause a change in market opportunities based upon levels of income and wealth?
    a. economic change
    b. sociological and demographic change
    c. technological change
    d. political change
    e. legal change
    a (Goods and services selection, moderate)

34. A product's life cycle is divided into four stages, which are
    a. introduction, growth, saturation, and maturity
    b. introduction, growth, stability, and decline
    c. introduction, maturity, saturation, and decline
    d. introduction, growth, maturity, and decline
    e. none of the above
    d (Goods and services selection, easy)

35. When should product strategy focus on forecasting capacity requirements?
    a. at the introduction stage of the product life cycle
    b. at the growth stage of the product life cycle
    c. at the maturity stage of the product life cycle
    d. at the decline stage of the product life cycle
    e. none of the above
    b (Goods and services selection, easy)

36. Which of the following statements regarding product life cycle and profitability is true?
    a. Profit is highest in the growth life cycle phase because the product is new and unique.
    b. Profit is lowest in the growth stage of the life cycle because costs are so high.
    c. Profit is at its greatest in the decline stage of the product life cycle.
    d. Breakeven is attained in the growth stage of the product life cycle.
    e. Cash flow turns positive in the maturity phase.
    c (Goods and services selection, moderate)

37. The analysis tool that helps determine what products to develop, and by what strategy, by listing products in descending order of their individual dollar contribution to the firm is
    a. decision tree analysis
    b. Pareto analysis
    c. breakeven analysis
    d. product-by-value analysis
    e. product life cycle analysis
    d (Goods and services selection, moderate)

38. In which stage of the product life cycle should product strategy focus on improved cost control?
    a. introduction
    b. growth
    c. maturity
    d. decline
    e. none of the above
    c (Goods and services selection, moderate)

39. _____ is used to rank a company's products to determine which products represent the best use of the firm's resources, or, perhaps, to determine which products are to be eliminated.
    a. Value analysis
    b. Value engineering
    c. Financial analysis
    d. Product-by-value analysis
    e. Product cost justification
    d (Goods and services selection, easy)

40. Which of the following represent an opportunity for generating a new product?
    a. understanding the customer
    b. demographic change, such as decreasing family size
    c. changes in professional standards
    d. economic change, such as rising household incomes
    e. All of the above are such opportunities.
    e (Generating new products, moderate)

41. Which of the following is **true** regarding value engineering?
    a. Value engineering occurs only after the product is selected and designed.
    b. Value engineering is the same as value analysis.
    c. Value engineering is oriented toward improvement of design.
    d. Value engineering occurs during production when it is clear the product is a success.
    e. Value engineering can save substantial amounts of product cost, but quality suffers.
    c (Product development, moderate)

42. Reducing the complexity of a product and improving a product's maintainability for use are activities of
    a. Product Lifecycle Management (PLM)
    b. product-by-value-analysis
    c. manufacturability and value engineering
    d. organizing for product development
    e. design for destruction (DFD)
    c (Product development, moderate)

43. Quality function deployment (QFD)
    a. determines what will satisfy the customer
    b. translates customer desires into the target design
    c. is used early in the design process
    d. is used to determine where to deploy quality efforts
    e. all of the above
    e (Product development, moderate)

44. A graphic technique for defining the relationship between customer desires and product/service is
    a. Product Lifecycle Management
    b. the House of Quality
    c. the moment of truth
    d. the assembly drawing
    e. the product development team
    b (Product development, moderate)

45. Which of the following is **true** regarding computer-aided design?
    a. It is too expensive to use in most manufacturing and design settings.
    b. It is an old technology, no longer in significant use.
    c. It results in longer development cycles for virtually all products.
    d. It is the use of computers to interactively design products and prepare engineering documentation.
    e. All of the above are true.
    d (Issues for product design, moderate) {AACSB: Use of IT}

46. Which of the following is **true** concerning CAD?
    a. Accurate information flows to other departments.
    b. Most product costs are determined at the design stage.
    c. Design options are easier to review before final commitments are made.
    d. Virtually all products have their development cycle shortened.
    e. All of the above are true.
    e (Issues for product design, moderate) {AACSB: Use of IT}

47. What country has become a popular destination for the disposal of electronic waste?
    a. Japan
    b. Hungary
    c. Vietnam
    d. China
    e. New Zealand
    d (Issues for product design, moderate)

48. Black & Decker's hand-powered tools and Hewlett-Packard's printer business are examples of using enhancements and migrations of existing products to build on a what?
    a. product template
    b. product pulpit
    c. product platform
    d. product dais
    e. product foundation
    c (Time-based competition, moderate)

49. An operations manager's most ethical activity is
    a. to enhance productivity while delivering desired goods and services
    b. to use less energy
    c. to use more recycled ingredients
    d. to use less harmful ingredients
    e. to follow appropriate OSHA and EPA regulations
    a (Issues for product design, moderate) {AACSB: Ethical Reasoning}

50. Value analysis takes place
    a. when the product is selected and designed
    b. during the initial stages of production when something needs to be done to assure product success
    c. when the product is first conceived
    d. during the production process when it is clear the new product is a success
    e. when the product cost is very low
    d (Issues for product design, moderate)

51. Which of the following makes products that are friendlier to the environment?
    a. using less materials
    b. more recycled materials
    c. using less energy
    d. using less harmful ingredients
    e. all of the above
    e (Issues for product design, moderate) {AACSB: Ethical Reasoning}

52. Products are more "environmentally friendly" when they are made
    a. using cheaper materials
    b. using less energy
    c. according to OSHA standards
    d. where environmental regulations are lax
    e. more difficult to disassemble
    b (Issues for product design, easy) {AACSB: Ethical Reasoning}

53. An operations manager's ethical responsibilities
    a. are limited to the production phase of product life cycle
    b. are limited to following published laws and regulations
    c. extend from design, to production, to final destruction/disposition of a product
    d. do not include being efficient with the firm's resources
    e. need not consider a product design's impact on the entire economy
    c (Issues for product design, moderate) {AACSB: Ethical Reasoning}

54. Which of the following is an example of an **external** product development strategy?
    a. new internally developed products
    b. enhancements to existing products
    c. alliances
    d. migrations of existing products
    e. All of the above are examples of internal product development strategy.
    c (Time-based competition, moderate)

55. Which of the following product development strategies has the highest risk?
    a. acquiring the developer
    b. alliances
    c. joint ventures
    d. new internally developed products
    e. purchasing technology
    d (Time-based competition, moderate)

56. An engineering drawing shows the
    a. dimensions, tolerances, materials, and finishes of a component
    b. dimensions, tolerances, cost, and sales or use volume of a component
    c. materials, finishes, machining operations, and dimensions of a component
    d. cost, materials, tolerances, and lead-time for a component
    e. cost, dimensions, and machining operations for a component
    a (Defining the product, moderate)

57. The dimensions, tolerances, materials, and finishes of a component are typically shown on a(n)
    a. assembly chart
    b. engineering drawing
    c. bill of material
    d. assembly drawing
    e. route sheet
    b (Defining the product, moderate)

58. Which of the following does **not** result from the effective use of group technology?
    a. reduced tooling setup time
    b. simplified training
    c. reduced raw materials and purchases
    d. simplified production planning and control
    e. improved layout, routing, and machine loading
    b (Defining the product, moderate)

59. Which of the following typically shows the components, their description, and the quantity of each required to make one unit of a product?
    a. an engineering drawing
    b. an assembly drawing
    c. a bill of material
    d. an assembly chart
    e. a route sheet
    c (Documents for production, moderate)

60. Which of the following shows in schematic form how a product is assembled?
    a. an engineering drawing
    b. an assembly routing
    c. an assembly chart
    d. a route sheet
    e. a process sheet
    c (Documents for production, moderate)

61. The components, their description, and the quantity of each required to make one unit of a product are documented on
    a. a group technology listing
    b. a route sheet
    c. a bill of materials
    d. an engineering drawing
    e. none of the above
    c (Documents for production, moderate)

62. A route sheet provides a(n)
    a. exploded view of the product
    b. instruction to make a given quantity of a particular item
    c. schematic showing how the product is assembled
    d. sequence of operations necessary to produce the component
    e. set of detailed instructions about how to perform a task
    d (Documents for production, moderate)

63. Group technology requires that
    a. each component be identified by a coding scheme that specifies the type of processing and the parameters of the processing
    b. a specific series of engineering drawings be prepared
    c. all bills of material be prepared using the same format
    d. engineering change notices be linked to each of the bills of material and engineering notices
    e. the final products be standardized
    a (Defining the product, moderate)

64. An assembly drawing
    a. shows, in schematic form, how the product is assembled
    b. shows an exploded view of the product
    c. lists the operations, including assembly and inspection, necessary to produce the component with the material specified in the bill of material
    d. provides detailed instructions on how to perform a given task
    e. describes the dimensions and finish of each component
    b (Documents for production, easy)

65. An assembly chart
    a. shows graphically how the product is assembled
    b. shows an exploded view of the product
    c. lists the operations, including assembly and inspection, necessary to produce the component with the material specified in the bill of material
    d. provides detailed instructions on how to perform a given task
    e. describes the dimensions and finish of each component
    a (Documents for production, easy)

66. A process sheet is a type of
    a. assembly drawing
    b. assembly chart
    c. route sheet
    d. work order
    e. bill of materials
    c (Documents for production, moderate)

67. Which of the following documents lists the operations (including assembly and inspection) necessary to produce the component with the material specified in the bill of material?
    a. an engineering drawing
    b. an assembly drawing
    c. a route sheet
    d. an assembly chart
    e. an operations chart
    c (Documents for production, moderate)

68. A restaurant kitchen contains a wall poster that shows, for each sandwich on the menu, a sketch of the ingredients and how they are arranged to make the sandwich. This is an example of a(n)
    a. assembly drawing
    b. route sheet
    c. bill of materials
    d. work order
    e. virtual technology
    a (Documents for production, moderate)

69. The document for production that gives the instruction to make a given quantity of a particular item, usually to a given schedule, is
    a. the work order
    b. the route sheet
    c. the bill of information
    d. the assembly chart
    e. the value analysis
    a (Documents for production, moderate)

70. Which of the following is **not** a service design technique used to reduce cost?
    a. increasing customer interaction
    b. delaying customization
    c. automation
    d. modularizing the product
    e. reducing customer interaction
    a (Service design, moderate)

71. Which of the following examples involves customer participation in the design of the service?
    a. investing in a mutual fund
    b. buying a life insurance policy
    c. providing the stockbroker with the desired distribution of the portfolio
    d. seeing a movie at the theater
    e. eating at a fast-food restaurant
    c (Service design, moderate) {AACSB: Communication}

72. Modern ATM machines are an automated example of a service design that
    a. reduces customer interaction
    b. modularizes the service
    c. delays service customization
    d. has no moment of truth
    e. has insufficient quality function deployment
    a (Service design, moderate)

73. For a full-time college student, which of the following moments of truth exemplifies the customer's standard expectations?
    a. Your advisor made you wait, even though you had an appointment.
    b. You had to visit more than once to reach your academic advisor.
    c. Your advisor was competent, helpful, and understanding.
    d. Your advisor failed to keep her appointment with you.
    e. Your advisor offered to work with you after regular work hours.
    c (Service design, difficult)

74. Which service design technique(s) would ordinarily **not** be appropriate for full-service restaurant meals?
    a. modularizing the product
    b. customization as late in the process as possible
    c. reducing customer interaction
    d. the moment of truth
    e. All of the above are appropriate.
    c (Service design, moderate)

75. Which of the following scenarios illustrates a moment that **exceeds** the customer's expectations?
    a. an express mail service that guarantees overnight delivery
    b. a flight attendant that responds shortly after being called
    c. a hairdresser that cuts your hair at the right length
    d. a professor that contacts people in several companies to find you a job
    e. a bank that sends you monthly account statements
    d (Service design, difficult)

76. Which of the following scenarios illustrates a moment that **meets** the customer's expectations?
    a. a sales clerk that called you by your name on your second visit to the store
    b. an express mail service that guarantees same day delivery
    c. a flight attendant that responds shortly after being called
    d. a professor that contacts people in several companies to find you a job
    e. a sales clerk at the clothing store that asked you to wait for a minute as soon as a wealthy-looking customer entered the store

    c (Service design, difficult)

77. The role of decision trees in product design is
    a. to rank products in descending order of their dollar contribution to the firm
    b. to better understand the customers' wants
    c. to calculate the expected value of each course of action
    d. to calculate the value of quality function deployment
    e. to calculate the value of the moment of truth

    c (Application of decision trees to product design, easy)

78. Payoffs, alternatives, and expected monetary values are terms associated with
    a. virtual reality
    b. Product Lifecycle Management
    c. Quality Function Deployment
    d. decision trees
    e. make-or-buy analysis

    d (Application of decision trees to product design, easy)

FILL-IN-THE-BLANK

79. Regal Marine's use of _____ has reduced product development time and reduced problems with tooling and production.
    CAD or Computer-aided Design (Global company profile, moderate) {AACSB: Use of IT}

80. In the _____ phase of the product life cycle, the product design has begun to stabilize.
    growth (Goods and services selection, moderate)

81. _____ lists products in descending order of the individual dollar contribution to the firm.
    Product-by-value analysis (Goods and service selection, moderate)

82. _____ is a process for determining customer requirements and translating them into attributes that each functional area can understand and act upon.
    Quality Function Deployment or QFD (Goods and service selection, moderate)

83. The _____ is a part of the quality function deployment process that utilizes a planning matrix to relate customer "wants" to "how" the firm is going to meet those "wants."
    House of Quality (Goods and service selection, moderate)

84. _____ provides a format allowing the electronic transmittal of three-dimensional data.
    Standard for the exchange of product data or STEP (Generating new products, moderate) {AACSB: Use of IT}

85. The use of information technology to control machinery is called _____.
computer-aided manufacturing or CAM (Generating new products, moderate) {AACSB: Use of IT}

86. If a design can be produced to requirements even when the production process has unfavorable conditions, the design is said to be _____.
robust (Issues for product design, moderate)

87. Products or services designed in easily segmented components are known as _____.
modular designs (Issues for product design, moderate)

88. _____ reviews successful products for improvement during the production process.
Value analysis (Issues for product design, moderate)

89. Sensitivity to a wide variety of environmental issues in production processes is referred to as _____.
green manufacturing (Issues for product design, moderate) {AACSB: Ethical Reasoning}

90. To view product design from a "systems" perspective, managers must view a product in terms of its impact on _____.
the entire economy (Issues for product design, easy)

91. Boeing's use of epoxy composites and titanium graphite laminate represent the ethical and environmentally friendly concept of _____.
use lighter components (Issues for product design, easy) {AACSB: Ethical Reasoning}

92. Rapidly developing products and moving them to the market is referred to as _____.
time-based competition (Time-based competition, easy)

93. A drawing that shows the dimensions, tolerances, materials, and finishes of a component is a(n) _____.
engineering drawing (Documents for production, easy)

94. A listing of the components, their description, and the quantity of each required to make one unit of product is the _____.
bill of materials (Documents for production, moderate)

95. Black & Decker’s hand-powered tools and Hewlett-Packard’s printer business are examples of using enhancements and migrations of existing products to build on _____.
product platforms (Time-based competition, moderate)

96. An exploded view of the product is a(n) _____.
assembly drawing (Documents for production, moderate)

97. The _____ is the crucial moment between the service provider and the customer that exemplifies, enhances, or detracts from the customer's expectations.
moment-of-truth (Service design, moderate)

98. In analyzing product design decisions, decision trees determine the _____ of each course of action.
expected value or EMV (Application of decision trees to product design, moderate)

SHORT ANSWER

99. What is the objective of the product decision?
Develop and implement a product strategy that meets the demands of the marketplace with a competitive advantage. (Goods and services selection, moderate)

100. What is a product-by-value analysis, and what type of decision does it help managers make?
A product-by-value analysis lists products in descending order of their individual dollar contribution to the firm, as well as the total annual dollar contribution of the product. It helps managers evaluate possible strategies for each product. The product-by-value report focuses management's attention on the strategic direction for each product. (Goods and services selection, moderate)

101. Identify the factors that influence new product opportunities.
Factors that influence new product opportunities include economic change, sociological and demographic change, technological change, political change, and other changes brought about through market practice, professional standards, suppliers, and distributors. (Goods and services selection, moderate)

102. "With respect to the product decision, managers must be able to accept risk and tolerate failure." Comment on why this is a necessary hazard in making new product decisions, given all the powerful tools and carefully built systems that support that decision.
The vast majority of new product ideas do not become marketable products, and most marketable products are failures. Perhaps 500 designs accompany each success. (Goods and services selection, moderate)

103. Identify the general benefits derived from CAD.
Product quality (better adherence to standards); shorter design time; production cost reductions (from better design); database availability (for new products); and new range of capabilities (ease programming of CNC machines). (Generating new products, moderate) {AACSB: Use of IT}

104. Is it possible for a product's life cycle stage to affect its product strategy? In particular, describe how one product in **growth** and another in **maturity** might have different product strategies.
There is no reason for the strategy to be static through the life cycle stages. Organizations often treat new products differently than older ones, in terms of support for changes, aggressiveness in pursuit of market, etc. In particular, growth is associated with stabilization of design, and with ensuring that sufficient capacity exists. Maturity is a time for high-volume operations and cost control. (Goods and services selection, moderate)

105. Desribe the benefits associated with value engineering.
Benefits include immediate cost reductions; reduced product complexity; additional standardization of components; improvement of functional aspects of the products; improved job design and job safety; improved maintainability (serviceability) of the product; and robust design. (Product development, moderate)

106. Provide some examples of recent product changes, i.e. new products that are replacing older ones.
Answers will vary. The list in the text includes: TV to HDTV, radio to satellite radio, coffee shops to Starbucks lifestyle coffee, traveling circuses to Cirque du Soleil, land lines to cell phones, cell phone to Blackberry, Walkman to iPod, and mops to Swiffers. (Generating new products, moderate) {AACSB: Reflective Thinking}

107. What is quality function deployment (QFD)?
QFD refers to determining what will satisfy the customer and translating those customer desires into the target design. (Product development, easy)

108. Identify the steps involved in building the House of Quality.
Identify customers' wants, identify product/service attributes, relate the customers' wants to the product/service how's, conduct an evaluation of competing products, develop performance specifications for product or service how's, and assign how's to the appropriate place in the transformation process. (Product development, moderate)

109. Explain the difference between value analysis and value engineering.
Value engineering is concerned with reducing cost and improving function in a preproduction setting; value analysis, with similar aims, takes place during production, when the product has shown that it will succeed. Techniques are similar. (Product development and Issues for product design, moderate)

110. Aggressive new product development requires that organizations build structures internally that contain what features?
They should have open communication with customers, innovative organizational cultures, aggressive R&D, strong leadership, formal incentives, and training. (Generating new products, difficult) {AACSB: Communication}

111. What two issues should be considered in combination in order to enhance the likelihood of ethical decision in the realm of product design? Why is each important?
The two issues are (1) view product design from a "systems" perspective, and (2) consider the life cycle of the product. The first issue causes managers to go beyond "what is best or cheapest for the firm?" The second causes managers to address environmental concerns over the life of the product, not just at time of manufacture. (Issues for product design, moderate) {AACSB: Ethical Reasoning}

112. Identify the specific guidelines that can help an operations manager achieve environmentally friendly designs.
Specifically, the following ideas are presented in the text: make products recyclable, use recycled material, use less harmful ingredients, use lighter components, use less energy, and use less material. (Issues for product design, moderate) {AACSB: Ethical Reasoning}

113. What are some of the benefits from using environmental teams for product design?
Environmental teams help develop safe and more environmentally sound products, minimize the waste of raw materials and energy, differentiate products from competition, reduce environmental liabilities, increase cost-effectiveness of complying with environmental regulations, and help the organization be recognized as a good corporate citizen. (Issues for product design, moderate) {AACSB: Ethical Reasoning}

114. Discuss the advisability of using modular assemblies in manufacturing. (What are the advantages and disadvantages?) To what extent can these arguments be utilized in service products?
Modules are easily segmented components; they add flexibility to production and marketing; allows mix-and-match of components (customization at point of customer contact). Use of modules usually means fewer parts, less design and tooling expense. Disadvantages include using a module in a product for which a more specific component would have been better. Modules exist in services, as in fast-food meals built to customer specification. (Issues for product design, difficult)

115. What is time-based competition?
Time-based competition is competition that is based on time. It involves rapid development of products, fast introduction to the marketplace. Often, the first company into production may have its product adopted as the "standard." (Time-based competition, moderate)

116. State the benefits of implementing group technology.
Benefits include improved design; reduced raw materials and purchases; simplified production planning and control; improved routing and machine loading; reduced tooling setup time, work-in-process, and production time; and development of work cells. (Defining the product, moderate)

117. Identify the external product development strategies; describe each in a sentence or two.
The external product development strategies include alliances, joint ventures, and purchase of technology or expertise by acquiring the developer. Alliances are cooperative agreements that allow firms to remain independent, but use complementing strengths to pursue strategies consistent with their individual missions. Joint ventures are combined ownership to pursue new products or markets. Purchasing technology or expertise is usually accomplished by acquiring entrepreneurial firms that have already developed the technology that fits the mission. The issue then becomes fitting the purchased organization, its technology, and its product line into the buying firm, rather than a product development issue. (Time-based competition, moderate)

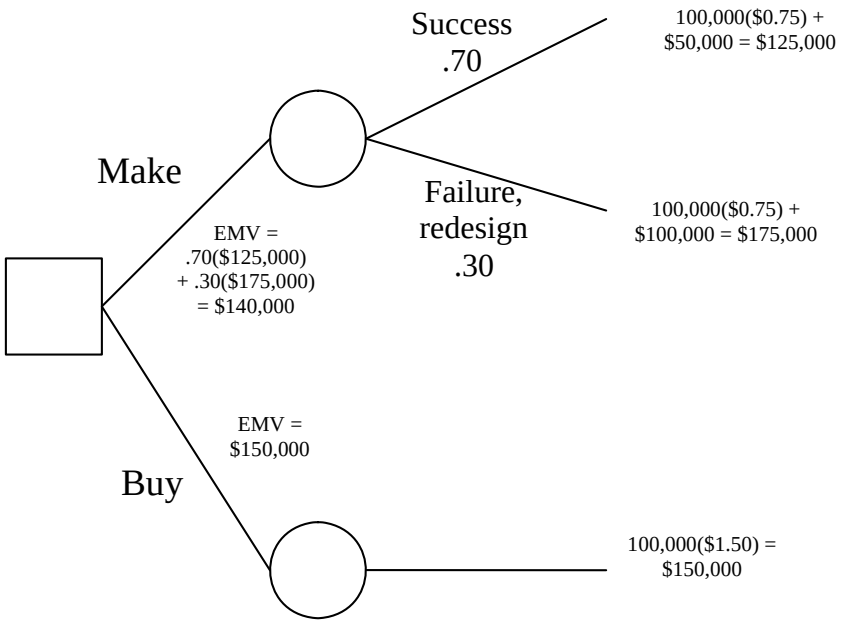
118. How does configuration management manifest itself when you ask for service on your automobile?
Configuration management is used by every automobile manufacturer to track all of the changes between and during a model year. To be specific about the part that is needed, the VIN (vehicle identification number) is often used. (Documents for production, moderate)

119. Briefly explain how Product Lifecycle Management (PLM) impacts product design.
PLM is an umbrella of software programs that attempts to bring together many phases of product design and manufacture. PLM products often start with product design (CAD/CAM); move on to design for manufacture and assembly (DFMA); and then into product routing, materials, layout, assembly, maintenance and even environmental issues. (Documents for production, moderate)

120. Identify the four methods of service design that can reduce costs and enhance the product.
Customizing as late in the process as possible; modularizing the product; identifying the service parts that lend themselves to automation or reduced customer interaction; and focusing design on the moment of truth. (Service design, moderate)

PROBLEMS

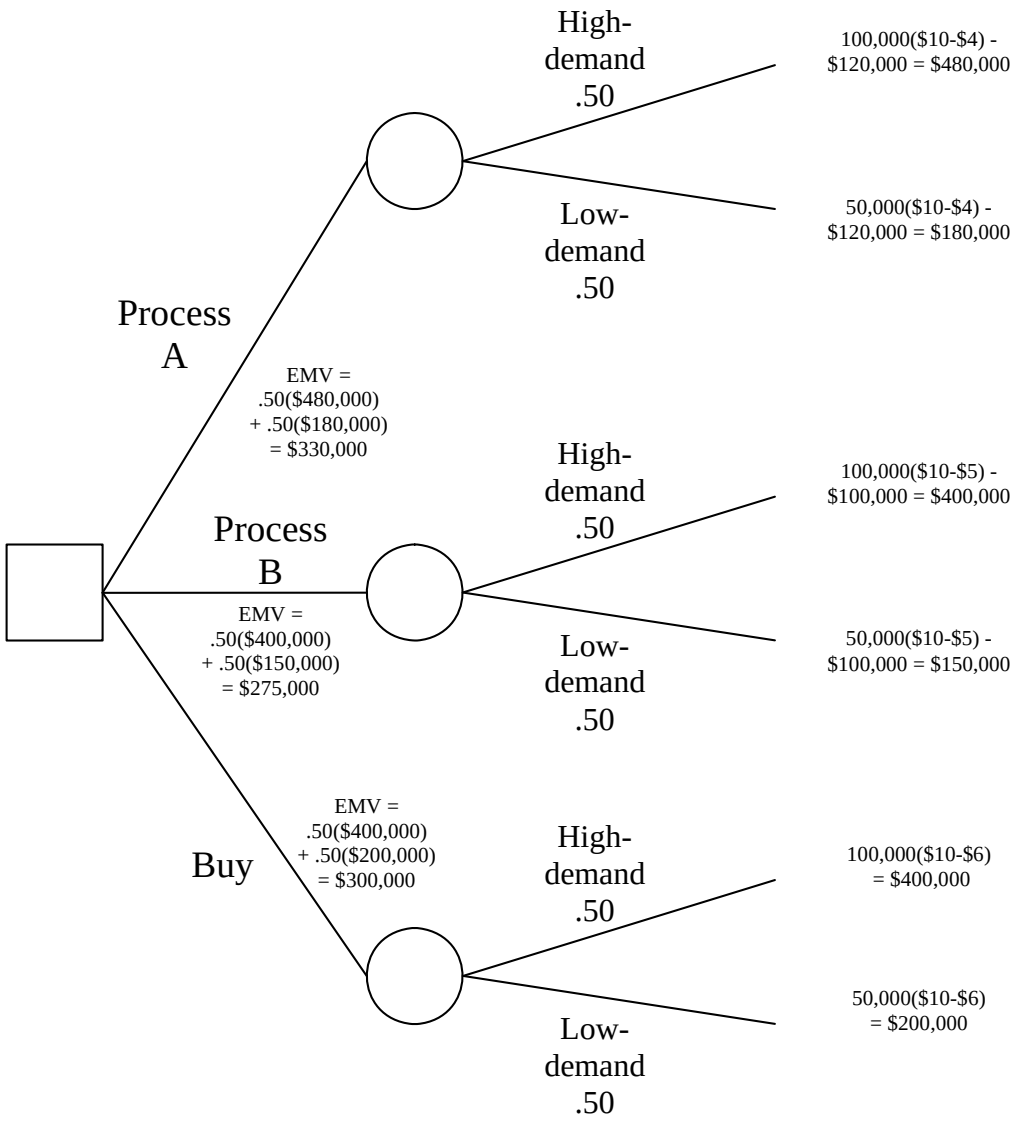
121. JDI, Inc. is trying to decide whether to make-or-buy a part (#J-45FPT). Purchasing the part would cost them $1.50 each. If they design and produce it themselves, it will result in a per unit cost of $0.75. However, the design investment would be $50,000. Further, they realize that for this type of part, there is a 30% chance that the part will need to be redesigned at an additional cost of $50,000. Regardless of whether they make-or-buy the part, JDI will need 100,000 of these parts. Using decision trees analysis and EMV, what should JDI do? Show the decision tree.
Since the expected values represent costs, JDI should select the lowest expected value, and make the part. Its expected monetary value (cost) is $140,000 versus $150,000 for the buy decision.



(Application of decision trees to product design, moderate) {AACSB: Analytic Skills}

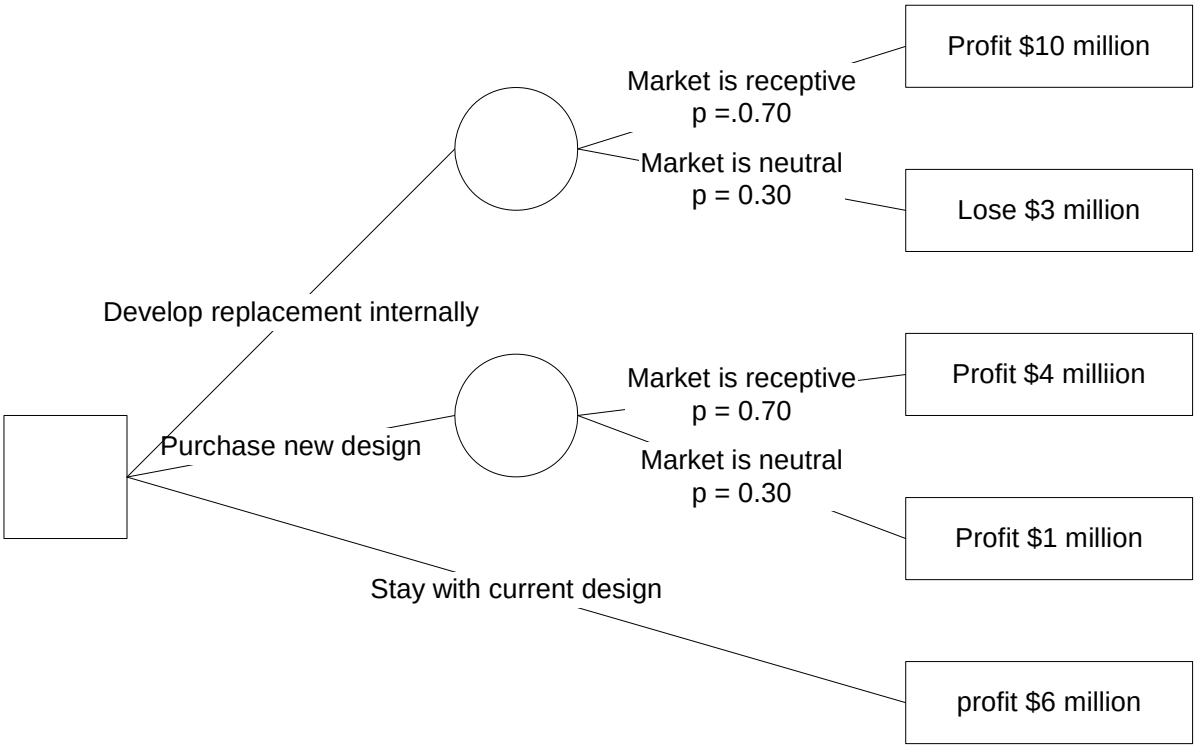
122. Tri-products is trying to decide whether to make-or-buy an accessory item for one of their products. It is projected that this item will sell for $10 each. If the item is outsourced, there is virtually no cost other than the $6 per unit that they would pay their supplier. Internally, they have two choices. Process A requires an investment of $120,000 for design and equipment, but results in a $4 per unit cost. Process B requires only a $100,000 investment, but its per unit cost is $5. Regardless of whether the item is subcontracted or produced internally, there is a 50% chance that they will sell 50,000 units, and a 50% chance that they will sell 100,000 units. Draw the decision tree appropriate to the alternatives and outcomes stated. Using decision trees and EMV, what is their best choice?

Process A promises the highest profit with an EMV of $330,000.



(Application of decision trees to product design, moderate) {AACSB: Analytic Skills}

123. A company manufactures specialty pollution-sensing devices for the offshore oil industry. One particular device has reached maturity, and the company is considering whether to replace it with a newer model. Technologies have not changed dramatically, so the new device would have similar functionality to the existing one, but would be smaller and lighter in weight. The firm's three choices are: keep the old model; design a replacement device with internal resources; and purchase a new design from a firm that is one of its suppliers. The market for these devices will be either "receptive" or "neutral" of the replacement model. The financial estimates are as follows: Keeping the old design will yield a profit of $6 million dollars. Designing the replacement internally will yield $10 million if the market is "receptive," but a $3 million loss if the market is "neutral." Acquiring the new design from the supplier will profit $4 million under "receptive," $1 million under "neutral." The company feels that the market has a 70 percent chance of being "receptive" and a 30 percent chance of being "neutral." Draw the appropriate decision tree. Calculate expected value for all courses of action. What action yields the highest expected value?



The three expected monetary values are:
Develop replacement internally: $10,000,000 x .7 -$3,000,000 x .3 = $6.1 million
Purchase new design: $4,000,000 x .7 + $1,000,000 x .3 = $3.1 million
Stay with current design: $6 million
The company should choose the highest value, and develop a replacement product design with internal resources. (Application of decision trees to product design, moderate) {AACSB: Analytic Skills}

CHAPTER 6: MANAGING QUALITY

TRUE/FALSE

1. Managers at Arnold Palmer Hospital take quality so seriously that the hospital typically is a national leader in several quality areas—so that continuous improvement is no longer necessary.
False (Global company profile, moderate)

2. An improvement in quality must necessarily increase costs.
False (Quality and strategy, easy)

3. For most, if not all organizations, quality is a tactical rather than a strategic issue.
False (Quality and strategy, moderate)

4. The definition of quality adopted by The American Society for Quality is a customer-oriented definition.
True (Defining quality, easy)

5. Conforming to standards is the focus of the product-based definition of quality.
False (Defining quality, moderate)

6. Internal failure costs are associated with scrap, rework, and downtime.
True (Defining quality, easy)

7. Philip Crosby is credited with both of these quality catch-phrases: "quality is free" and "zero defects."
True (Defining quality, easy)

8. Deming's writings on quality tend to focus on the customer and on fitness for use, unlike Juran's work that is oriented toward meeting specifications.
False (defining quality, moderate)

9. Improved quality can increase profitability via flexible pricing.
True (Defining quality, moderate)

10. ISO 9000 has evolved from a set of quality assurance standards toward a quality management system.
True (International quality standards, moderate)

11. Quality is mostly the business of the quality control staff, not ordinary employees.
False (Total quality management, moderate)

12. TQM is important because quality influences all of the ten decisions made by operations managers.
True (Total quality management, moderate)

13. The phrase Six Sigma has two meanings. One is statistical, referring to an extremely high process capability; the other is a comprehensive system for achieving and sustaining business success.
True (Quality and strategy, moderate)

14. Continuous improvement is based on the philosophy that any aspect of an organization can be improved.
True (Total quality management, moderate)

15. Kaizen is similar to TQM in that both are focused on continuous improvement.
True (Total quality management, moderate)

16. The Japanese use the term "poka-yoke" to refer to continuous improvement.
False (Total quality management, moderate) {AACSB: Multiculture and Diversity}

17. Quality circles empower employees to improve productivity by finding solutions to work-related problems in their work area.
True (Total quality management, moderate) {AACSB: Communication}

18. Benchmarking requires the comparison of your firm to other organizations; it is not appropriate to benchmark by comparing one of your divisions to another of your divisions.
False (Total quality management, moderate)

19. Line employees need the knowledge of TQM tools.
True (Total quality management, easy)

20. One of the ways that Just-In-Time (or JIT) influences quality is that by reducing inventory, bad quality is exposed.
True (Total quality management, moderate)

21. The quality loss function indicates that costs related to poor quality are low as long as the product is within acceptable specification limits.
False (Total quality management, moderate)

22. Pareto charts are a graphical way of identifying the few critical items from the many less important ones.
True (Tools of TQM, moderate)

23. A cause-and-effect diagram helps identify the source of a problem.
True (Tools of TQM, moderate)

24. Source inspection is inferior to inspection before costly operations.
False (The role of inspection, moderate)

25. Of the several determinants of service quality, **access** is the one that relates to keeping customers informed in language they can understand.
False (TQM in services, moderate)

26. High-quality products and services are the most profitable.
True (Defining quality, easy)

MULTIPLE CHOICE

27. Which of the following statements regarding Arnold Palmer Hospital is **false**?
    a. The hospital uses a wide range of quality management techniques.
    b. The culture of quality at the hospital includes employees at all levels.
    c. The hospital scores very highly in national studies of patient satisfaction.
    d. The hospital's high quality is measured by low readmission rates, not patient satisfaction.
    e. The design of patient rooms, even wall colors, reflects the hospital's culture of quality.
    d (Global company profile, moderate)

28. Arnold Palmer Hospital uses which of the following quality management techniques?
    a. Pareto charts
    b. flow charts
    c. benchmarking
    d. Just-in-Time
    e. The hospital uses all of the above techniques.
    e (Global company profile, easy)

29. Which of the following statements best describes the relationship between quality management and product strategy?
    a. Product strategy is set by top management; quality management is an independent activity.
    b. Quality management is important to the low-cost product strategy, but not to the response or differentiation strategies.
    c. High quality is important to all three strategies, but it is not a critical success factor.
    d. Managing quality helps build successful product strategies.
    e. Companies with the highest measures of quality were no more productive than other firms.
    d (Defining quality, moderate)

30. "Quality is defined by the customer" is
    a. an unrealistic definition of quality
    b. a user-based definition of quality
    c. a manufacturing-based definition of quality
    d. a product-based definition of quality
    e. the definition proposed by the American Society for Quality
    b (Defining quality, moderate)

31. "Making it right the first time" is
    a. an unrealistic definition of quality
    b. a user-based definition of quality
    c. a manufacturing-based definition of quality
    d. a product-based definition of quality
    e. the definition proposed by the American Society for Quality
    c (Defining quality, moderate)

32. Three broad categories of definitions of quality are
    a. product quality, service quality, and organizational quality
    b. user-based, manufacturing-based, and product-based
    c. internal, external, and prevention
    d. low-cost, response, and differentiation
    e. Pareto, Shewhart, and Deming
    b (Defining quality, easy)

33. According to the manufacturing-based definition of quality,
    a. quality is the degree of excellence at an acceptable price and the control of variability at an acceptable cost
    b. quality depends on how well the product fits patterns of consumer preferences
    c. even though quality cannot be defined, you know what it is
    d. quality is the degree to which a specific product conforms to standards
    e. quality lies in the eyes of the beholder
    d (Defining quality, moderate)

34. The role of quality in limiting a firm's product liability is illustrated by
    a. ensuring that contaminated products such as impure foods do not reach customers
    b. ensuring that products meet standards such as those of the Consumer Product Safety Act
    c. designing safe products to limit possible harm to consumers
    d. using processes that make products as safe or as durable as their design specifications call for
    e. All of the above are valid.
    e (Defining quality, easy) {AACSB: Ethical Reasoning}

35. Which of the following is **not** one of the major categories of costs associated with quality?
    a. prevention costs
    b. appraisal costs
    c. internal failures
    d. external failures
    e. none of the above; they are all major categories of costs associated with quality
    e (Defining quality, moderate)

36. All of the following costs are likely to decrease as a result of better quality **except**
    a. customer dissatisfaction costs
    b. inspection costs
    c. scrap costs
    d. warranty and service costs
    e. maintenance costs
    e (Defining quality, moderate)

37. Which of the following statements is not true?
    a. Self-promotion is not a substitute for quality products.
    b. Inferior products harm a firm's profitability and a nation's balance of payments.
    c. Product liability transfers from the manufacturer to the retailer once the retailer accepts delivery of the product.
    d. Quality—be it good or bad—will show up in perceptions about a firm's new products, employment practices, and supplier relations.
    e. Legislation such as the Consumer Product Safety Act sets and enforces product standards by banning products that do not reach those standards.

    c (Defining quality, moderate)

38. "Employees cannot produce goods that on average exceed the quality of what the process is capable of producing" expresses a basic element in the writings of
    a. Vilfredo Pareto
    b. Armand Feigenbaum
    c. Joseph M. Juran
    d. W. Edwards Deming
    e. Philip B. Crosby

    d (Defining quality, moderate)

39. "Quality Is Free," meaning that the costs of poor quality have been understated, is the work of
    a. W. Edwards Deming
    b. Joseph M. Juran
    c. Philip B. Crosby
    d. Crosby, Stills, and Nash
    e. Armand Feigenbaum

    c (Defining quality, moderate)

40. The philosophy of zero defects is
    a. the result of Deming's research
    b. unrealistic
    c. prohibitively costly
    d. an ultimate goal; in practice, 1 to 2% defects is acceptable
    e. consistent with the commitment to continuous improvement

    e (Total quality management, moderate)

41. Based on his 14 Points, Deming is a strong proponent of
    a. inspection at the end of the production process
    b. an increase in numerical quotas to boost productivity
    c. looking for the cheapest supplier
    d. training and knowledge
    e. all of the above

    d (Total quality management, moderate)

42. Stakeholders who are affected by the production and marketing of poor quality products include
    a. stockholders, employees, and customers
    b. suppliers and creditors, but not distributors
    c. only stockholders, creditors, and owners
    d. suppliers and distributors, but not customers
    e. only stockholders and organizational executives and managers
    a (Defining quality, moderate) {AACSB: Ethical Reasoning}

43. Regarding the quality of design, production, and distribution of products, an ethical requirement for management is to
    a. determine whether any of the organization's stakeholders are violated by poor quality products
    b. gain ISO 14000 certification for the organization
    c. obtain a product safety certificate from the Consumer Product Safety Commission
    d. have the organization's legal staff write disclaimers in the product instruction booklets
    e. compare the cost of product liability to the external failure cost
    a (Defining quality, moderate) {AACSB: Ethical Reasoning}

44. If 1 million passengers pass through the St. Louis Airport with checked baggage each month, a successful Six Sigma program for baggage handling would result in how many passengers with misplaced luggage?
    a. 3.4
    b. 6.0
    c. 34
    d. 2700
    e. 6 times the monthly standard deviation of passengers
    a (Total quality management, moderate) {AACSB: Analytic Skills}

45. Which of the following is **true** about ISO 14000 certification?
    a. It is not a prerequisite for ISO 9000 certification.
    b. It deals with environmental management.
    c. It offers a good systematic approach to pollution prevention.
    d. One of its core elements is life-cycle assessment.
    e. All of the above are true.
    e (International quality standards, moderate)

46. Suppose that a firm has historically been achieving “three-sigma” quality. If the firm later changes its quality management practices such that begins to achieve “six-sigma” quality, which of the following phenomena will result?
    a. The average number of defects will be cut in half.
    b. The specification limits will be moved twice as far from the mean.
    c. The average number of defects will be cut by 99.9997%.
    d. The average number of defects will be cut by 99.87%.
    e. The average number of defects will be cut by 99.73%.
    d (Total quality management, difficult) {AACSB: Analytic Skills}

47. To become ISO 9000 certified, organizations must
    a. document quality procedures
    b. have an onsite assessment
    c. have an ongoing series of audits of their products or service
    d. all of the above
    e. none of the above
    d (International quality standards, moderate)

48. Total quality management emphasizes
    a. the responsibility of the quality control staff to identify and solve all quality-related problems
    b. a commitment to quality that goes beyond internal company issues to suppliers and customers
    c. a system where strong managers are the only decision makers
    d. a process where mostly statisticians get involved
    e. ISO 14000 certification
    b (Total quality management, moderate)

49. A successful TQM program incorporates all of the following **except**
    a. continuous improvement
    b. employee involvement
    c. benchmarking
    d. centralized decision-making authority
    e. none of the above; a successful TQM program incorporates all of the above
    d (Total quality management, moderate)

50. "Kaizen" is a Japanese term meaning
    a. a foolproof mechanism
    b. just-in-time (JIT)
    c. a fishbone diagram
    d. setting standards
    e. continuous improvement
    e (Total quality management, easy) {AACSB: Multiculture and Diversity}

51. Which of the following statements regarding "Six Sigma" is **true**?
    a. The term has two distinct meanings—one is statistical; the other is a comprehensive quality system.
    b. Six Sigma means that about 94 percent of a firm's output is free of defects.
    c. The Six Sigma program was developed by Toyota in the 1970's.
    d. The Six Sigma program is for manufacturing firms, and is not applicable to services.
    e. Six Sigma certification is granted by the International Standards Organization (ISO).
    a (Total quality management, moderate)

52. Quality circles members are
    a. paid according to their contribution to quality
    b. external consultants designed to provide training in the use of quality tools
    c. always machine operators
    d. all trained to be facilitators
    e. none of the above; all of the statements are false
    e (Total quality management, moderate)

53. Techniques for building employee empowerment include
    a. building communication networks that include employees
    b. developing open, supportive supervisors
    c. moving responsibility from both managers and staff to production employees
    d. building high-morale organizations
    e. All of the above are techniques for employee empowerment.
    e (Total quality management, moderate)

54. Building high-morale organizations and building communication networks that include employees are both elements of
    a. ISO 9000 certification
    b. Six Sigma certification
    c. employee empowerment
    d. Taguchi methods
    e. the tools of TQM
    c (Total quality management, moderate) {AACSB: Communication}

55. The process of identifying other organizations that are best at some facet of your operations and then modeling your organization after them is known as
    a. continuous improvement
    b. employee empowerment
    c. benchmarking
    d. copycatting
    e. patent infringement
    c (Total quality management, moderate)

56. ISO 9000 seeks standardization in terms of
    a. products
    b. production procedures
    c. suppliers' specifications
    d. procedures to manage quality
    e. all of the above
    d (International quality standards, moderate)

57. Costs of dissatisfaction, repair costs, and warranty costs are elements of cost in the
    a. Taguchi Loss Function
    b. Pareto chart
    c. ISO 9000 Quality Cost Calculator
    d. process chart
    e. none of the above
    a (Total quality management, moderate)

58. A quality loss function includes all of the following costs **except**
    a. the cost of scrap and repair
    b. the cost of customer dissatisfaction
    c. inspection, warranty, and service costs
    d. sales costs
    e. costs to society
    d (Tools of TQM, moderate)

59. Pareto charts are used to
    a. identify inspection points in a process
    b. outline production schedules
    c. organize errors, problems, or defects
    d. show material flow
    e. all of the above
    c (Tools of TQM, moderate)

60. The "four Ms" of cause-and-effect diagrams are
    a. material, machinery/equipment, manpower, and methods
    b. material, methods, men, and mental attitude
    c. named after four quality experts
    d. material, management, manpower, and motivation
    e. none of the above
    a (Tools of TQM, moderate)

61. Among the tools of TQM, the tool ordinarily used to aid in understanding the sequence of events through which a product travels is a
    a. Pareto chart
    b. process chart
    c. check sheet
    d. Taguchi map
    e. poka-yoke
    b (Tools of TQM, moderate)

62. The process improvement technique that sorts the "vital few" from the "trivial many" is
    a. Taguchi analysis
    b. Pareto analysis
    c. benchmarking
    d. Deming analysis
    e. Yamaguchi analysis
    b (Tools of TQM, moderate)

63. A production manager at a pottery factory has noticed that about 70 percent of defects result from impurities in raw materials, 15 percent result from human error, 10 percent from machine malfunctions, and 5 percent from a variety of other causes. This manager is most likely using
    a. a Pareto chart
    b. a scatter diagram
    c. a Taguchi loss function
    d. a cause and effect diagram
    e. a flow chart
    a (Tools of TQM, easy)

64. A customer service manager at a retail clothing store has collected numerous customer complaints from the forms they fill out on merchandise returns. To analyze trends or patterns in these returns, she has organized these complaints into a small number of categories. This is most closely related to the _____ tool of TQM.
    a. Taguchi loss function
    b. cause and effect diagram
    c. scatter diagram
    d. histogram
    e. process control chart
    b (Tools of TQM, easy)

65. A manager tells her production employees, "It's no longer good enough that your work fall anywhere within the specification limits. I need your work to be as close to the target value as possible." Her thinking is reflective of
    a. internal benchmarking
    b. Six Sigma
    c. ISO 9000
    d. Taguchi concepts
    e. process control charts
    d (Tools of TQM, moderate)

66. A fishbone diagram is also known as a
    a. cause-and-effect diagram
    b. poka-yoke diagram
    c. Kaizen diagram
    d. Kanban diagram
    e. Taguchi diagram
    a (Tools of TQM, easy)

67. If a sample of parts is measured and the mean of the measurements is outside the control limits, the process is
    a. in control, but not capable of producing within the established control limits
    b. out of control and the process should be investigated for assignable variation
    c. within the established control limits with only natural causes of variation
    d. monitored closely to see if the next sample mean will also fall outside the control limits
    e. none of the above
    b (Tools of TQM, moderate)

68. A quality circle holds a brainstorming session and attempts to identify the factors responsible for flaws in a product. Which tool do you suggest they use to organize their findings?
    a. Ishikawa diagram
    b. Pareto chart
    c. process chart
    d. control charts
    e. activity chart
    a (Tools of TQM, moderate) {AACSB: Communication}

69. When a sample measurement falls inside the control limits, it means that
    a. each unit manufactured is good enough to sell
    b. the process limits cannot be determined statistically
    c. the process output exceeds the requirements
    d. if there is no other pattern in the samples, the process is in control
    e. the process output does not fulfill the requirements
    d (Tools of TQM, moderate,)

70. Which of the following is **false** regarding control charts?
    a. Values above the upper control limits always imply that the product's quality is exceeding expectations.
    b. Control charts are built so that new data can be quickly compared to past performance data.
    c. Control charts graphically present data.
    d. Control charts plot data over time.
    e. None of the above is false.
    a (Tools of TQM, moderate)

71. The goal of inspection is to
    a. detect a bad process immediately
    b. add value to a product or service
    c. correct deficiencies in products
    d. correct system deficiencies
    e. all of the above
    a (The role of inspection, moderate)

72. Which of the following is **not** a typical inspection point?
    a. upon receipt of goods from your supplier
    b. during the production process
    c. before the product is shipped to the customer
    d. at the supplier's plant while the supplier is producing
    e. after a costly process
    e (The role of inspection, moderate)

73. A good description of "source inspection" is inspecting
    a. materials upon delivery by the supplier
    b. the goods at the production facility before they reach the customer
    c. the goods as soon as a problem occurs
    d. goods at the supplier's plant
    e. one's own work, as well as the work done at the previous work station
    e (The role of inspection, moderate)

74. "Poka-yoke" is the Japanese term for
    a. card
    b. foolproof
    c. continuous improvement
    d. fishbone diagram
    e. just-in-time production
    b (The role of inspections, moderate) {AACSB: Multiculture and Diversity}

75. What refers to training and empowering frontline workers to solve a problem immediately?
    a. just-in-time
    b. poka-yoke
    c. benchmarking
    d. *kaizen*
    e. service recovery
    e (TQM in services, easy)

76. A recent consumer survey conducted for a car dealership indicates that, when buying a car, customers are primarily concerned with the salesperson's ability to explain the car's features, the salesperson's friendliness, and the dealer's honesty. The dealership should be **especially** concerned with which determinants of service quality?
    a. communication, courtesy, and credibility
    b. competence, courtesy, and security
    c. competence, responsiveness, and reliability
    d. communication, responsiveness, and reliability
    e. understanding/knowing customer, responsiveness, and reliability
    a (TQM in services, moderate) {AACSB: Communication}

77. Marketing issues such as advertising, image, and promotion are important to quality because
    a. they define for consumers the tangible elements of a service
    b. the intangible attributes of a product (including any accompanying service) may not be defined by the consumer
    c. they educate consumers on how to use the product
    d. they make the product seem more valuable than it really is
    e. they raise expenses and therefore decrease profitability
    b (TQM in services, moderate)

78. Which of the determinants of service quality involves having the customer's best interests at heart?
    a. access
    b. courtesy
    c. credibility
    d. responsiveness
    e. tangibles
    c (TQM in services, moderate)

79. Which of the determinants of service quality involves performing the service right the first time?
    a. access
    b. courtesy
    c. credibility
    d. reliability
    e. responsiveness
    d (TQM in services, moderate)

FILL-IN-THE-BLANK

80. Arnold Palmer Hospital uses _____ to seek new ways to reduce readmission rates.
    continuous improvement (Global company profile, easy)

81. _____ costs result from production of defective parts or services before delivery to the customer.
Internal failure (Defining quality, moderate)

82. _____ is a set of environmental standards developed by the International Standards Organization.
ISO 14000 (Defining quality, moderate) {AACSB: Ethical Reasoning}

83. The work by _____ regarding how people learn from each other's successes led to the field of cross-functional teamwork.
Armand Feigenbaum (Defining quality, moderate)

84. Not only customers, but stockholders, suppliers, and others, are among the _____ whose values must be protected in making ethical decisions concerning the quality of products.
stakeholders (Defining quality, easy) {AACSB: Ethical Reasoning}

85. _____ is the Japanese word for the ongoing process of incremental improvement.
Kaizen (Total quality management, moderate) {AACSB: Multiculture and Diversity}

86. Enlarging employee jobs so that the added responsibility and authority is moved to the lowest level possible in the organization is called _____.
employee empowerment (Total quality management, moderate)

87. Respect for _____ is a cornerstone of continuous improvement.
people (Total quality management, moderate)

88. _____ selects a demonstrated standard of performance that represents the very best performance for a process or activity.
Benchmarking (Total quality management, moderate)

89. A group of employees that meet on a regular basis with a facilitator to solve work-related problems in their work area is a(n) _____.
quality circle (Total quality management, easy) {AACSB: Communication}

90. _____ diagrams use a schematic technique to discover possible locations of quality problems.
Cause-and-effect, or fishbone or Ishikawa (Tools of TQM, moderate)

91. _____ are graphical presentations of data over time that show upper and lower control limits for processes we want to control.
Control charts (Tools of TQM, moderate)

92. _____ is doing the job properly with the operator ensuring that this is so.
Source inspection (The role of inspection, moderate)

SHORT ANSWER

93. Identify the four costs of quality. Which one is hardest to evaluate? Explain.
The four costs are internal, external, prevention, and appraisal. The hardest to estimate are external costs, or costs that occur after delivery of defective part or services. These costs are very hard to quantify. (Defining quality, moderate)

94. State the American Society for Quality's definition of quality. Of the three "flavors" or categories of quality definitions, which type is it? Explain.
Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs. This is user-based, as evidenced by the reference to needs, not to specifications or ingredients. (Defining quality, moderate)

95. Quality has at least three categories of definitions; identify them. Provide a brief explanation of each.
The three categories of quality are user-based (in the eyes of the beholder), manufacturing-based (conforming to standards), and product-based (measurable content of product). (Defining quality, moderate)

96. Identify the five steps of DMAIC.
(1) Define the project's purpose, scope, and outputs and then identify the required process information, keeping in mind the customer's definition of quality; (2) Measure the process and collect data; (3) Analyze the data, ensuring repeatability (the results can be duplicated), and reproducibility (others get the same result); (4) Improve, by modifying or redesigning, existing processes and procedures; and (5) Control the new process to make sure performance levels are maintained.
(Total quality management, difficult)

97. In a sentence or two, summarize the contribution of Philip Crosby to quality management.
In his book "Quality Is Free," Crosby pointed out that the costs of poor quality are understated, and that understatement made it easier for firms to accept low quality results. He also promoted "zero defects" and doing the job right the first time. (Defining quality, moderate)

98. Identify the five core elements of ISO 14000.
The five core elements of ISO 14000 are environmental management, auditing, performance evaluation, labeling, and life cycle assessment. (International quality standards, moderate)

99. Describe how ISO 9000 has evolved in the past several years.
The standards have become more of a quality management system. These changes came about primarily through the December 2000 revisions. They emphasize top management leadership and customer requirements and satisfaction, while documented procedures now receive less emphasis. (International quality standards, moderate)

100. What steps can be taken to develop benchmarks?
The steps are: determine what to benchmark, form a benchmarking team, identify benchmarking partners, collect and analyze benchmarking information, and take action to match or exceed the benchmark. (Total quality management, moderate)

101. Explain how just-in-time processes relate to the quality of an organization's outputs.
JIT relates to quality by cutting costs of quality, by lowering waste and scrap; by improving quality by shortening the time between error detection and error correction; and better quality means less inventory and better JIT system. (Total quality management, moderate)

102. What is the difference between conforming quality and target-oriented quality?
With conforming quality, any unit that meets specifications is acceptable, whether it is on the edges or center of the specification range. Target-oriented quality treats output as better the closer it is to exactly what the customer wants. (Total quality management, moderate)

103. Identify the major concepts of TQM.
The major concepts of total quality management are continuous improvement, Six Sigma, employee empowerment, benchmarking, just-in-time (JIT), Taguchi concepts, and knowledge of TQM tools. (Total quality management, moderate)

104. What is the quality loss function (QLF)?
The quality loss function identifies all costs connected with poor quality and shows how these costs increase as the product moves away from being exactly what the customer wants. (Total quality management, moderate)

105. Explain how a Pareto chart can identify the most important causes of errors in a process.
There will generally be some causes with much higher frequencies than others. The frequency plot will clearly show which cause has the highest frequency. (Tools of TQM, moderate)

106. How is source inspection related to employee empowerment?
Source inspection involves the operator ensuring that the job is done properly. These operators are empowered to self-check their own work. Employees that deal with a system on a daily basis have a better understanding of the system than anyone else, and can be very effective at improving the system. (The role of inspection, moderate)

107. What is a poka-yoke? Give an example.
A poka-yoke is a foolproof device or technique that ensures production of good units every time. Examples will vary, but include McDonald's french fry scoop and standard sized bags used to ensure the correct quantity, and prepackaged surgical coverings that contain exactly the items needed for a medical procedure. (The role of inspection, moderate)

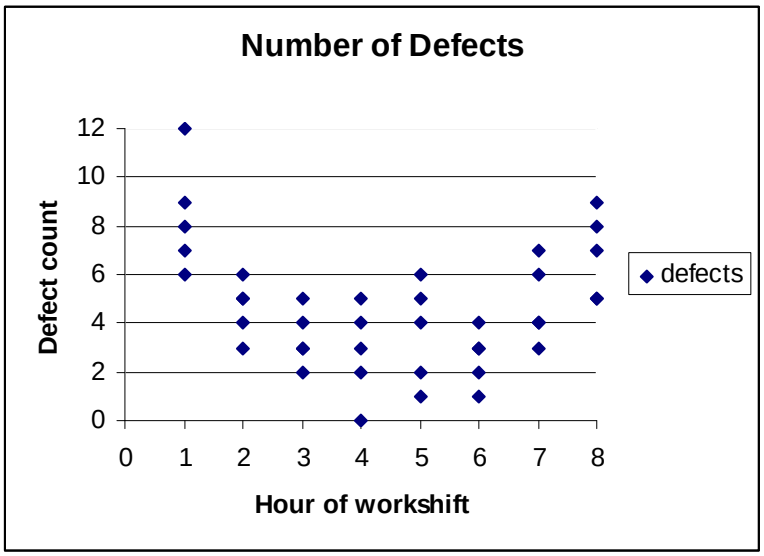
108. Identify the ten determinants of service quality. Describe two of them in a sentence or two each.
The ten are reliability, responsiveness, competence, access, courtesy, communication, credibility, security, understanding, and tangibles. Descriptions are found in Table 6.5. Here are two examples: Access involves approachability and ease of contact. Security is the freedom from danger, risk, or doubt. (TQM in services, moderate)

PROBLEMS

109. Management is concerned that workers create more product defects at the very beginning and end of a work shift than at other times of their eight hour workday. Construct a scatter diagram with the following data, collected last week. Is management justified in its belief?

	Number of defects				
	Monday	Tuesday	Wednesday	Thursday	Friday
First hour at work	12	9	6	8	7
Second hour at work	6	5	3	4	5
Third hour at work	5	2	4	3	3
Fourth hour at work	4	0	5	2	3
Fifth hour at work	1	6	2	4	5
Sixth hour at work	4	3	3	2	1
Seventh hour at work	7	4	4	6	3
Eighth hour at work	5	7	8	5	9

Solution:

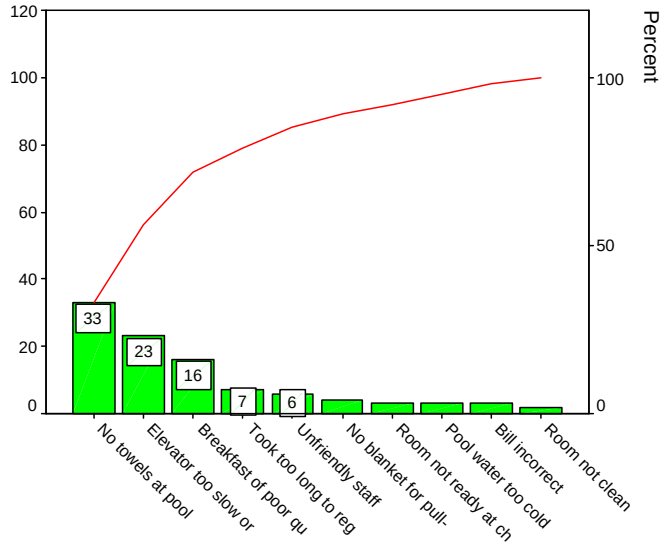


There is fairly convincing evidence that there are more defects in the first and last shift hours than at other times. (Tools of TQM, moderate) {AACSB: Analytic Skills}

110. Perform a Pareto analysis on the following information:

Reason for unsatisfying stay at hotel	Frequency
Unfriendly staff	6
Room not clean	2
Room not ready at check-in	3
No towels at pool	33
No blanket for pull-out sofa	4
Pool water too cold	3
Breakfast of poor quality	16
Elevator too slow or not working	23
Took too long to register	7
Bill incorrect	3
Total	100

Solution

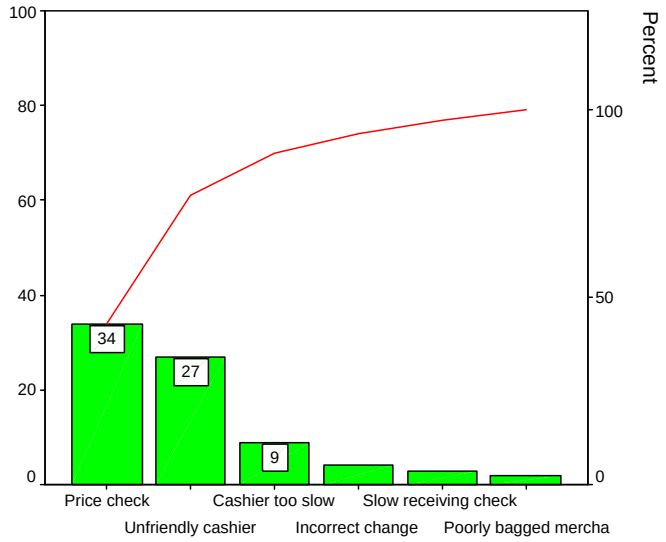


(Tools of TQM, moderate) {AACSB: Analytic Skills}

111. Perform a Pareto analysis on the following information:

Reason for unsatisfying check-out at store	Frequency
Unfriendly cashier	27
Incorrect change	4
Cashier too slow	9
Price check	34
Poorly bagged merchandise	2
Slow receiving check approval	3

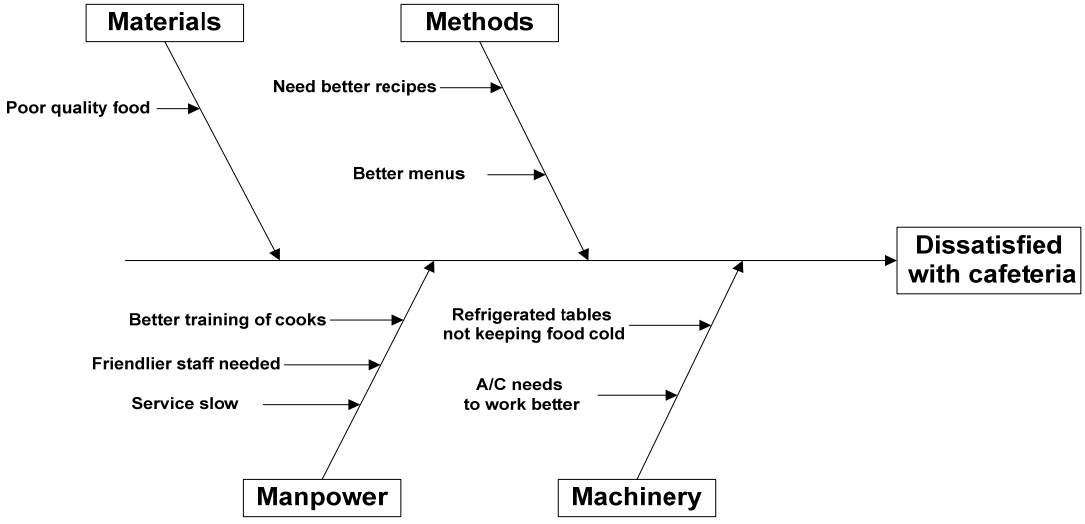
Solution



(Tools of TQM, moderate) {AACSB: Analytic Skills}

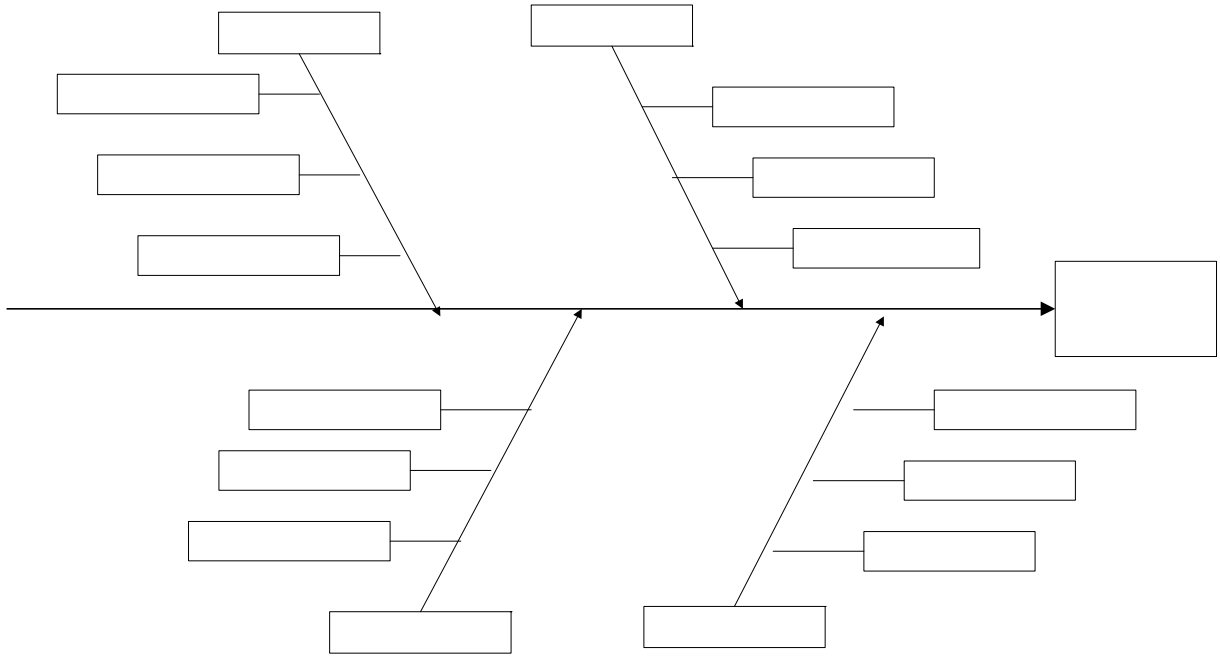
112. Construct a cause-and-effect diagram showing why a student might be dissatisfied with the cafeteria.

Solution: (Note that answers may vary considerably)



(Tools of TQM, Moderate) {AACSB: Analytic Skills}

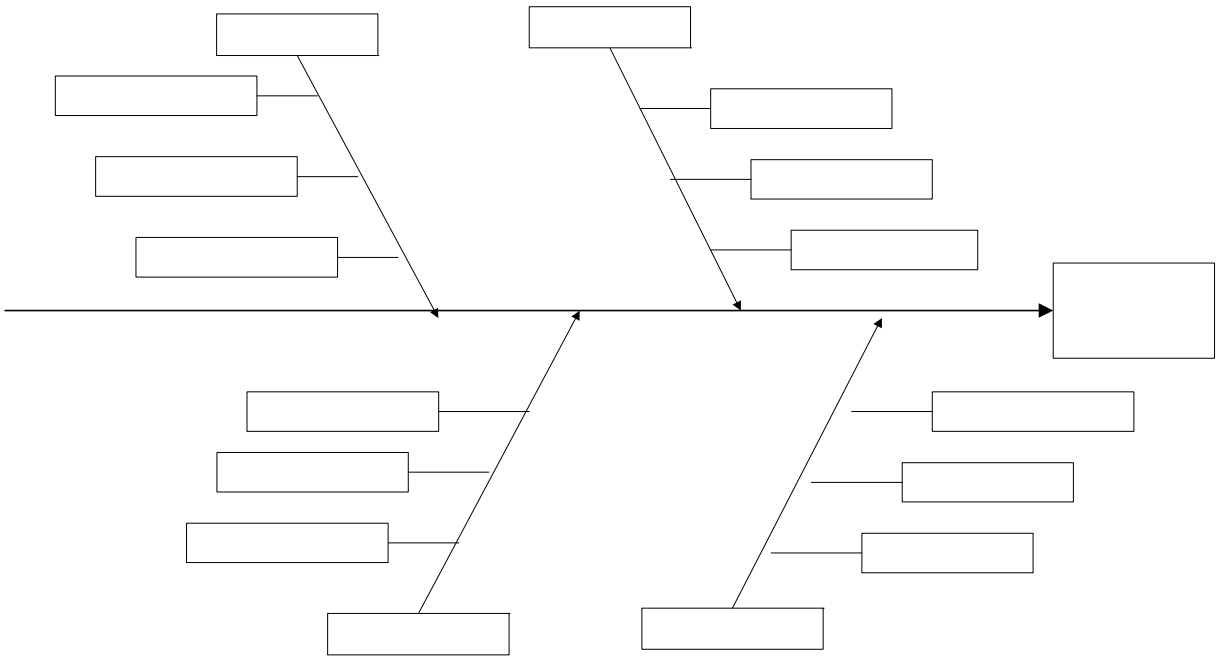
113. Pretend that you have just come from a relative's wedding reception. It didn't turn out as well as it should have, and the bride's parents are pretty mad at how things turned out. Use the supplied template to construct a conventional cause-and-effect diagram. Identify twelve sources of defects for the issue "dissatisfied customer of wedding reception caterer." (Your dozen need not be exactly three per main cause, but should be a balanced treatment.) Categorize each cause onto a main cause. Provide brief support for each of your choices



Solution: Individual responses may vary considerably; some of the variation in responses comes from differing views of what is the caterer's realm of responsibility, compared to what might be assigned to a wedding planner instead. Material: not enough plates, glassware, utensils; prepared wrong dish; food was cold; ran out of food; food was "bad." Machinery: air conditioning/heating was broken; room was dirty; room too small; furniture poorly arranged; wedding "props" ugly or shopworn. Method: not on time; overcharged; not enough workers. Manpower: wait staff not properly attired; wait staff not speedy; wait staff not courteous. Responses should comment as necessary to show why a fault lies on a certain main branch; as an example, "cold food" might be interpreted as Method, not Material. (Tools of TQM, moderate) {AACSB: Analytic Skills}

114. A refrigeration and heating company—one that installs and repairs home central air and heating systems—has asked your advice on how to analyze their service quality. They have logged customer complaints. Here's a recent sampling. Use the supplied template to construct a conventional cause-and-effect diagram. Place each of the complaints onto a main cause; justify your choice with a brief comment as necessary.

1. "I was overcharged—your labor rates are too high."
2. "The repairman left trash where he was working."
3. "You weren't here when you said you would be. You should call when you must be late."
4. "Your repairman smoked in my house."
5. "The part you installed is not as good as the factory original."
6. "Your repairman was here for over two hours, but he wasn't taking his work seriously."
7. "You didn't tighten some of the fittings properly—the system's leaking."
8. "Your estimate of repair costs was WAY off."
9. "I called you to do an annual inspection, but you've done more—work that I didn't authorize."
10. "Your mechanic is just changing parts—he doesn't have a clue what's really wrong."
11. "Your bill has only a total—I wanted to see detail billing."
12. "Your testing equipment isn't very new—are you sure you've diagnosed the problem?"
13. "One of the workmen tracked mud into my living room."



Solution: Individual responses may vary. A typical set of responses might be Material: item 5. Method: items 1, 3, 8, 9, 11. Machinery: item 12; Manpower: items 2, 4, 6, 7, 10, 13. Items 8 and 11 could be manpower or method. (Tools of TQM, moderate) {AACSB: Analytic Skills}

SUPPLEMENT 6: STATISTICAL PROCESS CONTROL

TRUE/FALSE

1. Some degree of variability is present in almost all processes.
   True (Statistical Process Control (SPC), easy)

2. The purpose of process control is to detect when natural causes of variation are present.
   False (Statistical Process Control (SPC), moderate)

3. A normal distribution is generally described by its two parameters: the mean and the range.
   False (Statistical Process Control (SPC), easy)

4. A process is said to be in statistical control when assignable causes are the only sources of variation.
   False (Statistical Process Control (SPC), moderate)

5. Mistakes stemming from workers' inadequate training represent an assignable cause of variation.
   True (Statistical Process Control (SPC), easy)

6. Averages of small samples, not individual measurements, are generally used in statistical process control.
   True (Statistical Process Control (SPC), moderate)

7. The X-bar chart indicates that a gain or loss of uniformity has occurred in dispersion of a production process.
   False (Statistical Process Control (SPC), moderate)

8. The Central Limit Theorem states that when the sample size increases, the distribution of the sample means will approach the normal distribution.
   True (Statistical Process Control (SPC), moderate)

9. In statistical process control, the range often substitutes for the standard deviation.
   True (Statistical Process Control (SPC), moderate)

10. If the process average is in control, then the process range must also be in control.
    False (Statistical Process Control (SPC), moderate)

11. A process range chart illustrates the amount of variation within the samples.
    True (Statistical Process Control (SPC), moderate)

12. Mean charts and range charts complement one another, one detecting shifts in process average, the other detecting shifts in process dispersion.
    True (Statistical Process Control (SPC), moderate)

13. X-bar charts are used when we are sampling attributes.
    False (Statistical Process Control (SPC), easy)

14. To measure the voltage of batteries, one would sample by attributes.
False (Statistical Process Control (SPC), easy)

15. A p-chart is appropriate to plot the number of typographic errors per page of text.
False (Statistical Process Control (SPC), easy)

16. A c-chart is appropriate to plot the number of flaws in a bolt of fabric.
True (Statistical Process Control (SPC), easy)

17. The x-bar chart, like the c-chart, is based on the exponential distribution.
False (Statistical Process Control (SPC), moderate)

18. A process that is in statistical control will always yield products that meet their design specifications.
False (Process capability, moderate)

19. The higher the process capability ratio, the greater the likelihood that process will be within design specifications.
True (Process capability, moderate)

20. The C_{pk} index measures the difference between desired and actual dimensions of goods or services produced.
True (Process capability, moderate)

21. Acceptance sampling accepts or rejects an entire lot based on the information contained in the sample.
True (Acceptance sampling, moderate)

22. A lot that is accepted by acceptance sampling is free of defects.
False (Acceptance sampling, moderate)

23. In acceptance sampling, a manager can reach the wrong conclusion if the sample is not representative of the population it was drawn from.
True (Acceptance sampling, moderate)

24. The probability of rejecting a good lot is known as consumer's risk.
False (Acceptance sampling, moderate)

25. An acceptance sampling plan must define "good lots" and "bad lots" and specify the risk level associated with each one.
True (Acceptance sampling, moderate)

26. The acceptable quality level (AQL) is the average level of quality we are willing to accept.
False (Acceptance sampling, moderate)

27. The steeper an OC curve, the better it discriminates between good and bad lots.
True (Acceptance sampling, moderate)

MULTIPLE CHOICE

28. If a sample of items is taken and the mean of the sample is outside the control limits the process is
    a. out of control and the cause should be established
    b. in control, but not capable of producing within the established control limits
    c. within the established control limits with only natural causes of variation
    d. monitored closely to see if the next sample mean will also fall outside the control limits
    e. producing high quality products
    a (Statistical Process Control (SPC), moderate)

29. The causes of variation in statistical process control are
    a. cycles, trends, seasonality, and random variations
    b. producer's causes and consumer's causes
    c. mean and range
    d. natural causes and assignable causes
    e. Type I and Type II
    d (Statistical Process Control (SPC), moderate)

30. Natural variations
    a. affect almost every production process
    b. are the many sources of variation that occur when a process is under control
    c. when grouped, form a pattern, or distribution
    d. are tolerated, within limits, when a process is under control
    e. All of the above are true.
    e (Statistical Process Control (SPC), moderate)

31. Natural variations
    a. are variations that are to be identified and eliminated
    b. are variations that can be traced to a specific cause
    c. are the same as assignable variations
    d. lead to occasional false findings that processes are out of control
    e. play no role in statistical process control
    d (Statistical Process Control (SPC), moderate)

32. Assignable variation
    a. is a sign that a process is under control
    b. is to be identified and eliminated
    c. is the same as random variation
    d. is variation that cannot be traced to a specific cause
    e. leads to a steep OC curve
    b (Statistical Process Control (SPC), moderate)

33. Assignable causes
    a. are not as important as natural causes
    b. are within the limits of a control chart
    c. depend on the inspector assigned to the job
    d. are also referred to as "chance" causes
    e. are causes of variation that can be identified and removed
    e (Statistical Process Control (SPC), moderate)

34. Control charts for variables are based on data that come from
    a. acceptance sampling
    b. individual items
    c. averages of small samples
    d. averages of large samples
    e. the entire lot
    c (Statistical Process Control (SPC), moderate)

35. The purpose of an $\overline{X}$ chart is to determine whether there has been a
    a. gain or loss in uniformity
    b. change in the percent defective in a sample
    c. change in the central tendency of the process output
    d. change in the number of defects in a sample
    e. change in the AOQ
    c (Statistical Process Control (SPC), moderate)

36. Statistical process control charts
    a. display the measurements on every item being produced
    b. display upper and lower limits for process variables or attributes, and signal when a process is no longer in control
    c. indicate to the process operator the average outgoing quality of each lot
    d. indicate to the operator the true quality of material leaving the process
    e. none of the above
    b (Statistical Process Control (SPC), moderate)

37. A sample of parts is measured. The mean of this sample is in the middle of the control limits, but some individual parts measure too low for design specifications and other parts measure too high. Which of the following is true?
    a. The process is out of control, and the cause should be established.
    b. The process is in control, but not capable of producing within the established control limits.
    c. The process is within the established control limits with only natural causes of variation.
    d. The process is outside the established control limits with only natural causes of variation.
    e. The process is in control, and there is nothing to worry about.
    b (Statistical Process Control (SPC), difficult)

38. The Central Limit Theorem
    a. is the theoretical foundation of the c-chart
    b. states that the average of assignable variations is zero
    c. allows managers to use the normal distribution as the basis for building some control charts
    d. states that the average range can be used as a proxy for the standard deviation
    e. controls the steepness of an operating characteristic curve
    c (Statistical Process Control (SPC), difficult)

39. For an x-bar chart where the standard deviation is known, the Upper Control Limit
    a. is $3 \cdot \sigma$ below the mean of sample means for a 3σ control chart
    b. is $3 \cdot \sigma$ above the mean of sample means for a 3σ control chart
    c. is $3 \cdot \sigma / \sqrt{n}$ below the mean of sample means for a 3σ control chart
    d. is $3 \cdot \sigma / \sqrt{n}$ above the mean of sample means for a 3σ control chart
    e. cannot be calculated unless the average range is known

    d (Statistical Process Control (SPC), moderate)

40. Up to three standard deviations above or below the centerline is the amount of variation that statistical process control allows for
    a. Type I errors
    b. about 95.5% variation
    c. natural variation
    d. all types of variation
    e. assignable variation

    c (Statistical Process Control (SPC), moderate)

41. A manager wants to build 3σ control limits for a process. The target value for the mean of the process is 10 units, and the standard deviation of the process is 6. If samples of size 9 are to be taken, the UCL and LCL will be
    a. -8 and 28
    b. 16 and 4
    c. 12 and 8
    d. 4 and 16
    e. 8 and 12

    b (Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

42. The type of inspection that classifies items as being either good or defective is
    a. variable inspection
    b. attribute inspection
    c. fixed inspection
    d. all of the above
    e. none of the above

    b (Statistical Process Control (SPC), moderate)

43. The x-bar chart tells us whether there has been a
    a. gain or loss in dispersion
    b. change in the percent defective in a sample
    c. change in the central tendency of the process output
    d. change in the number of defects in a sample
    e. none of the above

    c (Statistical Process Control (SPC), moderate)

44. The mean and standard deviation for a process for which we have a substantial history are $\bar{x}$ = 120 and σ = 2. For the variable control chart, a sample size of 16 will be used. What is the mean of the sampling distribution?
    a. 1/8 (0.125)
    b. 0.5
    c. 2
    d. 40
    e. none of the above
    e (Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

45. Jars of pickles are sampled and weighed. Sample measures are plotted on control charts. The ideal weight should be precisely 11 oz. Which type of chart(s) would you recommend?
    a. p-charts
    b. c-charts
    c. $\bar{x}$ - and R-charts
    d. $\bar{x}$ -, but not R-charts
    e. both p- and c-charts
    c (Statistical Process Control (SPC), moderate)

46. If $\bar{x}$ = 23 ounces, σ = 0.4 ounces, and n = 16, the $\pm 3\sigma$ control limits will be
    a. 21.8 to 24.2 ounces
    b. 23 ounces
    c. 22.70 to 23.30 ounces
    d. 22.25 to 23.75 ounces
    e. none of the above
    c (Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

47. The usual purpose of an R-chart is to signal whether there has been a
    a. gain or loss in dispersion
    b. change in the percent defective in a sample
    c. change in the central tendency of the process output
    d. change in the number of defects in a sample
    e. none of the above
    a (Statistical Process Control (SPC), moderate)

48. A manager wishes to build a 3σ range chart for a process. The sample size is five, the mean of sample means is 16.01, and the average range is 5.3. From Table S6.1, the appropriate value of D_3 is 0, and D_4 is 2.115. The UCL and LCL for this range chart are
    a. 33.9 and 11.2
    b. 33.9 and 0
    c. 11.2 and 0
    d. 6.3 and 0
    e. 31.91 and 0.11
    c (Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

49. Plots of sample ranges indicate that the most recent value is below the lower control limit. What course of action would you recommend?
    a. Since there is no obvious pattern in the measurements, variability is in control.
    b. One value outside the control limits is insufficient to warrant any action.
    c. Lower than expected dispersion is a desirable condition; there is no reason to investigate.
    d. The process is out of control; reject the last units produced.
    e. Variation is not in control; investigate what created this condition.
    e (Statistical Process Control (SPC), difficult)

50. To set $\bar{x}$ -chart upper and lower control limits, one must know the process central line, which is the
    a. average of the sample means
    b. total number of defects in the population
    c. percent defects in the population
    d. size of the population
    e. average range
    a (Statistical Process Control (SPC), moderate)

51. According to the text, the most common choice of limits for control charts is usually
    a. ± 1 standard deviation
    b. ± 2 standard deviations
    c. ± 3 standard deviations
    d. ± 3 standard deviations for means and ± 2 standard deviations for ranges
    e. none of the above
    c (Statistical Process Control (SPC), moderate)

52. Which of the following is true of a p-chart?
    a. The lower control limit is found by subtracting a fraction from the average number of defects.
    b. The lower control limit indicates the minimum acceptable number of defects.
    c. The lower control limit may be below zero.
    d. The lower control limit may be at zero.
    e. The lower control limit is the same as the lot tolerance percent defective.
    d (Statistical Process Control (SPC), moderate)

53. The normal application of a p-chart is in
    a. process sampling by variables
    b. acceptance sampling by variables
    c. process sampling by attributes
    d. acceptance sampling by attributes
    e. none of the above
    c (Statistical Process Control (SPC), moderate)

54. The statistical process chart used to control the number of defects per unit of output is the
    a. $\bar{x}$ -chart
    b. R-chart
    c. p-chart
    d. AOQ chart
    e c-chart
    e (Statistical Process Control (SPC), moderate)

55. The c-chart signals whether there has been a
    a. gain or loss in uniformity
    b. change in the number of defects per unit
    c. change in the central tendency of the process output
    d. change in the percent defective in a sample
    e. change in the AOQ
    b (Statistical Process Control (SPC), moderate)

56. The local newspaper receives several complaints per day about typographic errors. Over a seven-day period, the publisher has received calls from readers reporting the following number of errors: 4, 3, 2, 6, 7, 3, and 9. Based on these data alone, what type of control chart(s) should the publisher use?
    a. p-chart
    b. c-chart
    c. $\bar{x}$ -chart
    d. R-chart
    e. $\bar{x}$ - and R-charts
    b **(Statistical Process Control (SPC), moderate)**

57. A manufacturer uses statistical process control to control the quality of the firm's products. Samples of 50 of Product A are taken, and a defective/acceptable decision is made on each unit sampled. For Product B, the number of flaws per unit is counted. What type(s) of control charts should be used?
    a. p-charts for A and B
    b. p-chart for A, c-chart for B
    c. c-charts for both A and B
    d. p-chart for A, mean and range charts for B
    e. c-chart for A, mean and range charts for B
    b (Statistical Process Control (SPC), difficult)

58. A nationwide parcel delivery service keeps track of the number of late deliveries (more than 30 minutes past the time promised to clients) per day. They plan on using a control chart to plot their results. Which type of control chart(s) would you recommend?
    a. $\bar{x}$ - and R-charts
    b. p-charts
    c. c-charts
    d. $\bar{x}$ -, but not R-charts
    e. both p- and c-charts
    c (Statistical Process Control (SPC), moderate)

59. A run test is used
    a. to examine variability in acceptance sampling plans
    b. in acceptance sampling to establish control
    c. to examine points in a control chart to check for natural variability
    d. to examine points in a control chart to check for nonrandom variability
    e. none of the above
    d (Statistical Process Control (SPC), moderate)

60. Which of the following is **true** regarding the process capability index C_{pk}?
    a. A C_{pk} index value of 1 is ideal, meaning all units meet specifications.
    b. The larger the C_{pk}, the more units meet specifications.
    c. The C_{pk} index can only be used when the process centerline is also the specification centerline.
    d. Positive values of the C_{pk} index are good; negative values are bad.
    e. None of the above is true.
    b (Process capability, moderate)

61. If the C_{pk} index exceeds 1
    a. the AQL must be smaller than the LTPD
    b. σ must be less than one-third of the difference between the specification and the process mean
    c. the x-bar chart must indicate that the process is in control
    d. the process is capable of Six Sigma quality
    e. the process is characterized as "not capable"
    b (Process capability, moderate)

62. The statistical definition of Six Sigma allows for 3.4 defects per million. This is achieved by a C_{pk} index of
    a. 0
    b. 1
    c. 1.33
    d. 1.67
    e. 2
    e (Process capability), moderate)

63. A C_{pk} index of 1.00 equates to a defect rate of
    a. five percent
    b. 3.4 defects per million
    c. 2.7 per 1,000 items
    d. 97.23 percent
    e. one percent
    c (Process capability, moderate)

64. Acceptance sampling
    a. is the application of statistical techniques to the control of processes
    b. was developed by Walter Shewhart of Bell Laboratories
    c. is used to determine whether to accept or reject a lot of material based on the evaluation of a sample
    d. separates the natural and assignable causes of variation
    e. all of the above
    c (Acceptance sampling, moderate)

65. Acceptance sampling's primary purpose is to
    a. estimate process quality
    b. estimate lot quality
    c. detect and eliminate defectives
    d. decide if a lot meets predetermined standards
    e. determine whether defective items found in sampling should be replaced
    d (Acceptance sampling, difficult)

66. An acceptance sampling plan's ability to discriminate between low quality lots and high quality lots is described by
    a. a Gantt chart
    b. the Central Limit Theorem
    c. a process control chart
    d. an operating characteristics curve
    e. a range chart
    d (Acceptance sampling, moderate)

67. Acceptance sampling
    a. may involve inspectors taking random samples (or batches) of finished products and measuring them against predetermined standards
    b. may involve inspectors taking random samples (or batches) of incoming raw materials and measuring them against predetermined standards
    c. is more economical than 100% inspection
    d. may be either of a variable or attribute type, although attribute inspection is more common in the business environment
    e. All of the above are true.
    e (Acceptance sampling, moderate)

68. Which of the following statements on acceptance sampling is **true**?
    a. Acceptance sampling draws samples from a population of items, tests the sample, and accepts the entire population if the sample is good enough, and rejects it if the sample is poor enough.
    b. The sampling plan contains information about the sample size to be drawn and the critical acceptance or rejection numbers for that sample size.
    c. The steeper an operating characteristic curve, the better its ability to discriminate between good and bad lots.
    d. All of the above are true.
    e. All of the above are false.
    d (Acceptance sampling, moderate)

69. Acceptance sampling is usually used to control
    a. the number of units output from one stage of a process which are then sent to the next stage
    b. the number of units delivered to the customer
    c. the quality of work-in-process inventory
    d. incoming lots of purchased products
    e. all of the above
    d (Acceptance sampling, moderate)

70. An operating characteristic (OC) curve describes
    a. how many defects per unit are permitted before rejection occurs
    b. the sample size necessary to distinguish between good and bad lots
    c. the most appropriate sampling plan for a given incoming product quality level
    d. how well an acceptance sampling plan discriminates between good and bad lots
    e. none of the above
    d (Acceptance sampling, moderate)

71. An operating characteristics curve shows
    a. upper and lower product specifications
    b. product quality under different manufacturing conditions
    c. how the probability of accepting a lot varies with the population percent defective
    d. when product specifications don't match process control limits
    e. how operations affect certain characteristics of a product
    c (Acceptance sampling, moderate)

72. Producer's risk is the probability of
    a. accepting a good lot
    b. rejecting a good lot
    c. rejecting a bad lot
    d. accepting a bad lot
    e. none of the above
    b (Acceptance sampling, moderate)

73. Which of the following is true regarding the relationship between AOQ and the true population percent defective?
    a. AOQ is greater than the true percent defective.
    b. AOQ is the same as the true percent defective.
    c. AOQ is less than the true percent defective.
    d. There is no relationship between AOQ and the true percent defective.
    e. The relationship between these two cannot be determined.
    c (Acceptance sampling, difficult)

74. Average outgoing quality (AOQ) usually
    a. worsens with inspection
    b. stays the same with inspection
    c. improves with inspection
    d. may either improve or worsen with inspection
    e. is the average quality before inspection
    c (Acceptance sampling, moderate)

75. A Type I error occurs when
    a. a good lot is rejected
    b. a bad lot is accepted
    c. the number of defectives is very large
    d. the population is worse than the AQL
    e. none of the above
    a (Acceptance sampling, moderate)

76. A Type II error occurs when
    a. a good lot is rejected
    b. a bad lot is accepted
    c. the population is worse than the LTPD
    d. the proportion of defectives is very small
    e. none of the above
    b (Acceptance sampling, moderate)

77. In most acceptance sampling plans, when a lot is rejected, the entire lot is inspected and all defective items are replaced. When using this technique the AOQ
    a. worsens (AOQ becomes a larger fraction)
    b. improves (AOQ becomes a smaller fraction)
    c. is not affected, but the AQL is improved
    d. is not affected
    e. falls to zero
    b (Acceptance sampling, moderate)

78. An acceptance sampling plan is to be designed to meet the organization's targets for product quality and risk levels. Which of the following is true?
    a. n and c determine the AQL.
    b. AQL, LTPD, α and β collectively determine n and c.
    c. n and c are determined from the values of AQL and LTPD.
    d. α and β are determined from the values of AQL and LTPD.
    e. None of the above is true.
    b (Acceptance sampling, moderate)

79. A lot that is accepted by acceptance sampling
    a. has more defects than existed before the sampling
    b. has had all its defects removed by 100% inspection
    c. will have the same defect percentage as the LTPD
    d. has no defects present
    e. All of the above are false.
    e (Acceptance sampling, moderate)

80. Which of the following statements about acceptance sampling is **true**?
    a. The steeper an OC curve, the better it discriminates between good and bad lots.
    b. Acceptance sampling removes all defective items.
    c. Acceptance sampling of incoming lots is replacing statistical process control at the supplier.
    d. Acceptance sampling occurs continuously along the assembly line.
    e. All of the above are true.
    a (Acceptance sampling, moderate)

81. Which of the following is **true** regarding the average outgoing quality level?
    a. An AOQ value of 1 is ideal, because all defects have been removed.
    b. AOQ is always greater than AQL but less than LTPD.
    c. AOQ rises (worsens) following inspection of failed lots.
    d. AOQ is very low (very good) for extremely poor quality lots.
    e. None of the above is true.
    d (Acceptance sampling, difficult)

FILL-IN-THE-BLANK

82. _____ is variation in a production process that can be traced to specific causes.
    Assignable variation (Statistical Process Control (SPC), moderate)

83. The _____ is the chief way to control attributes.
    P-chart (Statistical Process Control (SPC), moderate)

84. If a process has only natural variations, _____ percent of the time the sample averages will fall inside the $\pm 3\sigma/n$ (or $\pm 3\sigma_{\bar{x}}$) control limits.
99.73 (Statistical Process Control (SPC), easy)

85. The _____ is a quality control chart that indicates when changes occur in the central tendency of a production process.
x-bar chart (Statistical Process Control (SPC), moderate)

86. The _____ are calculated to show how much allowance should be made for natural variation.
UCL and LCL, or upper and lower control limits (Statistical Process Control (SPC), easy)

87. The _____ is a quality control chart used to control the number of defects per unit of output.
c-chart (Statistical Process Control (SPC), moderate)

88. The term _____ is used to describe how well a process makes units within design specifications (or tolerances).
process capability (Process capability, moderate)

89. A C_{pk} index greater than _____ is a capable process, one that generates fewer than 2.7 defects per 1000 at the $\pm 3\sigma$ level.
unity, or 1 (Process capability, moderate)

90. _____ is a method of measuring samples of lots or batches of product against predetermined standards.
Acceptance sampling (Acceptance sampling, moderate)

91. A(n) _____ is a graph that describes how well an acceptance plan discriminates between good and bad lots.
OC or operating characteristics curve (Acceptance sampling, moderate)

92. The _____ is the poorest level of quality that we are willing to accept.
AQL or acceptable quality level (Acceptance sampling, moderate)

93. The _____ is the percent defective in an average lot of goods inspected through acceptance sampling.
AOQ or average outgoing quality (Acceptance sampling, moderate)

SHORT ANSWER

94. What is the basic objective of a process control system?
It is to provide a statistical signal when assignable causes of variation are present. (Statistical Process Control (SPC), moderate)

95. Briefly explain what the Central Limit Theorem has to do with control charts.
The CLT underlies the distribution of sample means and the standard deviation of sample means. It leads to the usability of the normal distribution in control charts. (Statistical Process Control (SPC), moderate)

96. What are the three possible results (or findings) from the use of control charts?
The results of a control chart can indicate (a) in control and capable, (b) in control but not capable, and (c) out of control. (Statistical Process Control (SPC), moderate)

97. Why do range charts exist? Aren't x-bar charts enough?
Range charts and mean charts perform different functions. The mean chart is used to detect changes in the average of a process. But that average might stay the same while output is getting more scattered. The purpose of the range chart is to detect changes in the dispersion of a process. (Statistical Process Control (SPC), moderate)

98. Examine the Statistical Process Control outputs below. Answer the following questions.
a. What is the sample size?
b. What is the number of samples?
c. What is the mean of sample 8; what is the range of sample 10?
d.. Is this process in control? Explain--a simple Yes or No is insufficient.
e. What additional steps should the quality assurance team take?

		Mean	Range			
UCL (Upper control limit)		12.6856	1.0193			
CL (Center line)		12.36	0.67			
LCL (Lower control limit)		12.0344	0			
Sample Number	Item1	Item2	Item3	Item4	Mean	Range
Sample 1	12.2	12.6	12	12.1	12.225	0.6
Sample 2	11.9	12.5	12.4	12.7	12.375	0.8
Sample 3	12	12.2	12.9	13.1	12.55	1.1
Sample 4	12.5	12.5	12.4	12.8	12.55	0.4
Sample 5	12.2	12.8	12.7	12	12.425	0.8
Sample 6	12.1	12.5	11.8	12.3	12.175	0.7
Sample 7	12.3	12.4	12.8	12.4	12.475	0.5
Sample 8	12	12.1	12.4	12.2	12.175	0.4
Sample 9	12.1	12.8	12.4	11.9	12.3	0.9
Sample 10	12.6	12.4	12.1	12.3	12.35	0.5

The sample size is 4; ten samples were taken. The mean of sample 8 is 12.175; the range of sample 10 is 0.5. This chart is built on 2-sigma limits, so the probability of a false signal is about 4.5%. The process is not in control—while all means are within limits, the range for sample 3 is too large. Investigate for assignable cause and eliminate that cause. (Statistical Process Control (SPC), difficult) {AACSB: Analytic Skills}

99. Can "in control" and "capable" be shown on the same chart?
Only indirectly. The chart illustrating control plots the averages of small samples, while "Capability" is based on the dimensions of individual units. Figure S6.2 suggests that an overly wide range for sample means implies an overly large range for individual values as well. (Statistical Process Control (SPC), moderate)

100. What is the difference between natural and assignable causes of variation?
Natural variations are those variations that are inherent in the process and for which there is no identifiable cause. These variations fall in a natural pattern. Assignable causes are variations beyond those that can be expected to occur because of natural variation. These variations can be traced to a specific cause. (Statistical Process Control (SPC), moderate)

101. Why are $\overline{X}$ and R-charts usually used hand in hand?
The ultimate goal of the $\overline{X}$ and *R*-charts is to ascertain, by a sampling procedure, that the relevant parameter is kept within specific upper and lower bounds. The *X*-bar chart alone tells us only that the average or variable values are within the appropriate limits. The combination of $\overline{X}$ and the *R*-charts allows one to determine that both the average and the deviations are within the limits. (Statistical Process Control (SPC), moderate)

102. What does it mean for a process to be "capable"?
Process capability implies that the natural variation of the process must be small enough to produce products that meet the specifications or tolerances required. (Process capability, moderate)

103. What is the difference between the process capability ratio C_p and the process capability index C_{pk}?
The C_p ratio does not consider how well the process average is centered on the target value. However, C_{pk} does consider how well the process is centered. (Process capability, moderate)

104. A process is operating in such a manner that the mean of the process is exactly on the lower specification limit. What must be true about the two measures of capability for this process?
The C_p ratio does not consider how well the process average is centered on the target value; its value is unaffected by the setting for the process mean. However, C_{pk} does consider how well the process is centered; with x-bar on the LSL, the formula guarantees a C_{pk} of zero. (Process capability, moderate)

105. What is acceptance sampling?
Acceptance sampling is a method of measuring random samples of lots or batches of products against predetermined standards. (Acceptance sampling, moderate)

106. Why doesn't acceptance sampling remove all defects from a batch?
Acceptance sampling is a method of measuring random samples of lots or batches of products against predetermined standards. Acceptance sampling is not 100 percent inspection. Based on sampling results, the entire batch is either accepted or rejected. A batch may contain small numbers of defects and still meet the standard for acceptance. (Acceptance sampling, moderate)

107. What is the purpose of the Operating Characteristics curve?
An OC curve plots the probability of acceptance against the percentage of defects in the lot. It therefore shows how well an acceptance sampling plan discriminates between good and bad lots. (Acceptance sampling, moderate)

108. What is the AOQ of an acceptance sampling plan?
The AOQ is the average outgoing quality. It is the percent defective in an average lot of goods inspected through an acceptance sampling plan. (Acceptance sampling, moderate)

109. Define consumer's risk. How does it relate to the errors of hypothesis testing? What is the symbol for its value?
The consumer's risk is the probability of accepting a bad lot. It is a Type II error; its value is beta. (Acceptance sampling, moderate)

110. What four elements determine the value of average outgoing quality? Why does this curve rise, peak, and fall?
The four elements are the true percent defective of the lot, the probability of accepting the lot, the number of items in the lot, and the number of items in the sample. AOQ is near zero for very good output (which has few defects to find) and for very bad output (which often fails inspection and has its defects removed). AOQ has higher values for output of intermediate quality, for which the probability of rejection is not very high. (Acceptance sampling, moderate)

111. What do the terms producer's risk and consumer's risk mean?
Producer's risk: **the risk of rejecting a good lot;** ***Consumer's risk:*** **the risk of accepting a defective lot (Acceptance sampling, moderate)**

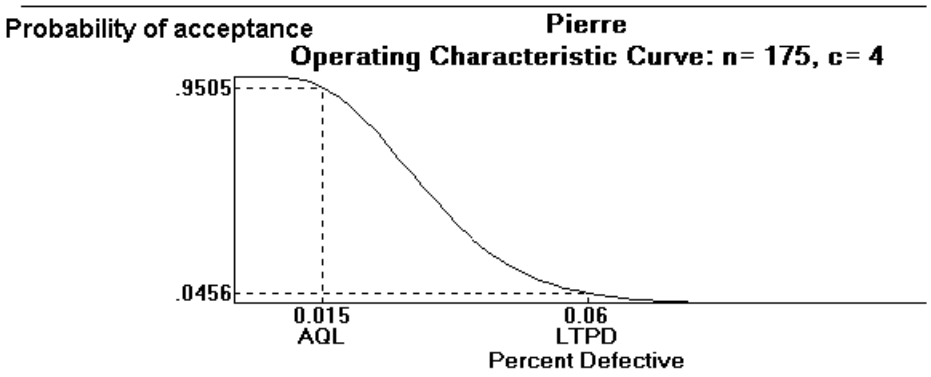
112. Pierre's Motorized Pirogues and Mudboats is setting up an acceptance sampling plan for the special air cleaners he manufactures for his boats. His specifications, and the resulting plan, are shown on the POM for Windows output below. In relatively plain English (someone else will translate for Pierre), explain exactly what he will do when performing the acceptance sampling procedure, and what actions he might take based on the results.

Quality Control Results

			Pierre Solution	
Parameter	Value		Result	Plan 1
AQL	0.015		Sample Size	175.
LTPD	0.06		Critical Value	5.
ALPHA	0.05		Actual Producer's risk	0.0495
BETA	0.1		Actual Consumer's risk	0.0456

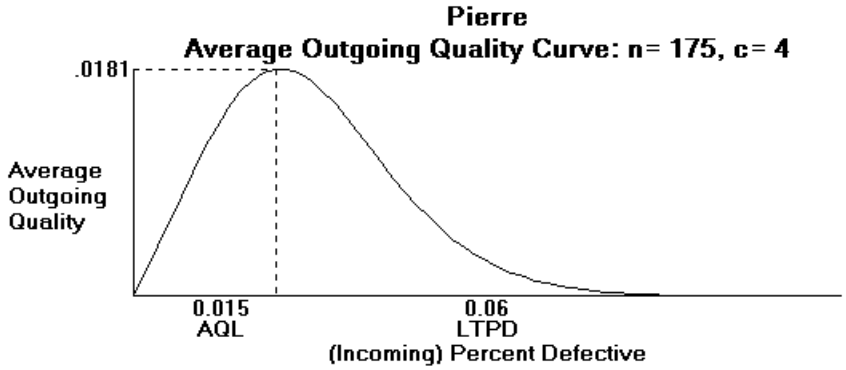
Pierre should select samples of size 175 from his lots of air cleaners. He should count the number of defects in each sample. If there are 4 or fewer defects, the lot passes inspection. If there are 5 or more defects, the lot fails inspection. Lots that fail can be handled several ways: they can be 100% inspected to remove defects; they can be sold at a discount; they can be destroyed; they can be sent back for rework, etc. (Acceptance sampling, moderate) {AACSB: Analytic Skills}

113. Pierre's Motorized Pirogues and Mudboats is setting up an acceptance sampling plan for the special air cleaners he manufactures for his boats. His specifications, and the resulting plan, are shown on the POM for Windows output below. Pierre is a bit confused. He mistakenly thinks that acceptance sampling will reject all bad lots and accept all good lots. Explain why this will not happen.



Acceptance sampling cannot discriminate perfectly between good and bad lots; this is illustrated by the OC curve that is not straight up and down. In this example, "good" lots will still be rejected almost 5% of the time. "Bad" lots will still be accepted almost 5% of the time. (Acceptance sampling, moderate)

114. Pierre's Motorized Pirogues and Mudboats is setting up an acceptance sampling plan for the special air cleaners he manufactures for his boats. His specifications, and the resulting plan, are shown on the POM for Windows output below. Pierre wants acceptance sampling to remove ALL defects from his production of air cleaners. Explain carefully why this won't happen.



Acceptance sampling is not intended to remove all defects, nor will it. Consider a lot with a defect rate of 0.005 in this example. If the sample is representative, the lot will pass inspection--which means that no one will inspect the lot for defects. The defects that were present before sampling are still there. Generally, acceptance sampling passes some lots and rejects others. Defects can only be removed from those lots that fail inspection. (Acceptance sampling, moderate)

PROBLEMS

115. A quality analyst wants to construct a sample mean chart for controlling a packaging process. He knows from past experience that the process standard deviation is two ounces. Each day last week, he randomly selected four packages and weighed each. The data from that activity appears below.

	Weight			
Day	Package 1	Package 2	Package 3	Package 4
Monday	23	22	23	24
Tuesday	23	21	19	21
Wednesday	20	19	20	21
Thursday	18	19	20	19
Friday	18	20	22	20

(a) Calculate all sample means and the mean of all sample means.
(b) Calculate upper and lower control limits that allow $\pm 2\sigma$ for natural variations.
(c) Is this process in control?

(a) The five sample means are 23, 21, 20, 19, and 20. The mean of all sample means is 20.6
(b) UCL = $20.6 + 2 \cdot 2/\sqrt{4}$ **= 22.6; LCL =** $20.6 - 2 \cdot 2/\sqrt{4}$ **= 18.6**
(c) Sample 1 is above the UCL; all others are within limits. The process is out of control.
(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

116. A quality analyst wants to construct a sample mean chart for controlling a packaging process. He knows from past experience that when the process is operating as intended, packaging weight is normally distributed with a mean of twenty ounces, and a process standard deviation of two ounces. Each day last week, he randomly selected four packages and weighed each. The data from that activity appears below.

	Weight			
Day	Package 1	Package 2	Package 3	Package 4
Monday	23	22	23	24
Tuesday	23	21	19	21
Wednesday	20	19	20	21
Thursday	18	19	20	19
Friday	18	20	22	20

(a) If he sets an upper control limit of 21 and a lower control limit of 19 around the target value of twenty ounces, what is the probability of concluding that this process is out of control when it is actually in control?
(b) With the UCL and LCL of part a, what do you conclude about this process—is it in control?

(a) These control limits are one standard error away from the centerline, and thus include 68.268 percent of the area under the normal distribution. There is therefore a 31.732 percent chance that, when the process is operating in control, a sample will indicate otherwise.
(b) The mean of sample 1 lies outside the control limits. All other points are on or within the limits. The process is not in control.
(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

117. An operator trainee is attempting to monitor a filling process that has an overall average of 705 cc. The average range is 17 cc. If you use a sample size of 6, what are the upper and lower control limits for the X-bar and R chart?

From table, $A_2 = 0.483$, $D_4 = 2.004$, $D_3 = 0$

$UCL_{\bar{x}} = \bar{\bar{x}} + A_2 * \bar{R}$	**$LCL_{\bar{x}} = \bar{\bar{x}} - A_2 * \bar{R}$**	**$UCL_R = D_4 * \bar{R}$**	**$LCL_R = D_3 * \bar{R}$**
= 705 + 0.483 x 17	**= 705 - 0.483 * 17**	**= 2.004 * 17**	**= 0 * 17**
= 713.211	**= 696.789**	**= 34.068**	**= 0**

(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

118. The defect rate for a product has historically been about 1.6%. What are the upper and lower control chart limits for a p-chart, if you wish to use a sample size of 100 and 3-sigma limits?

$$\mathbf{UCL_p} = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \qquad \mathbf{= 0.016 + 3 \cdot \sqrt{(0.016 * 0.984)/100} = .0536}$$

$$\mathbf{LCL_p} = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \qquad \mathbf{= 0.016 - 3 \cdot \sqrt{(0.016 * 0.984)/100} = -0.0216, \text{ or zero.}}$$

(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

119. A small, independent amusement park collects data on the number of cars with out-of-state license plates. The sample size is fixed at n=25 each day. Data from the previous 10 days indicate the following number of out-of-state license plates:

Day	Out-of-state Plates
1	6
2	4
3	5
4	7
5	8
6	3
7	4
8	5
9	3
10	11

(a) Calculate the overall proportion of "tourists" (cars with out-of-state plates) and the standard deviation of proportions.
(b) Using $\pm 3\sigma$ limits, calculate the LCL and UCL for these data.
(c) Is the process under control? Explain.

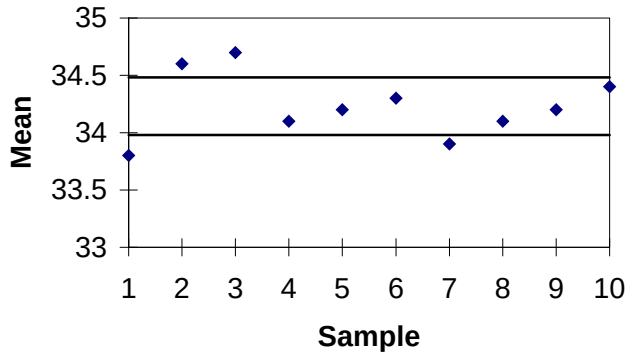
(a) p-bar is 56/250 = 0.224; the standard deviation of proportions is the square root of .224 x .776 / 25 = 0.0834
(b) UCL = .224 + 3 x 0.834 = .4742; LCL = .224 -3 x .0834 which is negative, so the LCL = 0
(c) The largest percentage of tourists (day 10) is 11/25 = .44, which is still below the UCL. Thus, all the points are within the control limits, so the process is under control. (Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

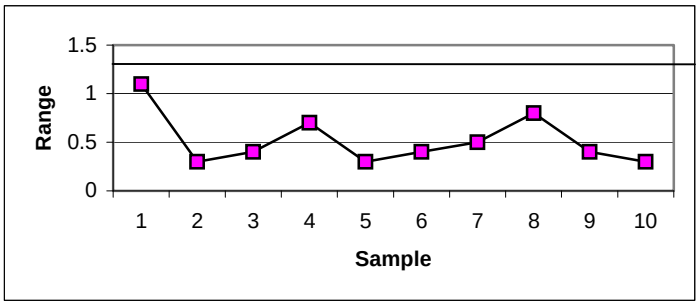
120. Cartons of Plaster of Paris are supposed to weigh exactly 32 oz. Inspectors want to develop process control charts. They take ten samples of six boxes each and weigh them. Based on the following data, compute the lower and upper control limits and determine whether the process is in control.

Sample	Mean	Range
1	33.8	1.1
2	34.6	0.3
3	34.7	0.4
4	34.1	0.7
5	34.2	0.3
6	34.3	0.4
7	33.9	0.5
8	34.1	0.8
9	34.2	0.4
10	34.4	0.3

n = 6; overall mean = 34.23; $\bar{R}$ = 0.52.

Upper control limit	**34.48116**	**1.04208**
Center line	**34.23**	**0.52**
Lower control limit	**33.97884**	**0**



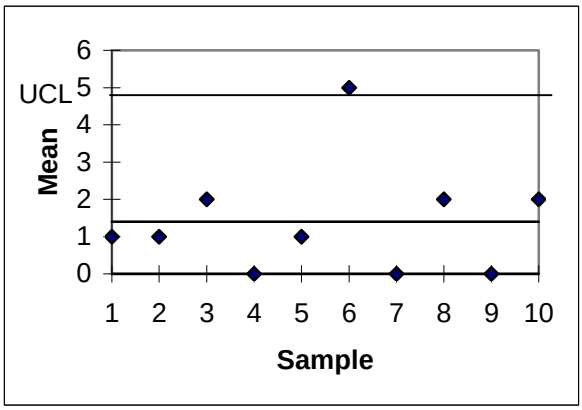


The mean values for samples 1, 2, 3, and 7 fall outside the control limits on the X-bar chart and sample 1 falls outside the upper limit on the R-chart. Therefore, the process is out of control. (Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

121. McDaniel Shipyards wants to develop control charts to assess the quality of its steel plate. They take ten sheets of 1" steel plate and compute the number of cosmetic flaws on each roll. Each sheet is 20' by 100'. Based on the following data, develop limits for the control chart, plot the control chart, and determine whether the process is in control.

Sheet	Number of flaws
1	1
2	1
3	2
4	0
5	1
6	5
7	0
8	2
9	0
10	2

Total units sampled	**10**
Total defects	**14**
Defect rate, c-bar	**1.4**
Standard deviation	**1.183216**
z value	**3**
Upper Control Limit	**4.949648**
Center Line	**1.4**
Lower Control Limit	**0**



Sample six is above the control limits; therefore, the process is out of control.
(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

122. The mean and standard deviations for a process are $\bar{x}$ = 90 and σ = 9. For the variable control chart, a sample size of 16 will be used. Calculate the standard deviation of the sampling distribution.
Sigma x-bar = $9/\sqrt{16} = 2.25$
(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

123. If $\bar{x}$ = 9 ounces, σ = 0.5 ounces, and n = 9, calculate the 3-sigma control limits.
8.50 to 9.50 ounces
(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

124. A hospital-billing auditor has been inspecting patient bills. While almost all bills contain some errors, the auditor is looking now for large errors (errors in excess of $250). Among the last 100 bills inspected, the defect rate has been 16%. Calculate the upper and lower limits for the billing process for 99.7% confidence.
0.16 plus or minus 3 x 0.03667, or .050 to 0.270
(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

125. A local manufacturer supplies you with parts, and you would like to install a quality monitoring system at his factory for these parts. Historically, the defect rate for these parts has been 1.25 percent (You've observed this from your acceptance sampling procedures, which you would like to discontinue). Develop $\pm 3\sigma$ control limits for this process. Assume the sample size will be 200 items.
p-bar is 0.0125; the standard error of the proportion is $\sqrt{[(0.0125)(0.9875)]/200}$ = 0.00786.
The upper control limit is 0.0125 + 3 x 0.00786 = 0.03608; the lower control limit is 0.0125 – 3 x 0.00786 which is negative, so the LCL is 0.
(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

126. Repeated sampling of a certain process shows the average of all sample ranges to be 1.0 cm. The sample size has been constant at n = 5. What are the 3-sigma control limits for this R-chart?
zero to 2.115
(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

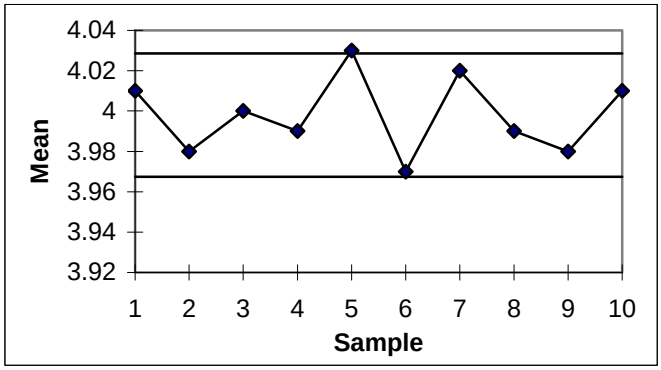
127. A woodworker is concerned about the quality of the finished appearance of her work. In sampling units of a split-willow hand-woven basket, she has found the following number of finish defects in ten units sampled: 4, 0, 3, 1, 2, 0, 1, 2, 0, 2.
a. Calculate the average number of defects per basket
b. If 3-sigma control limits are used, calculate the lower control limit, centerline, and upper control limit.
(a) 1.5; (b) 0, 1.5, and 5.2.
(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

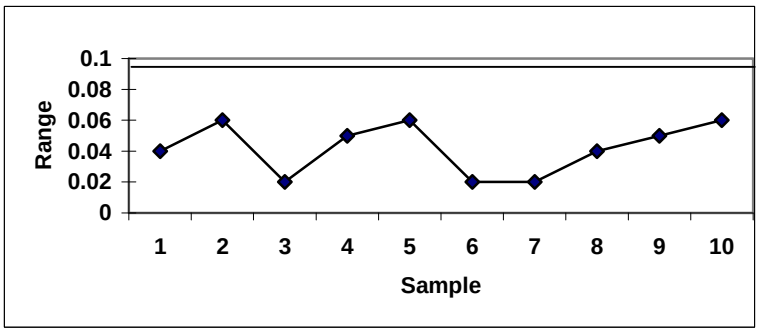
128. The width of a bronze bar is intended to be one-eighth of an inch (0.125 inches). Inspection samples contain five bars each. The average range of these samples is 0.01 inches. What are the upper and lower control limits for the X-bar and R-chart for this process, using 3-sigma limits?
X-bar: LCL = .119; UCL =.131. R: LCL = 0.0; UCL =.021
(Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

129. A part that connects two levels should have a distance between the two holes of 4". It has been determined that X-bar and R-charts should be set up to determine if the process is in statistical control. The following ten samples of size four were collected. Calculate the control limits, plot the control charts, and determine if the process is in control.

	Mean	Range
Sample 1	4.01	0.04
Sample 2	3.98	0.06
Sample 3	4.00	0.02
Sample 4	3.99	0.05
Sample 5	4.03	0.06
Sample 6	3.97	0.02
Sample 7	4.02	0.02
Sample 8	3.99	0.04
Sample 9	3.98	0.05
Sample 10	4.01	0.06

	X-bar	**Range**
x-bar value	**3.998**	
R bar	**0.042**	
Upper control limit	**4.029**	**0.096**
Center line	**3.998**	**0.042**
Lower control limit	**3.967**	**0**



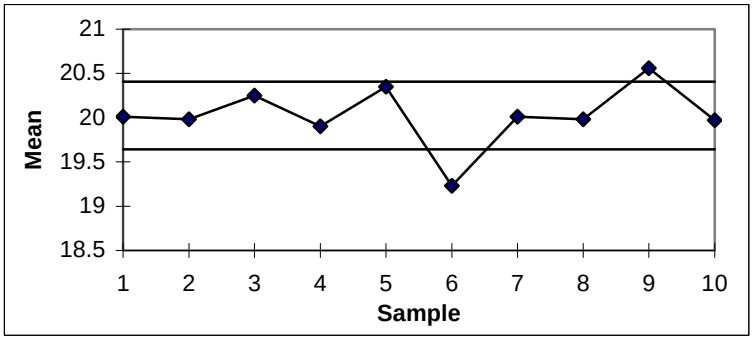


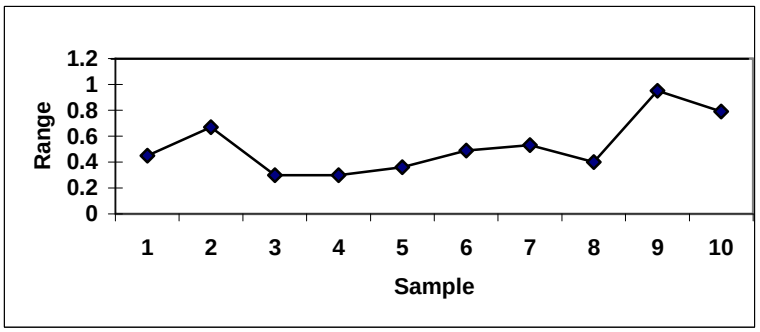
The process is out of control because of sample 5 on the X-bar chart. (Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

130. Ten samples of size four were taken from a process, and their weights measured. The sample averages and sample ranges are in the following table. Construct and plot an X-bar and R-chart using this data. Is the process in control?

Sample	Mean	Range
1	20.01	0.45
2	19.98	0.67
3	20.25	0.30
4	19.90	0.30
5	20.35	0.36
6	19.23	0.49
7	20.01	0.53
8	19.98	0.40
9	20.56	0.95
10	19.97	0.79

	X-bar	Range
x-bar value	**20.024**	
R bar	**0.524**	
Upper control limit	**20.406**	**1.196**
Center line	**20.024**	**0.524**
Lower control limit	**19.642**	**0**



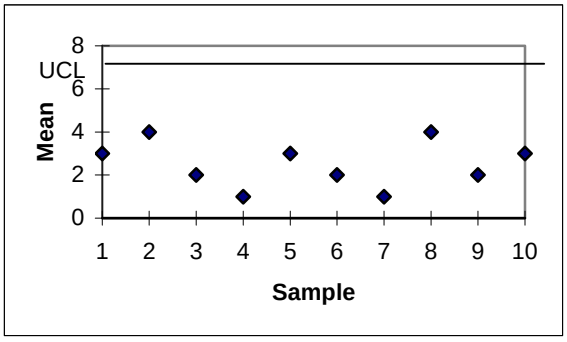


The X-bar chart is out of control, and therefore the process is out of control, because samples 6 and 9 are outside of the control limits. (Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

131. Larry's boat shop wants to monitor the number of blemishes in the paint of each boat. Construct a c-chart to determine if their paint process is in control using the following data.

Sample Number	Number of Defects
1	3
2	4
3	2
4	1
5	3
6	2
7	1
8	4
9	2
10	3

Total units sampled	**10**
Total defects	**25**
Defect rate, c-bar	**2.5**
Standard deviation	**1.581**
z value	**3**
Upper Control Limit	**7.243**
Center Line	**2.5**
Lower Control Limit	**0**



The process is in control. (Statistical Process Control (SPC), moderate) {AACSB: Analytic Skills}

132. The specifications for a manifold gasket that installs between two engine parts calls for a thickness of 2.500 mm $\pm$ .020 mm. The standard deviation of the process is estimated to be 0.004 mm. What are the upper and lower specification limits for this product? The process is currently operating at a mean thickness of 2.50 mm. (a) What is the C_p for this process? (b) About what percent of all units of this liner will meet specifications? Does this meet the technical definition of Six Sigma?
(a) LSL = 2.48 mm, USL = 2.52 mm. C_p = (2.52 – 2.48)/(6*0.004) = 1.67. (b) Each specification limit lies 5 standard deviations from the centerline, so practically 100 percent of units will meet specifications. However, this percentage is not quite as high as Six Sigma would call for. (Process capability, moderate) {AACSB: Analytic Skills}

133. The specifications for a manifold gasket that installs between two engine parts calls for a thickness of 2.500 mm $\pm$ .020 mm. The standard deviation of the process is estimated to be 0.004 mm. What are the upper and lower specification limits for this product? The process is currently operating at a mean thickness of 2.50 mm. (a) What is the C_p for this process? (b) The purchaser of these parts requires a capability index of 1.50. Is this process capable? Is this process good enough for the supplier? (c) If the process mean were to drift from its setting of 2.500 mm to a new mean of 2.497, would the process still be good enough for the supplier's needs?
(a) LSL = 2.48 mm, USL = 2.52 mm. C_p = (2.52 – 2.48)/(6*0.004) = 1.67. (b) Yes to both parts of the question. (c) The C_{pk} index is now relevant, and its value is the lesser of 1.917 and 1.417. The process is still capable, but not to the supplier's needs. (Process capability, moderate) {AACSB: Analytic Skills}

134. The specification for a plastic liner for concrete highway projects calls for a thickness of 6.0 mm ± 0.1 mm. The standard deviation of the process is estimated to be 0.02 mm. What are the upper and lower specification limits for this product? The process is known to operate at a mean thickness of 6.03 mm. What is the C_p and C_{pk} for this process? About what percent of all units of this liner will meet specifications?
LSL = 5.9 mm, USL = 6.1 mm. C_p **is (6.1-5.9)/6(.02) = 1.67. C_{pk} is the lesser of (6.1-6.03)/(3*0.02) = 1.17 and (5.9 - 6.03)/(3*0.02) = 2.17; therefore, 1.17. The upper specification limit lies about 3 standard deviations from the centerline, and the lower specification limit is further away, so practically all units will meet specifications. (Process capability, moderate) {AACSB: Analytic Skills}**

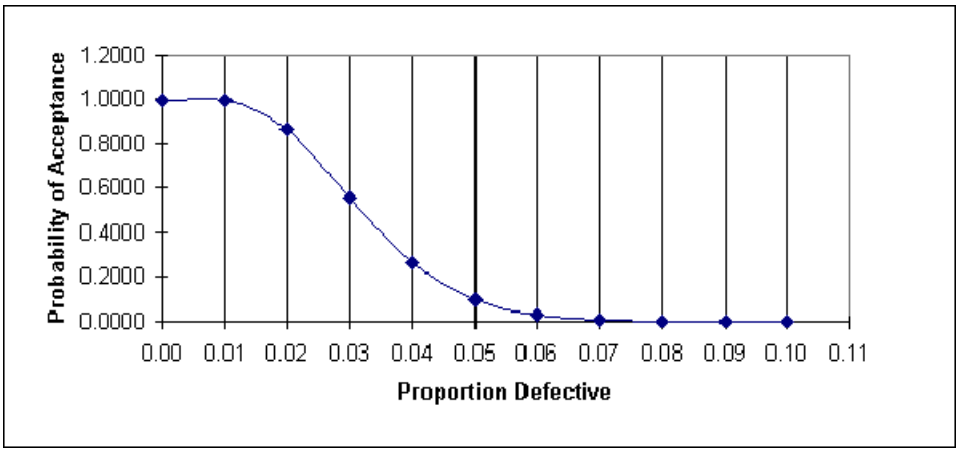
135. The specification for a plastic handle calls for a length of 6.0 inches ± .2 inches. The standard deviation of the process is estimated to be 0.05 inches. What are the upper and lower specification limits for this product? The process is known to operate at a mean thickness of 6.1 inches. What is the C_p and C_{pk} for this process? Is this process capable of producing the desired part?
LSL = 5.8 inches, USL = 6.2 inches. C_p **is (6.2-5.8)/6(.05) = 1.33. C_{pk} is the lesser of (6.2-6.1)/(3*0.05) = .67 and (5.8 - 6.1)/(3*0.02) = 2.00; therefore, .67. The process is capable based upon the C_p. However, the process is not centered (based upon its C_{pk}) and based upon its current center is not producing parts that are of an acceptable quality. (Process capability, moderate) {AACSB: Analytic Skills}**

136. In the table below are selected values for the OC curve for the acceptance sampling plan n=210, c=6. Upon failed inspection, defective items are replaced. Calculate the AOQ for each data point. (You may assume that the population is much larger than the sample.) Plot the AOQ curve. At approximately what population defective rate is the AOQ at its worst? Explain how this happens. How well does this plan meet the specifications of AQL=0.015, α=0.05; LTPD=0.05, β=0.10? Discuss.

Population percent defective	Probability of acceptance
0.00	1.00000
0.01	0.99408
0.02	0.86650
0.03	0.55623
0.04	0.26516
0.05	0.10056
0.06	0.03217
0.07	0.00905
0.08	0.00231
0.09	0.00054
0.10	0.00012

The plan meets the α and the β specification fairly well.

Population percent defective	**Probability of acceptance**	**AOQ**	
0.00	**1.000**	**0.0000**	
0.01	**0.994**	**0.0099**	
0.015	**0.958**	**0.0144**	**At AQL**
0.02	**0.867**	**0.0173**	**maximum**
0.03	**0.558**	**0.0167**	
0.04	**0.267**	**0.0107**	
0.05	**0.102**	**0.0051**	**At LTPD**
0.06	**0.033**	**0.0020**	
0.07	**0.009**	**0.0006**	
0.08	**0.002**	**0.0002**	
0.09	**0.001**	**0.0001**	

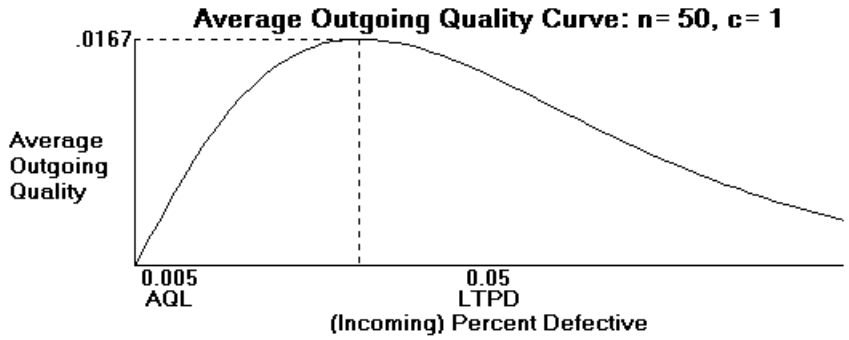


(Acceptance sampling, moderate) {AACSB: Analytic Skills}

137. In the table below are selected values for the OC curve associated with the acceptance sampling plan n=50, c=1. (Watch out--the points are not evenly spaced.) Assume that upon failed inspection, defective items are replaced. Calculate the AOQ for each data point. (You may assume that the population is much larger than the sample.) Plot the AOQ curve. At approximately what population defective rate is the AOQ at its worst? Explain how this happens. How well does this plan meet the specifications of AQL=0.0050, α=0.05; LTPD=0.05, $\cdot\beta$=0.10? Discuss.

Population percent defective	Probability of acceptance
0.005	0.97387
0.01	0.91056
0.02	0.73577
0.03	0.55528
0.04	0.40048
0.05	0.27943
0.06	0.19000
0.08	0.08271

This plan does not meet the specification very well. At .005 defective, the probability of acceptance is not 95% but over 97. At 0.05 defective, the acceptance rate is not 5% but 28.



Population percent defective	**Probability of acceptance**	**AOQ**	
0.005	**0.97387**	**0.004869**	**at AQL**
0.01	**0.91056**	**0.009106**	
0.02	**0.73577**	**0.014715**	
0.03	**0.55528**	**0.016658**	**maximum**
0.04	**0.40048**	**0.016019**	
0.05	**0.27943**	**0.013972**	**at LTPD**
0.06	**0.19000**	**0.0114**	
0.08	**0.08271**	**0.006617**	

(Acceptance sampling, moderate) {AACSB: Analytic Skills}

138. A bank's manager has videotaped 20 different teller transactions to observe the number of mistakes being made. Ten transactions had no mistakes, five had one mistake and five had two mistakes. Compute proper control limits at the 90% confidence level.
A c-chart should be used, and from Table S6.2, the *z*-value = 1.65.
The mean *c*-bar = [10(0) + 5(1) + 5(2)]/20 = 0.75.
UCL$_c$ $= 0.75 + 1.65\sqrt{0.75} = 2.18.$
LCL$_c$ $= 0.75 - 1.65\sqrt{0.75} = -0.68$ **(or 0).**
(Statistical process control (SPC), moderate) {AACSB: Analytic Skills}

139. A department chair wants to monitor the percentage of failing students in classes in her department. Each class had an enrollment of 50 students last spring. The number of failing students in the 10 classes offered that term were 1, 4, 2, 0, 0, 0, 0, 0, 0, and 3, respectively. Compute the control limits for a *p*-chart at the 95% confidence level. Is the process in control?
From Table S6.2, the *z*-value = 1.96.
The mean *p*-bar = [1+4+2+0+0+0+0+0+0+3]/(50×10) = 0.02.
$\sigma_{\hat{p}} = \sqrt{\dfrac{0.02(1-0.02)}{50}}$ **= 0.0198**
UCL$_p$ = 0.02 + 1.96(.0198) = 0.0589.
LCL$_p$ = 0.02 − 1.96(.0198) = −0.0189 (or 0).
Since the percent defects in classes 2 and 10 both exceeded 5.89%, the percentage of failing students is not in statistical control. The department chair should investigate.
(Statistical process control (SPC), moderate) {AACSB: Analytic Skills}

CHAPTER 7: PROCESS STRATEGY

TRUE/FALSE

1. Dell's approach to personal computer manufacturing is to use a product focus, which gives the company its low-cost competitive advantage.
False (Global company profile, easy)

2. A firm's process strategy is its approach to transforming resources into goods and services.
True (Introduction, easy)

3. Intermittent processes are organized around processes.
True (Four process strategies, easy)

4. In process-focused facilities, equipment utilization is low.
True (Four process strategies, moderate)

5. The typical full-service restaurant uses a product-focused process.
False (Four process strategies, moderate)

6. Harley-Davidson, because it has so many possible combinations of products, utilizes the process strategy of mass customization.
False (Four process strategies, moderate)

7. A value-stream map includes both (1) inventory quantities, and (2) symbols for customers and suppliers.
True (Process analysis and design, moderate)

8. The assembly line is a classic example of a repetitive process.
True (Four process strategies, easy)

9. One essential ingredient of mass customization is modular design.
True (Four process strategies, moderate)

10. The tool that calculates which process has the lowest cost at any specified production volume is a crossover chart.
True (Four process strategies, moderate)

11. The term *focused processes* refers to the quest for increased efficiency, whether in goods or services, that results from specialization.
True (Four process strategies, moderate)

12. Service blueprinting is a process analysis technique that focuses on the customer and the provider's interaction with the customer.
True (Process analysis and design, moderate)

13. Activity times should not be included in a service blueprint.
False (Process analysis and design, moderate)

14. A process map with the addition of a time axis becomes a process chart.
False (Process analysis and design, moderate)

15. Time-function mapping is a flow diagram with time added to the horizontal axis.
True (Process analysis and design, moderate)

16. Process maps use distance, but not time, to show the movement of material, product, or people through a process.
False (Process analysis and design, moderate)

17. Professional services typically require low levels of labor intensity.
False (Service process design, moderate)

18. An example of the *postponement* strategy for improving service productivity is having the customer wait until you have sufficient time to serve the customer.
False (Service process design, moderate)

19. Process control is the use of information technology to monitor and control a physical process.
True (Production technology, easy) {AACSB: Use of IT}

20. One use of camera-and-computer-based vision systems is to replace humans doing tedious and error-prone visual inspection activities.
True (Production technology, easy) {AACSB: Use of IT}

21. Automated storage and retrieval systems are commonly used in distribution facilities of retailers.
True (Production technology, moderate) {AACSB: Use of IT}

22. Flexible manufacturing systems, because of easily changed control programs, are able to perform such tasks as manufacturing one-of-a-kind parts economically.
True (Production technology, moderate) {AACSB: Use of IT}

23. Production technology has had a major impact on services, but as yet there has been little reduction in service labor requirements.
False (Technology in services, moderate) {AACSB: Use of IT}

24. Optical checkout scanners and ATMs are examples of technology's impact on services.
True (Technology in services, moderate) {AACSB: Use of IT}

25. Successful process redesign focuses on departmental areas where small, continuous improvements can be made.
False (Process redesign, moderate)

26. Processes can be environmentally friendly and socially responsible while still contributing to profitable strategies.
True (Ethics and environmentally friendly processes, easy) {AACSB: Ethical Reasoning}

27. In selecting new equipment and technology, decision-makers look for flexibility—the ability to respond with little penalty in time, cost, or customer value.
True (Selection of equipment and technology, moderate)

MULTIPLE CHOICE

28. Which of the following statements regarding Dell Computer is **false**?
    a. Dell is a practitioner of the mass customization process.
    b. Dell builds its computers overseas in order to gain a low-cost advantage.
    c. Dell keeps very little inventory of finished goods.
    d. Dell utilizes a global supply chain, but assembles its computers in the U.S.
    e. Dell's research focuses on manufacturing issues, not computer part design.
    b (Global company profile, moderate)

29. An organization's process strategy
    a. will have long-run impact on efficiency and flexibility of production
    b. is the same as its transformation strategy
    c. must meet various constraints, including cost
    d. is concerned with how resources are transformed into goods and services
    e. All of the above are true.
    e (Introduction, moderate)

30. A job shop is an example of a(n)
    a. repetitive process
    b. continuous process
    c. line process
    d. intermittent process
    e. specialized process
    d (Four process strategies, moderate)

31. Three types of processes are
    a. goods, services, and hybrids
    b. manual, automated, and service
    c. process focus, repetitive focus, and product focus
    d. modular, continuous, and technological
    e. input, transformation, and output
    c (Four process strategies, moderate)

32. Which of the following industries is likely to have low equipment utilization?
    a. auto manufacturing
    b. commercial baking
    c. television manufacturing
    d. chemical processing
    e. restaurants
    e (Four process strategies, moderate)

33. A product-focused process is commonly used to produce
    a. high-volume, high-variety products
    b. low-volume, high-variety products
    c. high-volume, low-variety products
    d. low-variety products at either high- or low-volume
    e. high-volume products of either high- or low-variety
    c (Four process strategies, moderate)

34. Which one of the following products is most likely made in a job shop environment?
    a. a daily newspaper
    b. paper forms
    c. television sets
    d. cigarettes
    e. canned vegetables
    b (Four process strategies, moderate)

35. Which of the following products is likely to be assembled on a repetitive process line?
    a. automobiles
    b. personal computers
    c. dishwashers
    d. television sets
    e. all of the above
    e (Four process strategies, moderate)

36. An assembly line is an example of a
    a. product-focused process
    b. process-focused process
    c. repetitive process
    d. line process
    e. specialized process
    c (Four process strategies, moderate)

37. Standard Register
    a. has dozens of U.S. plants in its Forms Division
    b. groups people and machines into departments that perform specific activities
    c. utilizes a product strategy to keep production volume high
    d. obtains its low-cost advantage by not spending money on CAD systems
    e. obtains its low-cost advantage by specializing in a relatively small number of products
    b (Four process strategies, moderate)

38. Which of the following transformations generally has the highest equipment utilization?
    a. process-focused process
    b. repetitive process
    c. product-focused process
    d. specialized process
    e. modular process
    c (Four process strategies, moderate)

39. Harley Davidson
    a. utilizes job shops to make each of its modules
    b. uses product focused manufacturing
    c. uses a large number of modules to build a small number of different bikes
    d. uses work cells to feed its assembly line
    e. All of the above are true.
    d (Four process strategies, moderate)

40. Which of the following is **false** regarding repetitive processes?
    a. They use modules.
    b. They allow easy switching from one product to the other.
    c. They are the classic assembly lines.
    d. They have more structure and less flexibility than a job shop layout.
    e. They include the assembly of basically all automobiles.
    b (Four process strategies, moderate)

41. When done correctly, mass customization
    a. increases pressure on supply chain performance
    b. helps eliminate the guesswork that comes with sales forecasting
    c. drives down inventories
    d. increases pressure on scheduling
    e. all of the above
    e (Four process strategies, moderate)

42. Which of the following phrases best describes *product focus*?
    a. low volume, high variety
    b. finished goods are usually made to order
    c. processes are designed to perform a wide variety of activities
    d. high fixed costs, low variable costs
    e. raw material inventories are low relative to the value of the product
    d (Four process strategies, difficult)

43. Which of the following phrases best describes *process focus*?
    a. low volume, high variety
    b. finished goods are usually made to a forecast and stored
    c. operators are modestly skilled
    d. high fixed costs, low variable costs
    e. raw material inventories are high relative to the value of the product
    a (Four process strategies, difficult)

44. Which of the following characteristics best describes *repetitive focus*?
    a. It uses sophisticated scheduling to accommodate custom orders.
    b. Its output is a standardized product produced from modules.
    c. It is too expensive when volumes are low or flexibility is required.
    d. It is widely used for the manufacture of steel.
    e. Its costs are often known only after a job is done.
    b (Four process strategies, difficult)

45. Utilization in process-oriented facilities is frequently low because
    a. the postponement strategy for improving service productivity is being used
    b. scheduling in process-oriented facilities is not very complex
    c. with high fixed costs, utilization is not very important
    d. excess capacity for peak demands is desirable
    e. low raw material inventories cause machines to be idled
    d (Four process strategies, moderate)

46. A quasi-custom product
    a. gets its apparent customization from the combinations available from a small number of modules
    b. is often the output of repetitive focus facilities
    c. is a valid description of a fast food sandwich
    d. is only possible when the *focus* strategy of service productivity improvement is in use
    e. All but **d** are true.

    e (Four process strategies, moderate)

47. Process A has fixed costs of $1000 and variable costs of $5 per unit. Process B has fixed costs of $500 and variable costs of $15 per unit. The crossover point between process A and process B is
    a. 50 units
    b. 200 units
    c. $2,500
    d. $5,000
    e. $9,500

    a (Four process strategies, moderate) {AACSB: Analytic Skills}

48. Process X has fixed costs of $10,000 and variable costs of $2.40 per unit. Process Y has fixed costs of $9,000 and variable costs of $2.25 per unit. Which of the following statements is **true**?
    a. The crossover point is approximately 6667 units.
    b. It is impossible for one process to have both of its costs lower than those of another process.
    c. Process Y is cheaper than process X at all volumes; there is no crossover point.
    d. Process X should be selected for very large production volumes.
    e. Process X is more profitable than process Y and should be selected.

    c (Four process strategies, moderate) {AACSB: Analytic Skills}

49. The crossover point is that production quantity where
    a. variable costs of one process equal the variable costs of another process
    b. fixed costs of a process are equal to its variable costs
    c. total costs equal total revenues for a process
    d. total costs for one process equal total costs for another process
    e. the process no longer loses money

    d (Four process strategies, moderate)

50. Product Focused processes
    a. allow more customization, but are not very efficient
    b. are desirable because resource needs increase slowly with the complexity of a process
    c. are processes that are specialized for relatively few products or customer groups
    d. apply only to service firms, not to manufacturers
    e. are profitable because customers demand flexibility, not specialization

    c (Process analysis and design, moderate)

51. Value Stream Mapping
    a. is a variation on time function mapping
    b. examines the supply chain to determine where value is added
    c. extends time function mapping back to the supplier
    d. starts with the customer and works backwards
    e. All of the above
    e (Process analysis and design, moderate)

52. One fundamental difference between a process chart and a process map is that
    a. the process chart uses a time dimension while a process map is not time-oriented
    b. the process chart includes the supply chain, while the process map stays within an organization
    c. the process chart is more like a table, while the process map is more like a schematic diagram
    d. the process chart focuses on the customer and on the provider's interaction with the customer, while the process map does not deal directly with the customer
    e. None of these is true, because a process chart and a process map are the same thing.
    c (Process analysis and design, moderate)

53. Service blueprinting
    a. provides the basis to negotiate prices with suppliers
    b. mimics the way people communicate
    c. determines the best time for each step in the process
    d. focuses on the provider's interaction with the customer
    e. can only be successful with two-dimensional processes
    d (Service process and design, moderate) {AACSB: Communication}

54. A drawing of the movement of material, product, or people is a
    a. flow diagram
    b. process chart
    c. service blueprint
    d. process map
    e. none of the above
    a (Process analysis and design, moderate)

55. Strategies for improving productivity in services are
    a. separation, self-service, automation, and scheduling
    b. lean production, strategy-driven investments, automation, and process focus
    c. reduce inventory, reduce waste, reduce inspection, and reduce rework
    d. high interaction, mass customization, service factory, and just-in-time
    e. none of the above
    a (Service process design, moderate)

56. In mass service and professional service, the operations manager should focus on
    a. automation
    b. equipment maintenance
    c. sophisticated scheduling
    d. human resources
    e. all of the above
    d (Service process design, moderate)

57. In mass service and service factory quadrants of the service process matrix, the operations manager could focus on all of the following **except**
    a. automation
    b. standardization
    c. tight quality control
    d. removing some services
    e. customization
    e (Service process design, moderate)

58. Which of the following is **true** regarding opportunities to improve service processes?
    a. Automation can do little to improve service processes, because services are so personal.
    b. Layout is of little consequence, since services seldom use an assembly line.
    c. If a work force is strongly committed, it need not be cross-trained and flexible.
    d. All of the above are true.
    e. None of the above is true.
    e (Service process design, moderate)

59. Which of the following are typical of process control systems?
    a. They have sensors.
    b. The digitized data are analyzed by computer, which generates feedback.
    c. Their sensors take measurements on a periodic basis.
    d. The sensors' measurements are digitized.
    e. all of the above
    e (Production technology, moderate) {AACSB: Use of IT}

60. Which of the following is **true** regarding vision systems?
    a. They are consistently accurate.
    b. They are modest in cost.
    c. They do not become bored.
    d. All of the above are true.
    e. None of the above is true.
    d (Production technology, moderate) {AACSB: Use of IT}

61. The use of information technology to monitor and control a physical process is known as
    a. process control
    b. computer-aided design
    c. information numeric control
    d. numeric control
    e. none of the above
    a (Production technology, moderate) {AACSB: Use of IT}

62. Which of the following technologies would enable a cashier to scan the entire contents of a shopping cart in seconds?
    a. ASRS
    b. AGV
    c. CAD/CAM
    d. RFID
    e. FMS
    d (Production technology, moderate) {AACSB: Use of IT}

63. "Automatic placement and withdrawal of parts and products into and from designated places in a warehouse" describes
    a. AGV
    b. CAD/CAM
    c. CIM
    d. ASRS
    e. FMS
    d (Production technology, moderate) {AACSB: Use of IT}

64. Computer-integrated manufacturing (CIM) includes manufacturing systems that have
    a. computer-aided design, a flexible manufacturing system, inventory control, warehousing and shipping integrated
    b. transaction processing, management information systems, and decision support systems integrated
    c. automated guided vehicles, robots, and process control
    d. robots, automated guided vehicles, and transfer equipment
    e. all of the above
    a (Production technology, moderate) {AACSB: Use of IT}

65. Which one of the following technologies is used **only** for material handling, **not** actual production or assembly?
    a. robots
    b. CNC
    c. CAD
    d. AGVs
    e. FMS
    d (Production technology, moderate) {AACSB: Use of IT}

66. A system using an automated work cell controlled by electronic signals from a common centralized computer facility is called a(n)
    a. adaptive control system
    b. robotics
    c. flexible manufacturing system
    d. automatic guided vehicle (AGV) system
    e. manufacturing cell
    c (Production technology, moderate) {AACSB: Use of IT}

67. "Operators simply load new programs, as necessary, to produce different products" describes
    a. CAD
    b. automated guided vehicles
    c. flexible manufacturing systems
    d. vision systems
    e. process control
    c (Production technology, moderate) {AACSB: Use of IT}

68. Which of the following is not one of the essential ingredients for mass customization?
    a. high machine utilizations
    b. personnel and facility flexibility
    c. reliance on modular design
    d. rapid throughput
    e. very effective scheduling
    a (Four process strategies, moderate)

69. Advances in technology
    a. have impacted the manufacturing sector only
    b. have had only limited impact on services
    c. have failed to change the level of customer interaction with an organization
    d. have had dramatic impact on customer interaction with services and with products
    e. have dramatically changed health care, but have not changed retailing
    d (Technology in services, moderate)

70. Process redesign
    a. is the fundamental rethinking of business processes
    b. can focus on any process
    c. tries to bring about dramatic improvements in performance
    d. focuses on activities that cross functional lines
    e. all of the above
    e (Process reengineering, moderate)

71. Ethical and environmentally friendly processes include which of the following?
    a. emission controls
    b. recycling
    c. efficient use of resources
    d. reduction of waste by-products
    e. all of the above
    e (Technology in services, moderate) {AACSB: Ethical Reasoning}

72. Making environmentally sound products through efficient processes
    a. is unprofitable, as long as recyclable materials prices are soft
    b. is known as lean manufacturing
    c. can still be profitable
    d. is easier for repetitive processes than for product-focused processes
    e. none of the above
    c (Ethical and environmentally friendly processes, moderate) {AACSB: Ethical Reasoning}

73. Flexibility can be achieved with
    a. movable equipment
    b. inexpensive equipment
    c. sophisticated electronic equipment
    d. modular equipment
    e. all of the above
    e (Selection of equipment and technology, moderate)

74. Which of the following statements regarding ethical and environmentally friendly processes is **true**?
    a. Operations managers can be environmentally sensitive, but they must avoid following a low cost strategy.
    b. Processes can be environmentally friendly or socially responsible, but not both.
    c. Operations managers can be environmentally sensitive and still follow a low cost strategy.
    d. Using energy-efficient lighting saves so little that it should not be labeled environmentally friendly.
    e. The only business strategy consistent with ethical and environmentally sensitive management is the differentiation strategy.

    c (Ethical and environmentally friendly processes, moderate) {AACSB: Ethical Reasoning}

75. Which of the following is **true** regarding the concept of **flexibility**?
    a. It is the ability to change production rates with little penalty in time, cost, or customer value.
    b. It can be accomplished with sophisticated electronic equipment.
    c. It may involve modular, movable, even cheap equipment.
    d. All of the above are true.
    e. None of the above is true.

    d (Selection of equipment and technology, moderate)

FILL-IN-THE-BLANK

76. An organization's approach to transforming resources into goods and services is called its _____.

    process strategy (Introduction, moderate)

77. The process strategy that is organized around processes to facilitate low-volume, high-variety processes is called a(n) _____.

    process focus (Four process strategies, moderate)

78. _____ is a process strategy that uses a product-oriented production process that uses modules.

    Repetitive focus (Four process strategies, moderate)

79. _____ is a rapid, low-cost production process that caters to constantly changing unique customer desires.

    Mass customization (Four process strategies, moderate)

80. _____ represent an organization's attempt to gain increased efficiency through specialization, which can include, for example, concentrating on certain classes of customers.

    Focused processes (Four process strategies, moderate)

81. A(n) _____ uses symbols to analyze the movement of people or material.

    process chart (Process analysis and design, easy)

82. A special form of time-function mapping, which goes beyond the organization into its supply chain, is _____.

    value stream mapping (Process analysis and design, moderate)

83. _____ is a process analysis technique that focuses on the customer and the producer's interaction with the customer.
Service blueprinting (Process analysis and design, easy)

84. The strategy for improving service productivity that customizes at delivery, rather than at production, is _____.
postponement (Service process design, moderate)

85. _____ involves the ability to respond with little penalty in time, cost, or customer value.
Flexibility (Selection of equipment and technology, moderate)

86. _____ is the use of information technology to control a physical process.
Process control (Production technology, moderate) {AACSB: Use of IT}

87. _____ is a computer-controlled warehouse that provides for the automatic placement of parts into and from designated places within the warehouse.
Automated storage and retrieval system or ASRS (Production technology, moderate) {AACSB: Use of IT}

88. A(n) _____ uses an automated work cell controlled by electronic signals from a common centralized computer facility.
flexible manufacturing system or FMS (Production technology, moderate) {AACSB: Use of IT}

89. _____ is the fundamental rethinking and radical redesign of business processes to bring about dramatic improvements in performance.
Process reengineering (Process redesign, moderate)

SHORT ANSWERS

90. What is Dell Computer's source of competitive advantage? In a short paragraph, explain some of the steps Dell has taken to develop this advantage.
Dell's competitive advantage is in its process strategy, which is mass customization. Dell spends most of its research budget on efficient installation and configuration of PCs, rather than on new computer parts. Dell builds PCs only when ordered. Dell utilizes various methods to keep inventory low. Dell utilizes the Internet to enhance productivity (Global company profile, moderate)

91. Why is Harley-Davidson identified as a repetitive manufacturer, not a mass customizer?
Harley-Davidson manufactures a variety of motorcycles on an assembly line. They are not a product-focused process. While Harley-Davidson's motorcycles display lots of variety, they are not as individualized as Dell's personal computers. The variety comes from choices in predefined modules, and there is apparently no place for a customer to get customization that would go beyond what is available in these modules. (Four process strategies, moderate)

92. What is the link between focused processes and specialization? What kinds of focus are possible?
Focused processes are a means of obtaining increased productivity through forms of specialization. Focus can take several forms, including concentrating on specific classes of customers, working only with products in selected product families, specializing in a specific service, or working with a narrow range of technology. (Four process strategies, moderate)

93. Describe Value Stream Mapping. Explain how it is different from process mapping.
Value Stream Mapping is a variation on time-function mapping or process mapping. The most fundamental difference between them is that Value Stream Mapping is not confined to the organization itself. In particular, in its analysis of where value is added, it extends the analysis to the organization's supply chain. (Process analysis and design, moderate)

94. How are modules useful in manufacturing processes?
Modules are parts or components of a product previously prepared. By using modules, the product can be quickly assembled. Using a different combination of modules allows for quasi-customization. (Four process strategies, moderate)

95. What is mass customization?
Mass customization is rapid, low-cost production of goods and services that fulfill increasingly unique customer desires. It brings us the variety of products traditionally provided by the process focus, with low costs associated with standardized high volume production (the product focus). (Four process strategies, moderate)

96. Name the four basic process strategies; describe them in a complete sentence or two each.
The four process strategies are process focus, product focus, repetitive focus, and mass customization. Process is a job shop--high variety and low volume; repetitive is an assembly line--relatively standardized products with options from modules; product is for high volume, low variety, such as oil refining, flour milling; mass customization is for high volume, high variety. (Four process strategies, moderate)

97. Why is equipment utilization in process-focused service industries often low?
Equipment utilization is low because excess capacity to meet peak demand loads is often desirable, and scheduling is typically difficult. (Four process strategies, moderate)

98. Compare an intermittent process to a continuous process on the basis of variety, volume, equipment utilization, and inventory.
Intermittent has high variety, low volume, low utilization, general purpose equipment. Since most output is made to order, there is little inventory of raw materials or finished goods. Continuous has low variety, high volume, high utilization, and specialized equipment. Just-in-time practices keep inventory very low. (Four process strategies, moderate)

99. The textbook described four basic process models, and hinted that there are others. Construct an example of a hybrid process. Can this process be applied in any well-known organization? How common do you think hybrid processes are?
Most students will graft elements of process onto elements of product or repetitive. Examples may include food service, where "process" may typify most operations, but salad bars add an element of "repetitive." In health care, hybrids of process and repetitive can readily be found. (Four process strategies, moderate) {AACSB: Reflective Thinking}

100. In an affluent society, how do we produce a wide number of options for products at low cost?
In an affluent society we produce a wide variety of options for products at low cost, primarily by use of modular components assembled in repetitive facilities, but automation is allowing more overlap of different types of production processes. (Four process strategies, moderate)

101. Name the tools of process analysis and design. Describe them in a sentence or two each.
Four tools of process analysis and design include flow diagrams, time-function mapping, process charts, and service blueprinting. Flow diagrams are a schematic or drawing of the movement of material, product, or people. Time-function mapping is a flow diagram, with the addition of time on the horizontal axis. Process charts use symbols, time, and distance to provide an objective and structured way to analyze and record the activities that make up a process. Service blueprinting focuses on the customer and the provider's interaction with the customer. (Process analysis and design, moderate)

102. Provide an example of the *focus* strategy for improving service productivity.
The focus strategy refers to restricting the offerings. Examples will vary, but a restaurant with a limited menu would be one example. (Service process design, moderate)

103. Provide an example of the *postponement* strategy for improving service productivity.
The postponement strategy refers to customizing the product at delivery, not at production. Examples will vary, but a home builder might leave some tasks unfinished until the house is sold, so that the buyer can make those final decisions. Carpeting, paint colors, cabinet doors, and some appliance choices might be good examples. (Service process design, moderate)

104. Identify the typical elements in a process control system.
Sensors collect data; analog devices read data on a periodic basis; measurements are digitized and transmitted to a computer; data are analyzed; and output occurs in the form of signals, diagrams, charts, messages, etc. (Production technology, moderate) {AACSB: Use of IT}

105. Identify the advances being made in technology to enhance production.
Technology used to enhance production include numerical control, process control, vision systems, robots, automated storage and retrieval systems, automated guided vehicles, flexible manufacturing systems, and computer integrated manufacturing. (Production technology, moderate) {AACSB: Use of IT}

106. Identify the techniques for improving service productivity. For any two techniques, describe in a short paragraph, and include an example.
The seven techniques are separation, self-service, postponement, focus, modules, automation, scheduling, and training.
- **Separation: structuring the service such that the customer must go where the service is offered (a medical facility)**
- **Self-service: let customers perform their own comparisons (supermarket shopping)**
- **Postponement: customizing at time of delivery or in the final stages of the process (dealer installed versus factory installed options on automobiles, boats, etc.; Wendy's Hamburgers)**
- **Focus: restricting the product offerings, options, or degree of customization allowed (limited number of factory installed options on a new automobile)**
- **Modules: services selected from modular choices (health insurance programs)**
- **Automation: identifying services that may lend themselves to automation (automatic teller machines)**
- **Scheduling: precise personnel scheduling (keep close watch on how many checkout lanes are needed)**
- **Training: clarifying options, teaching problem avoidance (maintenance personnel, counselors) (Service process design, difficult)**

107. Explain, in your own words, what a **flexible manufacturing system** is. List the benefits of flexible manufacturing systems.
An FMS is a system using an automated work cell controlled by electronic signals from a common centralized computer facility. Benefits of an FMS include improved capital utilization, low direct labor cost, reduced inventory, and consistent quality. (Production technology, moderate) {AACSB: Use of IT}

108. Describe some major challenges to implementing a successful build-to-order system?
Product design must be imaginative and fast. Process design must be rapid, flexible, and able to accommodate changes in design and technology. Inventory management requires tight control. Tight schedules that track orders and material from design through delivery can be effectively implemented only with dedicated personnel. Responsive partners in the supply chain yield effective collaboration. (Four process strategies, moderate)

109. Identify five examples of technology's impact on services. Specifically, identify one of these that has led to labor cost reductions. Discuss briefly. Can you add an item, not identified in the textbook, to this list?
Textbook identifies about three dozen examples. Students may add examples like PointCast (or other "push" information technologies), Amazon.com (fully electronic Internet-based shopping), or examples from entertainment (video gaming, network gaming). (Technology in services, moderate) {AACSB: Use of IT}

110. Why do modern operations managers look for flexibility in their equipment?
Flexibility in equipment provides managers the ability to respond to changes in demand with little penalty in time, cost, or customer value. (Selection of equipment and technology, moderate)

111. How are environmental issues linked to the process choice? Won't being an environmentally conscious firm drive up costs and take away any competitive advantage? Discuss, with examples to support your position.
Environmental issues are directly on point in the process decision. The process choice selects equipment that has emissions, creates waste in work or in packaging, etc. Not all environmentally conscious activities are cost-adding. But even if they were, cost is not the only thing affected. Customers may be attracted to products that are made from recycled materials, or that are more recyclable. This translates into revenue enhancement, not an element of cost. The competitive advantage centers on the customer, not the cost. (Environmentally friendly processes, moderate) {AACSB: Ethical Reasoning}

PROBLEMS

112. A product is currently made in a process-focused shop, where fixed costs are $9,000 per year and variable cost is $50 per unit. The firm is considering a fundamental shift in process, to repetitive manufacture. The new process would have fixed costs of $90,000, and variable costs of $5. What is the crossover point for these processes? For what range of outputs is each process appropriate?
The crossover is at 1800 units annually. For volumes under 1800, the process focus is cheaper; for volumes over 1800 units, the repetitive focus is cheaper. (Four process choices, moderate) {AACSB: Analytic Skills}

113. Big John's Manufacturing currently produces its lead product on a machine that has a variable cost of $0.32 per unit, and fixed costs of $75,000. Big John is considering purchasing a new machine that will drop the variable cost to $.28 per unit, but has a fixed cost of $150,000. What is the cross-over point between the two machines?
1,875,000 units (Four process choices, moderate) {AACSB: Analytic Skills}

114. The local convenience store makes personal pan pizzas. Currently, their process makes complete pizzas, fully cooked, for the customer. This process has a fixed cost of $20,000, and a variable cost of $1.75 per pizza. The owner is considering a different process that can make pizzas in two ways: completely cooked (as before), or partially cooked and then flash frozen, for the customer to finish at home. This alternate process has a fixed cost of $24,000, but a lower variable cost (because much less energy is used in baking) of $1.25 per pizza.
    a. What is the crossover point between the existing process and the proposed process?
    b. If the owner expects to sell 9,000 pizzas, should he get the new oven?
(a) the crossover is 8,000 units (b) for production quantities of 8,000 or larger, the new, more flexible process has lower cost. (Four process choices, moderate) {AACSB: Analytic Skills}

115. A firm is about to undertake the manufacture of a product, and is weighing the process configuration options. There are two intermittent processes under consideration, as well as a repetitive focus. The smaller intermittent process has fixed costs of $3,000 per month, and variable costs of $10 per unit. The larger intermittent process has fixed costs of $12,000 and variable costs of $2 per unit. A repetitive focus plant has fixed costs of $50,000 and variable costs of $1 per unit.
a. At what output does the large intermittent process become cheaper than the small one?
b. At what output does the repetitive process become cheaper than the larger intermittent process?
(a) at 1125 units, the large job shop becomes cheaper than the small job shop; (b) at 38,000 units, the repetitive shop is cheaper than the larger job shop. (Four process choices, moderate) {AACSB: Analytic Skills}

116. An organization is considering three process configuration options. There are two different intermittent processes, as well as a repetitive focus. The smaller intermittent process has fixed costs of $3,000 per month, and variable costs of $10 per unit. The larger intermittent process has fixed costs of $12,000 per month and variable costs of $2 per unit. A repetitive focus plant has fixed costs of $50,000 and variable costs of $1 per unit.
a. If the company produced 20,000 units, what would be its cost under each of the three choices?
b. Which process offers the lowest cost to produce 40,000 units? What is that cost?
(a) at 20,000 units, the costs are small intermittent = $203,000; large intermittent = $52,000; and repetitive = $70,000 (b) at 40,000 units, repetitive process is cheapest, at $90,000 (small intermittent = $403,000, and large intermittent = $92,000). (Four process choices, moderate) {AACSB: Analytic Skills}

117. A product is currently made in a process-focused shop, where fixed costs are $8,000 per year and variable cost is $40 per unit. The firm currently sells 200 units of the product at $200 per unit. A manager is considering a repetitive focus to lower costs (and lower prices, thus raising demand). The costs of this proposed shop are fixed costs = $24,000 per year and variable costs = $10 per unit. If a price of $80 will allow 400 units to be sold, what profit (or loss) can this proposed new process expect? Do you anticipate that the manager will want to change the process? Explain.
Old: TR = $40,000, TC = $16,000, therefore Profit = $24,000.
New: TR = $80 x 400 = $32,000, TC = $24,000 + $10 x 400 = $28,000, for a profit of $4,000.
Most will say NO; the larger repetitive process is less profitable than the smaller process-focused shop. (Four process choices, moderate) {AACSB: Analytic Skills}

118. Mary is considering purchasing a machine from two suppliers. Supplier A's machine has an annual fixed cost of $10,000 and a unit variable cost of $2.10. Supplier B's machine has an annual fixed cost of $16,000 and a unit variable cost of $3.00. How large should Mary's annual demand be in order to make Supplier B's machine the best choice?
The answer is that there is no demand for which Supplier B's machine will be best. The crossover point is -6667 units. (Four process choices, moderate) {AACSB: Analytic Skills}

SUPPLEMENT 7: CAPACITY PLANNING

TRUE/FALSE

1. Utilization is the number of units a facility can hold, receive, store, or produce in a period of time.
False (Capacity, easy)

2. Design capacity is the theoretical maximum output of a system in a given period under ideal conditions.
True (Capacity, moderate)

3. Capacity decisions are based on technological concerns, not demand forecasts.
False (Capacity, easy)

4. Expected output is sometimes referred to as rated capacity.
True (Capacity, moderate)

5. Price changes are useful for matching the level of demand to the capacity of a facility.
True (Capacity, moderate)

6. A useful tactic for increasing capacity is to redesign a product in order to get more throughput.
True (Capacity, moderate)

7. Changes in capacity may lead, lag, or straddle the demand.
True (Capacity planning, moderate)

8. Building an additional warehouse is an incremental expansion, not a one-step expansion.
False (Capacity planning, moderate)

9. Fixed costs are those costs that continue even if no units are produced.
True (Break-even analysis, moderate)

10. Break-even analysis identifies the volume at which fixed costs and revenue are equal.
False (Break-even analysis, moderate)

11. Break-even analysis is a powerful analytical tool, but is useful only when the organization produces a single product.
False (Break-even analysis, moderate)

12. A decision tree indicates at what quantity profit changes from negative to positive.
False (Break-even analysis, moderate)

13. A decision tree for analyzing capacity would have future demands or market favorability as the decision alternatives.
False (Applying decision trees to capacity decisions, moderate)

14. One limitation of the net present value approach to investments is that investments with identical net present values may have very different cash flows.
True (Applying investment analysis to strategy-driven investments, moderate)

15. The net present value of $10,000 to be received in exactly three years is considerably greater than $10,000.
False (Applying investment analysis to strategy-driven investments, easy)

MULTIPLE CHOICE

16. What is sometimes referred to as rated capacity?
a. efficiency
b. utilization
c. effective capacity
d. expected output
e. design capacity
d (Capacity, moderate)

17. Effective capacity is the
a. maximum output of a system in a given period
b. capacity a firm expects to achieve given the current operating constraints
c. average output that can be achieved under ideal conditions
d. minimum usable capacity of a particular facility
e. sum of all of the organization's inputs
b (Capacity, moderate)

18. Which of the following represents an aggressive approach to demand management in the service sector when demand and capacity are not particularly well matched?
a. inexpensive rates for weekend phone calls
b. appointments
c. reservations
d. first-come, first-served
e. none of the above
a (Capacity, moderate)

19. The Academic Computing Center has five trainers available in its computer labs to provide training sessions to students. Assume that the capacity of the system is 1900 students per semester and the utilization is 90%. If the number of students who actually got their orientation session is 1500, what is the efficiency of the system?
a. 1350 students
b. 1710 students
c. 75%
d. 87.7%
e. 90%
d (Capacity, moderate) {AACSB: Analytic Skills}

20. Christopher's Cranks uses a machine that can produce 100 cranks per hour. The firm operates 12 hours per day, five days per week. Due to regularly scheduled preventive maintenance, the firm expects the machine to be running during approximately 95% of the available time. Based on experience with other products, the firm expects to achieve an efficiency level for the cranks of 85%. What is the expected weekly output of cranks for this company?
    a. 5100
    b. 5700
    c. 4845
    d. 969
    e. 6783
    c (Capacity, moderate) {AACSB: Analytic Skills}

21. The staff training center at a large regional hospital provides training sessions in CPR to all employees. Assume that the capacity of this training system was designed to be 1200 employees per year. Since the training center was first put in use, the program has become more complex, so that 1050 now represents the most employees that can be trained per year. In the past year, 950 employees were trained. The efficiency of this system is approximately _____ and its utilization is approximately _____.
    a. 79.2 percent; 90.5 percent
    b. 90.5 percent; 79.2 percent
    c. 87.5 percent; 950 employees
    d. 950 employees; 1050 employees
    e. 110.5 percent; 114.3 percent
    b (Capacity, moderate) {AACSB: Analytic Skills}

22. Which of the following represents a common way to manage capacity in the service sector?
    a. appointments
    b. reservations
    c. changes in staffing levels
    d. first-come, first served service rule
    e. "early bird" specials in restaurants
    c (Capacity, easy)

23. If demand exceeds capacity at a new facility, an organization can use which of the following to move demand to an existing facility?
    a. aggressive marketing
    b. lower prices at all facilities
    c. build a facility of the correct size
    d. add a complementary product
    e. reduce lead times
    a (Capacity, moderate)

24. Adding a complementary product to what is currently being produced is a demand management strategy used when
    a. demand exceeds capacity
    b. capacity exceeds demand for a product which has stable demand
    c. the existing product has seasonal or cyclical demand
    d. price increases have failed to bring about demand management
    e. efficiency exceeds 100 percent
    c (Capacity, moderate)

25. An organization whose capacity is on that portion of the average unit cost curve that falls as output rises
    a. has a facility that is below optimum operating level and should build a larger facility
    b. has a facility that is above optimum operating level and should build a smaller facility
    c. is suffering from diseconomies of scale
    d. has utilization higher than efficiency
    e. has efficiency higher than utilization
    a (Capacity, moderate)

26. Of the four approaches to capacity expansion, the approach that "straddles" demand
    a. uses incremental expansion
    b. uses one-step expansion
    c. at some times leads demand, and at other times lags
    d. works best when demand is not growing but is stable
    e. Choices **a** and **c** are both correct.
    e (Capacity, moderate)

27. Which of the following is **not** one of the four approaches to capacity expansion?
    a. average capacity with incremental expansion
    b. lead demand with incremental expansion
    c. lag demand with incremental expansion
    d. lead demand with one-step expansion
    e. lag demand with one-step expansion
    e (Capacity, moderate)

28. Which of the following is **false** regarding capacity expansion?
    a. "Average" capacity sometimes leads demand, sometimes lags it.
    b. If "lagging" capacity is chosen, excess demand can be met with overtime or subcontracting.
    c. Total cost comparisons are a rather direct method of comparing capacity alternatives.
    d. Capacity may only be added in large chunks.
    e. All of the above are true.
    d (Capacity, moderate)

29. Break-even is the number of units at which
    a. total revenue equals price times quantity
    b. total revenue equals total variable cost
    c. total revenue equals total fixed cost
    d. total profit equals total cost
    e. total revenue equals total cost
    e (Break-even analysis, moderate)

30. Which of the following statements regarding fixed costs is **true**?
    a. Fixed costs rise by a constant amount for every added unit of volume.
    b. While fixed costs are ordinarily constant with respect to volume, they can "step" upward if volume increases result in additional fixed costs.
    c. Fixed costs are those costs associated with direct labor and materials.
    d. Fixed costs equal variable costs at the break-even point.
    e. Fixed cost is the difference between selling price and variable cost.

    b (Break-even analysis, moderate)

31. Which of the following costs would be incurred even if no units were produced?
    a. raw material costs
    b. direct labor costs
    c. transportation costs
    d. building rental costs
    e. purchasing costs

    d (Break-even analysis, moderate)

32. Basic break-even analysis typically assumes that
    a. revenues increase in direct proportion to the volume of production, while costs increase at a decreasing rate as production volume increases
    b. variable costs and revenues increase in direct proportion to the volume of production
    c. both costs and revenues are made up of fixed and variable portions
    d. costs increase in direct proportion to the volume of production, while revenues increase at a decreasing rate as production volume increases because of the need to give quantity discounts
    e. All of the above are assumptions in the basic break-even model.

    b (Break-even analysis, difficult)

33. Fabricators, Inc. wants to increase capacity by adding a new machine. The fixed costs for machine A are $90,000, and its variable cost is $15 per unit. The revenue is $21 per unit. The break-even point for machine A is
    a. $90,000 dollars
    b. 90,000 units
    c. $15,000 dollars
    d. 15,000 units
    e. cannot be calculated from the information provided

    d (Break-even analysis, moderate) {AACSB: Analytic Skills}

34. A fabrication company wants to increase capacity by adding a new machine. The firm is considering proposals from vendor A and vendor B. The fixed costs for machine A are $90,000 and for machine B, $75,000. The variable cost for A is $15.00 per unit and for B, $18.00. The revenue generated by the units processed on these machines is $21 per unit. If the estimated output is 5000 units, which machine should be purchased?
    a. machine A
    b. machine B
    c. either machine A or machine B
    d. no purchase because neither machine yields a profit at that volume
    e. purchase both machines since they are both profitable

    d (Break-even analysis, moderate) {AACSB: Analytic Skills}

35. Fred's Fabrication, Inc. wants to increase capacity by adding a new machine. The firm is considering proposals from vendor A and vendor B. The fixed costs for machine A are $90,000 and for machine B, $70,000. The variable cost for A is $9.00 per unit and for B, $14.00. The revenue generated by the units processed on these machines is $20 per unit. The crossover between machine A and machine B is
    a. 4,000 units, with A more profitable at low volumes
    b. 4,000 dollars, with A more profitable at low volumes
    c. 4,000 units, with B more profitable at low volumes
    d. 4,000 dollars, with B more profitable at low volumes
    e. none of the above
    c (Break-even analysis, moderate) {AACSB: Analytic Skills}

36. A shop wants to increase capacity by adding a new machine. The firm is considering proposals from vendor A and vendor B. The fixed costs for machine A are $90,000 and for machine B, $75,000. The variable cost for A is $15.00 per unit and for B, $18.00. The revenue generated by the units processed on these machines is $22 per unit. If the estimated output is 9,000 units, which machine should be purchased?
    a. machine A
    b. machine B
    c. either machine A or machine B
    d. no purchase because neither machine yields a profit at that volume
    e. purchase both machines since they are both profitable
    d (Break-even analysis, moderate) {AACSB: Analytic Skills}

37. Break-even analysis can be used by a firm that produces more than one product, but
    a. the results are estimates, not exact values
    b. the firm must allocate some fixed cost to each of the products
    c. each product has its own break-even point
    d. the break-even point depends upon the proportion of sales generated by each of the products
    e. None of these statements is true.
    d (Break-even analysis, moderate)

38. The basic break-even model can be modified to handle more than one product. This extension of the basic model requires
    a. price and sales volume for each product
    b. price and variable cost for each product, and the percent of sales that each product represents
    c. that the firm have very low fixed costs
    d. that the ratio of variable cost to price be the same for all products
    e. sales volume for each product
    b (Break-even analysis, moderate)

39. A product sells for $5, and has unit variable costs of $3. This product accounts for $20,000 in annual sales, out of the firm's total of $60,000. The weighted contribution of this product is approximately
    a. 0.133
    b. 0.200
    c. 0.40
    d. 0.667
    e. $1.667
    a (Break-even analysis, moderate) {AACSB: Analytic Skills}

40. When decision trees are used to analyze capacity decisions,
    a. "do nothing" is not a possible decision alternative
    b. probabilities must be assigned to each of the decision alternatives
    c. states of nature are often demand-based, as in "market favorability"
    d. states of nature must be known with certainty
    e. fixed costs are not relevant
    c (Applying decision trees to capacity decisions, moderate)

41. Net present value
    a. is gross domestic product less depreciation
    b. is sales volume less sales and excise taxes
    c. is profit after taxes
    d. ignores the time value of money
    e. is the discounted value of a series of future cash receipts
    e (Applying investment analysis to strategy-driven investments, moderate)

42. Net present value will be greater
    a. as a fixed set of cash receipts occurs later rather than earlier
    b. as the total of the cash receipts, made in same time periods, is smaller
    c. for one end-of-year receipt of $1200 than for twelve monthly receipts of $100 each
    d. for a 4% discount rate than for a 6% discount rate
    e. All of the above are true.
    d (Applying investment analysis to strategy-driven investments, moderate)

43. A capacity alternative has an initial cost of $50,000 and cash flow of $20,000 for each of the next four years. If the cost of capital is 5 percent, the net present value of this investment is
    a. greater than $80,000
    b. greater than $130,000
    c. less than $30,000
    d. impossible to calculate, because no interest rate is given
    e. impossible to calculate, because variable costs are not known
    c (Applying investment analysis to strategy-driven investments, moderate) {AACSB: Analytic Skills}

44. A capacity alternative has an initial cost of $50,000 and cash flow of $20,000 for each of the next four years. If the cost of capital is 5 percent, the net present value of this investment is approximately
    a. $20,920
    b. $26,160
    c. $49,840
    d. $70,920
    e. $106,990
    a (Applying investment analysis to strategy-driven investments, moderate) {AACSB: Analytic Skills}

FILL-IN-THE-BLANK

45. _____ is the amount a facility can hold, store, receive, or produce in a period of time.
    Throughput or Capacity (Capacity, moderate)

46. _____ is actual output as a percent of design capacity.
    Utilization (Capacity, moderate)

47. _____ is actual output as a percent of effective capacity.
    Efficiency (Capacity, moderate)

48. In the service sector, scheduling customers is _____, and scheduling the workforce is _____.
    demand management; capacity management (Capacity, moderate)

49. The capacity planning strategy that delays adding capacity until capacity is below demand, then adds a capacity increment so that capacity is above demand, is said to_____ demand.
    average or straddle (Capacity, moderate)

50. _____ analysis finds the point at which cost equals revenues.
    Break-even (Break-even analysis, moderate)

51. _____ cost is the cost that continues even if no units are produced.
    Fixed (Break-even analysis, moderate)

52. Multiproduct break-even analysis calculates the _____ of each product, _____ it in proportion to each product's share of total sales.
    contribution; weighting (Break-even analysis, moderate)

53. _____ is a means of determining the discounted value of a series of future cash receipts.
    Net present value or NPV (Applying investment analysis to strategy-driven investments, moderate)

SHORT ANSWERS

54. Some organizations use number of beds, number of rooms, or room size to measure capacity. There's no time period in this capacity, and no "throughput." Why are these firms using such a different concept of capacity?
Student answers will vary, since the answer is not explicitly covered in text. But it is a natural extension of what students know about services. It's easy for Krispy Kreme to say they produced 40,000 doughnuts in a day. But these firms may deliver services that are hard to quantify or add up, perhaps because each service is unique. So rather than measure produced output, they focus on certain inputs that are critical to their ability to serve customers. (Capacity, difficult) {AACSB: Reflective Thinking}

55. What is the fundamental distinction between design capacity and effective capacity? Provide a brief example.
Design capacity is the theoretical maximum output of a system in a given period under ideal conditions. Effective capacity, on the other hand, is the capacity that a firm expects to achieve given the current operating constraints. Effective capacity is often lower than design capacity because the facility may have been designed for an earlier version of the product or a different product mix than is currently being produced. As an example, a restaurant might have 100 seats, but it only opens up 60 every night because it cannot find enough qualified servers. (Capacity, moderate)

56. Distinguish between utilization and efficiency.
Both are ratios, not item counts. Both use actual output in the ratio numerator. Utilization is the ratio of actual output to design capacity, so it measures output as a fraction of ideal facility usage. Efficiency is the ratio of actual output to effective capacity, so it measures output as a fraction of the practical or current limits of the facility. (Capacity, moderate)

57. Why is the capacity decision important?
The capacity decision is important for several reasons. First, capacity costs represent a large portion of fixed costs. Second, a facility of the wrong size means that costs are not as low as they could be. If a facility is too large, and portions of it remain idle, the firm's costs are too high because of the higher fixed costs. If a plant is too small, costs are again higher than they might be due to inefficiencies of working in cramped and crowded spaces. Further, a facility too small may lead to lost sales, perhaps even lost markets. (Capacity, moderate)

58. A good capacity decision requires that it be tightly integrated with the organization's strategy and investments. But there are other "considerations" to making a good capacity decision. Name them. Describe each in a sentence or two.
The four considerations are forecast demand accurately, understand the technology and capacity increments, find the optimum operating level (volume), and build for change. Without a good demand forecast, no firm can expect to build a facility of the proper size. In some cases capacity can be obtained in small amounts, but in others, to add capacity might require an entire building or production line. There is an optimum operating level, at which average unit costs are least. That volume is found through the analysis of economic cost curves. Finally, the firm needs a plan for adding capacity as demand grows; this plan can lead demand, lag demand, or straddle demand. (Capacity, moderate)

59. A sugar mill receives sugar cane from farmers, extracts the juice, boils it into syrup, and then crystallizes the syrup into raw sugar. There has been an ongoing consolidation of sugar mills, and an increase in the capacity of those that remain. The number of mills in Louisiana was 48 in the 1960s, was 18 in 1999 and is currently 13. In 1999 the break-even point for a typical mill was 600,000 tons. But as the surviving mills have added capacity, the break-even point is now 1,000,000 tons. In 1999, the state's farmers produced 16,000,000 tons of cane, but by 2004, the crop was down to 13,000,000 tons. Analyze this situation with what you have learned about the capacity decision. Is the industry better off with fewer but larger mills, or not?
There are several possible paths students can take. The most obvious is the economic argument that economies of scale call for ever larger plants. Students may want to address the lead, lag, or straddle strategies of growing to meet demand. But demand is not growing very much —it's up from 890,000 tons per mill to 1,000,000 tons per mill over 5 years. Students may alternately try to analyze the considerations of matching capacity to demand, and describe pricing strategies or internal changes to meet demand. But the broadest view suggests that the *industry* (not individual mills!) operated somewhat above break-even in 1999, but is squarely at break-even now. The increased capacities do not seem much of an improvement. This question is drawn from an article in the New Orleans Times-Picayune, 30 January 2005. (Capacity, difficult) {AACSB: Reflective Thinking}

60. Identify the tactics for matching capacity to demand.
1. Making staffing changes (increasing or decreasing the number of employees), 2. Adjusting equipment (purchasing additional machinery or selling or leasing out existing equipment), 3. Improving processes to increase throughput, 4. Redesigning products to facilitate more throughput, 5. Adding process flexibility to better meet changing product preferences, and 6. Closing facilities. (Capacity, moderate)

61. Define *fixed costs*.
Fixed costs are those that continue even if no units are produced. (Break-even analysis, moderate)

62. Define *variable costs*. What special assumption is made about variable costs in the textbook?
Variable costs are those that vary with the number of units produced, linearity, or proportionality. (Break-even analysis, moderate)

63. How is break-even analysis useful in the study of the capacity decision? What limitations does this analytical tool have in this application?
Breakeven is defined as the volume for which cost equals revenue. It is useful to know the break-even point for each capacity alternative under consideration. In reality, costs may not be as linear as they are assumed to be in this model. (Break-even analysis, moderate)

64. Describe how a decision tree might be used to analyze a capacity decision.
The starting node of the tree is the capacity decision itself. There will be one branch from this node for each decision alternative (capacity choice). Each choice may have states of nature attached to it, such as whether demand is high or low. These states of nature will have probabilities assigned, and each terminal branch of the tree must be assigned a payoff. The expected value of each decision alternative is calculated, and the highest expected value chosen as the best capacity choice. (Applying decision trees to capacity decisions, moderate)

65. What are the assumptions of the net present value technique?
The assumptions of the *net present value* technique are:
- **Interest rates are known for the entire term of the investment.**
- **Payments are made at the end of each time period.**
- **Investments with similar net present values are similar in other respects (at least, we make this assumption if net present value is the *only* method of evaluation of investment used).**

(Applying investment analysis to strategy-driven investments, moderate)

PROBLEMS

66. The staff training center at a large regional hospital provides training sessions in CPR to all employees. Assume that the capacity of this training system was designed to be 1800 employees per year. Since the training center was first put in use, the program has become more complex, so that 1400 now represents the most employees that can be trained per year. In the past year, 1350 employees were trained. Calculate the efficiency and the utilization of this system.
Efficiency = 1350 / 1400 = .964 or 96.4 percent; utilization = 1350 / 1800 = .75 or 75 percent
(Capacity, moderate) {AACSB: Analytic Skills}

67. An executive conference center has the physical ability to handle 1,100 participants. However, conference management personnel believe that only 1,000 participants can be handled effectively for most events. The last event, although forecasted to have 1,000 participants, resulted in the attendance of only 950 participants. What are the utilization and efficiency of the conference facility?
Design Capacity = 1,100 participants
Effective Capacity = 1,000 participants
Actual Output = 950 participants

$$\text{Utilization} = \frac{\text{acutal output}}{\text{design capacity}} = \frac{950}{1{,}100} = 86.4\%$$

$$\text{Efficiency} = \frac{\text{actual output}}{\text{effective capacity}} = \frac{950}{1000} = 95.0\%$$

(Capacity, moderate) {AACSB: Analytic Skills}

68. A fleet repair facility has the capacity to repair 800 trucks per month. However, due to scheduled maintenance of their equipment, management feels that they can repair no more than 600 trucks per month. Last month, two of the employees were absent several days each, and only 400 trucks were repaired. What are the utilization and efficiency of the repair shop?
Design Capacity = 800 trucks
Effective Capacity = 600 trucks
Actual Output = 400 trucks

$$\text{Utilization} = \frac{\text{acutal output}}{\text{design capacity}} = \frac{400}{800} = 50.0\%$$

$$\text{Efficiency} = \frac{\text{actual output}}{\text{effective capacity}} = \frac{400}{600} = 66.7\%$$

(Capacity, moderate) {AACSB: Analytic Skills}

69. The local convenience store makes personal pan pizzas. Currently, their oven can produce 50 pizzas per hour. It has a fixed cost of $2,000, and a variable cost of $0.25 per pizza. The owner is considering a bigger oven that can make 75 pizzas per hour. It has a fixed cost of $3,000, but a variable cost of $0.20 per pizza.
a. At what quantity do the two ovens have equal costs?
b. If the owner expects to sell 9,000 pizzas, should he get the new oven?
(a) The crossover is where $2,000 + .25X = $3,000 + .20X. Simplifying, 0.05X = 1000, or X = 20,000 units (b) no, stay with the current oven. (Break-even analysis, moderate) {AACSB: Analytic Skills}

70. A product is currently made in a process-focused shop, where fixed costs are $9,000 per year and variable cost is $50 per unit. The firm sells the product for $200 per unit. What is the break-even point for this operation? What is the profit (or loss) on a demand of 200 units per year?
BEP = 60 units; TR = $40,000, TC = $19,000, therefore Profit = $21,000. (Break-even analysis, moderate) {AACSB: Analytic Skills}

71. A product is currently made in a process-focused shop, where fixed costs are $8,000 per year and variable cost is $40 per unit. The firm currently sells 200 units of the product at $200 per unit. A manager is considering a repetitive focus to lower costs (and lower prices, thus raising demand). The costs of this proposed shop are fixed costs = $24,000 per year and variable costs = $10 per unit. If a price of $80 will allow 400 units to be sold, what profit (or loss) can this proposed new process expect? Do you anticipate that the manager will want to change the process? Explain.
Old: TR = $40,000, TC = $16,000, therefore Profit = $24,000.
New: TR = $80 x 400 = $32,000, TC = $24,000 + $10 x 400 = $28,000, for a profit of $4,000. Most will say NO; the larger repetitive process is less profitable than the smaller process-focused shop. (Break-even analysis, moderate) {AACSB: Analytic Skills}

72. A firm sells two products. Product R sells for $20; its variable cost is $6. Product S sells for $50; its variable cost is $30. Product R accounts for 60 percent of the firm's sales, while S accounts for 40 percent. The firm's fixed costs are $4 million annually. Calculate the firm's break-even point.
The contribution for product R is 70 percent of selling price, or 0.70; the contribution for product S is 0.40. The weighted contribution for R is .70 x .60 = .42; the weighted contribution for S is .40 x .40 = .16. The sum of the weighted contributions is 0.58. The break-even point is $4,000,000 / 0.58 = $6,896,552. (Break-even analysis, moderate) {AACSB: Analytic Skills}

73. A firm is weighing three capacity alternatives: small, medium, and large job shop. Whatever capacity choice is made, the market for the firm's product can be "moderate" or "strong." The probability of moderate acceptance is estimated to be 40 percent; strong acceptance has a probability of 60 percent. The payoffs are as follows. Small job shop, moderate market = $24,000; Small job shop, strong market = $54,000. Medium job shop, moderate market = $20,000; medium job shop, strong market = $64,000. Large job shop, moderate market = -$2,000; large job shop, strong market = $96,000. Which capacity choice should the firm make?
The expected values for the three decision alternatives (capacities) are: small job shop = $42,000; medium job shop = $46,400; and large job shop = $56,800. The firm should choose the large job shop. (Applying decision trees to capacity decisions, moderate) {AACSB: Analytic Skills}

74. A firm produces three products in a repetitive process facility. Product A sells for $60; its variable costs are $20. Product B sells for $200; its variable costs are $80. Product C sells for $25; its variable costs are $15. The firm has annual fixed costs of $320,000. Last year, the firm sold 1000 units of A, 2000 units of B, and 10,000 units of C. Calculate the break-even point of the firm. The firm has some idle capacity at these volumes, and chooses to cut the selling price of A from $60 to $45, believing that its sales volume will rise from 1000 units to 2500 units. What is the revised break-even point?

Calculations for the original version of this problem are:

Product	Selling price P	Variable cost V	V/P	1-V/P	Sales	Percent of sales	Weighted contrib
A	**$60**	**$20**	**.333**	**.667**	**$60,000**	**.0845**	**.0564**
B	**$200**	**$80**	**.400**	**.600**	**$400,000**	**.5634**	**.3380**
C	**$25**	**$15**	**.600**	**.400**	**$250,000**	**.3521**	**.1408**
					$710,000	**1.0000**	**0.5352**

The original break-even for this firm was $320,000 / .5352 = $597,907. This is a calculator-based result; Excel reports $597,895.

When the price of A is reduced, the revised calculations are:

Product	Selling price P	Variable cost V	V/P	1-V/P	Sales	Percent of sales	Weighted contrib
A	**$45**	**$20**	**.444**	**.556**	**$112,500**	**.1475**	**.0820**
B	**$200**	**$80**	**.400**	**.600**	**$400,000**	**.5246**	**.3148**
C	**$25**	**$15**	**.600**	**.400**	**$250,000**	**.3279**	**.1312**
					$762,500	**1.0000**	**0.5280**

The firm's breakeven point has increased to $320,000 / .5280 = $606,061. (Calculator-based; Excel reports $606,211). (Break-even analysis, difficult) {AACSB: Analytic Skills}

75. Health Care Systems of the South is about to buy an expensive piece of diagnostic equipment. The company estimates that it will generate uniform revenues of $500,000 for each of the next eight years. What is the present value of this stream of earnings, at an interest rate of 6%? What is the present value if the machine lasts only six years, not eight? If the equipment cost $2,750,000, should the company purchase it?

S = R * X = 500,000 * 6.210 = $3,105,000; S = R * X = 500,000 * 4.917 = $2,458,500

The company should purchase the equipment if it believes it will last eight years, but not if it fears that it will last only six. (Applying investment analysis to strategy-driven investments, moderate) {AACSB: Analytic Skills}

76. A firm produces three products. Product A sells for $60; its variable costs are $20. Product B sells for $200; its variable costs are $120. Product C sells for $25; its variable costs are $10. Last year, the firm sold 1000 units of A, 2000 units of B, and 10,000 units of C. The firm has fixed costs of $320,000 per year. Calculate the break-even point of the firm.

Calculations for this problem are:

Product	Selling price P	Variable cost V	V/P	1-V/P	Sales	Percent of sales	Weighted contrib
A	**$60**	**$20**	**.333**	**.667**	**$60,000**	**.0845**	**.0564**
B	**$200**	**$120**	**.600**	**.400**	**$400,000**	**.5634**	**.2254**
C	**$25**	**$10**	**.400**	**.600**	**$250,000**	**.3521**	**.2113**
					$710,000	**1.0000**	**.4931**

Break-even for this firm is $320,000 / .4931 = $648,956. Note: this result reflects calculator rounding, as students might experience at exam time. Excel reports $649, 143. (Break-even analysis, moderate) {AACSB: Analytic Skills}

77. A firm is about to undertake the manufacture of a product, and is weighing three capacity alternatives: small job shop, large job shop, and repetitive manufacturing. The small job shop has fixed costs of $3,000 per month, and variable costs of $10 per unit. The larger job shop has fixed costs of $12,000 per month and variable costs of $3 per unit. The repetitive manufacturing plant has fixed costs of $30,000 and variable costs of $1 per unit. Demand for the product is expected to be 1,000 units per month with "moderate" market acceptance, but 2,000 under "strong" market acceptance. The probability of moderate acceptance is estimated to be 60 percent; strong acceptance has a probability of 40 percent. The product will sell for $25 per unit regardless of the capacity decision. Which capacity choice should the firm make?

The payoffs are as follows: small job shop, moderate acceptance = $12,000; small job shop, strong acceptance = $27,000; large job shop, moderate acceptance = $10,000; large job shop, strong acceptance = $32,000; repetitive manufacturing, moderate acceptance = -$6,000; and repetitive manufacturing, strong acceptance = $18,000. The expected value for the small job shop decision alternative is $18,000. The expected value of the large job shop alternative is $18,800. The expected value for the repetitive manufacturing alternative is $3600. The firm should choose the large job shop capacity alternative. (Applying decision trees to capacity decisions, difficult) {AACSB: Analytic Skills}

78. A new machine tool is expected to generate receipts as follows: $5,000 in year one; $3,000 in year two, nothing in the next year, and $2,000 in the fourth year. At an interest rate of 6%, what is the present value of these receipts? Is this a better present value than $2,500 each year over four years? Explain.

5,000 *x* .943 + 3,000 *x* .890 + 2,000 *x* .792 = $8,969 using Table S7.1 ($8,971.16 using Excel). The steady stream generates NPV of 2,500 x 3.465 = $8,662.5 ($8,662.76 using Excel). The irregular stream has the higher present value because the large receipts are early. (Applying investment analysis to strategy-driven investments, moderate) {AACSB: Analytic Skills}

79. Advantage Milling Devices is preparing to buy a new machine for precision milling of special metal alloys. This device can earn $300 per hour, and can run 3,000 hours per year. The machine is expected to be this productive for four years. If the interest rate is 6%, what is the present value? What is the present value if the interest rate is not 6%, but 0%? Why does present value fall when interest rates rise?
S = R * X = 300 * 3,000 * 3.465 = $3,118,500; S = R * X = 300 * 3,000 * 3.240 = $2,916,000
NPV falls because higher interest rates create a greater discount on future receipts.
(Applying investment analysis to strategy-driven investments, moderate) {AACSB: Analytic Skills}

80. Suppose that the market has a 70% chance of being favorable and a 30% chance of being unfavorable. A favorable market will yield a profit of $300,000, while an unfavorable market will yield a profit of $20,000. What is the expected monetary value (EMV) in this situation?
EMV = (0.7)($300,000) + (0.3)($20,000) = $210,000 + $6,000 = $216,000.
(Applying decision trees to capacity decisions, easy) {AACSB: Analytic Skills}

CHAPTER 8: LOCATION STRATEGIES

TRUE/FALSE

1. FedEx chose Memphis, Tennessee, for its central location, or "hub," primarily because of the incentives offered by the city of Memphis and the state of Tennessee.
False (Global company profile, easy)

2. Generally, the objective of the location decision is to maximize the firm's profit.
False (The strategic importance of location, easy)

3. Lists have been developed that rank countries on issues such as “competitiveness” and “corruption.”
True (Factors that affect location decisions, easy)

4. When innovation replaces cost as a firm's focus for location decisions, the presence of other state-of-the-art firms is a plus, not a negative, for the firm's competitiveness.
True (The strategic importance of location, moderate)

5. The ratio of labor cost per day to productivity, in units per day, is the labor cost per unit.
True (Factors that affect location decisions, moderate)

6. For a location decision, labor productivity may be important in isolation, but low wage rates are a more important criterion.
False (Factors that affect location decisions, moderate)

7. Unfavorable exchange rates can offset other savings in a location decision.
True (Factors that affect location decisions, moderate)

8. An example of an intangible cost, as it relates to location decisions, is the quality of education.
True (Factors that affect location decisions, moderate)

9. In location decisions, intangible costs are easier to measure than tangible costs.
False (Factors that affect location decisions, moderate)

10. Location decisions are based on many things, including costs, revenues, incentives, attitudes, and intangibles, but not on ethical considerations.
False (Factors that influence location decisions, easy) {AACSB: Ethical Reasoning}

11. Manufacturers may want to locate close to their customers, if the transportation of finished goods is expensive or difficult.
True (Factors that affect location decisions, moderate)

12. One reason for a firm locating near its competitors is the presence of a major resource it needs.
True (Factors that affect location decisions, moderate)

13. The graphic approach to location break-even analysis displays the range of volume over which each location is preferable.
True (Methods of evaluating location alternatives, moderate)

14. The factor-rating method can consider both tangible and intangible costs.
True (Methods of evaluating location alternatives, moderate)

15. The center-of-gravity method finds the location of a centralized facility, such as a distribution center, that will maximize the organization's revenue.
False (Methods of evaluating location alternatives, moderate)

16. The transportation model calculates an optimal shipping system between a central facility and several outlying customers.
False (Methods of evaluating location alternatives, moderate)

17. Service firms choose locations based, in part, on the revenue potential of a site.
True (Service location strategy, moderate)

18. Starbucks Coffee's approach to choosing new café locations is largely based on executive intuition, not sophisticated models and site selection technology.
False (Service location strategy, easy)

19. Labor cost and labor availability often drive the location decision in the call center industry.
True (Service location strategy, moderate)

20. The location decisions of goods-producing firms will generally pay more attention to parking, access, and traffic counts than will service location decisions.
False (Service location strategy, moderate)

21. Industrial location decisions often assume that costs are relatively constant for a given area.
False (Service location strategy, moderate)

22. Starbucks Coffee's use of geocoded demographic and consumer data in site selection decisions is an example of the use of a Geographic Information System, or GIS.
True (Service location strategy, moderate)

MULTIPLE CHOICE

23. FedEx chose Memphis, Tennessee, as its U.S. hub because
    a. the city is in the center of the U.S., geographically
    b. the airport has relatively few hours of bad weather closures
    c. it needed a means to reach cities to which it did not have direct flights
    d. the firm believed that a hub system was superior to traditional city-to-city flight scheduling
    e. All of the above are true.
    e (Global company profile, easy)

24. Which of the following statements regarding FedEx is **true**?
    a. Its hub in Memphis, Tennessee, was selected because of its low cost.
    b. Memphis, Tennessee, is the only hub in the company's global flight network.
    c. FedEx believes the hub system helps reduce mishandling and delays due to better controls.
    d. FedEx uses a hub system in the U.S., but a city-to-city network in other countries.
    e. Memphis is FedEx's only hub airport in the United States.
    c (Global company profile, easy)

25. Industrial location analysis typically attempts to
    a. reduce costs
    b. maximize sales
    c. focus more on human resources
    d. be environmentally friendly
    e. none of the above
    a (Strategic importance of location, easy)

26. Governmental attitudes toward issues such as private property, intellectual property, zoning, pollution, and employment stability may change over time. The term associated with this phenomenon is
    a. bureaucratic risk
    b. political risk
    c. legislative risk
    d. judicial risk
    e. democratic risk
    b (Factors that affect location decisions, moderate)

27. A location decision for an appliance manufacturer would tend to have a(n)
    a. cost focus
    b . labor focus
    c. revenue focus
    d. environmental focus
    e. education focus
    a (Strategic importance of location, moderate)

28. A location decision for a traditional department store (Macy's) would tend to have a(n)
    a. cost focus
    b. labor focus
    c. revenue focus
    d. environmental focus
    e. education focus
    c (Strategic importance of location, moderate)

29. Globalization of the location decision is the result of all of the following **except**
    a. market economics
    b. higher quality of labor overseas
    c. ease of capital flow between countries
    d. high differences in labor costs
    e. more rapid, reliable travel and shipping
    b (Factors that affect location decisions, moderate) {AACSB: Multiculture and Diversity}

30. In location planning, environmental regulations, cost and availability of utilities, and taxes are
    a. global factors
    b. country factors
    c. regional/community factors
    d. site-related factors
    e. none of the above
    c (Factors that affect location decisions, moderate)

31. A manufacturing firm finds a location that has a significant cost advantage over alternatives, but rejects that location because the educational infrastructure was insufficient to train the firm's workers in its special production technologies. The firm's action illustrates the link between _____ and location.
    a. innovation
    b. clustering
    c. tax incentives
    d. globalization
    e. proximity
    a (The strategic importance of location, easy)

32. Which of the following is usually **not** one of the top considerations in choosing a country for a facility location?
    a. availability of labor and labor productivity
    b. exchange rates
    c. attitude of governmental units
    d. zoning regulations
    e. location of markets
    d (Factors that affect location decisions, moderate) {AACSB: Multiculture and Diversity}

33. When making a location decision at the country level, which of these would be considered?
    a. corporate desires
    b. land/construction costs
    c. air, rail, highway, waterway systems
    d. zoning restrictions
    e. location of markets
    e (Factors that affect location decisions, moderate) {AACSB: Multiculture and Diversity}

34. Which of these factors would be considered when making a location decision at the region/community level?
    a. government rules, attitudes, stability, incentives
    b. cultural and economic issues
    c. zoning restrictions
    d. environmental impact issues
    e. proximity to raw materials and customers
    e (Factors that affect location decisions, moderate)

35. When making a location decision at the region/community level, which of these would be considered?
    a. government rules, attitudes, stability, incentives
    b. cultural and economic issues
    c. cost and availability of utilities
    d. zoning restrictions
    e. air, rail, highway, waterway systems
    c (Factors that affect location decisions, moderate)

36. Which of these factors would be considered when making a location decision at the site level?
    a. government rules, attitudes, stability, incentives
    b. cultural and economic issues
    c. zoning regulations
    d. cost and availability of utilities
    e. proximity to raw materials and customers
    c (Factors that affect location decisions, moderate)

37. Tangible costs include which of the following?
    a. climatic conditions
    b. availability of public transportation
    c. taxes
    d. quality and attitude of prospective employees
    e. zoning regulations
    c (Factors that affect location decisions, moderate)

38. Intangible costs include which of the following?
    a. quality of prospective employees
    b. quality of education
    c. availability of public transportation
    d. all of the above
    e. none of the above
    d (Factors that affect location decisions, moderate)

39. Operations managers will need to consider ethical and social responsibility issues when location decisions involve
    a. child labor issues
    b. sweatshop conditions
    c. allegiance to the firm's current location
    d. corruption
    e. all of the above
    e (Factors that affect location decisions, moderate) {AACSB: Ethical Reasoning}

40. A firm is seeking a new factory location, and is considering several countries worldwide. In some of these countries, child labor is prevalent; in others, working conditions and worker safety are inferior to conditions in the U.S. An operations manager paying attention to _____will factor these issues into the location decision.
    a. ethical and social responsibility issues
    b. critical success factors
    c. factor rating systems
    d. geographic information systems
    e. regression models
    a (Factors that influence location decisions, easy) {AACSB: Ethical Reasoning}

41. Which of the following statements regarding "proximity" in the location decision is **false**?
    a. Service organizations find that proximity to market is the most critical primary location factor.
    b. Manufacturers want to be near customers when their product is bulky, heavy, or fragile.
    c. Perishability of raw materials is a good reason for manufacturers to locate near the supplier, not the customer.
    d. Reduction in bulk is a good reason for a manufacturer to locate near the supplier.
    e. Clustering among fast food chains occurs because they need to be near their labor supply.

    e (Section, easy)

42. Which of the following is the best example of the proximity rule that, for service firms, proximity to market is the most important location factor?
    a. Soft drinks are bottled in many local plants, where carbonated water is added to proprietary syrups that may have been shipped long distances.
    b. Few people will travel out-of state for a haircut.
    c. Patients will travel very long distances to have their hernia surgeries performed at Shouldice Hospital.
    d. Furniture makers choose to locate near the source of good hardwoods, even though it means locating near other furniture manufacturers.
    e. Metal refiners (smelters) locate near mines to accomplish significant weight reduction near the metal's source.

    b (Factors that affect location decisions, moderate)

43. Which of the following worker characteristics would likely be *least* important for U.S. firms looking to open up call centers in different countries?
    a. willing to accept low wages
    b. have a high level of education
    c. speak English
    d. possess an in-depth knowledge of American popular culture
    e. are young

    e (Service location strategy, moderate) {AACSB: Multiculture and Diversity}

44. Community attitudes, zoning restrictions, and quality of labor force are likely to be considered in which of the following location decision methods?
    a. transportation method
    b. locational break-even analysis
    c. center-of-gravity method
    d. simulation
    e. factor rating method

    e (Methods of evaluating location alternatives, moderate)

45. Which of the following methods best considers intangible costs related to a location decision?
    a. crossover methods
    b. locational break-even analysis
    c. factor rating analysis
    d. the transportation method
    e. the assignment method

    c (Methods of evaluating location alternatives, moderate)

46. Evaluating location alternatives by comparing their composite (weighted-average) scores involves
    a. factor rating analysis
    b. cost-volume analysis
    c. transportation model analysis
    d. linear regression analysis
    e. crossover analysis
    a (Methods of evaluating location alternatives, moderate)

47. A clothing chain is considering two different locations for a new retail outlet. They have identified the four factors listed in the following table as the basis for evaluation, and have assigned weights as shown on the left. The manager has rated each location on each factor, on a 100-point basis, as shown on the right.

Factor	Factor Description	Weight
1	Average community income	.40
2	Community growth potential	.25
3	Availability of public transportation	.15
4	Labor cost	.20

Barclay	Chester
30	20
40	30
20	20
10	30

    What is the score for Chester?
    a. 10.00
    b. 24.50
    c. 25.75
    d. 27.00
    e. 100.00
    b (Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

48. An approach to location analysis that includes both qualitative and quantitative considerations is
    a. locational cost-volume
    b. factor rating
    c. transportation model
    d. assignment method
    e. make or buy analysis
    b (Methods of evaluating location alternatives, moderate)

49. On the crossover chart where the costs of two or more location alternatives have been plotted, the quantity at which two cost curves cross is the quantity at which
    a. fixed costs are equal for two alternative locations
    b. variable costs are equal for two alternative locations
    c. total costs are equal for all alternative locations
    d. fixed costs equal variable costs for one location
    e. total costs are equal for two alternative locations
    e (Methods of evaluating location alternatives, moderate)

50. A full-service restaurant is considering opening a new facility in a specific city. The table below shows its ratings of four factors at each of two potential sites.

Factor	Weight	Gary Mall	Belt Line
Affluence of local population	.20	30	30
Traffic flow	.40	50	20
Parking availability	.20	30	40
Growth potential	.20	10	30

The score for Gary Mall is _____ and the score for Belt Line is _____.
a. 120; 120
b. 22; 24
c. 18; 120
d. 34; 28
e. none of the above
d (Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

51. A firm is considering two location alternatives. At location A, fixed costs would be $4,000,000 per year, and variable costs 0.30 per unit. At alternative B, fixed costs would be $3,600,000 per year, with variable costs of $0.35 per unit. If demand is expected to be 10 million units, which plant offers the lowest total cost?
a. Plant A, because it is cheaper than Plant B for all volumes under 8,000,000 units
b. Plant B, because it is cheaper than Plant A for all volumes over 8,000,000 units
c. Plant A, because it is cheaper than Plant B for all volumes
d. Plant B, because it has the lower variable cost per unit
e. neither Plant A nor Plant B, because the crossover point is at 10 million units
b (Methods of evaluating location alternatives, easy) {AACSB: Analytic Skills}

52. The center-of-gravity method does **not** take into consideration the
a. location of markets
b. volume of goods shipped to the markets
c. value of the goods shipped
d. combination of volume and distance
e. center-of-gravity method considers none of the above
c (Methods of evaluating location alternatives, moderate)

53. The center-of-gravity method is used primarily to determine what type of locations?
a. service locations
b. manufacturing locations
c. distribution center locations
d. supplier locations
e. call center locations
c (Methods of evaluating location alternatives, moderate)

54. A regional bookstore chain is about to build a distribution center that is centrally located for its eight retail outlets. It will most likely employ which of the following tools of analysis?
a. assembly line balancing
b. load-distance analysis
c. center-of-gravity model
d. linear programming
e. all of the above
c (Methods of evaluating location alternatives, moderate)

55. East Texas Seasonings is preparing to build one processing center to serve its four sources of seasonings. The four source locations are at coordinates shown below. Also, the volume from each source is provided. What is the center of gravity?

	X-coordinate	Y-coordinate	Volume
Athens, Texas	30	30	150
Beaumont, Texas	20	10	350
Carthage, Texas	10	70	100
Denton, Texas	50	50	200

a. X = 28.125; Y = 31.25
b. X = 22000; Y = 24000
c. X = 27.5; Y = 40
d. center of gravity = 28
e. none of the above
a (Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

56. A county wants to build one centrally-located processing facility to serve the county's four recycling drop-off locations. The four drop-offs have characteristics as given in the table below. What is the approximate center of gravity of these four locations?

Location	X-coordinate	Y-coordinate	Tonnage
Drop-off point A	1	8	10
Drop-off point B	6	7	35
Drop-off point C	6	2	25
Drop-off point D	4	7	50

a. 4.75, 6.04
b. 17, 24
c. 33.5, 135.4
d. 6, 4.25
e. 570, 725
a (Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

57. Production and/or shipping costs are always considered in which of the following location decision methods?
    a. factor rating method
    b. transportation method
    c. locational break-even analysis
    d. center-of-gravity method
    e. crossover analysis
    b (Methods of evaluating location alternatives, moderate)

58. The transportation method, when applied to location analysis
    a. minimizes total fixed costs
    b. minimizes total production and transportation costs
    c. minimizes total transportation costs
    d. maximizes revenues
    e. minimizes the movement of goods
    b (Methods of evaluating location alternatives, moderate)

59. Which of the following is **not** among the eight components of revenue and volume for a service firm?
    a. quality of the management
    b. shipment cost of finished goods
    c. purchasing power of the customer-drawing area
    d. uniqueness of the firm's and the competitor's locations
    e. competition in the area
    b (Service location strategy, moderate)

60. Which of the following is among the eight components of revenue and volume for a service firm?
    a. uniqueness of the firm's and the competitor's locations
    b. quality of the competition
    c. quality of management
    d. purchasing power of the customer-drawing area
    e. all of the above
    e (Service location strategy, moderate)

61. Traffic counts and purchasing power analysis of drawing area are techniques associated with
    a. an industrial location decision
    b. a manufacturing location decision
    c. a retail or professional service location decision
    d. the factor rating method
    e. the transportation method
    c (Service location strategy, moderate)

62. Which of the following statements regarding Starbucks Coffee is **false**?
    a. The firm plans to open three new cafes per day around the world.
    b. The firm uses GIS to evaluate every site decision.
    c. The firm's cafes are exclusively in traditional settings: malls, tourist areas, and airports.
    d. The firm places cafes into ever more innovative locations.
    e. The firm put cafes in Japan, even though that country had no GIS data available.
    c (Methods of evaluating location decisions, easy)

63. LaQuinta Motor Inns has a competitive edge over its rivals because it
    a. uses regression analysis to determine which variables most influence profitability
    b. picks better locations than its rivals
    c. picks larger locations than its rivals
    d. builds only along interstate highways
    e. all of the above
    a (Service location strategy, moderate)

64. Traffic counts and demographic analysis of drawing areas are associated with
    a. industrial location decisions
    b. manufacturing location decisions
    c. service location decisions
    d. the transportation method
    e. none of the above
    c (Service location strategy, moderate)

65. What describes a system that stores and displays information that can be linked to a geographic location?
    a. AIS
    b. LOC
    c. GLOC
    d. LIS
    e. GIS
    e (Service location strategy, moderate) {AACSB: Use of IT}

66. Location analysis techniques typically employed by service organizations include
    a. factor rating method
    b. center-of-gravity method
    c. purchasing power analysis of area
    d. traffic counts
    e. all of the above
    e (Service location strategy, moderate)

67. Which of the following is most likely to affect the location decision of a service firm rather than a manufacturing firm?
    a. energy and utility costs
    b. attitude toward unions
    c. parking and access
    d. cost of shipping finished goods
    e. labor costs
    c (Service location strategy, moderate)

68. Which of the following is a location analysis technique typically employed by a service organization?
    a. purchasing power analysis
    b. linear programming
    c. queuing theory
    d. crossover charts
    e. cost-volume analysis
    a (Service location strategy, moderate)

69. A jewelry store is more likely than a jewelry manufacturer to consider _____ in making a location decision.
    a. transportation costs
    b. cost of raw materials
    c. parking and access
    d. climate
    e. taxes
    c (Service location strategy, moderate)

70. Which of the following is a location analysis technique typically employed by a manufacturing organization?
    a. transportation method
    b. queuing theory
    c. correlation analysis and traffic counts
    d. simulation
    e. demographic analysis
    a (Service location strategy, moderate)

71. Which of these assumptions is **not** associated with strategies for goods-producing location decisions?
    a. Most major costs can be identified explicitly for each site.
    b. Focus on identifiable cost.
    c. High customer contact issues are critical.
    d. Intangible costs can be evaluated.
    e. Location is a major determinant of cost.
    c (Service location strategy, moderate)

72. Which of the following is most likely to affect the location strategy of a manufacturing firm?
    a. appearance/image of the area
    b. utility costs
    c. purchasing power of drawing area
    d. competition in the area
    e. parking availability
    b (Service location strategy, moderate)

73. Geographic Information Systems can assist the location decision by
    a. automating center-of-gravity problems
    b. computerizing factor rating analysis
    c. combining geography with demographic analysis
    d. updating transportation method solutions
    e. giving good Internet placement for virtual storefronts
    c (Service location strategy, moderate) {AACSB: Use of IT}

FILL-IN-THE-BLANK

74. FedEx schedules its aircraft using a _____ system, which it credits with reducing package mishandling and delay in transit.
    central hub (Global company profile, easy)

75. _____ costs are readily identifiable and can be measured with precision.
    Tangible (Factors that affect location decisions, easy)

76. When _____, in addition to creativity and R&D investments, is critical to operations strategy, cost may cease to be the primary focus of location criteria.
    innovation (The strategic importance of location, easy)

77. Political risk, cultural issues, and exchange rates are among those _____ that affect which country will be selected for a location decision.
    Critical Success Factors (Factors that influence location decisions, easy)

78. Labor cost per unit is also referred to as _____.
    labor content (Factors that influence location decisions, easy)

79. When firms build supply chains that include foreign firms, _____ and _____ are issues that raise ethical and legal concerns with operations managers.
    bribery, corruption (Factors that influence location decisions, easy) {AACSB: Ethical Reasoning}

80. _____ occurs when competing companies locate near each other because of a critical mass of information, talent, venture capital, or natural resources.
    Clustering (Methods of evaluating location alternatives, moderate)

81. The _____ method is popular because a wide variety of factors, from education to recreation to labor skills, can be objectively included.
    factor-rating (Methods of evaluating location alternatives, moderate)

82. _____ is a cost-volume analysis to make an economic comparison of location alternatives.
    Locational break-even analysis (Methods of evaluating location alternatives, moderate)

83. The _____ is a mathematical technique used for finding the best location for a single distribution point that services several stores or areas.
    center-of-gravity method (Methods of evaluating location alternatives, moderate)

84. The _____ is used to determine the best pattern of shipments from several points of supply to several points of demand.
transportation method (Methods of evaluating location alternatives, moderate)

85. Industrial firms choose locations that minimize cost, but service firms look for locations with good demographics and traffic count because these variables are indicators of good _____.
revenue or volume of business (Section, easy)

86. Databases containing such variables as street maps, utilities, population age and income, and the software that analyzes such data for location decisions, are referred to as _____.
Geographic Information Systems or GIS (Service location strategy, easy) {AACSB: Use of IT}

SHORT ANSWERS

87. Why does FedEx use a "hub-and-spoke" airline network, rather than a "point-to-point" network? Describe FedEx's approach to choosing the airports that serve as its hubs.
The hub system is more centralized, and allows for greater control; greater control reduces package mishandling and transit delays. Their U.S. hub in Memphis reflects a need to be geographically centralized, and in a location where schedules can more reliably be kept. (Global company profile, moderate)

88. State the fundamental objective of a firm's location strategy. How is this basic objective carried out by industrial or goods-producing firms; how does that differ for service firms? Answer in a clear, convincing paragraph.
The fundamental objective is to maximize the benefit of location to the firm. For industrial location decisions, the focus is frequently on minimizing cost, because cost often varies dramatically from one location to another. Service location decisions focus on maximizing revenues. Service location alternatives may vary little in cost, but have dramatic differences in revenue or volume, because of differences in population, income, traffic count, or other variables. (The strategic importance of location, moderate)

89. Identify the changes that have fostered globalization.
Changes that foster globalization include better international communications; more rapid, reliable travel and shipping; ease of capital flow between countries; and high differences in labor costs. (The strategic importance of location, moderate) {AACSB: Multiculture and Diversity}

90. Motorola is in an industry where there are intense pressures to keep costs low. Why did Motorola reject a possible location that offered low manufacturing costs?
While there are pressures to keep costs low, cost is not the only driver for location choices. Motorola is also in an industry that values innovation and creativity; the firm needs high-quality labor inputs. Motorola felt that the location lacked infrastructure and education levels that would support its specific production technologies. (Factors that influence location decisions, moderate)

91. Consider the table of Critical Success Factors in your textbook. Why do some items appear at the country level only, while others are present at both country and regional levels? Select one CSF as an example, and use it in your discussion.
A critical success factor should appear wherever it is relevant. A factor loses its ability to differentiate one location from another if it is the same for all alternatives. For this reason, the CSF "exchange rates" is listed at the country level. There are significant costs and risks associated with foreign currency trading and foreign currency accounting; these costs and risks vary from country to country. But there is no exchange rate risk between two U.S. states or cities, or between two sites within a city. (Factors that affect location decisions, difficult) {AACSB: Reflective Thinking}

92. Identify five factors that affect location decisions at the site level.
Factors that affect location decisions at the site level include site size and cost; air, rail, highway, waterway systems; zoning restrictions; nearness of services/supplies needed; and environmental impact issues. (Factors that affect location decisions, moderate)

93. What is the role of labor productivity in location decisions? Why is it more important than low wages in location decisions?
Labor productivity is the number of units output per hour of labor input. For location decisions, this is more often displayed in the form of "labor content," which is the dollar labor cost per unit. Labor content provides a useful comparison in cases where wage rates and productivities vary greatly from country to country. (Factors that affect location decisions, moderate)

94. What is the impact of exchange rates on location decisions?
Exchange rates fluctuate, and can negate savings from low wage rates. (Factors that affect location decision, moderate) {AACSB: Multiculture and Diversity}

95. Why is "quality of life" an element of intangible costs associated with location decisions? Provide an example as part of your discussion.
Quality of life affects location decisions in at least one indirect way. Consider a firm that has narrowed its location to two cities. One city has an abundance of educational and recreational facilities, good hospitals and parks. The other has very little of these elements. If you were a prospective employee, in which city would you rather live? Low quality of life can drive up labor costs, and might also have an impact on training costs and health care costs. (Factors that affect location decisions, moderate) {AACSB: Reflective Thinking}

96. "Proximity" or closeness implies that a firm should locate "close" to something. What are the three kinds of proximity described in the text? What are the basic conditions under which each is appropriate? What kinds of firms are likely to use each of these?
The three are proximity to markets, proximity to suppliers, and proximity to competitors. Proximity to markets is appropriate when customers will not travel far to get the good or service, or when delivering the product to the customer is costly or difficult. Many services must be close to their markets, as must home construction. Proximity to suppliers is appropriate when raw materials are perishable, or when supplies are costly or bulky to transport. Seafood processors need to be near the docks, and smelters need to be near the mines. Proximity to competitors reflects a kind of synergy—retailers find that volume is higher when there are more competitors nearby, because this clustering brings higher traffic counts. (Factors that affect location decisions, difficult)

97. Consider the table of Critical Success Factors in your textbook. From items on that list, select two which might involve ethical issues or issues of social responsibility, and cite a possible example of each. Write a brief explanation of each of your examples. Cite and describe a third example, from an area not covered by the CSFs.
At the country level, good candidates are cultural and economic issues, labor availability and costs. (Bribery, corruption, child labor, slave labor, racial and gender discrimination in the work force all raise ethical issues.) At the regional level, environmental concerns, and land cost are good candidates. (Corruption, bribery, or cronyism might be associated with land deals; or managers might be tempted to locate where environmental laws are less likely to be enforced.) At the site level, zoning and environmental impact are easy targets. (There might be bribery or corruption related to zoning issues or environmental permits.) Off the list of CSFs, student examples can include corruption and bribery in exchange for incentives. (Factors that affect location decisions, difficult) {AACSB: Ethical Reasoning}

98. Identify those factors identified in the textbook as creating legal or ethical issues for operations mangers as they analyze location decisions.
The text identifies bribery, corruption, child labor, sweatshop and other poor working conditions. The text also identifies allegiance—does a firm owe anything to a town or state that it is about to depart from? (Factors that affect location decisions, moderate) {AACSB: Ethical Reasoning}

99. What is it called when competing companies locate next to each other? Why do they do this?
It is called clustering. In many cases, this occurs because of a critical mass of information, talent, venture capital, or natural resources. Alternately, clustering occurs because several firms close together create a larger total market than the same firms separated. (Factors that affect location decisions, moderate)

100. Identify the four major quantitative methods for solving location problems.
Factor rating method, locational break-even analysis, center-of-gravity method, and transportation method. (Methods of evaluating location alternatives, moderate)

101. What are the advantages and disadvantages of the use of factor rating schemes?
Factor rating can handle a mix of quantitative and qualitative variables; its calculations are simple and straightforward. Factor rating is subject to sensitivity to small swings in weights and scores, and is subject to subjectivity (different judges see different scores for same site). (Methods of evaluating location alternatives, moderate)

102. What kinds of location decisions are appropriate for use of crossover analysis? Write a brief paragraph explaining how crossover analysis (break-even analysis) can assist an operations manager choose among alternative sites in making a location decision.
Crossover analysis is appropriate when the primary focus of a location decision is cost. For each alternative site, crossover analysis constructs a total cost curve composed of a fixed cost and a variable cost that depends upon volume. Where these cost curves intersect (or cross over) is the point at which two alternatives have the same cost. The graph of the cost curves of all alternative sites will display the range of volumes over which each site has the lowest cost of all alternatives. (Methods of evaluating location decisions, moderate)

103. What kinds of location decisions are appropriate for use of center-of-gravity analysis? What variable is being optimized in this analysis?
The center-of-gravity technique is appropriate when the location decision must find a single centrally-located site to serve any number of outlying points; locating a distribution center to serve a dozen retail stores is an example. The analysis leads to a location that (approximately) minimizes the distribution cost (or total distance traveled) between all outlying points and the center or hub. (Methods of evaluating location decisions, moderate)

104. Is Starbucks Coffee a user of Geographic Information Systems? Support your answer with examples.
Starbucks is clearly a user of GIS. Databases reveal population, age, purchasing power, traffic count, and more, for the blocks around each potential site. Sites are compared on the basis of these variables. (Service location strategy, easy) {AACSB: Use of IT}

105. How does the Starbucks Coffee case illustrate the general principles of service location strategy?
Starbucks Coffee clearly selects sites on the basis of revenue or volume, not cost. They clearly pay attention to such variables as drawing power, competition, and traffic counts, all of which are appropriate for service location decisions. Starbucks Coffee is a user of GIS, which is more a tool of service location than of industrial location. There is no indication that Starbucks Coffee uses shipment costs, labor cost, break-even analysis, or transportation method, which are variables and tools associated with industrial location decisions. (Service location strategy, easy)

106. Service location strategies and goods-producing location strategies rely on very different sets of assumptions. What are the assumptions associated with goods-producing locations? How do these assumptions lead to a location strategy?
The assumptions for goods-producing locations are: location is a major determinant of cost; most major costs can be identified explicitly for each site; low customer contact allows focus on the identifiable costs; and intangible cost can be objectively evaluated. On the basis of these assumptions, the location strategy for goods-producing firms is usually aimed at minimizing cost. (Methods of evaluating location alternatives, moderate)

107. How do service facility location decisions differ from industrial location decisions in terms of the techniques used to analyze them?
Service location decisions tend to focus on the revenue function, whereas manufacturing/industrial location decisions tend to focus on costs. The service sector uses techniques such as correlation analysis, traffic counts, demographic analysis, and purchasing power analysis. The industrial decision uses transportation method, factor-weighting approach, break-even analysis, and crossover charts. (Service location strategy, moderate)

PROBLEMS

108. A manufacturing company preparing to build a new plant is considering three potential locations for it. The fixed and variable costs for the three alternative locations are presented below.

a. Complete a numeric locational cost-volume analysis.
b. Indicate over what range each of the alternatives A, B, C is the low-cost choice.
c. Is any alternative never preferred? Explain.

Costs	A	B	C
Fixed ($)	2,500,000	2,000,000	3,500,000
Variable ($ per unit)	21	25	15

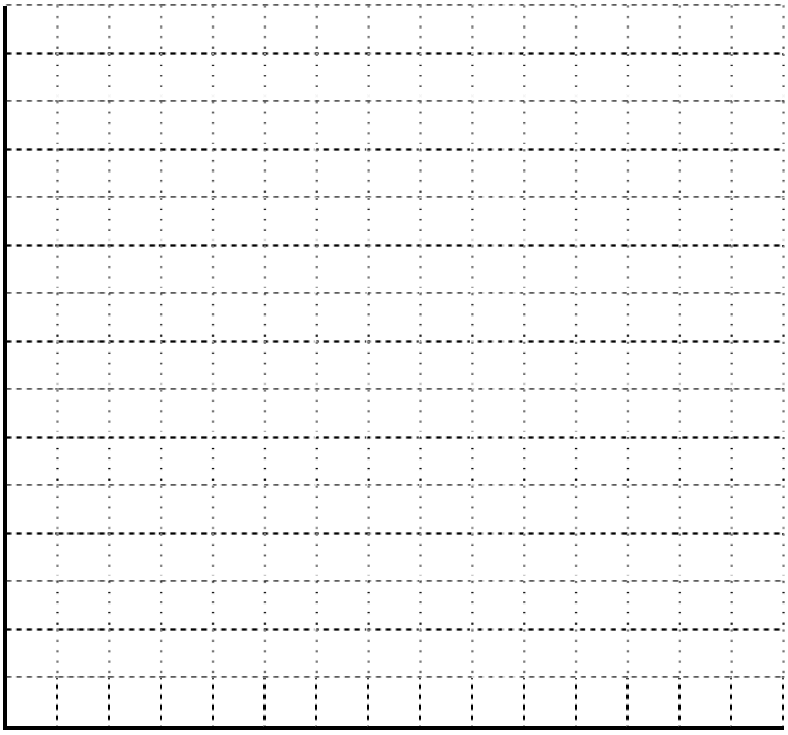
B is cheapest up to 125,000 units; C is cheapest after 166,667 units. A is cheapest in between. The B-C crossover is not relevant. Thus each alternative has an attractive range.

Break-even points	**Units**	**Dollars**
Option A vs. Option B	**125,000**	**5,125,000**
Option A vs. Option C	**166,667**	**6,000,000**
Option B vs. Option C	**150,000**	**5,750,000**

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

109. A farmers' cooperative association plans to build a new sugar mill in Southwestern Louisiana. The primary objective of the mill is to provide the farmers with a place to take their crop for processing that will reduce their transportation costs. The members of the co-op believe that the center-of-gravity method is appropriate for this objective. While there are over 200 sugar cane farms in the region, they are tightly clustered around six villages. Using the data below, use the center-of-gravity method to calculate the coordinates of the best location for this mill. On the grid below, plot the location of the six farm clusters and the calculated mill location. All mileage references use the city of Lake Charles as (0,0).

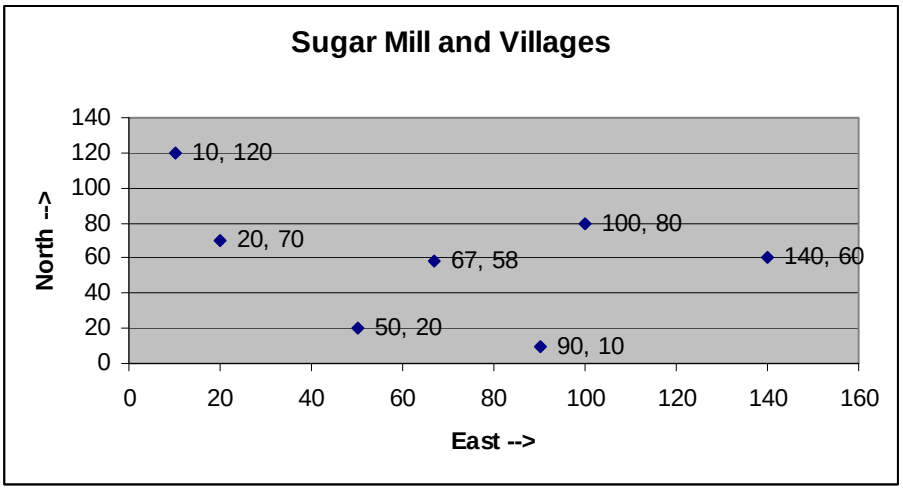
Village	Miles East of Lake Charles	Miles North of Lake Charles	Sugar Cane tonnage
Arceneaux	90	10	240,000
Boudreaux	140	60	320,000
Cancienne	20	70	450,000
Darbonne	50	20	120,000
Evangeline	100	80	60,000
Fontenot	10	120	140,000



SEE NEXT PAGE FOR SOLUTION.

The center of gravity, weighted by the tonnage at each village cluster, is about 66.8 miles east of Lake Charles and 58.0 miles north of Lake Charles.

				Sugar Mill Solution	
	Weight/# trips	x-coord	y-coord	X multiplied	Y multiplied
A	240.	90.	10.	21,600.	2,400.
B	320.	140.	60.	44,800.	19,200.
C	450.	20.	70.	9,000.	31,500.
D	120.	50.	20.	6,000.	2,400.
E	60.	100.	80.	6,000.	4,800.
F	140.	10.	120.	1,400.	16,800.
Total	1,330.	410.	360.	88,800.	77,100.
Average		68.3333	60.		
Weighted Average				66.7669	57.9699
Median	665.			50.	60.



(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

110. A clothing chain is considering two different locations for a new retail outlet. The organization has identified the four factors listed in the following table as the basis for evaluation, and has assigned weights as shown on the right side of this table. The manager has rated each location on each factor, on a 100-point basis (higher scores are better), as shown in the right-hand table.

a. Calculate the composite score for each alternative location.
b. Which site should be chosen?
c. Are you concerned about the sensitivity and subjectivity of this solution? Comment.

Factor	Factor Description	Weight
1	Average community income	.40
2	Community growth potential	.25
3	Availability of public transportation	.15
4	Labor cost	.20

Barclay	Chester
75	70
60	80
45	90
80	65

The higher rated site is Chester, 74.5 to 67.75. There is a margin of several points, which should overcome most levels of subjectivity. The site factor scores are quite different, so that a small swing in weights could produce swings in scores of a few points, but probably not the seven necessary to reverse the findings.

	Weight	Barclay	Chester
Factor 1	**0.40**	**75**	**70**
Factor 2	**0.25**	**60**	**80**
Factor 3	**0.15**	**45**	**90**
Factor 4	**0.20**	**80**	**65**
Total	**1.00**		
Weighted sum		**67.75**	**74.5**
Weighted average		**67.75**	**74.5**

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

111. A manufacturing company is considering two alternative locations for a new facility. The fixed and variable costs for the two locations are found in the table below. For which volume of business would the two locations be equally attractive? If the company plans on producing 50,000 units, which location would be more attractive?

	Glen Rose	Mesquite
Fixed Costs	$1,000,000	$1,500,000
Variable Costs ($ per unit)	25	23

Crossover is at 250,000 units. Below the crossover, Glen Rose must be cheaper as it has the lower fixed cost. Thus, for an estimated unit volume of 50,000, Glen Rose should be chosen.

Break-even points	**Units**	**Dollars**
Option 1 vs. Option 2	**250,000**	**7,250,000**
Volume analysis at 50,000 units		
	Option 1	**Option 2**
total cost	**$2,250,000.00**	**$2,650,000.00**

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

112. East Texas Seasonings is preparing to build one processing center to serve its four sources of seasonings. The four source locations are at coordinates shown below. Also, the volume from each source is provided.

a. Calculate the volume-weighted center of gravity.
b. Calculate the simple center of gravity (all cities weighted equally).
c. Explain why the two calculations differ.

	X-coordinate	Y-coordinate	Volume
Athens, Texas	30	40	100
Beaumont, Texas	20	15	400
Carthage, Texas	55	60	150
Denton, Texas	20	70	250

The weighted center of gravity is located at X = 24,250 / 900 = 26.9, Y = 36,500 / 900 = 40.6. The simple center of gravity is located at X = 125 / 4 = 31.25. Y = 185 / 4 = 46.25. The simple center is more to the east and north than the weighted center of gravity. A partial explanation is that the heaviest tonnage is from Beaumont, which is far to the west and south. Its influence pulls the weighted center toward the west and south.

East Texas Seasonings Solution					
	Weight/# trips	x-coord	y-coord	X multiplied	Y multiplied
A	100.	30.	40.	3,000.	4,000.
B	400.	20.	15.	8,000.	6,000.
C	150.	55.	60.	8,250.	9,000.
D	250.	20.	70.	5,000.	17,500.
Total	900.	125.	185.	24,250.	36,500.
Average		31.25	46.25		
Weighted Average				26.9444	40.5556
Median	450.			20.	40.

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

113. Location A would result in annual fixed costs of $300,000 and variable costs of $55 per unit. Annual fixed costs at Location B are $600,000 with variable costs of $32 per unit. Sales volume is estimated to be 30,000 units per year. Which location has the lower cost at this volume? How large is its cost advantage? At what volume are the two facilities equal in cost?
At 30,000 units, Location A has total costs of $1, 950,000, while Location B has total costs of $1,560,000. Location B is cheaper by $390,000. The crossover occurs where 600,000 + 32X = 300,000 + 55X, or at X = 300,000 / 23 = 13,043 units. (Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

114. Using the factor ratings shown below, determine which location alternative should be chosen on the basis of maximum composite score.

		Location		
Factor	Weight	A	B	C
Easy access	0.15	86	72	90
Parking facilities	0.20	72	77	91
Display area	0.18	86	90	90
Shopper (walking) traffic	0.21	94	86	80
Neighborhood wealth	0.16	99	89	81
Neighborhood safety	0.10	96	85	75

A is best (87.96), followed by C (85.16). B is somewhat further behind (83.20).

	Weight	**A**	**B**	**C**
Easy access	**0.15**	**86**	**72**	**90**
Parking facilities	**0.20**	**72**	**77**	**91**
Display area	**0.18**	**86**	**90**	**90**
Shopper (walking) traffic	**0.21**	**94**	**86**	**80**
Neighborhood wealth	**0.16**	**99**	**89**	**81**
Neighborhood safety	**0.10**	**96**	**85**	**75**
Total	**1.00**			
Weighted sum		**87.96**	**83.20**	**85.16**
Weighted average		**87.96**	**83.20**	**85.16**

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

115. A manager has received an analysis of several cities being considered for a new order fulfillment center (warehouse) for Shop at Home Network. The scores (scale is 10 points = best) are contained in the table below.

a. If the manager weights the factors equally, how would the locations be ranked?
b. If transportation costs and operating costs are given weights that are double the weights of the others, should the locations be ranked differently?

	Location			
Factor	W	X	Y	Z
Business services	7	9	5	4
Community services	5	7	6	7
Real estate cost	7	3	8	6
Construction costs	8	6	6	5
Operating costs	5	4	7	6
Business taxes	6	9	6	4
Transportation costs	8	6	7	8

SEE SOLUTION ON NEXT PAGE.

The locations are ranked W, Y, X, Z with equal weights; but W and Y tie for highest, and Z and X tie for lowest as revised.

	Weight	W	X	Y	Z
Business services	1	7	9	5	4
Community services	1	5	7	6	7
Real estate cost	1	7	3	8	6
Construction costs	1	8	6	6	5
Operating costs	1	5	4	7	6
Business taxes	1	6	9	6	4
Transportation costs	1	8	6	7	8
Total	7	46	44	45	40
Weighted average		6.579	6.286	6.429	5.714

	Weight	W	X	Y	Z
Business services	1	7	9	5	4
Community services	1	5	7	6	7
Real estate cost	1	7	3	8	6
Construction costs	1	8	6	6	5
Operating costs	2	5	4	7	6
Business taxes	1	6	9	6	4
Transportation costs	2	8	6	7	8
Total	9				
Weighted sum		59	54	59	54
Weighted average		6.56	6	6.56	6

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

116. A telecommunications firm is planning to lay fiber optic cable from several community college distance learning sites to a central studio, in such a way that the miles of cable are minimized. Some locations require more than one set of cables (these are the loads). Where should the studio be located to accomplish the objective?

College	Map Coordinate (x, y)	Load
A	(2,10)	3
B	(6,8)	2
C	(4,9)	4
D	(9,5)	1
E	(8,1)	3
F	(3,2)	2
G	(2,6)	1

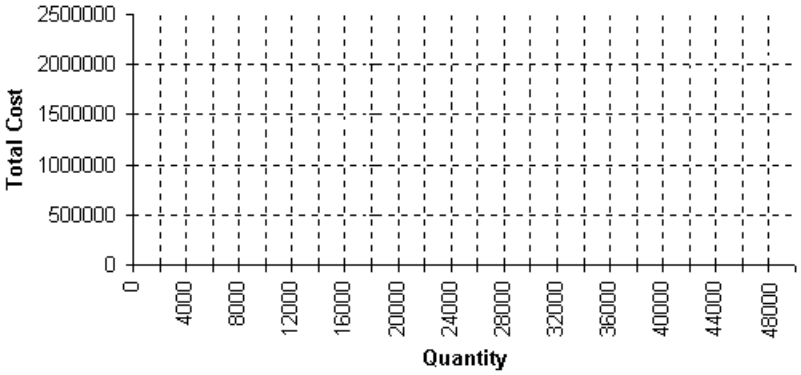
This is a center of gravity problem, even though it is not about shipping tangible items. The center of gravity is at coordinates X = 4.69, Y = 6.25.

	Weight	X coord	Y coord
Location 1	**3**	**2**	**10**
Location 2	**2**	**6**	**8**
Location 3	**4**	**4**	**9**
Location 4	**1**	**9**	**5**
Location 5	**3**	**8**	**1**
Location 6	**2**	**3**	**2**
Location 7	**1**	**2**	**6**
Sum	**16**	**34**	**41**
Average		**4.857**	**5.857**
Weighted Average		**4.6875**	**6.25**

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

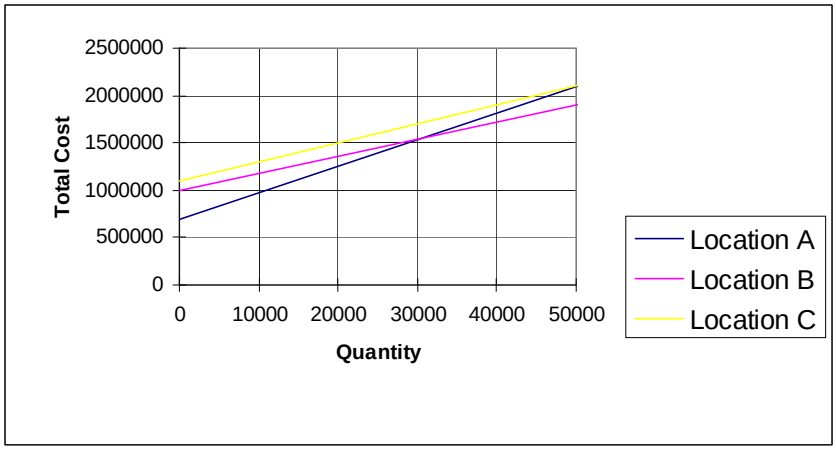
117. The owner of a millwork shop is considering three alternative locations for a new plant for building embossed-and-clad steel exterior doors for residences. Fixed and variable costs follow. Since the plant ships nationwide, revenue is assumed the same regardless of plant location. Plot the total cost lines in the chart provided below, and identify the range over which each location is best.

	Location		
Costs	A	B	C
Fixed	$700,000	$1,000,000	$1,100,000
Variable	$28	$18	$20



A is cheapest from 0 to about 30,000 units. B is cheapest thereafter. C can never be preferred.

Break-even points	**Units**	**Dollars**
Location A vs. Location B	**30,000**	**$1,540,000**
Location A vs. Location C	**50,000**	**$2,100,000**
Location B vs. Location C	**-50,000**	**$100,000**



(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

118. A manufacturing firm is considering three potential locations for a new parts manufacturing facility. A consulting firm has assessed three sites based on the four factors supplied by management as critical to the location's success. Given the management-supplied factor weights and the consultant team scores, which location should be selected? Scores are based on 50 = best. Do the results surprise you in any way? Comment.

		Location		
Factor	Weight	A	B	C
Labor Climate	10	35	45	20
Taxes	30	30	40	40
Utilities	20	25	20	45
Wages	40	10	25	25

C is clearly better than either A or B. This problem illustrates the importance of having good scores on important factors. B has scores that are about as high as those of C, but in the wrong places.

	Weight	**Location A**	**Location B**	**Location C**
Labor Climate	**10**	**35**	**45**	**20**
Taxes	**30**	**30**	**40**	**40**
Utilities	**20**	**25**	**20**	**45**
Wages	**40**	**10**	**25**	**25**
Total	**100**			
Weighted sum		**2150**	**3050**	**3300**
Weighted average		**21.5**	**30.5**	**33.0**

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

119. Environmental Glass Products, Inc. wants to build a new centralized facility to receive household, commercial, and industrial glass for recycling. This center will be supplied by trucks coming from four "collection points," where recyclable glass is dropped off by individuals and businesses. The volume and the map coordinates for the four collection centers are shown below. Where should the collection center be located?

Collection point	Load	(X,Y) Coordinates
A	9,000	(4,8)
B	4,000	(7,2)
C	2,000	(4,1)
D	5,000	(7,3)

The center should be built near coordinates (5.35, 4.85).

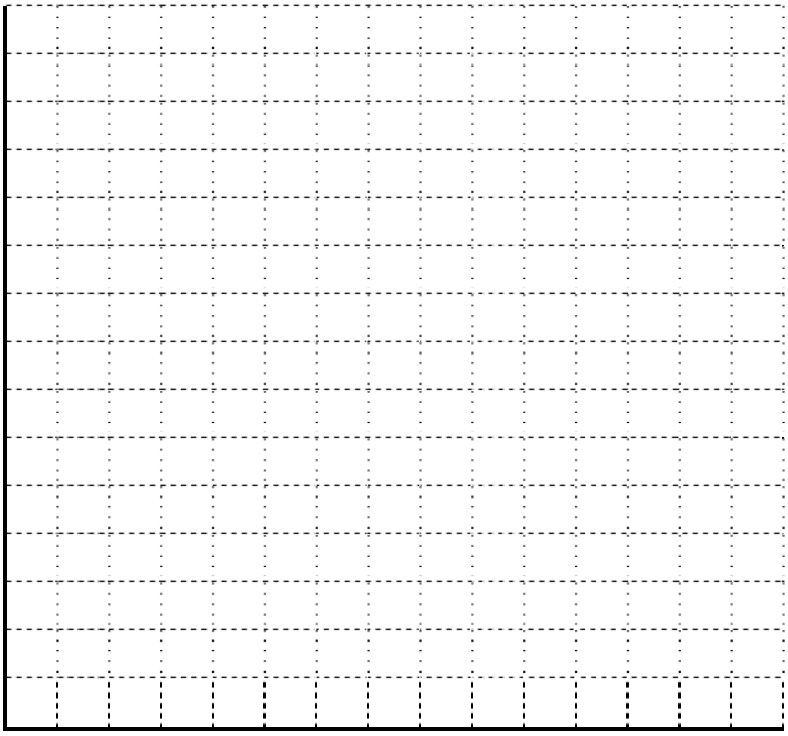
Collection Point	Weight	X coord	Y coord
A	9,000	4	8
B	4,000	7	2
C	2,000	4	1
D	5,000	7	3
Sum	20,000	22	14
Average		5.5	3.5
Weighted Average		5.35	4.85

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

120. A manufacturer of stamped metal auto parts has four parts factories in one city at the location coordinates shown below. Each coordinate unit represents a city block (roughly 100 meters). The yearly demand at each factory is also given.

Factories	Demand	X-Coord.	Y-Coord.
Rayburn Industrial Park	19,000	20	130
Port of Zavalla	3,000	60	40
Henderson Mfg. Center	5,000	70	100
Wax Mills Site	6,000	90	30

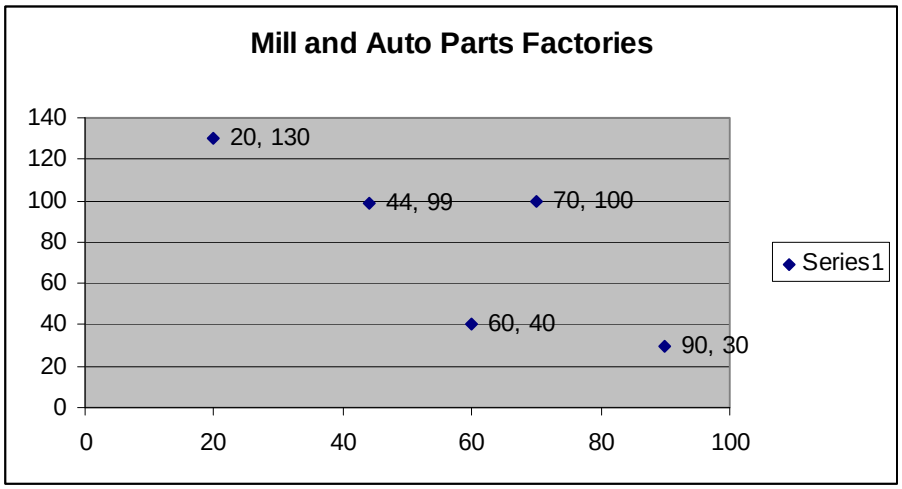
Management has decided to build a new sheet metal mill, to supply these factories, at a location central to these plants. What should be the map coordinates of the new plant? On the grid below, graph the locations of the four parts factories and the proposed sheet metal mill.



SEE SOLUTION ON NEXT PAGE.

The mill should be located near (44, 99). The center-of-gravity model does not favor any single data point; it is the weighted average of them all. In this case, being central does not mean being close to any single factory, but it is closer to the collection of all four than any other mill location could be.

Sheet Metal Mill Solution					
	Weight/# trips	x-coord	y-coord	X multiplied	Y multiplied
Rayburn	19.	20.	130.	380.	2,470.
Zavalla	3.	60.	40.	180.	120.
Henderson	5.	70.	100.	350.	500.
Wax Mills	6.	90.	30.	540.	180.
Total	33.	240.	300.	1,450.	3,270.
Average		60.	75.		
Weighted Average				43.9394	99.0909
Median	17.			20.	130.



(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

121. A small producer of music boxes wants to move to a larger facility. Two alternative facilities have been found. Site 1 has a fixed cost of $500,000 per year, with a variable cost of $25 per unit. Site 2 has a fixed cost of $800,000 per year, but a variable cost of $22 per unit.
    a. Write out the equation for total cost for each site.
    b. At what volume of output would the two locations have the same total cost?
    c. For what range of output would Site 1 be superior?
    d. For what range of output would Site 2 be superior?

(a) The equation for the total cost at site 1 is TC = 500,000 + 25X, where X is volume. The equation for total cost at Site 2 is TC = 800,000 + 22X. (b) Set these two equations equal and solve for X. 500,000 + 25X = 800,000 + 22X leads to 300,000 = 3X, then to X = 100,000. Site 1 is preferred for volumes up to 100,000 units, and site 2 is preferred after 100,000 units. (Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

122. A small manufacturer is considering several locations for a new facility. They have identified four factors that they consider to be important for their location decision. They have decided to assign scores to the four factors, with a higher score indicating a more favorable location. Use the information in the following table to perform a factor rating to select the best location.

	Weight	Location A	Location B	Location C
Wages	40	30	75	90
Labor Climate	30	40	70	40
Taxes	15	80	40	90
Utilities	15	75	60	10

Location B is the preferred location.

	Weight	**Location A**	**Location B**	**Location C**
Wages	**40**	**30**	**75**	**90**
Labor Climate	**30**	**40**	**70**	**40**
Taxes	**15**	**80**	**40**	**90**
Utilities	**15**	**75**	**60**	**10**
Total	**100**			
Weighted sum		**4725**	**6600**	**6300**
Weighted average		**47.25**	**66**	**63**

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

123. A contractor for the military is looking for a new location for a supply depot. The depot will supply four bases whose tonnage (demand) and map coordinates are shown below. If management wants the depot to have a central location, what should be its map coordinates?

Bases	(X,Y) Coordinates	Tonnage
Fort Able	(40,110)	30,000
Base Baker	(70,50)	60,000
Camp Charlie	(90,20)	35,000
Camp Delta	(70,80)	75,000

The depot should be located near X = 69, Y = 65.

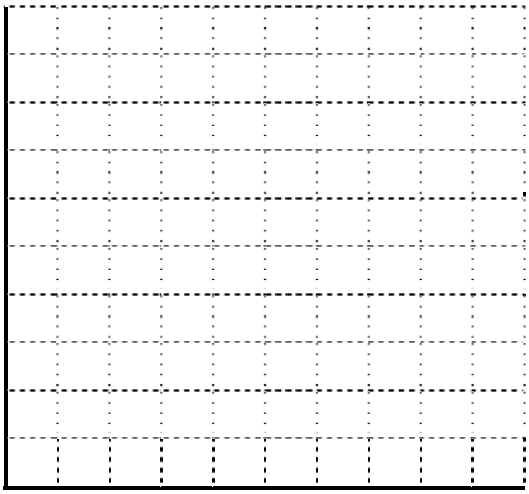
Bases	**Weight**	**X coord**	**Y coord**	**X mult.**	**Y mult.**
Fort Able	**30,000**	**40**	**110**	**1,200,000**	**3,300,000**
Base Baker	**60,000**	**70**	**50**	**4,200,000**	**3,000,000**
Camp Charlie	**35,000**	**90**	**20**	**3,150,000**	**700,000**
Camp Delta	**75,000**	**70**	**80**	**5,250,000**	**6,000,000**
Sum	**200,000**	**270**	**260**	**13,800,000**	**13,000,000**
Weighted Average				**69**	**65**

(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

124. A highway contractor needs to locate a single supply point to provide road building materials to four projects. The four projects, which are all approximately the same magnitude, are located at the following coordinates. Coordinate units are in miles.

	X (East)	Y (North)
Project A	50	10
Project B	15	60
Project C	40	60
Project D	30	20

a. On the grid below, plot the locations of the four road-building sites. Properly label all points.
b. What is the center of gravity?
c. If a single truck were sent from center to each project and back (four round trips), how many miles would be traveled? (Hint: use the Pythagorean Theorem $C = \sqrt{A^2 + B^2}$).
d. Add the calculated center of gravity to the grid.



The supply point should be at (33.75, 37.50).

	Weight	X coord	Y coord
Project A	**1**	**50**	**10**
Project B	**1**	**15**	**60**
Project C	**1**	**40**	**60**
Project D	**1**	**30**	**20**
Sum	**4**	**135**	**150**
Average		**33.75**	**37.5**
Weighted Average		**33.75**	**37.5**

	Distance to COG
Project A	**31.94**
Project B	**29.29**
Project C	**23.35**
Project D	**17.90**

(Methods of evaluating location alternatives, difficult) {AACSB: Analytic Skills}

125. Every month, a distribution center will deliver 14,000 units to Retailer A at coordinates (20, 10), 12,000 units to Retailer B at coordinates (30, -15), and 20,000 units to Retailer C at coordinates (4, 4). Assuming no constraints on location, at what coordinates should the distribution center be located (rounded to two decimal places)?
(15.65, 0.87), where 15.65 = [20(14) + 30(12) + 4(20)]/(14 + 12 + 20),
and 0.87 = [10(14) − 15(12) + 4(20)]/(14 + 12 + 20).
(Methods of evaluating location alternatives, moderate) {AACSB: Analytic Skills}

CHAPTER 9: LAYOUT STRATEGY

TRUE FALSE

1. McDonald's "Made for You" kitchen system represents a strategic layout decision even though an obvious benefit of the system is a dramatic reduction in the inventory of food prepared in advance.
True (Global company profile, easy)

2. The objective of layout strategy is to develop an effective and efficient layout that will meet the firm's competitive requirements.
True (The strategic importance of layout decisions, easy)

3. The work cell layout, a special arrangement of machinery and equipment to focus on the production of a single product or group of related products, is for manufacturing applications and has no relevance to services.
False (Types of layout, moderate)

4. The layout approach that addresses trade-offs between space and material handling is called the fixed position layout.
False (Types of layout, moderate)

5. Utilization of the total "cube" is the dominant consideration in office layout.
False (Office layout, moderate)

6. One guideline for a retail layout is to locate high-draw items around the periphery of the store.
True (Retail layout, moderate)

7. Category management is the use of computer software to evaluate the profitability of merchandising plans.
True (Retail layout, moderate)

8. Servicescape refers to the physical surrounding in which the service is delivered.
True (Retail layout, moderate)

9. One guideline for determining the arrangement and space allocation of a retail store is to place high-impulse and high-margin items such as housewares and beauty aids in prominent locations.
True (Retail layout, moderate)

10. **Cross-docking** processes items as they are received, rather than placing them in storage; this helps explain why "warehouses" are now called "distribution centers."
True (Warehousing and storage layouts, moderate)

11. The dominant problem associated with the fixed-position layout is that workers are fixed in position, and cannot be reassigned.
False (Fixed-position layout, moderate)

12. A process-oriented layout is the traditional way to support a product differentiation strategy.
True (Process-oriented layout, easy)

13. Job lots are groups or batches of parts processed together.
True (Process-oriented layout, easy)

14. Process-oriented layouts typically have low levels of work-in-process inventory.
False (Process-oriented layout, moderate)

15. CRAFT is software for balancing assembly lines.
False (Process-oriented layout, moderate) {AACSB: Use of IT}

16. The most common tactic to arrange departments in a process-oriented layout is to minimize material handling costs.
True (Process-oriented layout, moderate)

17. The work cell improves process layouts by reducing floor space and by reducing direct labor cost.
True (Work cells, moderate)

18. The balancing of work cells uses the same procedures as the balancing of an assembly line.
False (Work cells, moderate)

19. A focused work center is well suited to the production of a large family of products requiring similar processing, even if their demands are not very stable.
False (Process-oriented layout, moderate)

20. A fabrication line and an assembly line are both types of repetitive and product-focused layout, but only the fabrication line utilizes workstations.
False (Repetitive and product-oriented layout, moderate)

21. The biggest advantage of a product layout is its flexibility to handle a varied product mix.
False (Repetitive and product-oriented layout, moderate)

22. The minimum number of workstations depends upon the set of task times and the precedence chart, but not the number of units scheduled.
False (Repetitive and product-oriented layout, moderate)

23. A product requires 24 separate tasks, and the sum of those task times is 14 minutes; if the cycle time is 2 minutes, then at least 12 workstations will be needed.
False (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

24. If the schedule calls for the production of 120 units per day and 480 minutes of production time are available per day, the cycle time should be 4 minutes.
True (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

25. Product-oriented layouts tend to have high levels of work-in-process inventories.
False (Repetitive and product-oriented layout, moderate)

26. One drawback of a product-oriented layout is that work stoppage at any one point ties up the whole operation.
True (Repetitive and product-oriented layout, moderate)

27. Cycle time is the maximum time that the product is allowed at each work station.
True (Repetitive and product-oriented layout, moderate)

28. Heuristics are problem-solving procedures that mathematically optimize the solution.
False (Repetitive and product-oriented layout, moderate)

MULTIPLE CHOICE

29. Which of the following is **not** one of McDonald's "seven major innovations"?
a. the Happy Meal
b. drive-through windows
c. breakfast menus
d. play areas
e. a kitchen system to facilitate mass customization
a (Global company profile, moderate)

30. The layout strategy that deals with **low-volume, high-variety** production is
a. fixed-position layout
b. retail layout
c. warehouse layout
d. office layout
e. none of the above
e (Types of layout, moderate)

31. "A special arrangement of machinery and equipment to focus on production of a single product or group of related products" describes what layout type?
a. fixed-position layout
b. intermittent production
c. focused factory
d. work cell
e. warehouse layout
d (Types of layout, moderate)

32. A good layout requires determining
a. material handling requirements
b. capacity and space requirements
c. environment and aesthetics
d. cost of moving between various work areas
e. all of the above
e (Types of layout, moderate)

33. The **fixed-position** layout would be most appropriate in which of the following settings?
a. a fast-food restaurant
b. a doctor's office
c. a casual dining restaurant
d. a cruise ship assembly facility
e. none of the above
d (Fixed-position layout, moderate)

34. For which of the following operations would a fixed-position layout be most appropriate?
    a. assembling automobiles
    b. producing TV sets
    c. constructing a highway tunnel or bridge
    d. refining of crude oil
    e. running an insurance agency
    c (Fixed-position layout, difficult)

35. Because the fixed-position layout problem is so difficult to solve on-site, operations managers
    a. virtually never employ this layout strategy
    b. utilize this approach only for construction projects such as bridges and office towers
    c. increase the size of the site
    d. often complete as much of the project as possible off-site
    e. utilize this layout only for defense contractors
    d (Fixed-position layout, moderate)

36. One factor impacting the fixed-position layout strategy is
    a. minimizing difficulties caused by material flow varying with each product
    b. requiring frequent contact close to one another
    c. the provision of low-cost storage with low-cost material handling
    d. the movement of material to the limited storage areas around the site
    e. balancing product flow from one work station to the next
    d (Fixed-position layout, moderate)

37. The type of layout which features departments or other functional groupings in which similar activities are performed is
    a. process-oriented
    b. product-oriented
    c. fixed-position
    d. mass production
    e. unit production
    a (Process-oriented layout, moderate)

38. One of the major advantages of process-oriented layouts is
    a. high equipment utilization
    b. large work-in-process inventories
    c. flexibility in equipment and labor assignment
    d. smooth and continuous flow of work
    e. none of the above
    c (Process-oriented layout, moderate)

39. The main issue in designing process layouts concerns the relative positioning of
    a. safety devices
    b. departments
    c. raw materials
    d. entrances, loading docks, etc.
    e. supervisors to their employees
    b (Process-oriented layout, moderate)

40. Which of the following is **not** an information requirement for solving a load-distance problem?
    a. a list of departments or work centers
    b. a projection of work flows between the work centers
    c. the distance between locations
    d. a list of product cycle times
    e. the cost per unit of distance to move loads
    d (Process-oriented layout, moderate)

41. The major problem addressed by the process-oriented layout strategy is
    a. the movement of material to the limited storage areas around the site
    b. requiring frequent contact close to one another
    c. the provision of low-cost storage with low-cost material handling
    d. minimizing difficulties caused by material flow varying with each product
    e. balancing product flow from one work station to the next
    d (Process-oriented layout, moderate)

42. The most common tactic followed in process-layout planning is to arrange departments or work centers so they
    a. minimize the cost of skilled labor
    b. maximize the machine utilization
    c. allocate the available space equally to all the departments
    d. minimize the costs of material handling
    e. none of the above
    d (Process-oriented layout, moderate)

43. Which type of layout is specifically designed to encourage employees to interact?
    a. warehouse
    b. job shop
    c. open office
    d. retail
    e. repetitive/continuous
    c (Types of layout, easy) {AACSB: Communication}

44. Which of the following is **true** for process layouts, but **false** for product-oriented layouts?
    a. low in-process inventories
    b. flexibility in equipment and labor assignments
    c. low variety of products
    d. high volume of output
    e. often solved by assembly line balancing
    b (Process-oriented layout, moderate)

45. A big advantage of a process-oriented layout is
    a. its flexibility in equipment and labor assignments
    b. its low cost
    c. the simplified scheduling problem presented by this layout strategy
    d. the ability to employ low-skilled labor
    e. its high equipment utilization
    a (Process-oriented layout, moderate)

46. One disadvantage of process-oriented layouts arises from
    a. the use of special purpose equipment
    b. machine maintenance, which tends to seriously degrade the capacity of the entire system
    c. the use of specialized material handling equipment
    d. the need for stable demand
    e. the use of the general purpose machines and equipment
    e (Process-oriented layout, moderate)

47. The typical goal used when developing a process-oriented layout strategy is to
    a. minimize the distance between adjacent departments
    b. minimize the material handling costs
    c. maximize the number of different tasks which can be performed by an individual machine
    d. minimize the level of operator skill necessary
    e. maximize job specialization
    b (Process-oriented layout, moderate)

48. Which of the following is **true** of a **focused factory**?
    a. It may be focused in ways other than by product or layout.
    b. It may be focused only by processing requirements.
    c. It is much like a product facility within an otherwise process facility.
    d. All of the above are true.
    e. None of the above is true.
    a (Process-oriented layout, moderate)

49. In the Office Relationship Chart, which rating reflects the highest importance for two departments' closeness to each other?
    a. A
    b. E
    c. I
    d. O
    e. X
    a (Office layout, moderate)

50. Which of the statements below best describes **office layout**?
    a. groups workers, their equipment, and spaces/offices to provide for movement of information
    b. addresses the layout requirements of large, bulky projects such as ships and buildings
    c. seeks the best personnel and machine utilization in repetitive or continuous production
    d. allocates shelf space and responds to customer behavior
    e. deals with low-volume, high-variety production
    a (Office layout, moderate)

51. Which of the following constitutes a major trend influencing office layouts?
    a. downsizing
    b. globalization
    c. environmental issues
    d. off-site employees
    e. health issues
    d (Office layout, moderate)

52. Which of the following does **not** support the retail layout objective of maximizing customer exposure to products?
    a. locate high-draw items around the periphery of the store
    b. use prominent locations for high-impulse and high-margin items
    c. maximize exposure to expensive items
    d. use end-aisle locations
    e. convey the store's mission with the careful positioning of the lead-off department
    c (Retail layout, moderate)

53. Ambient conditions, spatial layout and functionality, and signs, symbols, and artifacts are all
    a. indicators of imbalance on an assembly line
    b. indicators that cross-docking has been successful
    c. elements of customization in a warehouse layout
    d. elements of servicescapes
    e. elements of successful office layouts
    d (Retail layout, moderate)

54. Balancing low-cost storage with low-cost material handling is important in a(n)
    a. fixed-position layout
    b. process-oriented layout
    c. office layout
    d. repetitive and product-oriented layout
    e. warehouse layout
    e (Warehousing and storage layouts, moderate)

55. Which of the following *requires* an information system that provides inbound product identification, its destination, and routing of the product to the designated outbound vehicle?
    a. phantom-docking
    b. random stocking
    c. ASRS
    d. customizing
    e. cross-docking
    e (Warehousing and storage layouts, moderate)

56. The major problem addressed by the warehouse layout strategy is
    a. minimizing difficulties caused by material flow varying with each product
    b. requiring frequent contact close to one another
    c. addressing trade-offs between space and material handling
    d. balancing product flow from one work station to the next
    e. none of the above
    c (Warehousing and storage layouts, moderate)

57. The concept of customizing in a warehouse layout
    a. is possible, but causes serious loss of oversight of the quality function
    b. cannot be considered seriously in today's high efficiency factories
    c. is theoretically sound, but several years away in practice
    d. is a new trend in value-added activities in warehouses
    e. none of the above
    d (Warehousing and storage layouts, moderate)

58. Which one of the following is **not** common to repetitive and product-oriented layouts?
    a. a high rate of output
    b. specialization of labor
    c. ability to adjust to changes in demand
    d. low unit costs
    e. All are common to product-oriented layouts.
    c (Repetitive and product-oriented layout, moderate)

59. Which of the following is **not** an advantage of work cells?
    a. reduced direct labor cost
    b. decreased use of equipment and machinery
    c. heightened sense of employee participation
    d. reduced raw material and finished goods inventory
    e. reduced investment in machinery and equipment
    b (Work cells, moderate)

60. Balancing a work cell is done
    a. before the work cell equipment is sequenced
    b. as part of the process of building an efficient work cell
    c. before takt time is calculated
    d. so that each assembly line workstation has exactly the same amount of work
    e. to minimize the total movement in a process layout
    b (Work cells, moderate)

61. **Takt time** is
    a. the total work time available divided by units required by the consumer
    b. the units required divided by workers required
    c. a fictional time increment similar to a therblig
    d. the same thing as cycle time in a process layout
    e. an important consideration in balancing an assembly line
    a (Work cells, moderate)

62. A process layout problem consists of 4 departments, each of which can be assigned to one of four rooms. The number of different solutions to this problem is _____, although not all of them may have different material handling costs.
    a. 1
    b. 4
    c. 16
    d. 24
    e. unknown
    d (Process-oriented layout, moderate) {AACSB: Analytic Skills}

63. Solving a load-distance problem for a process-oriented layout requires that
    a. the difficulty of movement be the same for all possible paths
    b. pickup and setdown costs vary from department to department
    c. the cost to move a load be the same for all possible paths
    d. takt time be less than 1
    e. CRAFT software examine all possible department configurations
    a (Process-oriented layout, moderate)

64. Which of the following layouts generally has the best machine utilization?
    a. fixed-position layout
    b. repetitive and product-oriented layout
    c. process-oriented layout
    d. office layout
    e. warehouse layout
    b (Repetitive and product-oriented layout, moderate)

65. Which of the following is not one of the requirements of cellular production?
    a. test (poka-yoke) at each station in the cell
    b. adequate volume for high equipment utilization
    c. a high level of training, flexibility, and empowerment of employees
    d. being self-contained, with its own equipment and resources
    e. identification of families of products, often through the use of group technology codes
    b (Work cells, moderate)

66. The assumption of stability of demand is important for justifying which of the following layout types?
    a. fixed-position layout
    b. product-oriented layout
    c. process-oriented layout
    d. all of the above
    e. none of the above
    b (Repetitive and product-oriented layout, moderate)

67. Which layout type assumes an adequate volume for high equipment utilization?
    a. product-oriented layout
    b. process-oriented layout
    c. fixed-position layout
    d. retail layout
    e. warehouse layout
    a (Repetitive and product-oriented layout, moderate)

68. A product-oriented layout would be most appropriate for which one of the following businesses?
    a. fast food
    b. steel-making
    c. insurance sales
    d. clothing alterations
    e. a grocery store
    b (Repetitive and product-oriented layout, moderate)

69. The assumptions necessary for a successful product layout include all of the following **except**
    a. adequate volume for high equipment utilization
    b. standardized product
    c. volatile product demand
    d. All of the above are appropriate assumptions.
    e. None of the above is an appropriate assumption.
    c (Repetitive and product-oriented layout, moderate)

70. Which of these layouts is most suitable for processing sugar from sugar beets or sugar cane?
    a. process-oriented layout
    b. fixed-position layout
    c. focused factory
    d. product-oriented layout
    e. work cell layout
    d (Repetitive and product-oriented layout, moderate)

71. Which of the following is **true** regarding fabrication lines?
    a. They are the same thing as assembly lines.
    b. They are the same thing as focused factories.
    c. They are a special type of process-oriented layout.
    d. Balancing their assembly line is more technological than worker oriented.
    e. None of the above is true.
    d (Repetitive and product-oriented layout, moderate)

72. The central problem in product-oriented layout planning is
    a. minimizing material handling within workstations
    b. minimizing labor movement between workstations
    c. equalizing the space allocated to the different workstations
    d. maximizing equipment utilization
    e. minimizing the imbalance in the work loads among workstations
    e (Repetitive and product-oriented layout, moderate)

73. A **disadvantage** of product-oriented layout is that
    a. there is a lack of flexibility in handling a variety of products or production rates
    b. high volume is required because of the large investment needed to set up the process
    c. work stoppage at any one point ties up the whole operation
    d. All of the above are disadvantages of product-oriented layouts.
    e. None of the above is a disadvantage of product-oriented layouts.
    d (Repetitive and product-oriented layout, moderate)

74. The main advantage of a product-oriented layout is typically
    a. low raw material cost
    b. employability of highly skilled labor
    c. high flexibility
    d. low capital cost
    e. low variable cost per unit
    e (Repetitive and product-oriented layout, moderate)

75. In a product-oriented layout, the process of deciding how to assign tasks to workstations is referred to as
    a. station balancing
    b. process balancing
    c. task allocation
    d. line balancing
    e. work allocation
    d (Repetitive and product-oriented layout, moderate)

76. In assembly line balancing, the minimum number of workstations is
    a. the ratio of the sum of all task times to cycle time
    b. always (when a fraction) rounded upward to the next larger integer value
    c. not always possible to reach when tasks are actually assigned to stations
    d. all of the above
    e. none of the above
    d (Repetitive and product-oriented layout, moderate)

77. In assembly line balancing, cycle time (the ratio of available production time to scheduled production) is the
    a. minimum time that a product is allowed at each workstation
    b. maximum time that a product is allowed at each workstation
    c. optimum time that a product is allowed at each workstation
    d. desired cycle time that a product is allowed at each workstation
    e. all of the above
    b (Repetitive and product-oriented layout, moderate)

78. A production line is to be designed to make 500 El-More dolls per day. Each doll requires 11 activities totaling 16 minutes of work. The factory operates 750 minutes per day. The cycle time for this assembly line is
    a. one-half minute
    b. one and one-half minutes
    c. two minutes
    d. 5,500 minutes
    e. cannot be determined from the information given
    b (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

79. A production line is to be designed for a job with four tasks. The task times are 2.4 minutes, 1.4 minutes, 0.9 minutes, and 1.7 minutes. The maximum cycle time is _____ and the minimum cycle time is _____ minutes.
    a. 1.8; 1.4
    b. 1.6; 0.9
    c. 6.4; 2.4
    d. 2.4; 0.9
    e. none of these
    c (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

80. Cycle time is computed as
    a. desired output divided by the daily operating time
    b. daily operating time divided by the product of desired output and the sum of job times
    c. the product of desired output and the sum of job times divided by daily operating time
    d. daily operating time divided by the scheduled output
    e. 1.00 minus station time
    d (Repetitive and product-oriented layout, moderate)

81. Daily capacity of a product layout is determined by
    a. operating time divided by cycle time
    b. cycle time divided by operating time
    c. operating time divided by total task time
    d. total task time divided by cycle time
    e. cycle time divided by total task time
    a (Repetitive and product-oriented layout, moderate)

82. Four hundred and eighty minutes of production time are available per day. Scheduled production is 120 units per day. What is the cycle time?
    a. 4 minutes
    b. 5 minutes
    c. 6 minutes
    d. 7 minutes
    e. 8 minutes
    a (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

83. A production line is to be designed for a product whose completion requires 21 minutes of work. The factory works 400 minutes per day. Can an assembly line with five workstations make 100 units per day?
    a. yes, with exactly 100 minutes to spare
    b. no, but four workstations would be sufficient
    c. no, it will fall short even with a perfectly balanced line
    d. yes, but the line's efficiency is very low
    e. cannot be determined from the information given
    c (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

84. Four hundred and eighty minutes of production time are available per day. The schedule calls for the production of 80 units per day. Each unit of the product requires 30 minutes of work. What is the theoretical minimum number of workstations?
    a. 2
    b. 3
    c. 4
    d. 5
    e. 6
    d (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

85. Which of the following is **not** a heuristic rule for assigning tasks to workstations in a product layout?
    a. longest tasks first
    b. in order of most number of following tasks
    c. median tasks first
    d. shortest tasks first
    e. in accordance with positional weight
    c (Repetitive and product-oriented layout, moderate)

86. If a layout problem is solved by use of "heuristics," this means that
    a. there was no other way to solve the problem
    b. no computer software was available
    c. the problem has only a few alternatives to evaluate
    d. no optimum solution exists
    e. a "satisfactory" solution is acceptable
    e (Repetitive and product-oriented layout, moderate)

87. Which of the following is a common heuristic for assembly line balancing?
    a. debits near the windows, credits near the door
    b. manufacturers locate near materials, retailers locate near customers
    c. earliest due date first
    d. ranked positional weight
    e. none of the above
    d (Repetitive and product-oriented layout, moderate)

88. An assembly line consists of 21 tasks grouped into 5 workstations. The sum of the 21 task times is 85 minutes. Cycle time for the line is 20 minutes. The efficiency of this line is
    a. 4.2 percent
    b. 17 percent
    c. 85 percent
    d. 100 percent
    e. none of the above
    c (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

89. An assembly line consists of 158 tasks grouped into 32 workstations. The sum of all task times is 105 minutes. Cycle time for the line is 4 minutes. The efficiency of this line is approximately
    a. 8 percent
    b. 21 percent
    c. 82 percent
    d. 100 percent
    e. none of the above
    c (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

FILL-IN-THE BLANK

90. McDonald's "Made for You" kitchen system represents a _____ use of layout decisions.
    strategic (Global company profile, easy)

91. _____ layouts deal with low-volume, high-variety production with like machines and equipment grouped together.
    Process-oriented (Process-oriented layout, easy)

92. A(n) _____ is a special product-oriented arrangement of machines and personnel in what is ordinarily a process-oriented facility.
    work cell (Process-oriented layout, moderate)

93. A(n) _____ groups workers, their equipment, and spaces/offices to provide for comfort, safety, and movement of information.
office layout (Office layout, moderate)

94. The _____ is a non-numeric method for determining which departments are located near one another, and which departments are kept further apart.
office relationship chart or relationship chart (Office layout, moderate)

95. A(n) _____ addresses flow, allocates space, and responds to customer behavior.
retail layout (Retail layout, moderate)

96. _____ are fees manufacturers pay to get their products displayed.
Slotting fees (Retail layout, moderate)

97. _____ refers to the physical surroundings in which a service takes place, and how they affect customers and employees.
Servicescape (Retail layout, moderate)

98. _____ avoids placing materials or supplies in storage by processing them as they are received for shipment.
Cross-docking (Warehousing and storage layouts, moderate)

99. The project remains in one place and workers and equipment come to that one work area in a _____ layout.
fixed-position (Retail layout, moderate)

100. _____ is the use of computer software to evaluate the profitability of merchandising plans in a retail layout.
Category management (Retail layout, moderate) {AACSB: Use of IT}

101. _____ is that element of balancing a work cell that superficially resembles cycle time.
Takt time (Work cells, moderate)

102. A(n) _____ line is a machine-paced product-oriented facility for building components.
fabrication (Repetitive and product-oriented layout, moderate)

103. _____ is the maximum time that the product is available at each workstation.
Cycle time (Repetitive and product-oriented layout, moderate)

SHORT ANSWERS

104. Identify McDonald's "seven major innovations
The seven major innovations are indoor seating, drive-through windows, breakfast menus, play areas, the "Made for You" kitchen system, the self-service kiosk, and the 21st century look. (Global company profile, moderate)

105. In what specific areas does the layout decision establish a firm's competitive priorities?
Layout decisions establish a firm's competitive priorities in the following areas: processes, flexibility, cost, capacity, and quality of work life. (The strategic importance of layout decisions, moderate)

106. To develop a good facility layout, what must be determined?
You need to consider the following to determine a good layout: selection of material handling equipment, capacity and space requirements, environment and aesthetics, flows of information, and cost of moving between various work areas. (Types of layouts, moderate)

107. Identify the seven fundamental layout strategies. Describe the use of each one very briefly.
1. Office layout: Positions workers, their equipment, and spaces/offices to provide for movement of information.
2. Retail layout: Allocates shelf space and responds to customer behavior.
3. Warehouse layout: Addresses trade-offs between space and material handling.
4. Fixed-position layout: Addresses the layout requirements of large, bulky projects such as ships and buildings
5. Process-oriented layout: Deals with low-volume, high-variety production.
6. Work cell layout: Arranges machinery and equipment to focus on the production of a single product or a group of related products
7. Product-oriented layout: Seeks the best personnel and machine utilization in repetitive or continuous production.
(Types of layout, moderate)

108. What techniques can be used to overcome the inherent problems of fixed-position layouts?
Some actions that can be taken to overcome the problems of a fixed-position layout are to develop good schedules, accurately define requirements, and take a rational approach to the layout, as opposed to politicizing the decision. (Fixed-position layout, moderate)

109. "Having a focused work center is like having a factory within a factory." Discuss. Include in your discussion what conditions make focused work centers appropriate.
A focused work center is a permanent product-oriented set of equipment within a process-oriented facility. It requires group technology or equivalent, a high level of staff training and flexibility, and good support or imagination to get started. (Process-oriented layout, moderate)

110. Why do work cells increase the use of equipment and machinery?
Work cells increase the use of equipment and machinery because of better scheduling and faster material flow. (Process-oriented layout, moderate)

111. What are the advantages of focused factories?
Focused factories are better able to stay in tune with their customers, produce quality products, and operate at higher margins. (Process-oriented layout, moderate)

112. Explain how a load-distance model helps solve problems in process layout.
The problem in process layout is to hold down material movement and material handling. The load-distance model calculates these movements from department to department, and can find that set of departmental space assignments that minimize the aggregate material handling cost. This is an optimal layout for a process layout, given the pattern of loads and distances. (Process-oriented layout, moderate)

113. Identify the four requirements for cellular production.
(1) identification of families of products, often through the use of group technology codes or equivalents; (2) a high level of training, flexibility, and empowerment of employees; (3) being self-contained, with its own equipment and resources; and (4) test (poka-yoke) at each station in the cell. (Process-oriented layout, moderate)

114. A facilities manager at a company headquarters once said, "I'd like to use Muther's office relationship chart or the load-distance model to solve our layout problems, but neither tool can optimize. I want the best layout possible." Discuss.
The manager should not be so quick to reject models that find satisfactory, but not necessarily optimal, solutions. The load-distance model can optimize relatively small problems, but large problems are beyond the explicit enumeration required for optimization. That's why CRAFT and other software seek "acceptable" solutions. The office relationship diagram is not an optimizing tool at all, as it uses labels, not numbers, to indicate desirability of closeness. (Office layout, moderate) {AACSB: Reflective Thinking}

115. What design guidelines help retail layouts to maximize customer exposure to products?
Design guidelines that help retail layouts maximize customer exposure to products include:
1. **locating the high-draw items around the periphery of the store**
2. **using prominent locations for high-impulse and high-margin items**
3. **distributing what are known in the trade as "power items" to both sides of an aisle, and dispersing them to increase the viewing of other items**
4. **using end aisle locations because they have a very high exposure rate**
5. **conveying the mission of the store by careful selection in the positioning of the lead-off department (Retail layout, moderate)**

116. Consider the five ideas for determining the overall arrangement of most retail stores. How are these ideas implemented (a) in a supermarket, and (b) in a fine department store? (Please consider the entire store--not just the areas where merchandise is displayed.)
(Suggested response) The five ideas are: 1. locating the high-draw items around the periphery of the store, 2. using prominent locations for high-impulse and high-margin items, 3. distributing what are known in the trade as "power items" to both sides of an aisle, and dispersing them to increase the viewing of other items, 4. using end aisle locations because they have a very high exposure rate, 5. conveying the image of the store by careful selection in the positioning of the lead-off department. Supermarkets make more use of aisles, where ideas 3 and 4 are featured. Department stores are meandering, so there's less use of end-caps. Both types of retail seem to follow ideas 1 and 5. Idea 2 seems to be implemented with impulse items near the checkouts for both retail types. The supermarket's straight lines convey its strategy of low cost; the department store's display areas convey its focus on image, browsing, etc. (Retail layout, difficult) {AACSB: Reflective Thinking}

117. Briefly explain what "slotting" is. Why is slotting considered a "controversial" practice? What ethical issues might arise with regard to slotting?
Slotting is the practice of manufacturers paying for retail shelf space. It is controversial because some managers approve of the practice, but others do not. Ethical issues involved with slotting are (1) such payments might be considered bribery, (2) such payments cost consumers more, and (3) such payments may interfere with efficient and profitable use of retail space. (Retail layout, difficult) {AACSB: Ethical Reasoning}

118. What is a servicescape? How is it related to the retail layout problem? What are the three elements of servicescape for dealing with these human issues?
Servicescape describes the physical surroundings in which a service takes place. Rather than design a retail space strictly for profitability, managers must consider how the surroundings—the layout—have a humanistic effect on customers and employees. The three elements are ambient conditions, spatial layout/functionality, and signs, symbols, and artifacts. (Retail layout, moderate)

119. What is cross-docking? Why is it appropriate for some forms of warehouse layout?
Cross-docking avoids placing materials or supplies in storage by processing them as they are received for shipment. It avoids storing the product, saves space and receiving time, and speeds up shipment to the ultimate destination. (Warehousing and storage layouts, moderate)

120. What are the two basic types of product layouts? Explain how they are alike, and how they are different.
The two types are fabrication lines and assembly lines. Fabrication lines build components on a series of machines, while assembly lines put the fabricated parts together at a series of workstations. Fabrication lines tend to be machine paced and require mechanical changes to facilitate balance, while assembly lines tend to be paced by work tasks assigned to individuals or to workstations and are therefore balanced by moving tasks from one individual to another. (Repetitive and product-oriented layout, difficult)

121. Explain what the purpose of assembly line balancing is. Describe briefly how it is done. Explain how assembly line balancing supports the needs of product layout.
Assembly line balancing attempts to put equal amounts of work into each of the workstations that assemble a product. The technique begins with a task list and precedence chart; to this is added demand data, from which cycle time can be computed. This is the speed at which the line must move. Then the theoretical number of stations is calculated. Each required task is then assigned into one workstation. This approach holds down the amount of idle time in a product layout, and leads to higher utilization of the plant, and to higher volume of output. (Repetitive and product-oriented layout, difficult)

122. Define the following terms that occur in assembly line balancing: cycle time, minimum number of workstations, and efficiency.
Cycle time is the ratio of allowed work time to units scheduled. The theoretical minimum number of workstations in an assembly line is determined by dividing the total task-duration time for the product by the cycle time. The efficiency of a line balance is determined by dividing the total task time assigned by the product of the number of workstations times the cycle time. (Repetitive and product-oriented layout, moderate)

123. What is the role of heuristics in solving layout problems? Provide a brief example, drawing from manufacturing situations, retailing situations, or other service situations.
Heuristics are used in problems too complex to model explicitly, such as assembly line balancing problems, fixed-position layouts, office layouts, and retail layouts. All of these layout types are quite complex, featuring very large numbers of alternative solutions and no single numeric objective for evaluating them. (Repetitive and product-oriented layout, moderate)

124. Assembly line balancing has just been used to solve a product layout problem. Two solutions look especially attractive to the plant managers. Both solutions make the same output per day, and both have the same number of workstations. The managers were going to break the tie by looking at line efficiency, but discovered that both lines had the same efficiency as well. Should they have been surprised at this? Explain.

No, they should not be surprised. Efficiency is the ratio of actual work needed per unit to time available. Work needed is clearly the same in both cases as the product is the same. Work available is also the same, since both lines have the same number of stations and the same cycle time. Once cycle time and number of stations are known, so is efficiency, no matter what tasks are assigned to what stations within that framework. (Repetitive and product-oriented layout, difficult) {AACSB: Analytic Skills}

125. What are the advantages and disadvantages of product layouts?

The advantages of a product layout are:

- **The low variable cost per unit usually associated with high-volume, standardized products.**
- **Low material handling costs.**
- **Reduced work-in-process inventories.**
- **Easier training and supervision.**
- **Rapid throughput.**

The disadvantages are:

- **The high volume required because of the large investment needed to establish the process.**
- **That work stoppage at any point ties up the whole operation.**
- **A lack of flexibility when handling a variety of products or production rates.**

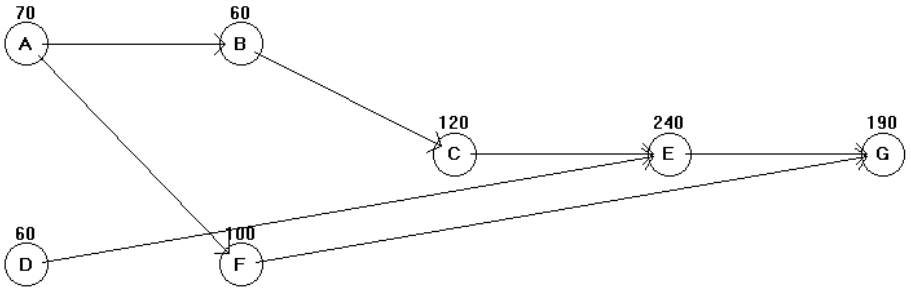
(Repetitive and product-oriented layout, moderate)

PROBLEMS

126. Develop a solution for the following line balancing problem, allowing a cycle time of 5 minutes.
a. Draw the precedence diagram for the set of tasks.
b. Calculate the theoretical minimum number of workstations.
c. Balance this line using the longest task time heuristic.
d. What tasks are assigned to which stations?
e. Does the solution have the minimum number of stations? Explain.
f. How much idle time is there, summed over all workstations?
g. What is the efficiency of this line?

Work Task	Task Time (seconds)	Task Predecessor(s)
A	70	-
B	60	A
C	120	B
D	60	-
E	240	C, D
F	100	A
G	190	E, F

The minimum number of workstations is 3. Balance places ABDF in station 1, C in station 2, E in station 3, and G in station 4. The solution uses four stations, not three. The POM for Windows solution is shown below. Idle time is distributed 10, 180, 60, and 110 per station. There are 360 seconds of idle time in the system. Efficiency is 70.0%.



Station	Task	Time (seconds)	Time left (seconds)	Ready tasks
				A,D
1	A	70.	230.	D,B,F
	F	100.	130.	D,B
	D	60.	70.	B
	B	60.	10.	C
2	C	120.	180.	E
3	E	240.	60.	G
4	G	190.	110.	
Summary Statistics				
Cycle time	300	seconds		
Time allocated (cycle time * #	1200	seconds/cycle		
Time needed (sum of task times)	840	seconds/unit		
Idle time (allocated-needed)	360	seconds/cycle		
Efficiency (needed/allocated)	70%			
Balance Delay (1-efficiency)	30%			
Min (theoretical) # of stations	3			

(Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

127. An assembly line has been designed to make battery-powered beverage mixers. Task details are shown in the table below:

Station	Task Assigned	Task Time (minutes)
1	1	3.0
2	3; 4	1.5; 2.0
3	2; 5; 6	1.5; 1.5; 1.0
4	7	3.0
5	8	2.5
6	9; 10; 11	2.0; 1.0; 1.0

a. What is the assigned cycle time (in minutes)?
b. What is the maximum output rate of this line in mixers per hour?
c. What is the total idle time per cycle?
d. What is the assembly line's efficiency?
Cycle time is 4.0 minutes (governed by stations 3 and 6). Maximum output is 60/4 = 15.0 units per hour. Idle time is 1.0 + 0.5 + 0.0 + 1.0 + 1.5 + 0 = 4.0 minutes. Efficiency is 20.0/24.0 = 83.3%. (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

128. Departments A, B, C, and D need to be assigned to four rooms 1, 2, 3, and 4. These rooms are arranged in a row, in that order, with 20 meters between each. The departmental work flows are contained in the table below.

a. What is the material handling total of assigning A-1, B-2, C-3, D-4?
b. What is the material handling total of assigning A-1, B-3, C-4, D-2?

Flow Matrix				
	Dept. A	Dept. B	Dept. C	Dept. D
Dept. A	0	30	5	20
Dept. B	5	0	40	20
Dept. C	0	10	0	40
Dept. D	10	5	0	0

(a)The material handling total of A-1, B-2, C-3, D-4 is 5500. Details: 1-2 (A-B): 20x30+20x5=700; 1-3 (A-C): 40x5+40x0=200; 1-4 (A-D): 60x20+60x10=1800; 2-3 (B-C): 20x40+20x10=1000; 2-4 (B-D): 40x20+40x5=1000; and 3-4 (C-D): 20x40+20x0=800. The sum of these six elements is 5,500.
(b) The material handling total of A-1, B-3, C-4, D-2 is 5400, which is also the optimal solution. Details: 1-2 (A-D): 20x20+20x10=600; 1-3 (A-B): 40x30+40x5=1400; 1-4 (A-C): 60x5+60x0=300; 2-3 (B-D): 20x20+20x5=500; 2-4 (C-D):40x40+40x0=1600; and 3-4 (B-C): 20x40+20x10=1000. These six elements sum to 5400. (Process-oriented layout, moderate) {AACSB: Analytic Skills}

129. The flow and distance data in the table below were input into a layout software program, and solved by "pairwise comparison." That solution called for assignments A-4, B-1, C-3, and D-2, with a total movement of 2430. Verify that result. Is that solution optimal? Can you offer an improved solution? What is the total movement of your alternate solution?

Flow Table	A	B	C	D	Fixed room
A	0	5	8	3	
B	0	0	7	6	
C	0	2	0	9	
D	5	12	4	0	
Distance Table	Room 1	Room 2	Room 3	Room 4	
Room 1	0	30	60	80	
Room 2	30	0	30	50	
Room 3	60	30	0	20	
Room 4	80	50	20	0	

The six elements of movement in the original solution are 1-2 (B-D): 6x30+12x30=540; 1-3 (B-C): 7x60+2x60=540; 1-4 (A-B): 5x80+0x80=400; 2-3 (C-D): 9x30+4x30=390; 2-4 (A-D): 3x50+5x50=400; and 3-4 (A-C): 8x20+0x20=160. The sum of these six elements is 2430. This solution is not necessarily optimal because the pairwise comparison technique does not inspect all possible solutions. Another possible solution is A-4, B-1, C-2, and D-3, which has a total movement of 2700. The optimal assignment of departments to rooms is A-1, B-4, C-2, and D-3, which has a total movement of 2320. C is thus put further from B and closer to A, which helps reduce movement. (Process-oriented layout, moderate) {AACSB: Analytic Skills}

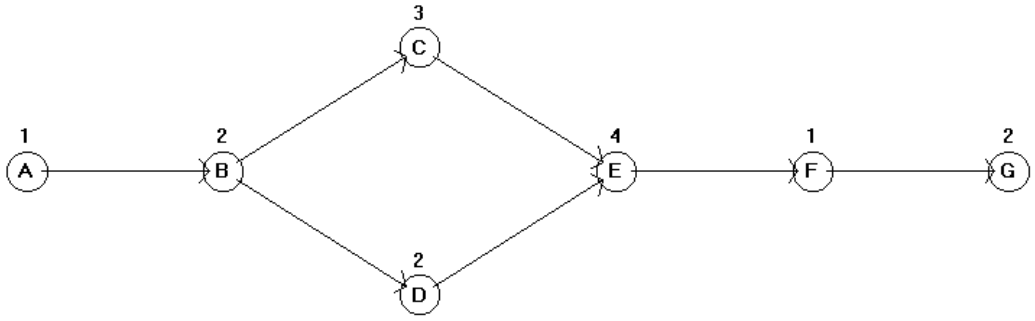
130. Cyclone Appliances has developed a new European-style convection oven that will be made on an assembly line. The schedule requires 80 ovens in an 8-hour day. The assembly includes seven tasks. The table below indicates the performance time and the sequence requirements for each task.

Task	Performance Time (minutes)	Task must follow Task listed below
A	1	
B	2	A
C	3	B
D	2	B
E	4	C, D
F	1	E
G	2	F

a. What is the cycle time for this assembly operation?
b. What is the minimum number of workstations?
c. Draw the precedence diagram.

SEE NEXT PAGE FOR SOLUTION.

(a) The cycle time is 480 minutes per day / 80 ovens = 6 minutes/oven. (b) The minimum number of workstations is the sum of all task times, 15 minutes, divided by the cycle time, 6 minutes; 15 / 6 = 2.5 or 3 workstations. (c) The precedence diagram appears below.



(Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

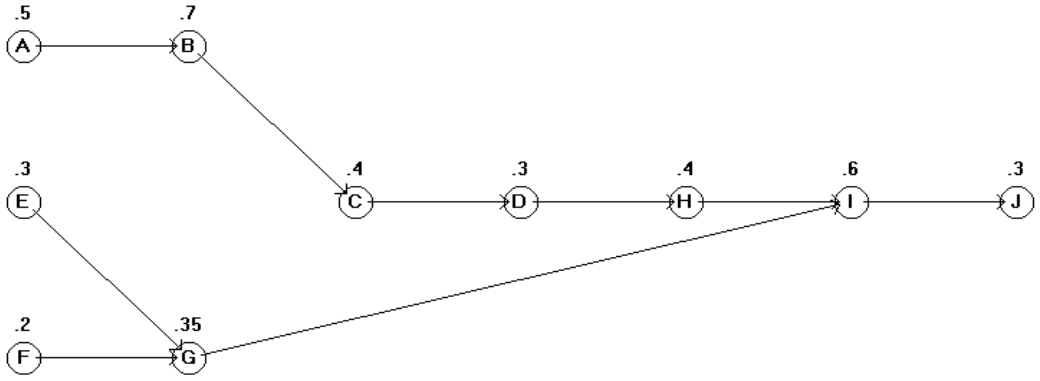
131. An electronics manufacturer makes remote control devices for interactive-cable-TV systems. The following assembly tasks must be performed on each device.

Task	Description	Predecessor(s)	Time (min.)
A	Place circuit into circuit frame	--	0.50
B	Solder circuit connections to central circuit control	A	0.70
C	Place circuit assembly in device frame	B	0.40
D	Attach circuit assembly to device frame	C	0.30
E	Place and attach display to frame	--	0.30
F	Place and attach keypad to frame	--	0.20
G	Place and attach top body of device to frame	E, F	0.35
H	Place and attach battery holder to frame	D	0.40
I	Place and attach bottom body of device to frame	G, H	0.60
J	Test device	I	0.30

a. Draw the precedence diagram for this problem.
b. What is the sum of the task times?
c. What cycle time will allow the production of 200 units over a ten-hour day?
d. What is the theoretical number of workstations needed?
e. Balance this assembly line using the heuristic most following tasks and the heuristic longest operation time.
f. How do these two solutions differ? Which do you prefer; why?

SEE NEXT PAGE FOR SOLUTION.

The sum of the task times is 4.05 minutes. The cycle time for 200 units output is 600/200 =3 minutes. The minimum number of stations is 4.05/3 = 1.35 or 2. Both solutions use two stations and have 67.5% efficiency.



Station	Task	Time (minutes)	Time left (minutes)	Ready tasks (# followers)
				A(6),E(3),F(3)
1	A	0.5	2.5	E(3),F(3),B(5)
	B	0.7	1.8	E(3),F(3),C(4)
	C	0.4	1.4	E(3),F(3),D(3)
	E	0.3	1.1	F(3),D(3)
	F	0.2	0.9	D(3),G(2)
	D	0.3	0.6	G(2),H(2)
	G	0.35	0.25	H(2)
2	H	0.4	2.6	I(1)
	I	0.6	2.	J(0)
	J	0.3	1.7	
Summary Statistics				
Cycle time	3	minutes		
Time allocated (cycle time * #	6	minutes/cycle		
Time needed (sum of task times)	4.05	minutes/unit		
Idle time (allocated-needed)	1.95	minutes/cycle		
Efficiency (needed/allocated)	67.5%			
Balance Delay (1-efficiency)	32.5%			
Min (theoretical) # of stations	2			

Station	Task	Time (minutes)	Time left (minutes)	Ready tasks
				A,E,F
1	A	0.5	2.5	E,F,B
	B	0.7	1.8	E,F,C
	C	0.4	1.4	E,F,D
	E	0.3	1.1	F,D
	D	0.3	0.8	F,H
	H	0.4	0.4	F
	F	0.2	0.2	G
2	G	0.35	2.65	I
	I	0.6	2.05	J
	J	0.3	1.75	
Summary Statistics				
Cycle time	3	minutes		
Time allocated (cycle time * #	6	minutes/cycle		
Time needed (sum of task times)	4.05	minutes/unit		
Idle time (allocated-needed)	1.95	minutes/cycle		
Efficiency (needed/allocated)	67.5%			
Balance Delay (1-efficiency)	32.5%			
Min (theoretical) # of stations	2			

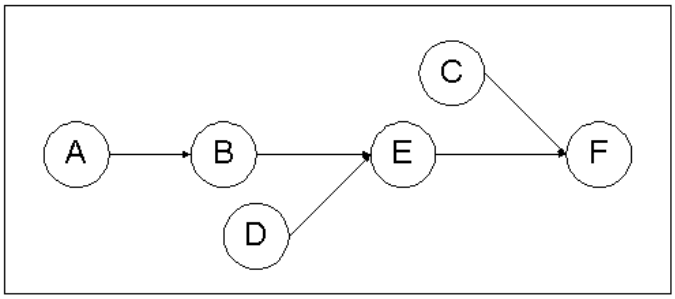
(Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

132. A company is designing a product layout for a new product. It plans to use this production line eight hours a day in order to meet a schedule of 400 units per day. The tasks necessary to produce this product are detailed in the table below.

Task	Predecessor	Time (seconds)
A	-	50
B	A	36
C	-	26
D	-	22
E	B, D	70
F	C, E	30

a. Draw the network described in the table.
b. Without regard to a production schedule, what is the minimum possible cycle time (in seconds) for this situation; what is the maximum?
c. What is the required cycle time (in seconds) in order to meet the schedule?
d. What is the minimum number of workstations needed to meet the schedule?
e. Balance this line using longest processing time.
f. What is the efficiency of the balance obtained in part e?

The network diagram appears below. Minimum cycle time is 70 seconds (the longest task time); maximum cycle time is 234 seconds (sum of the task times). Cycle time is 480/400 = 1.2 minutes or 72 seconds (which is barely feasible). The number of stations required is at least 234/72 = 3.25 or 4.



Station	Task	Time (seconds)	Time left (seconds)	Ready tasks
				A,C,D
1	A	50.	22.	C,D,B
	D	22.	0.	C,B
2	B	36.	36.	C,E
	C	26.	10.	E
3	E	70.	2.	F
4	F	30.	42.	
Summary Statistics				
Cycle time	72	seconds		
Time allocated (cycle time * #	288	seconds/cycle		
Time needed (sum of task times)	234	seconds/unit		
Idle time (allocated-needed)	54	seconds/cycle		
Efficiency (needed/allocated)	81.25%			
Balance Delay (1-efficiency)	18.75%			
Min (theoretical) # of stations	4			

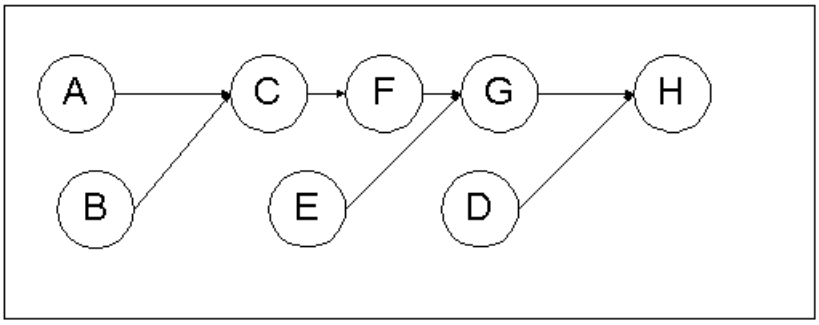
(Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

133. You have been asked to balance a flow shop assembly operation to achieve an output rate of 80 units per eight-hour day. Task times and precedence relationships are shown in the table below.

Task	Predecessor(s)	Duration (minutes)
A	--	1.4
B	--	0.8
C	A, B	0.4
D	--	1.8
E	--	0.4
F	C	2.1
G	E, F	2.0
H	D, G	1.2

a. Draw the precedence diagram.
b. Determine the desired cycle time.
c. Determine the minimum number of stations needed.
d. Balance this line using most following tasks.
e. What is the efficiency of the line obtained in part d?

The precedence diagram appears below. The desired cycle time for 80 units is 6 minutes. The minimum number of stations is 10.1 / 6 = 1.68 or 2.



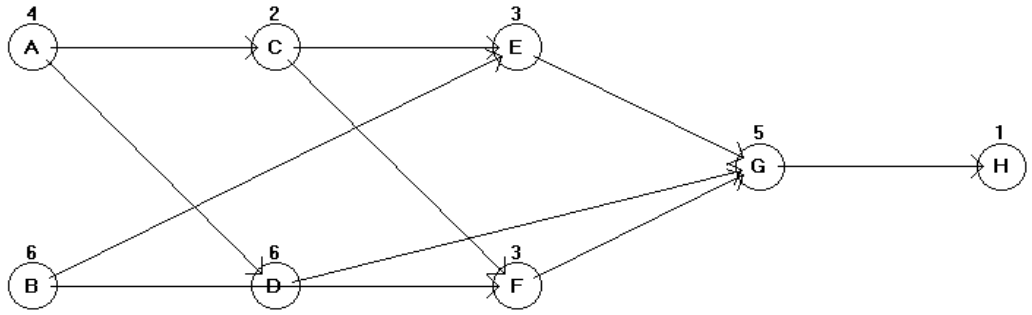
Station	Task	Time (minutes)	Time left (minutes)	Ready tasks (# followers)
				A(4),B(4),D(1),E(2)
1	A	1.4	4.6	B(4),D(1),E(2)
	B	0.8	3.8	D(1),E(2),C(3)
	C	0.4	3.4	D(1),E(2),F(2)
	E	0.4	3.	D(1),F(2)
	F	2.1	0.9	D(1),G(1)
2	D	1.8	4.2	G(1)
	G	2.	2.2	H(0)
	H	1.2	1.	
Summary Statistics				
Cycle time	6	minutes		
Time allocated (cycle time * #	12	minutes/cycle		
Time needed (sum of task times)	10.1	minutes/unit		
Idle time (allocated-needed)	1.900001	minutes/cycle		
Efficiency (needed/allocated)	84.16666%			
Balance Delay (1-efficiency)	15.83334%			
Min (theoretical) # of stations	2			

(Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

134. A firm operates a flow shop building kitchen cabinetry for recreational vehicles. The major activities of this process are listed below.

Task	Duration (hours)	Predecessor 1	Predecessor 2	Predecessor 4
A	4	--		
B	6	--		
C	2	A		
D	6	A		
E	3	B	C	
F	3	B	C	
G	5	D	E	F
H	1	G		

a. Draw the appropriate network for this project.
b. What would the cycle time be if the goal is to produce 20 units per month (the plant operates 160 hours per month)?
c. What is the minimum number of workstations needed?
d. Balance with the most following tasks heuristic. What tasks are assigned to which stations?
e. What is the efficiency of the line obtained in part d?



Station	Task	Time (hours)	Time left (hours)	Ready tasks (# followers)
				A(6),B(4)
1	A	4.	4.	B(4),C(4),D(2)
	C	2.	2.	B(4),D(2)
2	B	6.	2.	D(2),E(2),F(2)
3	D	6.	2.	E(2),F(2)
4	E	3.	5.	F(2)
	F	3.	2.	G(1)
5	G	5.	3.	H(0)
	H	1.	2.	
Summary Statistics				
Cycle time	8	hours		
Time allocated (cycle time * #	40	hours/cycle		
Time needed (sum of task times)	30	hours/unit		
Idle time (allocated-needed)	10	hours/cycle		
Efficiency (needed/allocated)	75%			
Balance Delay (1-efficiency)	25%			
Min (theoretical) # of stations	4			

(b) The cycle time is 160/20=8 hours; (c) This line requires at least 30/8=3.75 or 4 stations; (d) A and C are in Station 1; B is in Station 2; D is in Station 3; E and F occupy Station 4; and G and H are in Station 5. (e) Efficiency is 30/40=.75 or 75 percent. (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

135. There are three work centers (A, B, and C) behind the financial aid counter at a nearby university. They can each fit into any of three office spaces (1, 2, and 3) off the corridor behind the desk. There is no student contact in these areas, only workers. The distance 1-2 is 20 feet, 2-3 is 30 feet, and 1-3 is 50 feet. The matrix of work (trips per day) at the three centers is in the following table. Remember that each trip must be a round-trip (from 1 to 2 and back, for example).

	A	**B**	**C**
A	--	20	0
B	45	--	25
C	60	0	--

a. How many possible assignments are there? List them.
b. Calculate the total distance traveled in each of these assignments.
c. Which assignment minimizes distance traveled?
(a) There are 3! = 6 assignments, listed in the table below. (b) The cost, in feet, of each assignment appears in the table below. (c) The lowest cost assignment is A-2, B-1, C-3.

A	**B**	**C**	**Cost**
1	**2**	**3**	**10,100**
1	**3**	**2**	**10,400**
2	**1**	**3**	**8,700**
2	**3**	**1**	**8,800**
3	**1**	**2**	**11,100**
3	**2**	**1**	**10,900**

(Process-oriented layout, difficult) {AACSB: Analytic Skills}

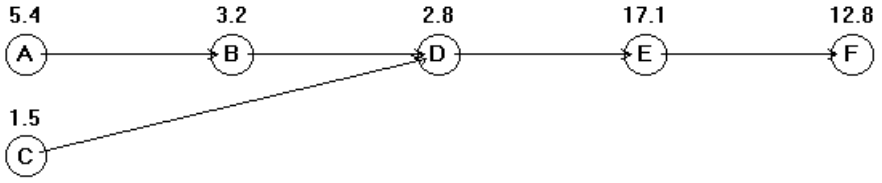
136. Hemo-tech, Inc., a biomedical technology and research laboratory, produces a standard blood filtering device on an assembly line basis. Six basic tasks are performed along an assembly line. The time to perform each task and the tasks that must immediately precede each task are in the table below. Twenty pumps per 450-minute day must be produced by the assembly line.

Task	Preceding Task	Time to perform (min.)
A	--	5.40
B	A	3.20
C	--	1.50
D	B, C	2.80
E	D	17.10
F	E	12.80

a. Draw the network diagram of the precedence relationships.
b. Identify the absolute minimum and maximum cycle times.
c. How many workstations are required to meet the schedule?
d. What is the cycle time required to meet demand?
e. Balance this line using most following tasks heuristic.
f. What is the efficiency of the line obtained in part e?
g. Can the efficiency of this solution be improved? Explain.

SEE NEXT PAGE FOR SOLUTION.

(a) The appropriate diagram appears below. (b)The absolute minimum cycle time is 17.10 minutes (the longest operation). The absolute maximum cycle time is 42.80 minutes (the sum of all task times). (c) The minimum number of stations is 42.8/22.5 = 1.90 or 2, but the actual number of stations needed is 3. (d) The cycle time is 450/20 = 22.5 minutes. (e) The balanced line appears below. (f) The line's efficiency is only 63%. (g) There is idle time at all stations; removing the smallest amount of idle time (5.4 minutes) from all stations reduces the cycle time from 22.5 minutes to 17.1 minutes. The efficiency of the line rises to 83 percent.



Station	Task	Time (minutes)	Time left (minutes)	Ready tasks (# followers)
				A(4),C(3)
1	A	5.4	17.1	C(3),B(3)
	C	1.5	15.6	B(3)
	B	3.2	12.4	D(2)
	D	2.8	9.6	E(1)
2	E	17.1	5.4	F(0)
3	F	12.8	9.7	
Summary Statistics				
Cycle time	22.5	minutes		
Time allocated (cycle time * #	67.5	minutes/cycle		
Time needed (sum of task times)	42.8	minutes/unit		
Idle time (allocated-needed)	24.7	minutes/cycle		
Efficiency (needed/allocated)	63.40741%			
Balance Delay (1-efficiency)	36.59259%			
Min (theoretical) # of stations	2			

Station	Task	Time (minutes)	Time left (minutes)	Ready tasks
1	A	5.4	11.7	C(3),B(3)
	C	1.5	10.2	B(3)
	B	3.2	7.	D(2)
	D	2.8	4.2	E(1)
2	E	17.1	0.	F(0)
3	F	12.8	4.3	
Summary Statistics				
Cycle time	17.1	minutes		
Time allocated (cyc*sta)	51.3	minutes/cycle		
Time needed (sum task)	42.8	minutes/unit		
Idle time (allocated-needed)	8.500004	minutes/cycle		
Efficiency (needed/allocated)	83.43079%			
Balance Delay (1-efficiency)	16.56921%			
Min (theoretical) # of stations	2			

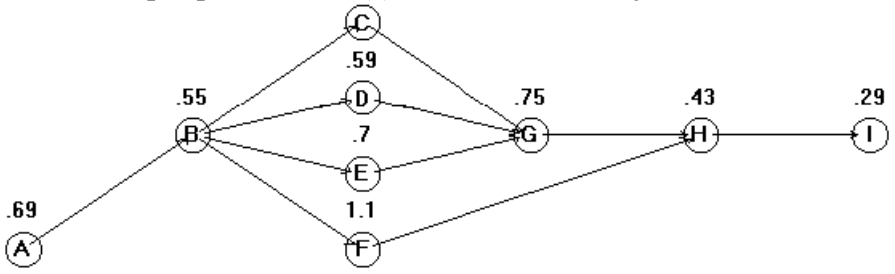
(Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

137. A firm is planning to set up an assembly line to assemble 40 units per hour, and 57 minutes per hour are productive. The time to perform each task and the tasks which precede each task are:

Task	Preceding Task	Time to perform (min.)
A	--	.69
B	A	.55
C	B	.92
D	B	.59
E	B	.70
F	B	1.10
G	C, D, E	.75
H	G, F	.43
I	H	.29

a. Draw a network diagram of precedence relationships.
b. Compute the cycle time per unit in minutes.
c. Compute the minimum number of workstations required to produce 40 units per hour.
d. Balance this line using longest processing time.
e. What is the efficiency of the line obtained in part d?

(a) The appropriate diagram appears below. (b) Cycle time is 57/40 = 1.425 minutes. (c) The number of stations required is 6.02/1.425 = 4.22 or 5. (d) The balanced line appears in the software output panel below. (e) The line's efficiency is 6.02 / 8/55 = 70.4%



Station	Task	Time (minutes)	Time left (minutes)	Ready tasks
				A
1	A	0.69	0.735	B
	B	0.55	0.185	C,D,E,F
2	F	1.1	0.325	C,D,E
3	C	0.92	0.505	D,E
4	E	0.7	0.725	D
	D	0.59	0.135	G
5	G	0.75	0.675	H
	H	0.43	0.245	I
6	I	0.29	1.135	
Summary Statistics				
Cycle time	1.425	minutes		
Time allocated (cycle time * #	8.549999	minutes/cycle		
Time needed (sum of task times)	6.02	minutes/unit		
Idle time (allocated-needed)	2.529999	minutes/cycle		
Efficiency (needed/allocated)	70.40936%			
Balance Delay (1-efficiency)	29.59064%			
Min (theoretical) # of stations	5			

(Repetitive and product-oriented layout, difficult) {AACSB: Analytic Skills}

138. An insurance claims processing center has six work centers, any of which can be placed into any of six physical departmental locations. Call the centers 1, 2, 3, 4, 5, and 6, and the departments A, B, C, D, E, and F. The current set of assignments is A-3, B-1, C-6, D-2, E-4, and F-5.

The (symmetric) matrix of departmental distances, in meters is

	1	**2**	**3**	**4**	**5**	**6**
1	--	5	30	20	15	20
2		--	40	15	10	10
3			--	50	20	5
4				--	10	35
5					--	5
6						--

The matrix of work flow (estimated trips per day) is among centers

	A	**B**	**C**	**D**	**E**	**F**
A	--	15	20	0	30	0
B	20	--	50	0	160	10
C	0	50	--	30	0	30
D	30	60	20	--	70	0
E	40	0	0	10	--	60
F	0	0	30	20	50	--

The firm estimates that each trip costs approximately $4.
a. What is the cost of the current assignment?
b. Use trial-and-error to find one improved assignment.
c. What is that assignment, and what is its cost?
(a) The current assignment costs 14,000 meters, or $56,000. (b,c) The optimal solution is 10,450 meters, or $41,800, with A-3, B-5, C-4, D-1, E-6, and F-2. Students may find improved solutions other than the optimal solution. (Process-oriented layout, difficult) {AACSB: Analytic Skills}

139. An assembly line with 11 tasks is to be balanced. The longest task is 2.4 minutes, the shortest task is 0.4 minutes, and the sum of the task times is 18 minutes. The line will operate for 600 minutes per day.

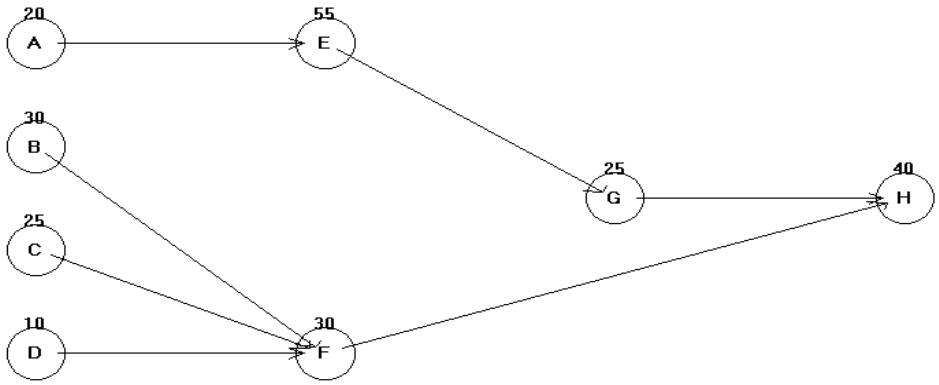
a. Determine the minimum and maximum cycle times.
b. What range of output is theoretically possible for the line?
c. What is the minimum number of stations needed if the maximum output rate is to be sought?
d. What cycle time will provide an output rate of 200 units per day?
Minimum cycle time is 2.4 minutes. Maximum cycle time is 18 minutes. Maximum output is 600/2.4 = 250; minimum output is 600/18 = 33.3. For maximum output, 18/2.4 = 7.5 or 8 stations will be needed. To produce 200 units per day requires a 3-minute cycle time. (Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

140. A facility is trying to set up an assembly line, and has identified the various tasks, and their relationship to each other, as shown in the following table. They wish to produce 600 units per day, working two 8-hour shifts.

Task	Preceding Task	Time to perform (sec.)
A	--	20
B	--	30
C	--	25
D	--	10
E	A	55
F	D, B, C	30
G	E	25
H	F, G	40

a. Draw a network diagram of precedence relationships.
b. Compute the cycle time per unit in seconds.
c. Compute the minimum number of workstations required to produce 600 units per day.
d. Balance this line using longest processing time.
e. What is the efficiency of the line obtained in part d?

(a) The precedence diagram appears below. (b) Cycle time is 96 seconds. (c) 3 workstations are needed. (d) The computer output places tasks A-B-C-D in station 1, E-F in station 2, and G-H in station 3. (e) Efficiency is about 82 percent.



Station	Task	Time (seconds)	Time left (seconds)	Ready tasks
				A,B,C,D
1	B	30.	66.	A,C,D
	C	25.	41.	A,D
	A	20.	21.	D,E
	D	10.	11.	E,F
2	E	55.	41.	F,G
	F	30.	11.	G
3	G	25.	71.	H
	H	40.	31.	
Summary Statistics				
Cycle time	96	seconds		
Time allocated (cycle time * #	288	seconds/cycle		
Time needed (sum of task times)	235	seconds/unit		
Idle time (allocated-needed)	53	seconds/cycle		
Efficiency (needed/allocated)	81.59722%			
Balance Delay (1-efficiency)	18.40278%			
Min (theoretical) # of stations	3			

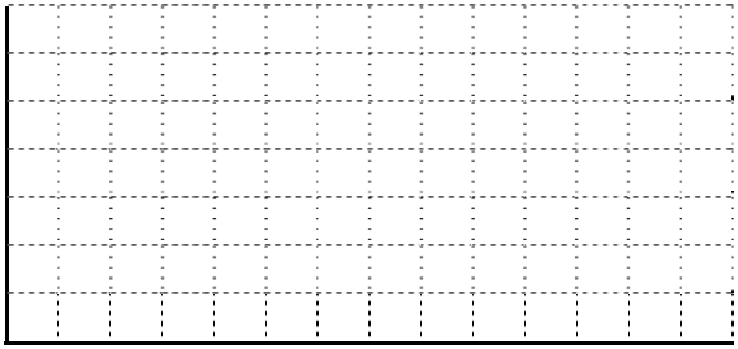
(Repetitive and product-oriented layout, moderate) {AACSB: Analytic Skills}

141. A work cell is required to make 200 computerized diagnostic assemblies (for installation into hybrid automobiles) each day. The cell currently works an eight hour shift, of which seven hours is available for productive work. What is takt time for this cell?
Takt time = 420 minutes / 200 units required = 2.1 minutes (Work cells, moderate) {AACSB: Analytic Skills}

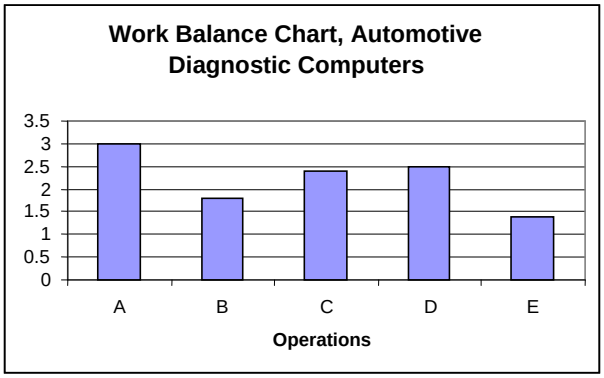
142. A work cell is scheduled to build 120 digital light processor (DLP) assemblies each week. These assemblies are later installed into home theater projection systems. The work cell has 7.5 hours of productive work each day, six days per week. What is takt time for this cell?
The cell has 7.5 x 6 = 45 hours (or 2700 minutes) of work time each week. Takt time = 2700 / 120 = 22.5 minutes. (Work cells, moderate) {AACSB: Analytic Skills}

143. A work cell is required to make 80 computerized diagnostic assemblies (for installation into hybrid automobiles) each day. The cell currently works an eight hour shift, of which seven hours is available for productive work. These assemblies require five operations, with times of 1.0, 0.8, 2.4, 2.5, and 1.4 minutes each. What is takt time for this cell? How many workers will be needed?
Takt time = 420 minutes / 80 units = 5.25 minutes. Total operation time is 1.0 + 1.8 + 2.4 + 2.5 + 1.4 = 9.1 minutes. Workers required = 9.1 / 5.25 = 1.73 or 2. (Work cells, moderate) {AACSB: Analytic Skills}

144. A work cell is required to make 140 computerized diagnostic assemblies (for installation into hybrid automobiles) each day. The cell currently works an eight hour shift, of which seven hours is available for productive work. These assemblies require five operations. Standard times for these operations are: Operation A, 3.0 minutes, B, 1.8 minutes, C, 2.4 minutes, D, 2.5 minutes, and E, 1.4 minutes. What is takt time for this cell? How many workers will be needed to achieve this schedule? Use the grid below to construct a work balance chart for this cell.



Takt time = 420 / 140 = 3 minutes/unit. Total operation time = 3.0 + 1.8 + 2.4 + 2.5 + 1.4 = 11.1 minutes. Four workers are required (11.1 / 3 = 3.7). The balance chart appears below.



(Work cells, moderate) {AACSB: Analytic Skills}

CHAPTER 10: HUMAN RESOURCES AND JOB DESIGN

TRUE/FALSE

1. Self-directed teams may mean having no supervision on the factory floor.
True (Job design, moderate)

2. The goal of a human resource strategy is to manage labor and design jobs so people are effectively and efficiently utilized.
True (Human resource strategy for competitive advantage, easy)

3. Equitable pay alone cannot achieve a reasonable quality of work life in an organization.
True (Human resource strategy for competitive advantage, moderate)

4. Mutual trust means that both management and employee strive to meet common objectives.
False (Human resource strategy for competitive advantage, moderate)

5. Technology, location, and layout decisions are all possible constraints on the human resource strategy.
True (Human resource strategy for competitive advantage, moderate)

6. Labor planning determines employment stability.
True (Labor planning, easy)

7. The two extremes of employment stability policy are "follow demand exactly" and "keep demand constant."
False (Labor planning, moderate)

8. Maintaining a stable workforce generally results in the firm paying higher wages than a firm that follows demand.
False (Labor planning, moderate)

9. Flextime is a system that allows employees, within limits, to determine their own work schedules.
True (Labor planning, moderate)

10. Labor specialization includes the development of specialized tools to reduce labor costs.
False (Job design, moderate)

11. An enlarged job has more responsibility than the same job enriched.
False (Job design, moderate)

12. Job rotation is an example of job enlargement.
True (Job design, moderate)

13. Fredrick W. Taylor is credited with introducing psychology into the workplace.
False (Job design, moderate)

14. Psychological factors have little relevance in the design of assembly line jobs since they involve physical products and production technology.
False (Job design, moderate)

15. Self-directed teams tend to be successful in work environments where there is little employee empowerment.
False (Job design, moderate)

16. The Hawthorne studies, which showed that there is a dynamic social system in the workplace, took place in the 1960s.
False (Job design, moderate)

17. Hackman and Oldham's five desirable characteristics of job design include job significance and autonomy.
True (Job design, moderate)

18. Job expansion can lead to increased labor cost because of the extra workers hired in the expansion.
False (Job design, moderate)

19. Profit-sharing is a motivation and incentive system where executives receive stock options.
False (Job design, moderate)

20. The physical environment in which employees work may affect the quality of work life, but it does not affect their performance and safety.
False (Job design, moderate)

21. Ergonomics is a branch of economics that deals with costs of scheduling workers.
False (Job design, moderate)

22. An operations chart, or right-hand/left-hand chart, points out wasted motion and idle time.
True (Job design, moderate)

23. Kanbans and andons are both elements of the visual workplace, because they are visual signals that replace printouts and paperwork.
True (The visual workplace, moderate) {AACSB: Communication}

24. "Visual workplace" is a term coined by Hawthorne, and refers to the need for proper lighting at employee workstations.
False (The visual workplace, moderate)

25. Because various employment laws now require it, "equal pay for equal work" is no longer an ethical concern in the work environment.
False (Ethics and the work environment, moderate) {AACSB: Ethical Reasoning}

26. Working around asbestos raised ethical concerns before its inherent dangers became known.
False (Ethics and the work environment, moderate) {AACSB: Ethical Reasoning}

27. The purpose of labor standards is to accurately define the skills required to complete a job.
False (Labor standards, moderate)

MULTIPLE CHOICE

28. Workers in which of the following countries probably experience the least amount of job expansion, on average?
    a. United States
    b. Sweden
    c. Japan
    d. Sweden and Japan experience about the same amount, and less than the U.S.
    e. They all experience about the same amount.
    a (Job design, difficult) {AACSB: Reflective thinking}

29. Which of the following best describes **mutual commitment** in an organization?
    a. an instance in which management is committed to the employees and the employees are committed to management
    b. both management and the employees are committed to the same objective
    c. both management and the employees are committed, but to different objectives
    d. management obtains the commitment of the employees to a stated objective
    e. both management and the employees can rely on each other
    b (Human resource strategy for competitive advantage, moderate)

30. Mutual trust is
    a. when employees have gained the trust of management
    b. reflected in reasonable, documented employment policies, honestly and equitably implemented to the satisfaction of both management and the employees
    c. when management has gained the trust of the employees
    d. when management recognizes that the employees are competent, motivated people both able and willing to perform at the level required to produce a quality product
    e. when management and the employees both agree on the objectives
    b (Human resource strategy for competitive advantage, moderate)

31. The objective of a human resource strategy is to
    a. produce the demand forecast at lowest labor cost
    b. match employment levels with demand
    c. achieve a reasonable quality of work life at low cost
    d. manage labor and design jobs so people are effectively and efficiently utilized
    e. all of the above
    d (Human resource strategy for competitive advantage, moderate)

32. The two most basic policies associated with employment stability are
    a. job enrichment and job enlargement
    b. employment for life and guaranteed minimum wage
    c. follow demand exactly and hold employment constant
    d. incentive plans and piece-rate plans
    e. none of the above
    c (Labor planning, moderate)

33. Four of the components of job design are
    a. employment stability, work schedules, work sampling, motivation, and incentive systems
    b. job specialization, job expansion, psychological components, and self-directed teams
    c. labor specialization and enrichment, motivation and incentive systems, employment stability, and work sampling
    d. ergonomics and work methods, method time measurement, work schedules, and incentive systems
    e. labor specialization, time studies, work sampling, and pre-determined time standards
    b (Job design, moderate)

34. Job rotation is an example of
    a. job enrichment
    b. job scheduling
    c. job training
    d. job enlargement
    e. job incentive
    d (Job design, moderate)

35. The behavioral approach to job design that involves giving the worker a larger portion of the total task is
    a. job enlargement
    b. job enrichment
    c. job enhancement
    d. job rotation
    e. job involvement
    a (Job design, moderate)

36. When a worker has a say in the work methods that he/she wishes to utilize, his/her job is characterized by
    a. skill variety
    b. job identity
    c. job significance
    d. feedback
    e. autonomy
    e (Job design, moderate)

37. Which of the following terms implies an increase in responsibility and control?
    a. job rotation
    b. job enrichment
    c. job re-design
    d. job enlargement
    e. job satisfaction
    b (Job design, moderate)

38. Which of the following statements describes job rotation?
    a. The job contains a larger number of similar tasks.
    b. The job includes some planning and control necessary for job accomplishment.
    c. The operator works on different shifts on a regular basis.
    d. The operator's schedule is flexible.
    e. The operator is allowed to move, for example, from one type of CNC machine to the other.
    e (Job design, moderate)

39. The difference between **job enrichment** and **job enlargement** is that
    a. enlarged jobs involve vertical expansion, while enriched jobs involve horizontal expansion
    b. enriched jobs enable an employee to do a number of boring jobs instead of just one
    c. job enlargement is more psychologically satisfying than job enrichment
    d. job enrichment is suitable for all employees, whereas job enlargement is not
    e. enriched jobs involve vertical expansion, while enlarged jobs involve horizontal expansion
    e (Job design, moderate)

40. A job characterized by _____ allows a worker to use his/her dexterity, physical strength, and skills to do his/her work.
    a. feedback
    b. skill variety
    c. job identity
    d. job significance
    e. autonomy
    b (Job design, difficult)

41. When a worker obtains clear and timely information about his/her performance, his/her job is characterized by
    a. feedback
    b. skill variety
    c. job identity
    d. job significance
    e. autonomy
    a (Job design, moderate)

42. Which of the following is **not** a limitation of job expansion?
    a. higher capital cost
    b. higher wage rates
    c. smaller labor pool
    d. higher training costs
    e. All of the above are limitations of job expansion.
    e (Job design, moderate)

43. Management and labor share the labor cost reductions in which of these compensation schemes?
    a. bonus system
    b. quota system
    c. Scantron plan
    d. Scanlon plan
    e. measured day work plan
    d (Job design, moderate)

44. Which of the following statements regarding incentive systems is **false**?
    a. Bonuses are often used at the executive levels.
    b. About half of all American manufacturing firms use productivity incentives.
    c. Knowledge-based pay systems are increasing in use.
    d. The Scanlon plan is based on team productivity.
    e. Increasing use of cross-training has led to increasing use of knowledge-based pay systems.
    d (Job design, moderate)

45. Ergonomics is **not** concerned with
    a. levels of illumination, noise, temperature, and humidity
    b. adjusting and providing input to the machine
    c. feedback (providing information to the operator)
    d. adequate compensation schemes
    e. the design of functional and comfortable office furniture
    d (Job design, moderate)

46. One of the elements of ergonomics is
    a. allocating work time based on economic studies
    b. the cost justification of technology
    c. designing tools and machines that facilitate human work
    d. the use of automation in a manufacturing organization
    e. the establishment of time standards
    c (Job design, moderate)

47. Managers should seek to control such work environment factors as
    a. illumination
    b. noise and vibration
    c. temperature
    d. air quality
    e. all of the above
    e (Job design, moderate)

48. Which of the following is **not** an analytical target of methods analysis?
    a. movement of capital
    b. body movement
    c. movement of individuals
    d. movement of materials
    e. crew activity
    a (Job design, moderate)

49. Methods analysis focuses on
    a. the design of the machines used to perform a task
    b. establishing time standards
    c. reducing the number of skills needed for the completion of a task
    d. issues such as the movement of individuals or materials
    e. evaluating training programs to see if they are efficient
    d (Job design, moderate)

50. Which of the following is used by methods analysis in analyzing body movement at the workstation level?
    a. MTM chart
    b. flow diagram
    c. operations chart
    d. process chart
    e. improvement chart
    c (Job design, moderate)

51. "Designed to show economy of motion by pointing out waste motion and idle time" describes
    a. flow diagrams
    b. an activity chart
    c. an operations chart
    d. all of the above
    e. none of the above
    c (Job design, moderate)

52. In a large aerospace company, it has been discovered that some insulators have been damaged. A methods specialist is sent out to follow the insulators through the production and storage processes and to try to find out where in the process they are damaged. The specialist should use
    a. left- and right-hand charts
    b. man-machine charts
    c. job analysis charts
    d. flow diagrams
    e. activity charts
    d (Job design, difficult)

53. Methods analysis employs which of the following charts in its analysis of the movement of workers and materials?
    a. micro-motion chart
    b. flow diagram
    c. activity chart
    d. man-machine chart
    e. movement chart
    b (Job design, moderate)

54. Flow diagrams are used to analyze
    a. movement of people and materials
    b. utilization of an operator and machine
    c. body movements
    d. time taken by various activities
    e. unnecessary micro-motions
    a (Job design, moderate)

55. Activity charts help analyze
    a. movement of people and materials
    b. utilization of an operator and machine
    c. body movements
    d. activities that can cause injuries
    e. unnecessary micro-motions
    b (Job design, moderate)

56. "Schematic used to investigate movement of people or material" describes a(n)
    a. flow diagram
    b. activity chart
    c. operations chart
    d. right-hand / left-hand chart
    e. none of the above
    a (Job design, moderate)

57. The visual workplace includes
    a. painted symbols to indicate the proper place for tools and equipment
    b. labeling of parts, bins, and tools to reduce waste
    c. kanbans, andons, and statistical process control (SPC) charts
    d. color-coded lights and signs to indicate that there is a problem
    e. all of the above
    e (The visual workplace, moderate) {AACSB: Communication}

58. Shadow boards and foot printing are elements of
    a. the Hawthorne studies
    b. workplace noise reduction
    c. project management in service firms
    d. the visual workplace
    e. specialization of labor
    d (The visual workplace, moderate) {AACSB: Communication}

59. The visual workplace
    a. uses low-cost visual devices to share information
    b. is an effective means of rapid communication in a dynamic workplace
    c. helps with both "big picture" and "housekeeping" issues in the workplace
    d. eliminates non-value added activities by making problems and standards visual
    e. all of the above
    e (The visual workplace, moderate) {AACSB: Communication}

60. Ethical work environment decisions by managers may be guided by
    a. state agencies
    b. trade associations
    c. insurers
    d. employees
    e. all of the above
    e (Ethics and the work environment, moderate) {AACSB: Ethical Reasoning}

61. Which of the following is an ergonomics issue with ethical implications?
    a. job enrichment
    b. equal opportunity
    c. equal pay for equal work
    d. a noisy workplace
    e. foot printing
    d (Ethics and the work environment, moderate) {AACSB: Ethical Reasoning}

62. Which of the following is **not** a work environment issue with ethical implications?
    a. hazardous materials in the workplace
    b. equal opportunity
    c. equal pay for equal work
    d. danger on the job
    e. All of the above have ethical implications.
    e (Ethics and the work environment, moderate) {AACSB: Ethical Reasoning}

63. **Labor standards** are defined as the
    a. preset activities required to perform a job
    b. amount of space required by a specific crew to perform the job
    c. standard set of procedures to perform the job
    d. standard labor agreements
    e. amount of time required to perform a job or part of a job
    e (Labor standards, moderate)

FILL-IN-THE-BLANK

64. _____ means a job that is not only reasonably safe and for which the pay is equitable, but which also achieves an appropriate level of both physical and psychological requirements.
    Quality of work life (Human resource strategy for competitive advantage, moderate)

65. _____ is a means of determining staffing policies dealing with employment stability and work schedules.
    Labor planning (Labor planning, moderate)

66. _____ refers to a work schedule that deviates from the normal or standard five 8-hour days.
    Flexible workweek (Labor planning, moderate)

67. _____ is an approach that specifies the tasks that constitute a job for an individual or a group.
    Job design (Job design, easy)

68. _____ is the grouping of a variety of tasks using the same approximate skill level.
    Job enlargement (Job design, moderate)

69. _____ is a method of giving an employee more responsibility that includes some of the planning and control necessary for job accomplishment.
    Job enrichment (Job design, moderate)

70. _____ showed that there is a dynamic social system in the workplace.
    The Hawthorne studies (Job design, moderate)

71. _____ involves enlarging employee jobs so that the added responsibility and authority is moved to the lowest possible level in the organization.
Employee empowerment (Job design, moderate)

72. A(n) _____ is a group of empowered individuals working together to reach a common goal.
self-directed team (Job design, moderate)

73. _____ is a system providing some portion of any profit for distribution to employees.
Profit sharing (Job design, moderate)

74. The study of work, often called human factors, is called _____.
ergonomics (Job design, moderate)

75. _____ are drawings used to analyze movement of people or material.
Flow diagrams (Job design, moderate)

76. Painted symbols that indicate the proper place for tools and machinery are called _____ and _____.
shadow boards and foot prints (The visual workplace, moderate) {AACSB: Communication}

77. Keyboard design, noisy work environment, and dangerous materials or operations in the workplace are all _____ issues with ethical implications.
ergonomic (Ethics and the work environment, moderate) {AACSB: Ethical Reasoning}

SHORT ANSWER

78. Provide examples of *non-monetary* incentives.
Awards, recognitions, certain preferences such as a preferred work schedule, promotion and achievement. (Job design, moderate)

79. What is quality of work life? What is its relation to a firm's human resource strategy?
Quality of work life means a reasonably safe job with equitable pay that adheres to an appropriate level of both physical and psychological requirements. Quality of work life is one of the two primary goals of a human resource strategy, the other of which is efficient utilization of people. (Human resource strategy for competitive advantage, moderate)

80. Describe some impacts of noise in the workplace.
Specific answers will vary, but should include some of the following. High levels of sound will damage hearing. Extended periods of exposure to decibel levels above 85 dB are permanently damaging. (Private business offices average about 50 dB.) OSHA requires ear protection if exposure to 85dB equals or exceeds 8 hours. Even at low levels, noise and vibration can be distracting and can raise a person's blood pressure, so most managers make substantial effort to reduce noise and vibration through good machine design, enclosures, or insulation. Finally, recent research shows that noise in the work environment can increase the risk of heart attack by 50% or more. (Ergonomics and the work environment, moderate)

81. What is mutual trust? What is its link to a firm's human resource strategy?
Mutual trust is intended to mean reasonable, documented employment policies that are honestly and equitably implemented to the satisfaction of both management and employee. This is the atmosphere that nurtures reasonable quality of life. (Human resource strategy for competitive advantage, moderate)

82. What are the advantages and the disadvantages of the employment-stability policy "holding employment constant?"
Holding employment levels constant maintains a trained workforce and keeps hiring, termination, and unemployment costs to a minimum. But when demand is low, people may be underutilized, and when demand is high, the firm may be unable to respond. (Labor planning, moderate)

83. How does labor specialization assist in reducing labor costs (list three ways)?
Labor specialization assists in reducing labor costs by development of dexterity and faster learning by the employee because of repetition; less loss of time because the employee will not be changing jobs so frequently; development of specialized tools and a reduction in investment because each employee will require only a few tools for a particular task. (Job design, moderate)

84. Identify the limitations to job expansion.
Limitations of job expansion include higher capital cost; many individuals prefer simpler jobs; higher wage rates are required; smaller labor pools exist; and higher training costs. (Job design, moderate)

85. Explain how job expansion can lead to higher pay rates.
As expansion leads to workers having greater skills, they tend to be paid according to their highest skill. (Job design, moderate)

86. It is said that job expansion has both a vertical component and a horizontal component. Explain, with reference to such terms as job enrichment, job rotation, job enlargement, and employee empowerment.
Vertical expansion gives employees more planning and/or control over their work, which is job enrichment. Horizontal expansion adds tasks, through job rotation or job enlargement. Job enrichment relates primarily to increasing the cognitive or intellectual requirements for the job. Job enlargement relates primarily to an increase in the number of tasks to be performed. Job rotation implies a formal arrangement for job switching among a particular group of workers within a specific set of jobs. Employee empowerment is the practice of enriching jobs so that employees accept responsibility for a variety of decisions normally associated with staff specialists. (Job design, moderate)

87. What impact did the Hawthorne studies have on human resource strategy?
The Hawthorne studies introduced psychology into the workplace. They proved that there is a dynamic social system in the workplace, and that this social system can be more important than physical working conditions. (Job design, easy)

88. Identify the five components of job design.
The five components of job design include job specialization, job expansion, psychological components, self-directed teams, and motivation & incentive systems. (Job design, moderate)

89. List Hackman and Oldham's five desirable characteristics of job design.
According to Hackman and Oldham, the desirable characteristics of job design include skill variety, job identity, job significance, autonomy, and feedback. (Job design, moderate)

90. To maximize team effectiveness, managers need to do more then just form teams. What should managers do to maximize team effectiveness?
They should ensure that those who have a legitimate contribution are on the team, provide management support, ensure the necessary training, and endorse clear objectives. (Job design, moderate)

91. Describe how supervisors might need to change their roles after organizing self-directed teams.
Supervisors must release some control and learn to accept different job responsibilities. Self-directed teams may mean having no supervisors on the factory floor. (Job design, moderate)

92. Identify three forms of monetary rewards.
Pick three of the following: bonuses, profit sharing, gain sharing, incentive systems, and knowledge-based pay systems. (Job design, moderate)

93. What is methods analysis?
Methods analysis focuses on *how* a task is accomplished. It involves developing work procedures that are safe and produce quality products efficiently. (Job design, easy)

94. What are operations charts used for?
Operations charts are used to analyze body movement. They are designed to show economy of motion by pointing out wasted motion and idle time. (Job design, moderate)

95. How might ergonomics be used to help design an employee workstation?
Ergonomics deals with the human factors of work. Ergonomic studies take into account the height, weight, range of motion, and other physical attributes typical of employees, along with variations from those norms. Ergonomic influences should result in workstations that are the proper height for employees, comfortable for the range of motions of that job, and free from unnecessary danger, noise, or other environmental detriments to work. (Job design, moderate) {AACSB: Reflective Thinking}

96. Describe how the "visual workplace" can increase information flow, improve efficiency, and eliminate non-value-adding activities. Support your argument with a few examples.
Visuals reduce the time spent sharing information, especially in signaling hazards, low-stock conditions, poor quality, etc. Time spent reading instructions or taking measurements are non-value-adding if a simple visual can replace them. Examples include graphs of stock conditions, painted warnings, markers, kanbans, andons, shadow boards, foot prints, and others. (The visual workplace, moderate) {AACSB: Communication}

97. What is meant by the visual workplace? Provide two examples.
The visual workplace brings low-cost visual systems to the workplace so information that is vital in the workplace can be shared. Good visual systems are designed to increase the possibility that what is supposed to happen does happen. One example is the timing clock that is increasingly found in fast-food restaurants, which indicates the length of time that a customer has waited. Another example is a painted shadow board which indicates the proper place for tools to be stored when not in use. Other examples include andon lights which signal a problem, containers of the optimum size or with indentations for each part or type of part, color coding and symbols for parts containers. (The visual workplace, moderate) {AACSB: Communication}

98. The visual workplace improves communications at three levels: big picture, performance, and housekeeping. Cite an example of each type; explain your examples in a sentence each.
Big picture is illustrated by a posting of a company's stock price, reminding employees of their role in company efficiency and profitability. Performance is illustrated by kanbans—visuals that signal the need for additional production (SPC charts and production quotas are other examples). Housekeeping is illustrated by foot prints and shadow boards, which indicate the proper place for tools and equipment (other examples include andons and labels). (The visual workplace, moderate) {AACSB: Communication}

99. List two ethical concerns that arise from work environment issues that are ergonomic in nature; list two more that are not ergonomic in nature.
Ethical concerns arise in ergonomic work environment issues such as (students may name any two of the following): danger in performing the job, exposure to dangerous ingredients on the job, unnecessary noise, vibration, heat, humidity, and incorrect lighting. Ethical issues which are not based in ergonomics arise with respect to fairness and equity. These include equal opportunity and equal pay for equal work. (Ethics and the work environment, easy) {AACSB: Ethical Reasoning}

100. A female employee in a male-dominated workplace comes to you and says "I'm having difficulty with a certain task because the workstation was designed for the men, who are generally taller and have greater arm's length than I." What are the basic ethical issues here (if any), and what are the various guidelines and sources that could help you? (You are not asked to SOLVE her problem.)
The basic ethical issue is equal opportunity, even though the problem arises because of ergonomics. There may be OSHA or state law to assist your deliberations; you may also consult with your firm's legal or human resource department. (Ethics and the work environment, moderate) {AACSB: Ethical Reasoning}

SUPPLEMENT 10: WORK MEASUREMENT

TRUE/FALSE

1. Two uses of labor standards are to determine the labor content of items produced and to determine staffing needs.
   True (Labor standards and work measurement, easy)

2. One use of labor standards is to determine what makes a fair day's work.
   True (Labor standards and work measurement, easy)

3. Labor standards based on historical experience are relatively inexpensive to obtain.
   True (Historical experience, easy)

4. Labor standards based on historical experience are the preferred method of choice.
   False (Historical experience, easy)

5. Standard time may be less than average observed time.
   True (Time studies, moderate)

6. The classical stopwatch study, or time study, was originally proposed by Western Electric's Hawthorne Commission in the 1920s.
   False (Time studies, moderate)

7. A time-study procedure involves timing a sample of worker's performance and using it to set a standard.
   True (Time studies, moderate)

8. The allowance factor that increases normal time to standard time compensates for inadequate worker training and lack of worker dexterity.
   False (Time studies, moderate)

9. Normal time is always less than the average observed time.
   False (Time studies, moderate)

10. Standard time is always greater than normal time, due to the inclusion of allowances for personal time, delay, and fatigue.
    True (Time studies, moderate)

11. Rest allowances can include amounts for the effects of lighting, heat and humidity, and noise.
    True (Time studies, moderate)

12. The rest allowances that convert normal time to standard time have three components: personal time allowances, delay allowances, and fatigue allowances.
    True (Time studies, moderate)

13. In constructing the standard time for a task, the elements that make up the task must use the same performance ratings factor.
    False (Time studies, moderate)

14. If a manager conducting a time study needed an accuracy of ± 0.1 minutes, rather than ± 0.2 minutes, the adequate sample size would have to be twice as large.
False (Time studies, moderate)

15. UPS may run the "tightest ship in the shipping business," but they got that high level of efficiency without time standards, because their contract with the Teamsters Union forbids them.
False (Time studies, moderate)

16. A modern "stopwatch" study can be conducted using a special-purpose PDA, one which can digitally capture events, times, and other variables for later analysis on a spreadsheet.
True (Time studies, moderate) {AACSB: Use of IT}

17. Work sampling and time studies are similar in that the analyst in both cases records the time taken by the worker to accomplish each step of the task.
False (Time studies, and Work sampling, moderate)

18. A Therblig is a very small amount of time, one hundred-thousandth of an hour.
False (Time studies, moderate)

19. Because service jobs are so much more variable than manufacturing jobs, time measurement standards similar to MTM do not exist for most services.
False (Predetermined time standards, moderate)

20. An advantage of predetermined time standards is that the standard can be set before a task is actually performed.
True (Predetermined time standards, moderate)

21. Most unions do not accept the use of predetermined time standards.
False (Predetermined time standards, moderate)

22. Work sampling estimates the percent of time that a worker spends on various tasks.
True (Work sampling, easy)

23. An advantage of work sampling is that it completely breaks down work elements.
False (Work sampling, moderate)

24. Normal time equals the average observed time multiplied by the allowance factor.
False (Time studies, moderate)

MULTIPLE CHOICE

25. Which of the following is **not** a use of labor standards?
    a. labor content of items produced
    b. cost and time estimates prior to production
    c. crew size and work balance
    d. basis of wage-incentive plans
    e. All of the above are uses of labor standards.
    e (Labor standards and work measurement, moderate)

26. Labor standards can help a firm determine expected production, which in turn enables
    a. crew sizes to be determined
    b. managers and workers to know what constitutes a fair day's work.
    c. labor cost to be calculated
    d. work cells and assembly lines to be balanced
    e. work sampling to take place
    b (Labor standards and work measurement, moderate)

27. Which of the following techniques may **not** provide reliable and accurate time standards?
    a. historical experience
    b. method time measurement (MTM)
    c. time studies
    d. work sampling
    e. predetermined time standards
    a (Historical experience, moderate)

28. Timing a sample of a worker's performance and using it to set a standard is the work measurement technique of
    a. predetermined time standards
    b. time studies
    c. work sampling
    d. methods time measurement
    e. left-hand, right-hand charting
    b (Time studies, moderate)

29. For a time study, the three factors that determine how large a sample size to take are
    a. the level of confidence, the z-value, and normal time
    b. needed accuracy, desired confidence, and absolute amount of error
    c. the level of confidence, the z-value, and the work sampling idle percent
    d. actual time, normal time, and standard time
    e. actual time, standard time, and mean time
    b (Time studies, moderate)

30. A manager who is conducting a time study now needs an accuracy of ±0.1 minutes, rather than ±0.2 minutes as in the past. Because of this change in accuracy, the adequate sample size becomes
    a. one-fourth as large
    b. one-half as large
    c. twice as large
    d. four times as large
    e. none of the above
    e (Time studies, moderate)

31. In time studies, average observed time for an element is
    a. the ratio of normal time to standard time
    b. the difference between normal time and the allowance factors
    c. for all observations, the sum of all times recorded divided by the number of observations
    d. the percent of a worker's time spent performing that element
    e. how many observations must be taken in order to achieve a specified level of accuracy
    c (Time studies, moderate)

32. A time study is being conducted to determine the standard time for a job that is made up of several elements. This standard time requires as input(s)
    a. the average observed time for each element
    b. one average observed time for all elements
    c. one performance rating factor to be used by all elements
    d. a separate allowance factor for each element
    e. all of the above
    a (Time studies, moderate)

33. In time studies, normal time is
    a. average observed time multiplied by a performance rating factor
    b. larger than standard time
    c. determined by historical experience
    d. converted to standard time by the performance rating factor
    e. one hour later during the summer months
    a (Time studies, moderate)

34. Standard time
    a. needs to be adjusted for worker performance ratings
    b. needs to be adjusted for worker fatigue
    c. is average observed time divided by the allowance factor
    d. accounts for performance rating factors and for allowances
    e. is normal time divided by the performance rating factor
    d (Time studies, moderate)

35. The smaller the percentage established for allowances
    a. the closer is normal time to standard time
    b. the closer is average observed time to normal time
    c. the larger is the performance rating factor
    d. the larger is the adequate sample size
    e. the larger is the number of observations in the work sampling
    a (Time studies, moderate)

36. In a stopwatch time study, the average time it takes a given worker to perform a task a certain number of times, without correction for performance rating or allowances, is the
    a. average observed time
    b. standard time
    c. performance rating time
    d. normal time
    e. allowance time
    a (Time studies, moderate)

37. Which of the following are **true** regarding allowances in time studies?
    a. They have a "constant" and a "variable" component.
    b. They are adjusted for work conditions such as heating, lighting, and noise.
    c. They include allowances for personal time, delay, and fatigue.
    d. They represent the adjustment between normal time and standard time.
    e. All of the above are true.
    e (Time studies, moderate)

38. In work measurement, personal time allowances are often established in the range of
    a. 0 - 2%
    b. 3 - 5%
    c. 4 - 7%
    d. 6 - 10%
    e. 10-15%
    c (Time studies, moderate)

39. The actual average observed time for a given job is 10 minutes. The performance rating is 80%, and allowances are set by contract at 10%. What is the time standard?
    a. 8.80 minutes
    b. 8.88 minutes
    c. 10 minutes
    d. 19.0 minutes
    e. 19.8 minutes
    b (Time studies, moderate) {AACSB: Analytic Skills}

40. The data below represent time study observations for an assembly operation. Assume a 7% allowance factor. What is the normal time for element 3?

		Observations (times in minutes)				
Element	**Performance Rating**	**1**	**2**	**3**	**4**	**5**
1	100%	1.5	1.6	1.4	1.5	1.5
2	90%	2.3	2.2	2.1	2.2	2.4
3	115%	1.7	1.9	1.9	1.4	1.6
4	100%	3.5	3.6	3.6	3.6	3.2

    a. 1.7 min.
    b. 1.96 min.
    c. 2.11 min.
    d. 10.1 min.
    e. 11.2 min.
    b (Time studies, moderate) {AACSB: Analytic Skills}

41. The accuracy of a labor standard is to be within 5%, and the confidence level is 95%. The standard deviation of the sample is 2 and the mean is 8. What sample size should be used?
    a. 8
    b. 10
    c. 96
    d. 127
    e. cannot be determined from the information given
    c (Time studies, moderate) {AACSB: Analytic Skills}

42. Which of these is the most common predetermined time standard?
    a. CSD
    b. TMU
    c. RCH
    d. SAE
    e. MTM
    e (Predetermined time standards, moderate)

43. A work sampling study requires an acceptable error level of 10 percent and z = 2 for 95.45 percent confidence. The adequate sample size is _____ if the sample proportion is thought to be as large as 50 percent, but _____ if the sample proportion is thought to be about 20 percent.
    a. 50; 20
    b. 100; 64
    c. 100; 16
    d. 20; 50
    e. cannot be determined from the information given
    b (Work sampling, moderate) {AACSB: Analytic Skills}

44. Sample observations of a claims processor made over a 160-hour work month reveal that the worker produced a total of 384 completed claims forms. The performance rating was 80%. The worker was idle 20% of the time (so that idle time should be subtracted from the total time when computing the average observed time). The allowance factor is 8%. What is the normal time per unit?
    a. 0.42 minutes
    b. 16.0 minutes
    c. 17.4 minutes
    d. 20.0 minutes
    e. 21.7 minutes
    b (Time studies, moderate) {AACSB: Analytic Skills}

45. Sample observations of a claims processor made over a 160-hour work month reveal that the worker produced a total of 384 completed claims forms. The performance rating was 80%. The worker was idle 20% of the time (so that idle time should be subtracted from the total time when computing the average observed time). The allowance factor is 8%. What is the standard time per unit?
    a. 0.42 minutes
    b. 16.0 minutes
    c. 17.4 minutes
    d. 20.0 minutes
    e. 21.7 minutes
    c (Work sampling, moderate) {AACSB: Analytic Skills}

46. A Time Measurement Unit, or TMU, is
    a. the same as a Therblig
    b. 0.00001 minute
    c. 0.00001 hour
    d. the duration of the easiest GET motion
    e. an historical experience standard
    c (Time studies, moderate)

47. Therbligs
    a. were invented by Frederick W. Taylor
    b. were used during the scientific management era, and are no longer in use
    c. are hyperactive rodent-like pets, whose name is associated with time standards
    d. were named by Frank Gilbreth
    e. none of the above
    d (Predetermined time standards, moderate)

48. Therbligs are
    a. the smallest unit of time used in methods time measurement exercises
    b. the largest unit of time used in methods time measurement exercises
    c. the smallest unit of basic motion used in methods time measurement exercises
    d. the largest unit of basic motion used in methods time measurement exercises
    e. the smallest amount of time required to complete a job
    c (Predetermined time standards, moderate)

49. Predetermined time standards are an outgrowth of basic motions called
    a. flow diagrams
    b. activity charts
    c. SAE standards
    d. man-machine charts
    e. therbligs
    e (Predetermined time standards, moderate)

50. Among the advantages of predetermined time standards are all of the following **except**
    a. unions accept them as fair
    b. they are available before a task is actually performed
    c. they can only be determined after work actually takes place
    d. they can be established in a laboratory setting
    e. All of the above are advantages.
    c (Predetermined time standards, moderate)

51. All of the following are advantages of predetermined time standards **except**
    a. they are customized to your company
    b. they are well accepted
    c. no performance ratings are necessary
    d. the standard can be set before the task is done and then can be used for planning
    e. they are based on a large number of workers
    a (Predetermined time standards, moderate)

52. Which of the following is **true** regarding work sampling?
    a. The technique was developed in the 1890s.
    b. It can be used to estimate the percentage of time workers spend in unavoidable delays.
    c. The method was developed by Frank Gilbreth.
    d. The method makes extensive use of rest allowances.
    e. All of the above are false.
    b (Work sampling, moderate)

53. A technique for estimating the proportion of time a worker spends on various activities is
    a. stopwatch time study
    b. simultaneous motion study
    c. work sampling
    d. standard elemental (historical) times
    e. predetermined (published) time standards
    c (Work sampling, moderate)

54. A bank manager wants to determine the percent of time the bank's tellers are working and idle. He decides to use work sampling, and his initial estimate is that the tellers are idle 20% of the time. Approximately how many observations should be taken to be 95% confident that the results will not be more than 5% away from the true result?
    a. 6
    b. 16
    c. 44
    d. 210
    e. 246
    e (Work sampling, moderate) {AACSB: Analytic Skills}

55. The tally sheet data from a work sampling study provides information regarding
    a. the number of wasted motions
    b. the level of difficulty in a motion
    c. the percent of time spent on various tasks
    d. the quality of the work environment
    e. the number of micro-motions involved
    c (Work sampling, moderate)

56. An advantage of work sampling is that
    a. no observation is required
    b. it involves study of the equipment only
    c. a performance rating is necessary
    d. the time spent observing the employee is relatively short
    e. it is more effective than time studies when task times are short
    d (Work sampling, moderate)

57. A disadvantage of work sampling is that
    a. it tends to be less accurate, particularly when task times are short
    b. it observes several workers simultaneously
    c. it is more expensive than time-study methods
    d. it is more intrusive than time-study methods, and therefore generates more complaints
    e. All of the above are disadvantages of work sampling.
    a (Work sampling, moderate)

FILL-IN-THE-BLANK

58. Properly set labor standards represent the amount of time that it should take an average employee to perform specific job activities under _____.
    normal working conditions (Labor standards and work measurement, easy)

59. _____ allowances are those that depend upon the distance from employees to restrooms, water fountains, and other facilities.
Personal time (Time studies, easy)

60. _____ involves timing a sample of a worker's performance and using it as a basis for setting a standard time.
Time study (Time studies, easy)

61. _____ divide(s) manual work into small basic elements that have established and widely accepted times.
Predetermined time standards (Time studies, moderate)

62. _____ estimates, by sampling, the percent of time that a worker spends on various tasks.
Work sampling (Work sampling, easy)

63. The two most complex motions in the methods time measurement (MTM) system are _____ and _____.
GET; PLACE (Predetermined time standards, easy)

SHORT ANSWERS

64. List the seven things that labor standards can be used to determine.
1. labor content; 2. staffing needs; 3. cost and time estimates prior to production; 4. crew size and work balance; 5. expected production (what constitutes a fair day's work); 6. basis of wage-incentive plans; and 7. efficiency of employees and supervision. (Labor standards and work measurement, easy)

65. Explain in broad terms, not fine detail, using a sentence or two, what is meant by a "classical stopwatch study."
A classical stopwatch study, or time study, procedure involves timing a sample of a worker's performance and using it to set a standard. This is still the most widely used time-study method. (Time studies, easy)

66. List the eight steps used to develop a time study-based labor standard.
The eight steps used to develop a time study-based labor standard are 1. define the task to be studied; 2. divide the task into precise elements; 3. decide how many times to measure the task; 4. time and record the elemental times and ratings of performance; 5. compute the average observed time; 6. compute performance rating and the normal time for each element; 7. compute total normal time (the sum of the normal times of each element); and 8. compute the standard time. (Time studies, moderate)

67. If historical experience data are so widely available and so easy to obtain, why aren't they more widely used to set labor standards?
Historical experience data were not obtained in a controlled environment. These data are not objective and have unknown levels of accuracy. It is unknown whether they represent a reasonable work pace or not, or whether unusual occurrences are included. (Historical experience, moderate)

68. Define the average observed time.
The actual average task time is computed by dividing the sum of the times recorded to perform each element by the number of observations. It is adjusted for unusual influences. (Time studies, moderate)

69. Define standard time.
The standard time for a task provides allowances for personal needs, unavoidable delays, etc. The standard time is determined by dividing the normal time for a task by the quantity (1- allowance factor). (Time studies, moderate)

70. How do we establish a fair day's work?
We establish a "fair day's work" by developing a standard representing the work rate of an average employee performing specific job activities under normal working conditions. (Labor standards and Time studies, moderate)

71. What three broad categories do allowances fall into? Discuss why "allowances" are included to adjust normal time to standard time. Support your position with a few simple examples.
Allowances are categorized as personal, fatigue, and delay. Personal account for breaks for restrooms, water, etc., and should depend upon the nearness to facilities. Delay allowances are based on actual studies of delays. Fatigue allowances take into account various physical and environmental conditions. Examples will vary. (Time studies, moderate)

72. What is a "normal" pace, and what is its connection to normal time and labor standards?
A normal pace is the pace or speed at which a normal worker could expect to accomplish a task. It is the same thing as a 100% pace. Average observed time is multiplied by the performance rating factor to obtain normal time. This adjusts for average observed times measured on workers whose pace is not "normal." (Time studies, moderate)

73. How is the statistical tool of adequate sample sizing used in work measurement?
The two applications are in time studies and in work sampling. Both determine how many measurements need to be taken before specified levels of accuracy and confidence are achieved. This prevents users of time studies and work sampling from drawing faulty conclusions from too-small samples. (Time studies, and Work sampling, moderate)

74. What are predetermined time standards?
Predetermined time standards divide manual work into small basic elements that already have established times. (Predetermined time standards, easy)

75. List the steps in the work-sampling procedure.
The five steps in the work-sampling procedure are 1. take a preliminary sample to obtain an estimate of the parameter value; 2. compute the sample size required; 3. prepare a schedule for observing the worker at appropriate times; 4. observe and record worker activities; and 5. determine how workers spend their time. (Work sampling, moderate)

76. What kind of work circumstances call for the use of work sampling instead of stopwatch study?
Work sampling is preferred over time study when workers allocate their time among various activities, and are not performing a single repeated activity. (Work sampling, moderate)

77. What are the advantages of work sampling over time-study methods?
The advantages include: work sampling is less expensive; observers usually don't require much training, and no timing devices are needed; and the study can be delayed temporarily at any time with little impact on the results. And because work sampling uses instantaneous observations over a long period, the worker has little chance of affecting the study's outcome. (Work sampling, moderate)

78. What are the disadvantages of work sampling?
The disadvantages of work sampling include: it does not break down work elements as completely as time studies; it can yield biased or incorrect results if the observer does not follow random routes of travel and observation, and it is less effective than time studies when task times are short. (Work sampling, moderate)

PROBLEMS

79. A time study of a certain service task found an average time of 15 minutes, with a standard deviation of 5 minutes. These figures were based on a sample of 100 measurements. Is the sample large enough that we are 95% confident that standard time is within 5% of its true value?

$$n = \left(\frac{z \cdot s}{h \cdot \bar{x}}\right)^2 = \left(\frac{1.96 \cdot 5}{.05 \cdot 15}\right)^2 = 171$$

No, the sample was too small. (Time studies, moderate) {AACSB: Analytic Skills}

80. How many observations would be necessary for a time studies analyst to be 99% confident that the average time is within .1 minutes of the true value if the average time is 10.5 minutes and the standard deviation is 3 minutes?

$$n = \left(\frac{z \cdot s}{h \cdot \bar{x}}\right)^2 = \left(\frac{2.58 \cdot 3}{.1 \cdot 10.5}\right)^2 = 54$$

(Time studies, moderate) {AACSB: Analytic Skills}

81. A work sampling study requires an acceptable error level of 10 percent and 95 percent confidence.
a. What is the adequate sample size if the sample proportion is as large as 50 percent?
b. What is the adequate sample size if the sample proportion is estimated to be about 20 percent?
a. 1.96^2 x .5 x.5 / $.1^2$ = 98
b. 1.96^2 x .2 x.8 / $.1^2$ = 61.46 or 62
(Work sampling, moderate) {AACSB: Analytic Skills}

82. In a preliminary work sample of an operation, out of 50 observations the operator was observed idle in 5 observations. What sample size is required for a work sampling study if the desired confidence level is 98% and the desired accuracy level is 5%?

$$n = \frac{z^2 p(1-p)}{h^2} = \frac{2.33^2 \cdot 0.1 \cdot 0.9}{0.05^2} = 195.4 \text{ or } 195$$

(Work sampling, moderate) {AACSB: Analytic Skills}

83. A brake system installer in an auto factory has an actual average time of 10 minutes on her task. The performance rating of the worker timed was estimated at 110%. Practice in this department is to allow 9% for the constant allowances. There is currently no variable allowance.
a. Find the normal time for the operation.
b. Compute the standard time for the operation.
c. Recompute the standard time if a variable allowance of 7% is factored in.
a. Normal time = 10 minutes * 1.10 = 11 minutes

b. $$\text{Standard time} = \frac{\text{Normal time}}{\text{1 - Allowance factor}} = \frac{11}{1 - 0.09} = 12.09 \text{ minutes}$$

c. $$\text{New standard time} = \frac{\text{Normal time}}{\text{1 - Allowance factor}} = \frac{11}{1 - 0.16} = 13.10 \text{ minutes}$$

(Time studies, moderate) {AACSB: Analytic Skills}

84. The data in the following table represent time-study observations on a new operation with three work elements. On the basis of these observations, find the standard time for the process. Assume an 8% allowance factor.

		Observations (times in seconds)			
Element	**Performance Rating**	**1**	**2**	**3**	**4**
1	105%	110.2	110.8	112.3	108.7
2	90%	114.7	115.7	114.8	114.2
3	115%	109.2	109.3	109.2	108.9

Answer:

		Observations (times in seconds)					
Element	**Rating**	**1**	**2**	**3**	**4**	**Average**	**Normal Time**
1	**105%**	**110.2**	**110.8**	**112.3**	**108.7**	**110.50**	**116.025**
2	**90%**	**114.7**	**115.7**	**114.8**	**114.2**	**114.85**	**103.365**
3	**115%**	**109.2**	**109.3**	**109.2**	**108.9**	**109.15**	**125.523**

Normal time for process = 116.025 + 103.365 + 125.523 = 344.91 seconds

$$\text{Standard time for job} = \frac{\text{Normal time}}{\text{1 - Allowance fraction}} = \frac{344.91}{1 - .08} = 374.9 \text{ seconds}$$

(Time studies, moderate) {AACSB: Analytic Skills}

85. A Methods and Measurements Analyst needs to develop a time standard for a certain task. The task involves use of ruler, square, and portable electric saw to mark and cut the "notch" in a rafter (a standard carpentry task of home construction). In a preliminary study, he observed one of his workers perform this task five times. The observations were made in an air-conditioned, well-lighted training facility, at ground level, with all tools and equipment clean and readily available.

Observation:	1	2	3	4	5
Task time (seconds):	82	74	80	83	76

a. What is the actual average time for this task?
b. What is the normal time for this task if the employee worked at a 20% faster pace than is typical for adequately trained workers?
c. What is standard time for this task if allowances are 8% constant and 6% variable?
d. If the analyst then thought more carefully about his experiment, and decided that the variable allowances needed to be increased to match the real (outside, unair-conditioned) work environment, and that the proper variable allowance was not 6% but 12%, what is the revised standard time?

a. Actual average time is 79 seconds. b. Normal time is 79 * 1.20 = 94.8 seconds. c. Standard time is 94.8 / (1-.14) = 110.23 seconds. d. The revised standard time is 94.8 / (1-.20) = 118.5 seconds. (Time studies, difficult) {AACSB: Analytic Skills}

86. A task involves positioning two metal parts with a rubber gasket sandwiched between them, inserting two bolts into predrilled holes, threading a nut onto each bolt, and tightening each bolt with a pneumatic wrench. In a preliminary study, the manager observed one of his workers perform this task five times. The observations were made in an air-conditioned, well-lighted training facility, at ground level, with all tools and equipment clean and readily available.

Observation:	1	2	3	4	5
Task time (seconds):	50	54	60	145	56

a. What is the average observed time for this task?
b. What is the normal time for this task if the employee worked at a 10% slower pace than is typical for adequately trained workers?
c. What is standard time for this task if allowances are 8% constant and 6% variable?

Note that the fourth time must be discarded as an unusual event. a. Actual observed time is 220 / 4 = 55 seconds. b. Normal time is 55 * 0.90 = 49.5 seconds. c. Standard time is 49.5 / (1-.14) = 57.6 seconds. (Time studies, difficult) {AACSB: Analytic Skills}

87. The data in the following table represent time-study observations on a new operation with three work elements. On the basis of these observations, find the standard time for the process. Assume a 15% allowance factor.

		Observations (times in seconds)			
Element	Performance Rating	1	2	3	4
1	120%	90.3	91.5	92.4	90.2
2	100%	30.5	32.3	29.6	31.1
3	105%	130.5	128.9	132	130.5

Answer:

		Observations (times in seconds)					
Element	**Rating**	**1**	**2**	**3**	**4**	**Average**	**Normal Time**
1	**120%**	**90.3**	**91.5**	**92.4**	**90.2**	**91.10**	**109.32**
2	**100%**	**30.5**	**32.3**	**29.6**	**31.1**	**30.88**	**30.88**
3	**105%**	**130.5**	**128.9**	**132**	**130.5**	**130.48**	**137.00**

Normal time for process = 109.32 + 30.88 + 137.00 = 277.20 seconds

$$\textbf{Standard time for job} = \frac{\textbf{Normal time}}{\textbf{1 - Allowance fraction}} = \frac{\textbf{277.20}}{\textbf{1 – .15}} = \textbf{326.12 seconds}$$

(Time studies, moderate) {AACSB: Analytic Skills}

88. An operation in a television factory has an average observed time of 6 minutes. The performance rating of the worker timed was estimated at 90%. Practice in this department is to allow 8% for the constant allowances. Currently, there is no variable allowance.
a. Find the normal time for the operation.
b. Compute the standard time for the operation.
c. Recompute the standard time if a variable allowance of 8% is factored in.
a. Normal time = 6 minutes * .90 = 5.4 minutes

$$\textbf{b. Standard time} = \frac{\textbf{Normal time}}{\textbf{1 - Allowance factor}} = \frac{\textbf{5.4}}{\textbf{1 – 0.08}} = \textbf{5.87 minutes}$$

$$\textbf{c. New standard time} = \frac{\textbf{Normal time}}{\textbf{1 - Allowance factor}} = \frac{\textbf{5.4}}{\textbf{1 – 0.16}} = \textbf{6.43 minutes}$$

(Time studies, moderate) {AACSB: Analytic Skills}

89. An initial analysis of a laboratory activity resulted in the first table below. After this analysis, the managers determined that their element descriptions were not as accurate as they should have been—they had left out an element, underestimated a distance, and understated the need for accuracy. They revised the table of element data, which appears in the second table.

Original Activity: Pouring tube specimen

Element description	Element code	TMU
Get tube from rack	AA2	35
Get stopper, place on counter	AA2	35
Get centrifuge, place at sample tube	AD2	45
Pour (3 sec.)	PT	83
Place tubes in rack (simo)	PC2	40
TOTAL TMU		

Revised Activity: Pouring tube specimen

Element description	Element code	TMU
Get tube from rack	AC3	70
Get stopper, place on counter	AA2	35
Get centrifuge, place at sample tube	AD2	45
Pour (3 sec.)	PT	83
Get stopper, place on tube	AC1	40
Place tubes in rack (simo)	PC2	40
TOTAL TMU		

Calculate the total standard minutes for the original activity "pouring tube specimen." Calculate the total standard minutes for the revised activity "pouring tube specimen." What is the increase, in seconds, from the first version to the second?
The elements of the original description add to 238 TMU. The total standard minutes for the original description is thus 238 x .0006 = 0.1428 minutes. After the elements were revised, the activity totals 313 TMU. Total standard minutes rises to 313 x .0006 = 0.1878 minutes. The increase is 0.150 minutes or 9 seconds. (Predetermined time standards, moderate) {AACSB: Analytic Skills}

CHAPTER 11: SUPPLY CHAIN MANAGEMENT

TRUE/FALSE

1. Operations managers are finding online auctions a fertile area for disposing of discontinued inventory.
True (E-procurement, moderate) {AACSB: Use of IT}

2. The key to effective supply chain management is to get many suppliers to compete with each other, in order to drive down prices.
False (The supply chain's strategic importance, easy)

3. Even though a firm may have a low cost strategy, supply chain strategy can select suppliers primarily on response or differentiation.
False (The supply chain's strategic importance, moderate)

4. The supply chain for a brewery would include raw ingredients such as hops and barley but not the manufactured goods such as bottles and cans.
False (The supply chain's strategic importance, moderate)

5. Supply chain management faces additional challenges, such as those related to quality production and distribution systems, when companies enter growing global markets.
True (Supply chain economics, moderate) {AACSB: Multiculture and Diversity}

6. McDonald's was able to utilize existing plants and transportation systems in preparing the supply chain for opening its stores in Moscow.
False (The supply chain's strategic importance, moderate)

7. When using the low-cost strategy for supply chain management, the firm should invest aggressively to reduce production lead time.
False (The supply chain's strategic importance, moderate)

8. Savings in the supply chain exert more leverage as the firm has a lower net profit margin.
True (Supply chain economics, moderate)

9. A reduction in inventory costs is one reason for making rather than buying.
False (Supply chain economics, moderate)

10. Outsourcing refers to transferring a firm's activities that have traditionally been internal to external suppliers.
True (Supply chain economics, moderate)

11. Outsourcing is a form of specialization that allows the outsourcing firm to focus on its critical success factors.
True (Supply chain economics, moderate)

12. Supply chain decisions are not generally strategic in nature, because purchasing is an ordinary expense to most firms.
False (Supply chain economics, easy)

13. The objective of the make-or-buy decision is to help identify the products and services that can be obtained externally.
True (Supply chain economics, moderate)

14. Because service firms do not acquire goods and services externally, their supply chain management issues are insignificant.
False (Supply chain economics, easy)

15. Because the supply chain has become so electronic and automated, opportunities for unethical behavior have been greatly reduced.
False (Ethics in the supply chain, easy) {AACSB: Ethical Reasoning}

16. With the many-suppliers strategy, the order usually goes to the supplier that offers the best quality.
False (Supply chain strategies, moderate)

17. Developing long-term, "partnering" relationships with a few suppliers is a long-standing American purchasing strategy.
False (Supply chain strategies, moderate)

18. Vertical integration, whether forward or backward, requires the firm to become more specialized.
False (Supply chain strategies, moderate)

19. A fast-food retailer that acquired a spice manufacturer would be practicing backward integration.
True (Supply chain strategies, moderate)

20. Keiretsus offer a middle ground between few suppliers and vertical integration.
True (Supply chain strategies, moderate)

21. In several industries, online exchanges have been created by buyers.
True (E-procurement, moderate) {AACSB: Use of IT}

22. The bullwhip effect refers to the increasing fluctuations in orders that often occur as orders move through the supply chain.
True (Managing the supply chain, moderate)

23. Vendor Managed Inventory is a form of outsourcing.
True (Managing the supply chain, easy)

24. In the vendor evaluation phase, most companies will use the same list of criteria and the same criteria weights.
False (Vendor selection, moderate)

25. One classic type of negotiation strategy is the market-based price model.
True (Vendor selection, moderate)

26. Drop shipping results in time and shipping cost savings.
True (Managing the supply chain, easy)

27. The supply chain management opportunity called postponement involves delaying deliveries to avoid accumulation of inventory at the customer's site.
False (Managing the supply chain, moderate)

28. Channel assembly, which sends components and modules to be assembled by a distributor, treats these distributors as manufacturing partners.
True (Managing the supply chain, moderate)

29. Blanket orders are a long-term purchase commitment to a supplier for items that are to be delivered against short-term releases to ship.
True (Managing the supply chain, moderate)

30. Bar code and radio frequency technology, like that used to track UPS or FedEx packages on their global journeys, can also be used to track objects within the boundaries of a warehouse or shop.
True (Inventory tracking, easy) {AACSB: Use of IT}

31. Waterways are an attractive distribution system when speed is more important than shipping cost.
False (Logistics management, moderate)

32. Logistics management can provide a competitive advantage through improved customer service.
True (Logistics management, moderate)

33. With the growth of just-in-time practices, railroads have made large gains in the share of the nation's transport that they haul.
False (Logistics management, moderate)

34. Improvements in security, especially regarding the millions of shipping containers that enter the U.S. each year, are being held back by the lack of technological advances.
False (Logistics management, easy)

35. Benchmark firms have driven down costs of supply chain performance.
True (Measuring supply chain performance, moderate)

MULTIPLE CHOICE

36. The three major variations of online catalogs are
    a. catalogs by vendors, catalogs by intermediaries, and exchanges provided by buyers
    b. EDI, ERP, and ASN
    c. cost-based, market-based, and competitive bidding
    d. drop shipping, channel assembly, and postponement
    e. all auction-based
    a (E-procurement, moderate) {AACSB: Use of IT}

37. Visibility throughout the supply chain is a requirement among supply chain members for
    a. mutual agreement on goals
    b. mutual trust
    c. compatible organizational cultures
    d. local optimization
    e. the bullwhip effect
    b (Managing the supply chain, moderate)

38. Which of the following is **not** a concern of the supply chain?
    a. warehousing and inventory levels
    b. credit and cash transfers
    c. suppliers
    d. distributors and banks
    e. maintenance scheduling
    e (The supply chain's strategic importance, moderate)

39. What type of negotiating strategy requires the supplier to open its books to the purchasers?
    a. cost-based price model
    b. market-based price model
    c. competitive bidding
    d. price-based model
    e. none of the above
    a (Vendor selection, moderate)

40. Which of the following statements is **true** regarding the leverage of supply chain savings?
    a. Supply chain leverage is about the same for all industries.
    b. Supply chain savings exert more leverage as the firm's purchases are a smaller percent of sales.
    c. Supply chain savings exert more leverage as the firm has a lower net profit margin.
    d. Supply chain leverage depends only upon the percent of sales spent in the supply chain.
    e. None of the above is true.
    c (Supply chain economics, moderate)

41. One dollar saved in purchasing is
    a. equivalent to a dollar earned in sales revenue
    b. worth even more than a dollar earned in sales revenue
    c. worth slightly more than a dollar earned because of taxes
    d. worth from 35% in the technical instrument industry to 70% in the food products industry
    e. only worthwhile if you are in the 50% tax bracket and still have a low profit margin
    b (Supply chain economics, moderate)

42. Which one of the following statements about purchasing is **true**?
    a. The cost of purchases as a percent of sales is often small.
    b. Purchasing provides a major opportunity for price increases.
    c. Purchasing is always more efficient than making an item.
    d. Purchasing has an impact on the quality of the goods and services sold.
    e. Competitive bidding is a major factor in long-term cost reductions.
    d (Supply chain economics, moderate)

43. In the make-or-buy decision, one of the reasons for making is
    a. to reduce inventory costs
    b. to obtain technical or management ability
    c. inadequate capacity
    d. reciprocity
    e. to assure adequate supply in terms of quantity
    e (Supply chain economics, moderate)

44. In the make-or-buy decision, which of the following is a reason for **making** an item?
    a. management can focus on its primary business
    b. lower production cost
    c. inadequate capacity
    d. reduce inventory costs
    e. None of the above is a reason for making an item.
    b (Supply chain economics, moderate)

45. In the make-or-buy decision, one of the reasons for **buying** is
    a. to assure adequate supply
    b. to obtain desired quality
    c. to remove supplier collusion
    d. inadequate capacity
    e. to maintain organizational talents
    d (Supply chain economics, moderate)

46. In the make-or-buy decision, which of the following is **not** a reason for buying?
    a. inadequate capacity
    b. to obtain desired quality
    c. patents or trade secrets
    d. lower inventory costs
    e. All of the above are reasons for buying.
    b (Supply chain economics, moderate)

47. Outsourcing
    a. transfers traditional internal activities to outside vendors
    b. utilizes the efficiency which comes with specialization
    c. lets the outsourcing firm focus on its critical success factors
    d. None of the above are true of outsourcing.
    e. All of the above are true of outsourcing.
    e (Supply chain economics, moderate)

48. The transfer of some of what are traditional internal activities and resources of a firm to outside vendors is
    a. a standard use of the make or buy decision
    b. not allowed by the ethics code of the Supply Management Institute
    c. offshoring
    d. outsourcing
    e. keiretsu
    d (Supply chain economics, moderate)

49. The Institute for Supply Management
    a. establishes laws and regulations for supply management
    b. is an agency of the United Nations charged with promoting ethical conduct globally
    c. publishes the principles and standards for ethical supply management conduct
    d. prohibits backward integration into developing economies
    e. All of the above are true.
    c (Ethics in the supply chain, moderate) {AACSB: Ethical Reasoning}

50. In supply chain management, ethical issues
    a. are particularly important because of the enormous opportunities for abuse
    b. may be guided by company rules and codes of conduct
    c. become more complex the more global is the supply chain
    d. may be guided by the principles and standards of the Institute for Supply Management
    e. All of the above are true.
    e (Ethics in the supply chain, moderate) {AACSB: Ethical Reasoning}

51. Keeping a product generic as long as possible before customizing is known as
    a. postponement
    b. *keiretsu*
    c. channel assembly
    d. forward integration
    e. backward integration
    a (Managing the supply chain, moderate)

52. Which one of the following is **not** a supply chain strategy?
    a. negotiation with many suppliers
    b. vertical integration
    c. keiretsu
    d. short-term relationships with few suppliers
    e. virtual companies
    d (Supply chain strategies, moderate)

53. A disadvantage of the "few suppliers" strategy is
    a. the risk of not being ready for technological change
    b. the lack of cost savings for customers and suppliers
    c. possible violations of the Sherman Antitrust Act
    d. the high cost of changing partners
    e. All of the above are disadvantages of the "few suppliers" strategy.
    d (Supply chain strategies, moderate)

54. The purchasing approach that holds the suppliers responsible for maintaining the necessary technology, expertise, and forecasting ability plus cost, quality, and delivery competencies is
    a. few suppliers
    b. many suppliers
    c. Keiretsu
    d. vertical integration
    e. virtual companies
    b (Supply chain strategies, moderate)

55. Which of the following is **not** an advantage of the "few suppliers" concept?
    a. suppliers' willingness to participate in JIT systems
    b. trust
    c. vulnerability of trade secrets
    d. creation of value by allowing suppliers to have economies of scale
    e. suppliers' willingness to provide technological expertise
    c (Supply chain strategies, moderate)

56. Which of the following supply chain strategies creates value by allowing suppliers to have economies of scale?
    a. suppliers becoming part of a company coalition
    b. vertical integration
    c. long-term partnering with a few suppliers
    d. negotiating with many suppliers
    e. developing virtual companies
    c (Supply chain strategies, moderate)

57. Which of the following is **not** a condition that favors the success of vertical integration?
    a. availability of capital
    b. availability of managerial talent
    c. required demand
    d. small market share
    e. All of the above favor the success of vertical integration.
    d (Supply chain strategies, moderate)

58. Which of the following best describes vertical integration?
    a. to sell products to a supplier or a distributor
    b. to develop the ability to produce products which complement the original product
    c. to produce goods or services previously purchased
    d. to develop the ability to produce the specified good more efficiently than before
    e. to build long-term partnerships with a few suppliers
    c (Supply chain strategies, moderate)

59. A fried chicken fast-food chain that acquired feed mills and poultry farms has performed
    a. horizontal integration
    b. forward integration
    c. backward integration
    d. current transformation
    e. job expansion
    c (Supply chain strategies, moderate)

60. Vertical integration appears particularly advantageous when the organization has
    a. a very specialized product
    b. a large market share
    c. a very common, undifferentiated product
    d. little experience operating an acquired vendor
    e. purchases that are a relatively small percent of sales
    b (Supply chain strategies, moderate)

61. A rice mill in south Louisiana purchases the trucking firm that transports packaged rice to distributors. This is an example of
    a. horizontal integration
    b. forward integration
    c. backward integration
    d. current transformation
    e. keiretsu
    b (Supply chain strategies, moderate)

62. Japanese manufacturers often take a middle ground between purchasing from a few suppliers and vertical integration. This approach is
    a. kanban
    b. keiretsu
    c. samurai
    d. poka-yoke
    e. kaizen
    b (Supply chain strategies, moderate) {AACSB: Multiculture and Diversity}

63. The Japanese concept of a company coalition of suppliers is
    a. poka-yoke
    b. kaizen
    c. keiretsu
    d. dim sum
    e. illegal
    c (Supply chain strategies, moderate) {AACSB: Multiculture and Diversity}

64. Which of the following is **not** an advantage of a virtual company?
    a. speed
    b. total control over every aspect of the organization
    c. specialized management expertise
    d. low capital investment
    e. flexibility
    b (Supply chain strategies, moderate)

65. Local optimization is a supply chain complication best described as
    a. optimizing one's local area without full knowledge of organizational needs
    b. obtaining very high production efficiency in a decentralized supply chain
    c. the prerequisite of global optimization
    d. the result of supply chains built on suppliers with compatible corporate cultures
    e. the opposite of the bullwhip effect
    a (Managing the supply chain, moderate)

66. The “bullwhip” effect
    a. occurs as orders are relayed from retailers to wholesalers
    b. results in increasing fluctuations at each step of the sequence
    c. increases the costs associated with inventory in the supply chain
    d. occurs because of distortions in information in the supply chain
    e. all of the above
    e (Managing the supply chain, moderate)

67. Which of the following is **not** an opportunity for effective management in the supply chain?
    a. accurate "pull" data
    b. vendor managed inventory
    c. postponement
    d. local optimization
    e. channel assembly
    d (Managing the supply chain, moderate)

68. Which of the following is an opportunity for effective management in the supply chain?
    a. random "pull" data
    b. multistage control of replenishment
    c. the bullwhip effect
    d. customer managed inventory
    e. channel assembly
    e (Managing the supply chain, moderate)

69. Drop shipment
    a. is equivalent to cross-docking
    b. is the opposite of a blanket order
    c. means the supplier will ship directly to the end consumer, rather than to the seller
    d. is the same thing as keiretsu
    e. is a good reason to find a new firm to ship your products
    c (Managing the supply chain, moderate)

70. A carpet manufacturer has delivered carpet directly to the end consumer rather than to the carpet dealer. The carpet manufacturer is practicing
    a. postponement
    b. cross-docking
    c. channel assembly
    d. drop shipping
    e. float reduction
    d (Managing the supply chain, moderate)

71. Hewlett-Packard withholds customization of its laser printers as long as possible. This is an example of
    a. vendor managed inventory
    b. standardization
    c. backward integration
    d. postponement
    e. timely customization
    d (Managing the supply chain, moderate)

72. All of the following are "opportunities" for supply chain management **except**
    a. postponement
    b. drop shipment
    c. blanket orders
    d. channel assembly
    e. line balancing
    e (Managing the supply chain, moderate)

73. Which of the following is an advantage of the postponement technique?
    a. reduction in automation
    b. early customization of the product
    c. better quality of the product
    d. reduction in training costs
    e. reduction in inventory investment
    e (Managing the supply chain, moderate)

74. A furniture maker has delivered a dining set directly to the end consumer rather than to the furniture store. The furniture maker is practicing
    a. postponement
    b. drop shipping
    c. channel assembly
    d. passing the buck
    e. float reduction
    b (Managing the supply chain, moderate)

75. What is the average capacity utilization in the motor carrier (trucking) industry?
    a. 25%
    b. 50%
    c. 75%
    d. 95%
    e. 99%
    b (Logistics management, moderate)

76. What term is used to describe the outsourcing of logistics?
    a. E-Logistics
    b. Shipper Managed Inventory (SMI)
    c. Hollow Logistics
    d. Sub-Logistics
    e. Third-Party Logistics
    e (Logistics management, easy)

77. E-procurement
    a. works best in long-term contract situations, and is not suited for auctions
    b. is the same thing as Internet purchasing
    c. represents only the auction and bidding components of Internet purchasing
    d. is illegal in all states except Nevada and New Jersey
    e. All of the above are true of e-procurement.
    b (E-Procurement, moderate) {AACSB: Use of IT}

78. The three classic types of negotiation strategies are
    a. vendor evaluation, vendor development, and vendor selection
    b. Theory X, Theory Y, and Theory Z
    c. many suppliers, few suppliers, and keiretsu
    d. cost-based price model, market-based price model, and competitive bidding
    e. None of the above is correct.
    d (Vendor selection, moderate)

79. Consider a firm with a 2007 net income of $20 million, revenue of $60 million and cost of goods sold of $25 million. If the balance sheet amounts show $2 million of inventory and $500,000 of property, plant & equipment, what is the inventory turnover?
    a. 12.50
    b. 10.00
    c. 42.00
    d. 4.16
    e. 20.00
    a (Measuring supply chain performance, moderate) {AACSB: Analytic Skills}

80. The three stages of vendor selection, in order, are
    a. vendor evaluation, vendor development, and negotiations
    b. vendor development, vendor evaluation, and vendor acquisition
    c. introduction, growth, and maturity
    d. vendor evaluation, negotiations, and vendor development
    e. EDI, ERP, and ASN
    a (Vendor selection, easy)

81. Which one of the following distribution systems offers quickness and reliability when emergency supplies are needed overseas?
    a. trucking
    b. railroads
    c. airfreight
    d. waterways
    e. pipelines
    c (Logistics management, easy)

82. With the growth of JIT, which of the following distribution systems has been the biggest loser?
    a. trucking
    b. railroads
    c. airfreight
    d. waterways
    e. pipelines
    b (Logistics management, moderate)

83. By which distribution system is 90 percent of the nation's coal shipped?
    a. railroads
    b. trucks
    c. waterways
    d. pipelines
    e. none of the above
    a (Logistics management, easy)

84. Which distribution system is the fastest growing mode of shipping?
    a. railroads
    b. trucks
    c. airfreight
    d. waterways
    e. pipelines
    c (Logistics management, moderate)

85. Which of the following devices represents an opportunity for technology to improve security of container shipments?
    a. devices that identify truck and container location
    b. devices that sense motion
    c. devices that measure radiation or temperature
    d. devices that can communicate the breaking of a container lock or seal
    e. all of the above
    e (Logistics management, easy)

86. Which one of the following performance measures is **not** true of a world class firm?
    a. short time placing an order
    b. high percentage of accepted material
    c. large lead time
    d. high percentage of on-time deliveries
    e. low number of shortages per year
    c (Measuring supply chain performance, easy)

87. Consider a firm with a 2007 net income of $20 million, revenue of $60 million and cost of goods sold of $25 million. If the balance sheet amounts show $2 million of inventory and $500,000 of property, plant & equipment, how many weeks of supply does the firm hold?
    a. 12.50
    b. 5.20
    c. 2.60
    d. 0.08
    e. 4.16
    e (Measuring supply chain performance, moderate) {AACSB: Analytic Skills}

FILL-IN-THE BLANK

88. _____ is the management of activities that procure raw materials, transform those materials into intermediate goods and final products, and deliver the products through a distribution system.
    Supply chain management (The supply chain's strategic importance, easy)

89. The _____ decision involves choosing between producing a component or a service internally and purchasing it externally.
make-or-buy (Supply chain economics, easy)

90. Transferring to external vendors a firm's activities that have traditionally been internal is known as _____.
outsourcing (Supply chain economics, easy)

91. The _____is an organization that has published principles and standards for ethical supply management conduct.
Institute for Supply Management (Ethics in the supply chain, easy) {AACSB: Ethical Reasoning}

92. The supply chain strategy of _____ increases the willingness to participate in JIT.
few suppliers (Supply chain strategies, moderate)

93. _____ is developing the ability to produce goods or services previously purchased or actually buying a supplier or a distributor.
Vertical integration (Supply chain strategies, moderate)

94. _____ is a Japanese term to describe suppliers who become part of a company coalition.
Keiretsu (Supply chain strategies, moderate)

95. _____ rely on a variety of supplier relationships to provide services on demand.
Virtual companies (Supply chain strategies, moderate)

96. Local optimization, incentives, and large lots all contribute to _____ about what is really occurring in the supply chain.
distortion of information (Managing the supply chain, moderate)

97. _____ involves delaying any modifications or customization to the product as long as possible in the production process.
Postponement (Managing the supply chain, moderate)

98. _____ postpones final assembly of a product so the distribution channel can assemble it.
Channel assembly (Managing the supply chain, moderate)

99. _____ involves reducing the number of variations in materials and components as an aid to cost management.
Standardization (Managing the supply chain, moderate)

100. _____ is a standardized data-transmittal format for computerized communications between organizations.
Electronic data interchange (EDI) (E-Procurement, moderate) {AACSB: Use of IT}

101. _____ is the term describing purchasing facilitated through the internet.
E-Procurement (E-Procurement, easy) {AACSB: Use of IT}

102. Of the three stages of vendor selection, the stage at which criteria, weights, and scores allow a numeric comparison is _____.
vendor evaluation (Vendor selection, moderate)

103. _____ is an approach that seeks efficiency of operations through the integration of all material acquisition, movement, and storage activities.
Logistics management (Logistics management, moderate)

104. The fastest growing mode of shipping is _____.
airfreight (Logistics management, easy)

SHORT ANSWER

105. What is e-procurement?
Purchasing facilitated through the Internet. (E-procurement, easy) {AACSB: Use of IT}

106. As the firm strategies vary from low-cost to response to differentiation, how does this impact the criteria used for selection of a supply chain strategy?
The supply chain must support the operations management strategy. For a firm using the low-cost strategy, supplier selection should be based primarily on cost. When using the response strategy, the selection criteria are capacity, speed, and flexibility. For differentiation strategy, the supplier is selected based on product development skills. (The supply chain's strategic importance, moderate)

107. What are the three versions of online catalogs?
The three versions of online catalogues are: (1) catalogs provided by vendors, (2) catalogs provided by intermediaries, and (3) exchanges provided by buyers. (E-procurement, moderate) {AACSB: Use of IT}

108. What are the special requirements of supply chain systems in global environments?
Supply chains in a global environment must be flexible, so that the firm can react to sudden changes that might occur in parts availability or currency rates. They must be able to use latest information technology for scheduling and managing shipments of parts and products. And they must be staffed with specialists to handle duties, customs, and political issues in other countries. (The supply chain's strategic importance, moderate) {AACSB: Multiculture and Diversity}

109. Identify the reasons for **making** in the make-or-buy decision.
The reasons for making in the make-or-buy decision include: (1) maintain core competence, (2) lower production cost, (3) unsuitable suppliers, (4) assure adequate supply, (5) utilize surplus labor or facilities and make a marginal contribution, (6) obtain desired quality, (7) remove supplier collusion, (8) obtain unique item that would entail a prohibitive commitment for a supplier, (9) protect personnel from a layoff, (10) protect proprietary design or quality, and (11) increase or maintain size of the company (management preference) (Supply chain economics, moderate)

110. Identify the reasons for **buying** in the make-or-buy decision.
The reasons for buying in the make-or-buy decision include freeing management to focus on primary business; lower acquisition cost; preserve supplier commitment; obtain technical or managerial ability; inadequate capacity; reduce inventory costs; ensure alternative sources of supply; inadequate managerial or technical resources; reciprocity; and item is protected by patent or trade secret. (Supply chain economics, moderate)

111. How are outsourcing and vertical integration related? Can a single firm successfully do both?
Outsourcing transfers what were traditional internal activities to outside vendors. It is a way of increasing specialization which allows the firm to focus on its core strengths, and not try to do all possible tasks. Vertical integration is much the opposite, decreasing a firm's specialization so that it can perform additional functions along its supply chain. Vertical integration has become increasingly difficult in the face of increasing specialization. It seems unlikely that firms which make significant use of outsourcing would do much vertical integration, but it is possible that a firm's set of competitive advantages would support outsourcing in some functions and vertical integration in others. (Managing the supply chain, difficult) {AACSB: Reflective Thinking}

112. Of all areas of the organization, why is the supply chain especially vulnerable to ethical lapses?
The supply chain offers more opportunities for ethical issues than some other functions in the organization. Some of these opportunities arise from the large sums of money involved. Perhaps these opportunities arise because of the close and long-term personal contact between buyer and seller. Globalization adds even more complexity to the decisions made in the supply chain. (Ethics in the supply chain, moderate) {AACSB: Ethical Reasoning}

113. Identify and describe briefly the five supply chain strategies.
1. *Many suppliers* is the traditional American approach of negotiating with many suppliers and playing one supplier off against another.
2. The strategy of *few suppliers* develops long, "partnering" relationships with a few suppliers who will work with the purchaser in satisfying the end customer.
3. Firms that practice *vertical integration* may decide to pursue backward integration by actually buying the supplier.
4. Suppliers become part of a company coalition in the *keiretsu* strategy.
5. With the *virtual companies* strategy, firms use suppliers on an as-needed basis.
(Supply chain strategies, moderate)

114. Can an organization's plans for vertical integration be supported by the tools of make-or-buy analysis? Explain; provide an example.
Yes; the decision to acquire the provider of an upstream operation is the same as choosing to make whatever has been provided. Not to acquire is the equivalent of "buy." The analysis also holds for downstream operations: the acquisition of a delivery fleet is equivalent to "make" in the downstream operation of distribution. (Supply chain strategies, moderate) {AACSB: Reflective Thinking}

115. Identify the advantages and disadvantages of using the few suppliers approach.
Advantages: long-term suppliers better understand firm, suppliers may gain economies of scale, trust, and willingness to participate in JIT. Disadvantages: concern about trade secrets and suppliers venturing out, high cost of changing partners, and risk of poor supplier performance. (Supply chain strategies, moderate)

116. Describe some ways that effective supply chain partners build and utilize mutual trust.
Members of the chain must enter into a relationship that shares information. Visibility throughout the supply chain is a requirement. Risk and cost savings should be shared. Activities such as end-customer research, sales analysis, forecasting, and production planning should be joint activities. (Managing the supply chain, moderate) {AACSB: Communication}

117. What opportunities exist for reducing the "bullwhip" effect, and improving the supply chain?
The opportunities include accurate "pull" data, lot size reduction, single control of replenishment, vendor managed inventory (VMI), blanket orders, standardization, postponement, drop shipping and special packaging, pass-through facility, and channel assembly. (Managing the supply chain, moderate)

118. What is a keiretsu?
A keiretsu is a network of suppliers. Usually the suppliers are partially owned or debtors to the purchasing organization. This structure is quite common in Japan. (Supply chain strategies, easy)

119. Describe the state of capacity utilization in the motor carrier (trucking) industry. What, if anything, has been implemented by the industry to address the issue?
The motor carrier industry averages a capacity utilization of only 50%. That underutilized space costs the U.S. economy over $31 billion per year. To improve logistics efficiency, the industry is establishing Web sites that let shippers and truckers find each other to use some of this idle capacity. Shippers may pick from thousands of approved North American carriers that have registered. (Logistics management, moderate)

120. Describe vendor managed inventory (VMI). How is it related to outsourcing? Cite an example from your experiences as a shopper.
In vendor managed inventory, the supplier maintains material for the buyer, often delivering directly to the buyer's using department. It is a form of outsourcing, because the buying firm has transferred the shipping, stocking, and receiving tasks to an external vendor. There are many instances of VMI in today's retail model; shelves of snack foods and soft drinks are routinely managed by the distributor, not the retailer. (Managing the supply chain, easy) {AACSB: Reflective Thinking}

121. Name three common things that contribute to distortion of information about the supply chain?
The occurrences include local optimization, incentives (sales incentives, quantity discounts, and promotions), and large lots. (Managing the supply chain, moderate)

122. Why is channel assembly popular in the personal computer industry?
Channel assembly is popular in the personal computer industry because of better market response with less investment. This is possible because the late-stage assembly and customization is a natural part of a rapidly changing industry. (Managing the supply chain, moderate)

123. Define EDI.
Electronic data interchange is a standardized data transmittal format for computerized communications between organizations. (E-Procurement, moderate) {AACSB: Use of IT}

124. What advantages may result from effectively outsourcing the logistics function to a third party?
Driving down inventory investment and costs while improving delivery reliability and speed. (Logistics management, moderate)

125. What are the three negotiation strategies? Briefly describe each of them.
The three strategies for negotiating with vendors are the cost-based model, the market-based price model, and competitive bidding. In the cost-based model, contract price is a function of vendor costs, such as those for time and materials. In the market-based price model, price is set by some form of published, auction, or index price. Competitive bidding may be used when vendors are not open to the cost-based model, or where information is not perfect enough for market-based pricing. (Vendor selection, moderate)

126. Identify three specific measures that indicate how well assets are utilized. What are the formulas for each measure?
Percent invested in inventory = (Total inventory investment/Total assets) × 100
Inventory turnover = Cost of goods sold/Inventory investment
Weeks of supply = Inventory investment/(Annual cost of goods sold/52 weeks)
(Measuring supply chain performance, moderate)

127. What are the advantages of shipping by truck?
The advantages of shipping by truck include flexibility, on-time behavior, no damage, paperwork in order, and low cost. (Logistics management, moderate)

128. Identify some technological advances that can serve to improve logistics management and also improve shipping security.
Several technological advances can serve both security and logistics purposes. They may provide environmental information that is useful for product quality as well as security, or geospatial information useful to JIT as well as security. They include devices that can detect a broken seal on a shipping container, devices that can detect whether a container is in motion, devices that sense and transmit temperature and humidity, and devices that can transmit truck or container location. (Logistics management, moderate) {AACSB: Use of IT}

PROBLEMS

129. A regional grocery chain spends 70 percent of its sales in the supply chain, and has a net profit margin of 2 percent. They have just initiated an Internet-based inventory management program that is expected to save the chain $500,000 per year. What is the equivalent increase in sales to this saving? Use Table 11.3, reproduced below.

TABLE 11.3 ■ Dollars of Additional Sales Needed to Equal $1 Saved through the Supply Chain[a]

Percent Net Profit of Firm	Percent of Sales Spent in the Supply Chain						
	30%	40%	50%	60%	70%	80%	90%
2	$2.78	$3.23	$3.85	$4.76	$6.25	$9.09	$16.67
4	$2.70	$3.13	$3.70	$4.55	$5.88	$8.33	$14.29
6	$2.63	$3.03	$3.57	$4.35	$5.56	$7.69	$12.50
8	$2.56	$2.94	$3.45	$4.17	$5.26	$7.14	$11.11
10	$2.50	$2.86	$3.33	$4.00	$5.00	$6.67	$10.00

The relevant entry in Table 11.3, 70% of sales and 2% net profit, is $6.25. If $500,000 can be saved, the equivalent value of increased sales is $500,000 x 6.25 = $3,125,000. (Supply chain economics, moderate) {AACSB: Analytic Skills}

130. A container of ball-bearings valued at $25,000, currently located in Houston, TX, needs to be delivered to the Morton, IL, plant. The standard shipment method takes two days. However, for an additional charge of $500, the container can be sent overnight. The annual holding cost rate for this type of item has been estimated at 28%. What option is more economical?
Daily cost of holding the item is .28(25,000)/365 = $19.18.

Since the extra shipping cost is $500, the $19.18 savings does not offset the extra shipping cost. Send the shipment using the standard method. (Logistics management, moderate) {AACSB: Analytic Skills}

131. A shipment of parts valued at $75,000 needs to be shipped from Tampa, FL, to Chicago, IL. They could be shipped by rail, taking 15 days at a cost of $1,575, or by truck, taking 4 days at a cost of $2,640. The annual holding cost rate for this type of item has been estimated at 22%. What option is more economical?
Daily cost of holding the item is .22(75,000)/365 = $45.21
Days saved by using truck is 15-5=11 days
11 days x $45.21 = $497.27
Extra shipping cost = $2,640 - $1,575 = $1,065
The $497.27 savings does not offset the extra shipping cost of $1,065. Send the shipment by rail. (Logistics management, moderate) {AACSB: Analytic Skills}

132. A transportation firm spends 60 percent of its sales in the supply chain, and has a net profit margin of 6 percent. The company is about to invest $100,000 in one of two ventures. One venture is advertising-based, and is expected to increase revenues (sales) by $600,000 (after spending the $100,000). The other venture applies the money in supply chain efficiencies that are expected to save $200,000 (again, after spending the $100,000). Which of these two ventures offers the larger increase in profit to the firm? Use Table 11.3, reproduced below.

TABLE 11.3 ■ Dollars of Additional Sales Needed to Equal $1 Saved through the Supply Chain[a]

Percent Net Profit of Firm	Percent of Sales Spent in the Supply Chain						
	30%	40%	50%	60%	70%	80%	90%
2	$2.78	$3.23	$3.85	$4.76	$6.25	$9.09	$16.67
4	$2.70	$3.13	$3.70	$4.55	$5.88	$8.33	$14.29
6	$2.63	$3.03	$3.57	$4.35	$5.56	$7.69	$12.50
8	$2.56	$2.94	$3.45	$4.17	$5.26	$7.14	$11.11
10	$2.50	$2.86	$3.33	$4.00	$5.00	$6.67	$10.00

The relevant entry in Table 11.3, 60% of sales and 6% net profit, is $4.35. If $200,000 can be saved, the equivalent value of increased sales is $200,000 x 4.35 = $870,000. In other words, $200,000 in supply chain savings and $870,000 in increased sales yield the same increase in profit. Since the expected increase in sales is only $600,000, the better use of the $100,000 is to pursue the supply chain efficiencies. (Supply chain economics, moderate) {AACSB: Analytic Skills}

133. A company is about to select a vendor for the outsourcing of all of its engineering, environmental, and CAD requirements. It has identified four criteria critical to the selection. These criteria, and their importance weights, appear below. Three firms, A, C, and E, have indicated that they are interested in this position. The company has scored each of the three candidates on these criteria, using a 1-10 scale, where 10 is best. Candidate A scored 7, 7, 7, and 5 on the four criteria. Candidate C scored 9, 4, 8, and 6. Candidate E scored 5, 10, 10, and 7. Which vendor has the highest composite score?

Criterion	Weight
Engineering expertise	.40
Financial and managerial strength	.20
Integrity	.15
Staff experience and qualifications	.25

Criterion	**Weight**	**Company A**		**Company C**		**Company E**	
Engineering expertise	**.40**	**7**	**2.80**	**9**	**3.60**	**5**	**2.00**
Financial and managerial strength	**.20**	**7**	**1.40**	**4**	**.80**	**10**	**2.00**
Integrity	**.15**	**7**	**1.05**	**8**	**1.20**	**10**	**1.50**
Staff experience and qualifications	**.25**	**5**	**1.25**	**6**	**1.50**	**7**	**1.75**
Total	**1.00**		**6.50**		**7.10**		**7.25**

Company E has the highest score, and should be selected. (Vendor selection, moderate) {AACSB: Analytic Skills}

134. The following data are pulled from Walsh Manufacturing's 2007 annual report.

Assets	
Raw material inventory	$120,000
Work-in-process inventory	$50,000
Finished goods inventory	$300,000
Property, plant & equipment	$500,000
Other assets	$200,000
Total assets	$1,170,000

Condensed Income Statement	
Revenue	$2,000,000
Cost of goods sold	$600,000
Other expenses	$1,000,000
Net income	$400,000

Calculate: (a) Percent invested in inventory, (b) Inventory turnover, and (c) Weeks of supply.

(a) Percent invested in inventory = (120,000+50,000+300,000)/1,170,000 = 40.17%
(b) Inventory turnover = 600,000/(120,000+50,000+300,000) = 1.28
(c) Weeks of supply = (120,000+50,000+300,000)/(600,000/52) = 40.73
(Measuring supply chain performance, moderate), {AACSB: Analytic Skills}

SUPPLEMENT 11: OUTSOURCING AS A SUPPLY CHAIN STRATEGY

TRUE/FALSE

1. Some organizations use outsourcing to replace entire purchasing, information systems, marketing, finance, and operations departments.
True (Introduction, moderate)

2. Offshoring is the practice of procuring from foreign external sources services or products that are normally part of an organization.
False (What is outsourcing?, moderate)

3. Outsouring is the practice of procuring from external sources services or products that are normally part of an organization.
True (What is outsourcing?, moderate)

4. Outsourcing is the practice of moving a business process to a foreign country but retaining control of it.
False (What is outsourcing?, moderate)

5. Offshoring is the practice of moving a business process to a foreign country but retaining control of it.
True (What is outsourcing?, moderate)

6. A firm that outsources its internal business activities is called the client firm.
True (What is outsourcing?, moderate)

7. A firm that outsources its internal business activities is called the outsource provider.
False (What is outsourcing?, moderate)

8. A firm that provides outsourcing activity is called the client firm.
False (What is outsourcing?, moderate)

9. Outsourcing is not a new concept; it is simply an extension of the long-standing practice of subcontracting production activities.
True (What is outsourcing?, moderate)

10. Outsourcing has expanded to become a major strategy in business due to the continuing move toward specialization in an increasingly technological society.
True (What is outsourcing?, moderate) {AACSB: Use of IT}

11. Some business activities, such as human resources and legal processes, cannot be outsourced.
False (What is outsourcing?, moderate)

12. Nearly any business activity can be outsourced.
True (What is outsourcing?, moderate)

13. An organization's unique skills, talents, and capabilities are referred to as its core competencies.
True (Strategic planning and core competencies, easy)

14. Core competencies are good candidates for outsourcing.
False (Strategic planning and core competencies, easy)

15. The theory of *competitive* advantage states that you should allow another firm to perform work activities for your company if that company can do it more productively than you can.
False (Strategic planning and core competencies, moderate)

16. The theory of *comparative* advantage states that you should allow another firm to perform work activities for your company if that company can do it more productively than you can.
True (Strategic planning and core competencies, moderate)

17. The term "China price" has become the global benchmark—interchangeable with "lowest price possible."
True (Strategic planning and core competencies, moderate) {AACSB: Multiculture and Diversity}

18. The term "India price" has become the global benchmark—interchangeable with "lowest price possible."
False (Strategic planning and core competencies, moderate) {AACSB: Multiculture and Diversity}

19. The term "Mexico price" has become the global benchmark—interchangeable with "lowest price possible."
False (Strategic planning and core competencies, moderate) {AACSB: Multiculture and Diversity}

20. U.S. government data suggest that foreigners outsource far more services to the U.S. than American companies send abroad.
True (Outsourcing trends and political repercussions, moderate)

21. U.S. government data suggest that foreigners outsource far fewer services to the U.S. than American companies send abroad.
False (Outsourcing trends and political repercussions, moderate)

22. The term *renewal* has been created to describe the return of business activity to the client firm.
False (Outsourcing trends and political repercussions, moderate)

23. Research indicates that of all the reasons given for outsourcing failure, the most common is that the decision was made without sufficient understanding of the options through quantitative analysis.
True (Risks in outsourcing, moderate)

24. The factor-rating method is an excellent tool for dealing with both country risk assessment and source provider selection problems.
True (Methodologies for outsourcing, easy)

25. A client firm should not include its home country when conducting a country risk assessment.
False (Methodologies for outsourcing, moderate)

26. Nearshoring is the practice of choosing an outsource provider in the home country or in a nearby country.
True (Methodologies for outsourcing, moderate)

27. The number-one reason driving outsourcing for many firms is to focus on core competencies.
False (Advantages and disadvantages of outsourcing, moderate)

MULTIPLE CHOICE

28. What is the practice of procuring from external sources services or products that are normally part of an organization?
a. nearshoring
b. farshoring
c. offshoring
d. outsourcing
e. backsourcing
d (What is outsourcing?, moderate)

29. What is the practice of moving a business process to a foreign country but retaining control of it?
a. exporting
b. farshoring
c. offshoring
d. outsourcing
e. backsourcing
c (What is outsourcing?, moderate)

30. Outsourcing is simply an extension of the long-standing practice of
a. subcontracting
b. importing
c. exporting
d. postponement
e. e-procurement
a (What is outsourcing?, easy)

31. Which of the following is not true regarding core competencies?
a. They may include specialized knowledge.
b. They may represent a small portion of an organization's total business.
c. They may include proprietary technology or information.
d. They may be good candidates for outsourcing.
e. They may include unique production methods.
d (Strategic planning and core competencies, moderate)

32. What theory states that you should allow another firm to perform work activities for your company if that company can do it more productively than you can?
    a. theory of competitive advantage
    b. theory of core competencies
    c. theory of comparative advantage
    d. theory of outsourcing
    e. theory of offshoring
    c (Strategic planning and core competencies, moderate)

33. Which term has become interchangeable with "lowest price possible?"
    a. "China price"
    b. "Mexico price"
    c. "India price"
    d. "Russia price"
    e. "Korea price"
    a (Strategic planning and core competencies, moderate){AACSB: Multiculture and Diversity}

34. The term "China price" has become interchangeable with
    a. negotiated price
    b. fixed exchange rates
    c. price of the lowest quality item
    d. lowest price possible
    e. price multiplier based on the Hong Kong stock exchange level
    d (Strategic planning and core competencies, moderate) {AACSB: Multiculture & Diversity}

35. What term has been created to describe the return of business activity to the client firm?
    a. renewal
    b. backsourcing
    c. reversal
    d. reversesourcing
    e. insourcing
    b (Outsourcing trends and political repercussions, moderate)

36. Which of the following statements is most accurate?
    a. Nearly all outsourcing relationships do not last beyond two years.
    b. Nearly all U.S. firms that outsourced processes to India have backsourced them.
    c. Approximately half of all outsourcing agreements fail.
    d. Outsourcing is a relatively risk-free activity.
    e. More than 90% of outsourcing agreements succeed.
    c (Risks in outsourcing, moderate)

37. According to research, which of the following is the most common reason cited for outsourcing failure?
    a. core competencies identified as non-core
    b. erratic power grids in foreign countries
    c. unable to control product development, schedules, and quality
    d. decisions made without sufficient understanding of the options through quantitative analysis
    e. political and exchange rate uncertainty
    d (Risks in outsourcing, moderate)

38. The practice of choosing an outsource provider in the home country or in a nearby country is referred to as
    a. homeshoring
    b. homesourcing
    c. nearshoring
    d. nearsourcing
    e. backsourcing
    c (Methodologies for outsourcing, moderate)

39. Which of the following is not an advantage of outsourcing?
    a. cost savings
    b. gaining outside expertise
    c. improving operations and service
    d. outsourcing core competencies
    e. gaining outside technology
    d (Advantages and disadvantages of outsourcing, easy)

40. Which of the following is the number-one reason driving outsourcing for many firms?
    a. cost savings
    b. gaining outside expertise
    c. improving operations and service
    d. focusing on core competencies
    e. gaining outside technology
    a (Advantages and disadvantages of outsourcing, moderate)

41. Outsourcing manufacturing is also known as
    a. license manufacturing
    b. sublease manufacturing
    c. concurrent manufacturing
    d. hollow manufacturing
    e. contract manufacturing
    e (What is outsourcing?, moderate)

FILL-IN-THE BLANK

42. _____ is the practice of procuring from external sources services or products that are normally part of an organization.
    Outsourcing (What is outsourcing?, moderate)

43. _____ is the practice of moving a business process to a foreign country but retaining control of it.
    Offshoring (What is outsourcing?, moderate)

44. Offshoring is the practice of moving a business process to a foreign country but retaining _____.
    control of it (What is outsourcing?, moderate)

45. Offshoring is the practice of moving a business process to a foreign country _____ control of it.
but retaining (What is outsourcing?, moderate)

46. An organization that outsources is called the _____.
client firm (What is outsourcing?, moderate)

47. Outsourcing is an extension of the long-standing practice of _____ production activities.
subcontracting (What is outsourcing?, moderate)

48. An organization's unique skills, talents, and capabilities are referred to as its _____.
core competencies (Strategic planning and core competencies, moderate)

49. The theory of _____ states that you should allow another firm to perform work activities for your company if that company can do it more productively than you can.
comparative advantage (Strategic planning and core competencies, moderate)

50. The term _____ has become the global benchmark—interchangeable with "lowest price possible."
"China price" (Strategic planning and core competencies, moderate) {AACSB: Multiculture and Diversity}

51. The term "China price" has become the global benchmark—interchangeable with _____.
"lowest price possible" (Strategic planning and core competencies, moderate) {AACSB: Multiculture and Diversity}

52. The term _____ has been created to describe the return of business activity to the original firm.
backsourcing (Outsourcing trends and political repercussions, moderate)

53. The factor-rating method is an excellent tool for dealing with both _____ and _____ problems.
country risk assessment and source provider selection (Methodologies for outsourcing, moderate)

54. _____ is the practice of choosing an outsource provider in the home country or in a nearby country.
Nearshoring (Methodologies for outsourcing, moderate)

55. _____ is the number-one reason driving outsourcing for many firms.
Cost savings (Advantages and disadvantages of outsourcing, moderate)

56. Whatever the outsourced product or service, agreements must specify ongoing _____ and expected _____.
performance measures and outcomes (Audits and metrics to evaluate outsourcing performance, moderate)

57. In the electronics industry, the _____ sets environmental standards, bans child labor and excessive overtime, and audits outsourcing producers to ensure compliance.
Electronics Industry Code of Conduct (or EICC) (Ethical issues in outsourcing, moderate) {AACSB: Ethical Reasoning}

58. Outsourcing manufacturing is also known as _____.
contract manufacturing (What is outsourcing?, moderate)

SHORT ANSWER

59. Describe the difference between outsourcing and offshoring.
Outsourcing means procuring from external suppliers services or products that are normally a part of an organization. On the other hand, if a company moves some of its business processes to a foreign country but retains control, this move is defined as offshoring, not outsourcing. (What is outsourcing?, moderate)

60. Identify three factors fueling the continuing growth of outsourcing.
(1) increasing expertise, (2) reduced costs of more reliable transportation, and (3) the rapid development and deployment of advancements in telecommunications and computers. (What is outsourcing?, moderate) {AACSB: Communication}

61. Identify some business processes that are outsourced.
Answers will vary, but should include some of the following: (1) purchasing, (2) logistics, (3) R&D, (4) operation of facilities, (5) management of services, (6) human resources, (7) finance/accounting, (8) customer relations, (9) sales/marketing, (10) training, and (11) legal processes. (What is outsourcing?, moderate)

62. What do you think would be a major risk for a government trying to promote its country as a low-cost producer, filled with ready and willing outsourcing providers?
Answers will vary. One major risk is that today's low-cost leader may not be tomorrow's. For example, in recent years firms have moved from Mexico to China to chase even lower wage rates. Another concern is that developing countries worry that developed nations may exploit their labor and markets and dominate their economic landscapes. (Strategic planning and core competencies and Outsourcing trends and political repercussions, moderate) {AACSB: Reflective Thinking}

63. Has there been any political backlash in the United States resulting from outsourcing in foreign countries? Explain.
Yes. The loss of U.S. jobs has fueled anti-outsourcing rhetoric and action from government officials. While some action has been taken at the federal level, individual states seem to be taking the lead. Almost 100 bills aimed at keeping jobs in the U.S. have been introduced in 30 states. (Outsourcing trends and political repercussions, moderate)

64. Identify several risks in outsourcing.
Answers should include some of the following: (1) erratic power grids in some foreign countries, (2) difficulties with local government officials, (3) inexperienced managers, (4) unmotivated employees, (5) core activities incorrectly identified as non-core, (6) incorrectly assuming that an outsource provider can perform the function more competently and efficiently than the client firm, (7) failure to understand the change in resources and talents needed internally, (8) goals set so high that failure is certain, (9) wrong outsourcing provider selected, (10) misinterpretation of measures and goals, how they are measured, and what they mean, (11) inability to control product development, schedules, and quality, (12) a non-responsive partner, (13) unstable currency, (14) political instability, (15) cultural and language differences may inhibit successful operations, and (16) lack of understanding of the timing necessary to manage flows to different facilities and markets. Students may also point to some of the stated disadvantages of outsourcing including, (1) increased transportation costs, (2) loss of control, (3) creating future competition, (4) negative impact on employees, and (5) longer-term impact than outsourcing advantages. (Risks in outsourcing and Advantages and disadvantages of outsourcing, moderate) {AACSB: Multiculture and Diversity}

65. Identify several outsourcing processes, that is, activities that firms should undertake when embarking on outsourcing.
Answers will vary, but they should include some of the following: (1) identify non-core competencies, (2) identify non-core activities that should be outsourced, (3) identify impact on existing facilities, capacity, and logistics, (4) establish goals and draft outsourcing agreement specifications, (5) identify and select outsourcing provider, (6) negotiate goals and measures of outsourcing performance, (7) monitor and control current outsourcing program, (8) evaluate and give feedback to outsource provider, (9) evaluate international political and currency risks, and (10) evaluate coordination needed for shipping and distribution. (Risks in outsourcing, moderate)

66. Identify five main advantages of outsourcing.
(1) cost savings, (2) gaining outside expertise, (3) improving operations and service, (4) focusing on core competencies, and (5) gaining outside technology (Advantages and disadvantages of outsourcing, moderate)

67. What permits CEOs who prefer short-term planning and are interested only in bottom-line improvements to use the outsourcing strategy to make quick gains at the expense of longer-term objectives?
Some disadvantages of outsourcing tend to be longer term than the advantages of outsourcing. In other words, many of the risks that firms run by outsourcing may not show up on the bottom line until some time in the future. (Advantages and disadvantages of outsourcing, moderate) {AACSB: Ethical Reasoning}

68. Identify some ethical principles as applied to outsourcing.
Answers will vary, but they should include some of the following: (1) don't use outsourcing in a way that violates religious holidays, (2) don't use outsourcing to move pollution from one country to another, (3) don't use outsourcing to take advantage of cheap child labor that leads to child abuse, (4) don't accept outsourcing that violates basic human rights, (5) don't accept outsourcing as a short-term arrangement to reduce costs; view it as a long-term partnership, (6) use the inevitable sharing of technology to build a good relationship with foreign outsourcing firms. (Ethical issues in outsourcing, moderate) {AACSB: Ethical Reasoning}

PROBLEMS

69. A firm is evaluating country risk as a first step in its outsourcing provider selection process. Legal issues, currency risk, political risk, and cultural compatibility have been assigned weights of 30%, 10%, 20%, and 40%, respectively. Three countries were scored on each of those risk factors (see table below) using a scale of 1-10, with a score of 1 meaning high risk and 10 meaning minor risk. Using the factor-rating method, which country appears to have the least risk overall?

	Country A	Country B	Country C
Legal issues	2	6	10
Currency risk	8	4	2
Political risk	5	8	2
Cultural compatibility	3	1	2

Country A: 2(.3) + 8(.1) + 5(.2) + 3(.4) = 3.6
Country B: 6(.3) + 4(.1) + 8(.2) + 1(.4) = 4.2
Country C: 10(.3) + 2(.1) + 2(.2) + 2(.4) = 4.4
Since a high score implies low risk in this problem, Country C has the least risk.
(Methodologies for outsourcing, moderate) {AACSB: Analytic Skills}

70. A firm is considering outsourcing its production. Currently, in-house production costs $3,000,000 per year plus $12.00 per unit. The outsourcing option would cost $5,000,000 per year to operate, but the variable production costs would be $4.00 per unit. What level of production would the firm need to have in order to make outsourcing an economically viable option?
Q = (3,000,000 − 5,000,000) / (4−12) = 250,000 units
(Methodologies for outsourcing, moderate) {AACSB: Analytic Skills}

71. A manufacturing firm has an annual demand of 300,000 units. Using its current operation, the firm pays $800,000 in annual fixed costs and $15.00 per unit in variable costs. A potential outsourcing provider has offered to produce the product for the manufacturer. Annual fixed costs would drop to $200,000, but variable costs would increase to $18.00 per unit. Should the manufacturer outsource?
Q = (800,000 − 200,000) / (18−15) = 200,000 units. So outsourcing would only be worthwhile if demand were no greater than 200,000 units. Since demand is 300,000 units, the firm should continue to produce in-house.
(Methodologies for outsourcing, moderate) {AACSB: Analytic Skills}

CHAPTER 12: INVENTORY MANAGEMENT

TRUE/FALSE

1. According to the global company profile, Amazon.com's advantage in inventory management comes from its almost fanatical use of economic order quantity and safety stock calculations.
False (Global company profile, easy)

2. A major challenge in inventory management is to maintain a balance between inventory investment and customer service.
True (Introduction, easy)

3. Which item to order and with which supplier the order should be placed are the two fundamental issues in inventory management.
False (Introduction, moderate)

4. One function of inventory is to take advantage of quantity discounts.
True (Functions of inventory, easy)

5. Work-in-process inventory is devoted to maintenance, repair, and operations.
False (Functions of inventory, easy)

6. ABC analysis classifies inventoried items into three groups, usually based on annual units or quantities used.
False (Inventory management, easy)

7. In ABC analysis, "A" Items are the most tightly controlled.
True (Inventory management, moderate)

8. ABC analysis is based on the presumption that carefully controlling all items is necessary to produce important inventory savings.
False (Inventory management, easy)

9. Cycle counting is an inventory control technique exclusively used for cyclical items.
False (Inventory management, moderate)

10. One advantage of cycle counting is that it maintains accurate inventory records.
True (Inventory management, moderate)

11. In cycle counting, the frequency of item counting and stock verification usually varies from item to item depending upon the item's classification.
True (Inventory management, moderate)

12. Retail inventory that is unaccounted for between receipt and time of sale is known as shrinkage.
True (Inventory management, moderate)

13. The demand for automobiles would be considered an independent demand.
True (Inventory models, moderate)

14. Insurance and taxes on inventory are part of the costs known as setup or ordering costs.
False (Inventory models, easy)

15. If setup costs are reduced by substantial reductions in setup time, the production order quantity is also reduced.
True (Inventory models, and Inventory models for independent demand, easy)

16. The EOQ model is best suited for items whose demand is dependent on other products.
False (Inventory models for independent demand, moderate)

17. In the simple EOQ model, if annual demand were to increase, the EOQ would increase proportionately.
False (Inventory models for independent demand, moderate)

18. At the economic order quantity, holding costs are equal to purchasing costs.
False (Inventory models for independent demand, moderate)

19. In the simple EOQ model, if the carrying cost were to double, the EOQ would also double.
False (Inventory models for independent demand, moderate)

20. In the production order quantity (POQ) model, inventory does not arrive in a single moment but flows in at a steady rate, resulting in a larger lot size than in an otherwise identical EOQ problem.
True (Inventory models for independent demand, moderate)

21. The reorder point is the inventory level at which action is taken to replenish the stocked item.
True (Inventory models for independent demand, moderate)

22. In the quantity discount model, it is possible to have a cost-minimizing solution where annual ordering costs do not equal annual carrying costs.
True (Inventory models for independent demand, moderate)

23. In the quantity discount model, the cost of acquiring goods (product cost) is not a factor in determining lot size.
False (Inventory models for independent demand, easy)

24. Service level is the complement of the probability of a stockout.
True (Probabilistic models and safety stock, moderate)

25. Units of safety stock are additions to the reorder point that allow for variability in the rate of demand, the length of lead time, or both.
True (Probabilistic models and safety stock, easy)

26. Safety stock in inventory systems depends only on the average demand during the lead time.
False (Probabilistic models and safety stock, moderate)

27. The fixed-period inventory model can have a stockout during the review period as well as during the reorder period, which is why fixed-period models require more safety stock than fixed-quantity models.
True (Inventory models for independent demand, easy)

MULTIPLE CHOICE

28. Which of the following statements regarding Amazon.com is **false**?
    a. The company was opened by Jeff Bezos in 1995.
    b. The company was founded as, and still is, a "virtual retailer" with no inventory.
    c. The company is now a world-class leader in warehouse management and automation.
    d. The company uses both United Parcel Service and the U.S. Postal Service as shippers.
    e. Amazon obtains its competitive advantage through inventory management.
    b (Global company profile, moderate)

29. Which of the following is a function of inventory?
    a. to decouple or separate parts of the production process
    b. to decouple the firm from fluctuations in demand and provide a stock of goods that will provide a selection for customers
    c. to take advantage of quantity discounts
    d. to hedge against inflation
    e. All of the above are functions of inventory.
    e (Functions of inventory, moderate)

30. Which of the following would **not** generally be a motive for a firm to hold inventories?
    a. to decouple or separate parts of the production process
    b. to provide a stock of goods that will provide a selection for customers
    c. to take advantage of quantity discounts
    d. to minimize holding costs
    e. All of the above are functions of inventory.
    d (Functions of inventory, moderate)

31. Which of the following is **not** one of the four main types of inventory?
    a. raw material inventory
    b. work-in-process inventory
    c. maintenance/repair/operating supply inventory
    d. safety stock inventory
    e. All of these are main types of inventory.
    d (Functions of inventory, moderate)

32. Which of the following statements about ABC analysis is **false**?
    a. ABC analysis is based on the presumption that controlling the few most important items produces the vast majority of inventory savings.
    b. In ABC analysis, "A" Items are tightly controlled, have accurate records, and receive regular review by major decision makers.
    c. In ABC analysis, "C" Items have minimal records, periodic review, and simple controls.
    d. ABC analysis is based on the presumption that all items must be tightly controlled to produce important cost savings.
    e. All of the above statements are true.
    d (Inventory management, moderate)

33. All of the following statements about ABC analysis are true **except**
    a. inventory may be categorized by measures other than dollar volume
    b. it categorizes on-hand inventory into three groups based on annual dollar volume
    c. it is an application of the Pareto principle
    d. it states that all items require the same degree of control
    e. it states that there are the critical few and the trivial many inventory items
    d (Inventory management, moderate)

34. ABC analysis is based upon the principle that
    a. all items in inventory must be monitored very closely
    b. there are usually a few critical items, and many items which are less critical
    c. an item is critical if its usage is high
    d. more time should be spent on class "C" items because there are more of them
    e. an item is critical if its unit price is high
    b (Inventory management, moderate)

35. ABC analysis divides on-hand inventory into three classes, generally based upon
    a. item quality
    b. unit price
    c. the number of units on hand
    d. annual demand
    e. annual dollar volume
    e (Inventory management, moderate)

36. Cycle counting
    a. is a process by which inventory records are verified once a year
    b. provides a measure of inventory accuracy
    c. provides a measure of inventory turnover
    d. assumes that all inventory records must be verified with the same frequency
    e. assumes that the most frequently used items must be counted more frequently
    b (Inventory management, moderate)

37. Which of the following statements regarding control of service inventories is **true**?
    a. Service inventory is a fictional concept, because services are intangible.
    b. Service inventory needs no safety stock, because there's no such thing as a service stockout.
    c. Effective control of all goods leaving the facility is one applicable technique.
    d. Service inventory has carrying costs but not setup costs.
    e. All of the above are true.
    c (Inventory management, moderate)

38. The two most basic inventory questions answered by the typical inventory model are
    a. timing and cost of orders
    b. quantity and cost of orders
    c. timing and quantity of orders
    d. order quantity and service level
    e. ordering cost and carrying cost
    c (Inventory models for independent demand, moderate)

39. Among the advantages of cycle counting is that it
    a. makes the annual physical inventory more acceptable to management
    b. does not require the detailed records necessary when annual physical inventory is used
    c. does not require highly trained people
    d. allows more rapid identification of errors and consequent remedial action than is possible with annual physical inventory
    e. does not need to be performed for less expensive items
    d (Inventory management, moderate)

40. Which of the following are elements of inventory holding costs?
    a. housing costs
    b. material handling costs
    c. investment costs
    d. pilferage, scrap, and obsolescence
    e. All of the above are elements of inventory holding cost.
    e (Inventory models, moderate)

41. Which of the following is **not** an assumption of the economic order quantity model shown below?

$$Q^* = \sqrt{\frac{2 \cdot D \cdot S}{H}}$$

    a. Demand is known, constant, and independent.
    b. Lead time is known and constant.
    c. Quantity discounts are not possible.
    d. Production and use can occur simultaneously.
    e. The only variable costs are setup cost and holding (or carrying) cost.
    d (Inventory models for independent demand, moderate)

42. The primary purpose of the basic economic order quantity model shown below is

$$Q^* = \sqrt{\frac{2 \cdot D \cdot S}{H}}$$

    a. to calculate the reorder point, so that replenishments take place at the proper time
    b. to minimize the sum of carrying cost and holding cost
    c. to maximize the customer service level
    d. to minimize the sum of setup cost and holding cost
    e. to calculate the optimum safety stock
    d (Inventory models for independent demand, moderate)

43. If the actual order quantity is the economic order quantity in a problem that meets the assumptions of the economic order quantity model shown below, the average amount of inventory on hand

$$Q^* = \sqrt{\frac{2 \cdot D \cdot S}{H}}$$

    a. is smaller the smaller is the holding cost per unit
    b. is zero
    c. is one-half of the economic order quantity
    d. is affected by the amount of product cost
    e. All of the above are true.
    c (Inventory models for independent demand, difficult)

44. A certain type of computer costs $1,000, and the annual holding cost is 25%. Annual demand is 10,000 units, and the order cost is $150 per order. What is the approximate economic order quantity?
    a. 16
    b. 70
    c. 110
    d. 183
    e. 600
    c (Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

45. Most inventory models attempt to minimize
    a. the likelihood of a stockout
    b. the number of items ordered
    c. total inventory based costs
    d. the number of orders placed
    e. the safety stock
    c (Inventory models for independent demand, easy)

46. In the basic EOQ model, if the cost of placing an order doubles, and all other values remain constant, the EOQ will
    a. increase by about 41%
    b. increase by 100%
    c. increase by 200%
    d. increase, but more data is needed to say by how much
    e. either increase or decrease
    a (Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

47. In the basic EOQ model, if D=6000 per year, S=$100, H=$5 per unit per month, the economic order quantity is approximately
    a. 24
    b. 100
    c. 141
    d. 490
    e. 600
    c (Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

48. Which of the following statements about the basic EOQ model is **true**?
    a. If the ordering cost were to double, the EOQ would rise.
    b. If annual demand were to double, the EOQ would increase.
    c. If the carrying cost were to increase, the EOQ would fall.
    d. If annual demand were to double, the number of orders per year would increase.
    e. All of the above statements are true.
    e (Inventory models for independent demand, difficult)

49. Which of the following statements about the basic EOQ model is **false**?
    a. If the setup cost were to decrease, the EOQ would fall.
    b. If annual demand were to increase, the EOQ would increase.
    c. If the ordering cost were to increase, the EOQ would rise.
    d. If annual demand were to double, the EOQ would also double.
    e. All of the above statements are true.
    d (Inventory models for independent demand, moderate)

50. A product whose EOQ is 40 experiences a decrease in ordering cost from $90 per order to $10. The revised EOQ is
    a. three times as large
    b. one-third as large
    c. nine times as large
    d. one-ninth as large
    e. cannot be determined
    b (Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

51. A product whose EOQ is 400 experiences a 50% increase in demand. The new EOQ is
    a. unchanged
    b. increased by less than 50%
    c. increased by 50%
    d. increased by more than 50%
    e. cannot be determined
    b (Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

52. For a certain item, the cost-minimizing order quantity obtained with the basic EOQ model was 200 units and the total annual inventory (carrying and setup) cost was $600. The inventory carrying cost per unit per year for this item is
    a. $1.50
    b. $2.00
    c. $3.00
    d. $150.00
    e. not enough data to determine
    c (Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

53. A product has demand of 4000 units per year. Ordering cost is $20 and holding cost is $4 per unit per year. The EOQ model is appropriate. The cost-minimizing solution for this product will cost _____ per year in total annual inventory costs.
    a. $400
    b. $800
    c. $1200
    d. zero; this is a class C item
    e. cannot be determined because unit price is not known
    b (Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

54. A product has demand of 4000 units per year. Ordering cost is $20 and holding cost is $4 per unit per year. The cost-minimizing solution for this product is to order
    a. all 4000 units at one time
    b. 200 units per order
    c. every 20 days
    d. 10 times per year
    e. none of the above
    b (Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

55. Which of the following statements regarding the reorder point is **true**?
    a. The reorder point is that quantity that triggers an action to restock an item.
    b. There is a reorder point even if lead time and demand during lead time are constant.
    c. The reorder point is larger than d x L if safety stock is present.
    d. The fixed-period model has no reorder point.
    e. All of the above are true.
    e (Inventory models for independent demand, and Probabilistic models and safety stock, moderate)

56. The EOQ model with quantity discounts attempts to determine
    a. what is the lowest amount of inventory necessary to satisfy a certain service level
    b. what is the lowest purchasing price
    c. whether to use fixed-quantity or fixed-period order policy
    d. how many units should be ordered
    e. what is the shortest lead time
    d (Inventory models for independent demand, moderate)

57. An inventory decision rule states "when the inventory level goes down to 14 gearboxes, 100 gearboxes will be ordered." Which of the following statements is true?
    a. One hundred is the reorder point, and 14 is the order quantity.
    b. Fourteen is the reorder point, and 100 is the order quantity.
    c. The number 100 is a function of demand during lead time.
    d. Fourteen is the safety stock, and 100 is the reorder point.
    e. None of the above is true.
    b (Inventory models for independent demand, moderate)

58. Which of the following statements regarding the production order quantity model is **true**?
    a. It applies only to items produced in the firm's own production departments.
    b. It relaxes the assumption that all the order quantity is received at one time.
    c. It relaxes the assumption that the demand rate is constant.
    d. It minimizes the total production costs.
    e. It minimizes inventory.
    b (Inventory models for independent demand, moderate)

59. Which of these statements about the production order quantity model is **false**?
    a. The production order quantity model is appropriate when the assumptions of the basic EOQ model are met, except that receipt is noninstantaneous.
    b. Because receipt is noninstantaneous, some units are used immediately, not stored in inventory.
    c. Average inventory is less than one-half of the production order quantity.
    d. All else equal, the smaller the ratio of demand rate to production rate, the larger is the production order quantity.
    e. None of the above is false.

    d (Inventory models for independent demand, difficult)

60. The assumptions of the production order quantity model are met in a situation where annual demand is 3650 units, setup cost is $50, holding cost is $12 per unit per year, the daily demand rate is 10 and the daily production rate is 100. The production order quantity for this problem is approximately
    a. 139
    b. 174
    c. 184
    d. 365
    e. 548

    c (Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

61. A production order quantity problem has daily demand rate = 10 and daily production rate = 50. The production order quantity for this problem is approximately 612 units. The average inventory for this problem is approximately
    a. 61
    b. 245
    c. 300
    d. 306
    e. 490

    b (Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

62. Which category of inventory holding costs is much higher than average for rapid-change industries such as PCs and cell phones?
    a. housing costs
    b. material handling costs
    c. labor cost
    d. parts cost
    e. pilferage, scrap, and obsolescence

    e (Inventory models, moderate)

63. When quantity discounts are allowed, the cost-minimizing order quantity
    a. is always an EOQ quantity
    b. minimizes the sum of holding and ordering costs
    c. minimizes the unit purchase price
    d. may be a quantity below that at which one qualifies for that price
    e. minimizes the sum of holding, ordering, and product costs

    e (Inventory models for independent demand, moderate)

64. Which of the following statements about quantity discounts is **false**?
    a. The cost-minimizing solution may or may not be where annual holding costs equal annual ordering costs.
    b. In inventory management, item cost becomes relevant to inventory decisions only when a quantity discount is available.
    c. If carrying costs are expressed as a percentage of value, EOQ is larger at each lower price in the discount schedule.
    d. The larger annual demand, the less attractive a discount schedule will be.
    e. The smaller the ordering cost, the less attractive a discount schedule will be.
    d (Inventory models for independent demand, moderate)

65. If the standard deviation of demand is six per week, demand is 50 per week, and the desired service level is 95%, approximately what is the statistical safety stock?
    a. 8 units
    b. 10 units
    c. 16 units
    d. 64 units
    e. cannot be determined without lead time data
    e (Probabilistic models with constant lead time, moderate)

66. A specific product has demand during lead time of 100 units, with a standard deviation of 25 units. What safety stock (approximately) provides a 95% service level?
    a. 41
    b. 55
    c. 133
    d. 140
    e. 165
    a (Probabilistic models with constant lead time, moderate) {AACSB: Analytic Skills}

67. Demand for dishwasher water pumps is 8 per day. The standard deviation of demand is 3 per day, and the order lead time is four days. The service level is 95%. What should the reorder point be?
    a. about 18
    b. about 24
    c. about 32
    d. about 38
    e. more than 40
    e **(Probabilistic models with constant lead time, moderate) {AACSB: Analytic Skills}**

68. The purpose of safety stock is to
    a. replace failed units with good ones
    b. eliminate the possibility of a stockout
    c. eliminate the likelihood of a stockout due to erroneous inventory tally
    d. control the likelihood of a stockout due to the variability of demand during lead time
    e. protect the firm from a sudden decrease in demand
    d (Probabilistic models with constant lead time, moderate)

69. The proper quantity of safety stock is typically determined by
    a. minimizing an expected stockout cost
    b. carrying sufficient safety stock so as to eliminate all stockouts
    c. meeting 95% of all demands
    d. setting the level of safety stock so that a given stockout risk is not exceeded
    e. minimizing total costs
    d (Probabilistic models with constant lead time, moderate)

70. If demand is not uniform and constant, then stockout risks can be controlled by
    a. increasing the EOQ
    b. placing an extra order
    c. raising the selling price to reduce demand
    d. adding safety stock
    e. reducing the reorder point
    d (Probabilistic models with constant lead time, moderate)

71. If daily demand is normally distributed with a mean of 15 and standard deviation of 5, and lead time is constant at 4 days, 90 percent service level will require safety stock of approximately
    a. 7 units
    b. 10 units
    c. 13 units
    d. 16 units
    e. 26 units
    c (Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

72. If daily demand is constant at 10 units per day, and lead time averages 12 days with a standard deviation of 3 days, 95 percent service requires a safety stock of approximately
    a. 28 units
    b. 30 units
    c. 49 units
    d. 59 units
    e. 114 units
    c (Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

73. In a safety stock problem where both demand and lead time are variable, demand averages 150 units per day with a daily standard deviation of 16, and lead time averages 5 days with a standard deviation of 1 day. The standard deviation of demand during lead time is approximately
    a. 15 units
    b. 100 units
    c. 154 units
    d. 500 units
    e. 13,125 units
    c (Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

74. The fixed-period inventory model requires more safety stock than the fixed-quantity models because
    a. a stockout can occur during the review period as well as during the lead time
    b. this model is used for products that have large standard deviations of demand
    c. this model is used for products that require very high service levels
    d. replenishment is not instantaneous
    e. setup costs and holding costs are large
    a (Probabilistic models and safety stock, moderate)

75. A disadvantage of the fixed-period inventory system is that
    a. it involves higher ordering costs than the fixed quantity inventory system
    b. additional inventory records are required
    c. the average inventory level is decreased
    d. since there is no count of inventory during the review period, a stockout is possible
    e. orders usually are for larger quantities
    d (Fixed-period systems, moderate)

76. An advantage of the fixed-period inventory system is that
    a. the supplier will be more cooperative
    b. there is no physical count of inventory items when an item is withdrawn
    c. no inventory records are required
    d. orders usually are for smaller order quantities
    e. the average inventory level is reduced
    b (Fixed-period systems, moderate)

FILL-IN-THE BLANK

77. Amazon's original concept of operating without inventory has given way to a model in which Amazon is a world-class leader in _____.
    warehouse management and automation (Global company profile, easy)

78. Inventory that separates various parts of the production process performs a _____ function.
    decoupling (Functions of inventory, easy)

79. _____ inventory is material that is usually purchased, but has yet to enter the manufacturing process.
    Raw material (Functions of inventory, easy)

80. _____ is a method for dividing on-hand inventory into three classifications based on annual dollar volume.
    ABC analysis (Inventory management, easy)

81. _____ is a continuing reconciliation of inventory with inventory records.
    Cycle counting (Inventory management, easy)

82. _____ is the time between placement and receipt of an order.
    Lead time (Inventory models for independent demand, easy)

83. In an economic order quantity problem, the total annual cost curve is at its _____ where holding costs equal setup costs.
minimum (Inventory models for independent demand, easy)

84. For a given level of demand, annual holding cost is larger as the order quantity is _____.
larger (Inventory models for independent demand, easy)

85. A(n) _____ model gives satisfactory answers even with substantial variations in its parameters.
robust (Inventory management, moderate)

86. In the production order quantity model, the fraction of inventory that is used immediately and not stored is represented by the ratio of_____.
demand rate to production rate (Inventory models for independent demand, easy)

87. _____ is extra stock that is carried to serve as a buffer.
Safety stock (Inventory management, easy)

88. In a quantity discount problem, if the savings in product cost is smaller than the increase in the sum of setup cost and holding cost, the discount should be _____.
rejected or refused (Inventory models for independent demand, easy)

89. _____ is the complement of the probability of a stockout.
Service level (Probabilistic models with constant lead time, moderate)

90. If a safety stock problem includes parameters for average daily demand, standard deviation of demand, and lead time, then _____ is variable and _____ is constant.
demand, lead time (Probabilistic models and safety stock, easy)

91. When demand is constant and lead time is variable, safety stock computation requires three inputs: the value of z, _____, and the standard deviation of lead time.
daily demand (Probabilistic models and safety stock, moderate)

92. A(n) _____ system triggers inventory ordering on a uniform time frequency.
fixed-period (Fixed-period systems, moderate)

SHORT ANSWERS

93. Explain what "decoupling" means in the context of inventory management.
Decoupling means to separate various parts of the production process. Each of the parts can then function at its own best pace. (Functions of inventory, moderate)

94. What are the main reasons that an organization has inventory?
Reasons to carry inventory include decoupling or separating parts of the production process, decoupling the firm from fluctuations in demand and providing a stock of goods that will provide a selection for customers, taking advantage of quantity discounts, and providing a hedge against inflation. (Introduction, moderate)

95. List the four types of inventory.
The four types of inventory are raw material, work-in-process, maintenance/repair/operating supply (MRO), and finished goods. (Functions of inventory, easy)

96. What is MRO an acronym for? What is the function of MRO inventories?
MRO inventories are devoted to maintenance/repair/operating supplies. They exist because the need and timing for maintenance and repair of some equipment are unknown. (Functions of inventory, easy)

97. Describe ABC inventory analysis in one sentence. What are some policies that may be based upon the results of an ABC analysis?
ABC inventory analysis is a method for dividing on-hand inventory into three classifications based on annual dollar volume. Some policies include: purchasing resources expended on supplier development should be higher for individual A items than for C items; A items should have tighter physical inventory control, and forecasting A items may warrant more care. (Inventory management, moderate)

98. What is cycle counting?
Cycle counting is an audit to reconcile inventory with inventory records. (Inventory management, easy)

99. Define shrinkage. List three or more examples of shrinkage.
Shrinkage is retail inventory that is unaccounted for between receipt and sale. Examples will vary, but may include inventory damaged prior to sale, stolen prior to sale, and inventory "lost" due to sloppy paperwork. (Inventory management, easy)

100. What are the techniques to control service inventories?
Techniques to control service inventories include good personnel selection, training, and discipline; tight control of incoming shipments; and effective control of all goods leaving the facility. (Inventory management, moderate)

101. When is a good time for cycle-counting personnel to audit a particular item?
In deciding when to verify inventory through cycle counting, the important considerations are (a) the verification takes place according to a formal schedule, and (b) inventory records of particularly important items are verified more often, those of less important items, less often. As the text suggests, the schedule can be weekly, monthly, or any other criteria, such as when an item goes to zero or when the item is to be ordered. (Inventory management, moderate)

102. Several inventory models assume "independent demand." Explain what that term means and why the assumption is important.
Independent demand means that demand for one particular item does not affect, and is not affected by, demand for a different item. When item demands are *dependent*, such as when wheels are demanded for assembly onto lawnmowers, independent ordering with *EOQ* may not be appropriate.

103. List the typical components that constitute inventory holding or carrying costs.
Typical components of inventory holding or carrying costs include housing costs, material handling costs, labor cost from extra handling, investment costs, pilferage, scrap, and obsolescence. (Inventory models, moderate)

104. Describe the costs associated with ordering and maintaining inventory.
Costs that are associated with ordering and maintaining inventory include initial purchase cost of the item, holding cost (insurance, space, heat, light, security, warehouse personnel, etc.), obsolescence or deterioration cost (particularly important in perishable goods or in a product that is undergoing rapid technological evolution), and ordering or setup cost (cost of forms, clerical processing, etc., or cost of machine setup). (Inventory models, moderate)

105. List the typical cost components that constitute ordering costs in inventory systems.
Typical components of ordering costs include cost of supplies, forms, order processing, clerical support, and so forth. (Inventory models, moderate)

106. Compare the assumptions of the production order quantity model to those of the basic EOQ model.
All are the same, except the assumption that receipt of inventory is instantaneous, which holds for EOQ, but not POQ. (Inventory models for independent demand, moderate)

107. In some inventory models, the optimal behavior occurs where ordering costs and carrying costs are equal to one another. Provide an example of a model where this "rule" does not hold; explain how the model's results are optimal anyway.
This rule will not hold in all instances of quantity discount models. In order to take advantage of a discount, it may be cheaper to order a quantity that is not an EOQ. The goal in quantity discount models is to minimize the sum of ordering, carrying, and purchase costs. (Inventory models for independent demand, moderate)

108. In the basic economic order quantity model and in the production order quantity model, optimal behavior occurs where annual setup costs equal annual holding costs. Is this a coincidence, or a fundamental element of these models? Answer in a well-constructed paragraph.
This equality is not a coincidence. It follows from the objective of both models, which is the minimization of total inventory costs for that product. In both of these models, total cost minimization occurs where the setup cost and holding cost elements intersect. The formulas for Q^* and Q^*_P follow from that point of equality. (Inventory models for independent demand, moderate)

109. What are the assumptions of the EOQ model?
The more important assumptions of the basic *EOQ* model are demand is known and constant over time, the lead time, that is, the time between the placement of the order and the receipt of the goods, is known and constant, the receipt of the inventory is instantaneous; i.e., the goods arrive in a single batch, at one instant in time, quantity discounts are not possible, the only variable costs are the cost of setting up or placing an order and the cost of holding or storing inventory over time, and if orders are placed at the right time, stockouts or shortages can be completely avoided. (Inventory models for independent demand, moderate)

110. Assume two inventory problems with identical demand, holding cost, and setup cost. In one, goods arrive instantly, but in the other goods arrive at a measurable rate. Which of these problems will have the larger optimal order quantity? Why?
The problem with instantaneous delivery is an EOQ problem, and its optimal order quantity is Q^*. The problem with noninstantaneous delivery is a POQ problem, with optimal order quantity Q^*_P. The POQ problem will yield a higher order quantity than the basic model, other things equal, because the maximum inventory level (and thus the effective carrying charge) is less. Maximum inventory is less because some items are used immediately and never enter inventory. (Inventory models for independent demand, moderate)

111. How sensitive is the EOQ to variations in demand or costs?
The *EOQ* is relatively insensitive to small changes in demand or setup or carrying costs because the cost curve is relatively flat around the EOQ. For example, if demand increases by 10%, *EOQ* will increase by approximately 5%. (Inventory models for independent demand, moderate)

112. What is a reorder point?
A reorder point is the inventory level (point) at which action is taken (an order placed) to replenish the stocked item. (Inventory models for independent demand, easy)

113. Define service level.
The service level is the percentage of demand met by available stock; it is the complement of the probability of a stockout. (Probabilistic models and safety stock, moderate)

114. What happens to the cost of the inventory policy when the service level increases?
The cost of the inventory policy increases dramatically with increases in service level. (Probabilistic models and safety stock, moderate)

115. How would a firm go about determining service level?
Service level is a difficult parameter to determine. Basically, the firm uses its subjective judgment to balance the cost of additional inventory against the cost of lost goodwill due to stockouts or shortages. (Probabilistic models and safety stock, moderate)

116. What is a fixed-period system?
It is a system in which inventory orders are made at regular time intervals. (Fixed-period systems, easy)

117. Describe the difference between a fixed-quantity and a fixed-period inventory system?
In a *fixed-quantity* inventory system, when the quantity on hand reaches the reorder point, an order is placed for the specified quantity. In a *fixed-period* inventory system, an order is placed at the end of the period. The quantity ordered is that needed to bring on-hand inventory up to a specified level. (Fixed-period systems, moderate)

PROBLEMS

118. Lead time for one of Montegut Manufacturing's fastest moving products is 4 days. Demand during this period averages 100 units per day. What would be an appropriate re-order point?
Re-order point = demand during lead time = 100 units/day * 4 days = 400 units.
(Inventory models for independent demand, easy) {AACSB: Analytic Skills}

119. Montegut Manufacturing produces a product for which the annual demand is 10,000 units. Production averages 100 per day, while demand is 40 per day. Holding costs are $2.00 per unit per year; set-up costs $200.00. If they wish to produce this product in economic batches, what size batch should be used? What is the maximum inventory level? How many order cycles are there per year? How much does management of this good in inventory cost the firm each year?
This problem requires economic order quantity, noninstantaneous delivery.

$$Q^*_P = \sqrt{\frac{2DS}{H(1-d/p)}} = \sqrt{\frac{2*10000*200}{2.00(1-40/100)}} = 1825.7 \text{ or } 1826 \text{ units.}$$

The maximum inventory level is $Q \cdot \left(1 - \frac{d}{p}\right) = 1825.7 \cdot \left(1 - \frac{40}{100}\right) = 1095.45$ **or 1095 units.**

There are approximately $N = \frac{D}{Q} = \frac{10000}{1826} = 5.48$ **cycles per year.**

Annual inventory management costs total $5.48 \cdot \$200 + (1095.45/2) \cdot \$2 =$ **$2,190.89 or $2,191.**
(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

120. Your company has compiled the following data on the small set of products that comprise the specialty repair parts division. Perform ABC analysis on the data. Which products do you suggest the firm keep the tightest control over? Explain.

SKU	Annual Demand	Unit Cost
R11	250	$250
S22	75	$90
T33	20	$60
U44	150	$150
V55	100	$75

R11 and U44 represent over 80% of the firm's volume in this area. R11 is classified A, U44 is classified B, and all others are C. The tightest controls go to R11, then U44 because of their high percentage of sales volume.

	Volume	Unit cost		Dollar volume	% Dollar volume	Cumulative $-vol %	Class
R11	250	$250		$62,500	62.22%	62.22%	A
U44	150	$150		$22,500	22.40%	84.62%	B
V55	100	$75		$7,500	7.47%	92.09%	C
S22	75	$90		$6,750	6.72%	98.81%	C
T33	20	$60		$1,200	1.19%	100.00%	C
			Total	$100,450			

(Inventory management, moderate) {AACSB: Analytic Skills}

121. Perform an ABC analysis on the following set of products.

Item	Annual Demand	Unit Cost
A211	1200	$9
B390	100	$90
C003	4500	$6
D100	400	$150
E707	35	$2000
F660	250	$120
G473	1000	$90
H921	100	$75

The table below details the contribution of each of the eight products. Item G473 is clearly an A item, and items A211, B390, and H921 are all C items. Other classifications are somewhat subjective, but one choice is to label E707 and D100 as A items, and F660 and C003 as B items.

Item	Annual Demand	Unit Cost	Volume	Cumulative volume	Cumulative percent
G473	**1000**	**$90**	**$90,000**	**$90,000**	**29.6%**
E707	**35**	**$2,000**	**$70,000**	**$160,000**	**52.6%**
D100	**400**	**$150**	**$60,000**	**$220,000**	**72.3%**
F660	**250**	**$120**	**$30,000**	**$250,000**	**82.2%**
C003	**4500**	**$6**	**$27,000**	**$277,000**	**91.0%**
A211	**1200**	**$9**	**$10,800**	**$287,800**	**94.6%**
B390	**100**	**$90**	**$9,000**	**$296,800**	**97.5%**
H921	**100**	**$75**	**$7,500**	**$304,300**	**100.0%**
			$304,300		

(Inventory management, moderate) {AACSB: Analytic Skills}

122. Thomas' Bike Shop stocks a high volume item that has a normally distributed demand during the reorder period. The average daily demand is 70 units, the lead time is 4 days, and the standard deviation of demand during the reorder period is 15.
a. How much safety stock provides a 95% service level to Thomas?
b. What should the reorder point be?

a. SS = 1.65 x 15 = 24.75 units or 25 units

b. ROP = (70* 4) + 25 = 305 units.

(Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

123. The annual demand, ordering cost, and the inventory carrying cost rate for a certain item are D = 600 units, S = $20/order and I = 30% of item price. Price is established by the following quantity discount schedule. What should the order quantity be in order to minimize the total annual cost?

Quantity	1 to 49	50 to 249	250 and up
Price	$5.00 per unit	$4.50 per unit	$4.10 per unit

The firm should order 250 units at a time, paying $4.10 per unit. Holding costs are much larger than ordering costs, but this is offset by the unit price reduction. The annual total cost is $2,661.75. The EOQ value for the $4.50 price has an annual cost of $2,880.

	Range 1	Range 2	Range 3
Minimum quantity	**1**	**50**	**250**
Unit Price, P	**$5.00**	**$4.50**	**$4.10**
Q* (Square root formula)	**126.49**	**133.33**	**139.69**
Order Quantity	**Discarded**	**133.33**	**250**
Holding cost		**$90.00**	**$153.75**
Setup cost		**$90.00**	**$48.00**
Unit costs		**$2,700.00**	**$2,460.00**
Total cost, T_c		**$2,880.00**	**$2,661.75**

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

124. The new office supply discounter, Paper Clips, Etc. (PCE), sells a certain type of ergonomically correct office chair which costs $300. The annual holding cost rate is 40%, annual demand is 900, and the order cost is $20 per order. The lead time is 4 days. Because demand is variable (standard deviation of daily demand is 2.4 chairs), PCE has decided to establish a customer service level of 90%. The store is open 300 days per year.
a. What is the optimal order quantity?
b. What is the safety stock?
c. What is the reorder point?

(a) The optimal order quantity is $Q^* = \sqrt{\frac{2 \cdot 900 \cdot 20}{.4 \cdot 300}} = 17.32$ **or 17 chairs.**

(b) Safety Stock is $SS = 1.29 \cdot 2.4 \cdot \sqrt{4} = 6.19$ **or 6 chairs.**
(c) ROP= lead time demand + safety stock = (3 chairs/day * 4) + 6.19 = 18 chairs.
(Inventory models for independent demand, and Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

125. Central University uses $123,000 of a particular toner cartridge for laser printers in the student computer labs each year. The purchasing director of the university estimates the ordering cost at $45 and thinks that the university can hold this type of inventory at an annual storage cost of 22% of the purchase price. How many months' supply should the purchasing director order at one time to minimize the total annual cost of purchasing and carrying?
First, calculate the EOQ from the data provided. In this problem, the "units" are dollars, and the "price" of each is 1.

$$Q^* = \sqrt{\frac{2 \cdot 123000 \cdot 45}{.22}} = 7093.53$$

One month's usage is 123000/12 = $10,250. EOQ = 7094. Month's usage = 7094/10250 = 0.69, or about three week's usage. (This is supported by the order frequency of 17 per year). (Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

126. The soft goods department of a large department store sells 175 units per month of a certain large bath towel. The unit cost of a towel to the store is $2.50 and the cost of placing an order has been estimated to be $12.00. The store uses an inventory carrying charge of 27% per year. Determine the optimal order quantity, order frequency, and the annual cost of inventory management. If, through automation of the purchasing process, the ordering cost can be cut to $4.00, what will be the new economic order quantity, order frequency, and annual inventory management cost? Explain these results.
Annual demand is 175 x 12 = 2100. At S=$12, the EOQ is 273 units, and there are about 8 orders per year. Annual costs of inventory management are $184.44. These results are detailed in the calculations below.

$$\boldsymbol{Q^* = \sqrt{\frac{2 \cdot 2100 \cdot 12}{.27 \cdot 2.5}} = 273.25;\ N = \frac{2100}{273.25} = 7.69}$$

$$\boldsymbol{TC = \frac{2100}{273.25} \cdot 12 + \frac{273.25}{2} \cdot .27 \cdot 2.5 = 92.22 + 92.22 = 184.44}$$

At S=$4, EOQ falls to 158, and order frequency rises to 13. Annual inventory management costs fall to $106.48. The lower order cost encourages smaller, more frequent orders.

$$\boldsymbol{Q^* = \sqrt{\frac{2 \cdot 2100 \cdot 4}{.27 \cdot 2.5}} = 157.76;\ N = \frac{2100}{157.76} = 13.31}$$

$$\boldsymbol{TC = \frac{2100}{157.76} \cdot 12 + \frac{157.76}{2} \cdot .27 \cdot 2.5 = 53.24 + 53.24 = 106.48}$$

(Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

127. A firm that makes electronic circuits has been ordering a certain raw material 250 ounces at a time. The firm estimates that carrying cost is 30% per year, and that ordering cost is about $20 per order. The current price of the ingredient is $200 per ounce. The assumptions of the basic EOQ model are thought to apply. For what value of annual demand is their action optimal?
This problem reverses the unknown of a standard EOQ problem.

$$\boldsymbol{250 = \sqrt{\frac{2 \cdot D \cdot 20}{.3 \cdot 200}};\ \text{solving for D results in D} = \frac{250^2 \cdot .3 \cdot 200}{2 \cdot 20} = 93{,}750}$$

(Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

128. A printing company estimates that it will require 1,000 reams of a certain type of paper in a given period. The cost of carrying one unit in inventory for that period is 50 cents. The company buys the paper from a wholesaler in the same town, sending its own truck to pick up the orders at a fixed cost of $20.00 per trip. Treating this cost as the order cost, what is the optimum number of reams to buy at one time? How many times should lots of this size be bought during this period? What is the minimum cost of maintaining inventory on this item for the period? Of this total cost, how much is carrying cost and how much is ordering cost?

This is an EOQ problem, even though the time period is not a year. All that is required is that the demand value and the carrying cost share the same time reference. This will require approximately 3.5 orders per period. Setup costs and carrying costs are each $70.71, and the annual total is $141.42.

$$EOQ = \sqrt{\frac{2 \cdot 1000 \cdot 20}{0.50}} = 283 \; ; \; N = \frac{1000}{282.84} = 3.54$$

$$\text{Carrying cost} = \frac{282.84}{2} \cdot .50 = 70.71 \text{ ; setup cost} = \frac{1000}{282.82} \cdot 20 = 70.71$$

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

129. The Rushton Trash Company stocks, among many other products, a certain container, each of which occupies four square feet of warehouse space. The warehouse space currently available for storing this product is limited to 600 square feet. Demand for the product is 15,000 units per year. Holding costs are $4 per container per year; Ordering costs are $5 per order.

a. What is the cost-minimizing order quantity decision for Rushton?

b. What is the total inventory-related cost of this decision?

c. What is the total inventory-related cost of managing the inventory of this product, when the limited amount of warehouse space is taken into account?

d. What would the firm be willing to pay for additional warehouse space?

The warehouse will hold only 150 containers. The annual cost at Q=150 is 100 x 5 + 75 x 4 = $800. The EOQ is about 194, more than there is room to store. Total cost at Q=194 is $774.60. This cost is $25.40 less than current cost, which reflects the limited storage space. Rushton would consider paying up to $25.40 for a year's rental of enough space to store 44 additional containers. (Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

130. Given the following data: D=65,000 units per year, S = $120 per setup, P = $5 per unit, and I = 25% per year, calculate the EOQ and calculate annual costs following EOQ behavior.

EOQ is 3533 units, for a total cost of $4,415.88

$$Q^* = \sqrt{\frac{2 \cdot 65000 \cdot 120}{.25 \cdot 5}} = 3532.7$$

$$TC = \frac{D}{Q} \cdot S + \frac{Q}{2} \cdot H = \frac{65000}{3533} \cdot 120 + \frac{3533}{2} \cdot .25 \cdot 5 = 2207.94 + 2207.94 = 4415.88$$

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

131. A toy manufacturer makes its own wind-up motors, which are then put into its toys. While the toy manufacturing process is continuous, the motors are intermittent flow. Data on the manufacture of the motors appears below.

Annual demand (D) = 50,000 units
Setup cost (S) = $85 per batch
Carrying cost = $.20 per unit per year
Daily subassembly production rate = 1,000
Daily subassembly usage rate = 200

a. To minimize cost, how large should each batch of subassemblies be?
b. Approximately how many days are required to produce a batch?
c. How long is a complete cycle?
d. What is the average inventory for this problem?
e. What is the total inventory cost (rounded to nearest dollar) of the optimal behavior in this problem?

(a) $Q^*_P = \sqrt{\frac{2DS}{H(1-d/p)}} = \sqrt{\frac{2*50000*85}{.2*(1-200/1000)}} = 7288.7$ **or 7289 units.**

(b) It will take approximately 7289/ 1000 = 7.3 days to make these units.

(c) A complete cycle will last approximately 7289 / 200 = 36 days.

(d) The maximum inventory level is $Q \cdot \left(1 - \frac{d}{p}\right) = 7288.7 \cdot \left(1 - \frac{200}{1000}\right) = 5831$ **units.**

Average inventory is 5831 / 2 = 2,915 (not one-half of 7283).

(e) Total inventory management costs are

$$TC = \frac{50000}{7289} \cdot 85 + \frac{5831}{2} \cdot .2 = 583.09 + 583.09 = \$1{,}166.19$$

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

132. Louisiana Specialty Foods can produce their famous meat pies at a rate of 1650 cases of 48 pies each per day. The firm distributes the pies to regional stores and restaurants at a steady rate of 250 cases per day. The cost of setup, cleanup, idle time in transition from other products to pies, etc., is $320. Annual holding costs are $11.50 per case. Assume 250 days per year.

a. Determine the optimum production run.
b. Determine the number of production runs per year.
c. Determine maximum inventory.
d. Determine total inventory-related (setup and carrying) costs per year.

(a) $Q^*_P = \sqrt{\frac{2DS}{H(1-d/p)}} = \sqrt{\frac{2*62500*320}{11.5*(1-250/1650)}} = 2024.7$ **or 2025 cases.**

(b) There will be 62,500 / 2024.7 = 30.87 runs per year.

(c) The maximum inventory level is $Q \cdot \left(1 - \frac{d}{p}\right) = 2024.7 \cdot \left(1 - \frac{250}{1650}\right) = 1717.9$ **units.**

(d) Total inventory management costs are

$$TC = \frac{62500}{2024.7} \cdot 320 + \frac{1717.9}{2} \cdot 11.5 = 9878.04 + 9878.04 = \$19{,}756.09$$

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

133. Holstein Computing manufactures an inexpensive audio card (Audio Max) for assembly into several models of its microcomputers. The annual demand for this part is 100,000 units. The annual inventory carrying cost is $5 per unit and the cost of preparing an order and making production setup for the order is $750. The company operates 250 days per year. The machine used to manufacture this part has a production rate of 2000 units per day.

a. Calculate the optimum lot size.
b. How many lots are produced in a year?
c. What is the average inventory for Audio Max?
d. What is the annual cost of preparing the orders and making the setups for Audio Max?

This problem requires the production order quantity model. The optimum lot size is 6,124; this lot size will be repeated 16.33 times per year. The total inventory management cost will be $24,494.90, and average inventory will be 2,449.49 units.

(a) $Q^*_P = \sqrt{\frac{2DS}{H(1-d/p)}} = \sqrt{\frac{2*100000*750}{5.00(1-400/2000)}} = 6123.7$ **or 6124 units.**

(b) There are approximately $N = \frac{D}{Q} = \frac{100000}{6123.7} = 16.33$ **cycles per year.**

(c) The maximum inventory is $Q \cdot \left(1 - \frac{d}{p}\right) = 6123.7 \cdot \left(1 - \frac{400}{2000}\right) = 4899$ **units; average inventory is 4899 / 2 = 2449.5 units.**

(d) Annual inventory management costs are 16.33 x 750+ 2449.5 x 5 = $12,247.45+$12,247.45 = $24,494.90

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

134. Huckaby Motor Services, Inc. rebuilds small electrical items such as motors, alternators, and transformers, all using a certain type of copper wire. The firm's demand for this wire is approximately normal, averaging 20 spools per week, with a standard deviation of 6 spools per week. Cost per spool is $24; ordering costs are $25 per order; inventory handling cost is $4.00 per spool per year. Acquisition lead time is four weeks. The company works 50, 5-day weeks per year.
a. What is the optimal size of an order, if minimization of inventory system cost is the objective?
b. What are the safety stock and reorder point if the desired service level is 90%?

Demand is 20 x 50 = 1000 spools per year

a. $Q^* = \sqrt{\frac{2 \cdot 20 \cdot 50 \cdot 25}{4}} = 111.8$**. Huckaby should order 112 spools at one time.**

b. $SS = 1.29 \cdot 6 \cdot \sqrt{4} = 15.48$ **or about 16 spools. The ROP is thus 20 · 4 + 16 = 96 spools.**

(Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

135. Demand for ice cream at the Ouachita Dairy can be approximated by a normal distribution with a mean of 47 gallons per day and a standard deviation of 8 gallons per day. The new management desires a service level of 95%. Lead time is four days; the dairy is open seven days a week. What reorder point would be consistent with the desired service level?

SS = 1.65 · 8 · $\sqrt{4}$ **= 26.4 gallons; and ROP = 47* 4 + 26.4 = 214.4 gallons.**

(Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

136. The Winfield Distributing Company has maintained an 80% service level policy for inventory of string trimmers. Mean demand during the reorder period is 170 trimmers, and the standard deviation is 60 trimmers. The annual cost of carrying one trimmer in inventory is $6. The area sales people have recently told Winfield's management that they could expect a $400 improvement in profit (based on current figures of cost per trimmer) if the service level were increased to 99%. Is it worthwhile for Winfield to make this change?

This is solved with a cost comparison: total costs status quo compared to total costs at higher service, as amended by the increased profit. First calculate their safety stock. SS = 0.84 · 60 = 50.4 trimmers at $6 each, this safety stock policy costs about $302.40. At a service level of 99%, the safety stock rises to 2.33 · 60 = 139.8, which will cost $838.80. The added cost is $536.40, which is more than the added profit, so Winfield should not increase its service level. (Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

137. Daily demand for a product is normally distributed with a mean of 150 units and a standard deviation of 15 units. The firm currently uses a reorder point system, and seeks a 75% service level during the lead time of 6 days.
a. What safety stock is appropriate for the firm?
b. What is the reorder point?

SS = 0.67 · 15 · $\sqrt{6}$ = 24.6; ROP = 150 · 6 + 24.6 = 924.6

(Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

138. Daily demand for a product is normally distributed with a mean of 200 units and a standard deviation of 20 units. The firm currently uses a reorder point system, with a lead time of 4 days.
a. What safety stock provides a 50% service level?
b. What safety stock provides a 90% service level?
c. What safety stock provides a 99% service level?

Standard deviation during lead time is 20 · $\sqrt{4}$ = 40 units. Z is 0 for 50% service level, 1.29 for 90%, and 2.33 for 99%. The resulting safety stocks are 0, 51.6, and 93.2.
(Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

139. Average daily demand for a product is normally distributed with a mean of 5 units and a standard deviation of 1 unit. Lead time is fixed at four days.
a. What is the reorder point if there is no safety stock?
b. What is the reorder point if the service level is 80 percent?
c. How much more safety stock is required if the service level is raised from 80 percent to 90 percent?

This problem requires formula 12-15, since demand is variable but lead time is constant.
(a) With no safety stock, the reorder point is D x L = 5 x 4 = 20 units.
(b) For 80 percent service level, z is 0.85. The reorder point is
$ROP = D \cdot L + z \cdot \sigma_d \cdot \sqrt{LT} = 5 \cdot 4 + 0.85 \cdot 1 \cdot \sqrt{4} = 20 + 1.7 = 21.7$**. Safety stock is 1.7 units.**

(c) At 90 percent service, z=1.29. Safety stock is $1.29 * 1 * \sqrt{4} = 2.58$**, an increase of about 0.9 units. (Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}**

140. Average daily demand for a product is normally distributed with a mean of 20 units and a standard deviation of 3 units. Lead time is fixed at 25 days. What reorder point provides for a service level of 95 percent?
This problem requires formula 12-15, since demand is variable but lead time is constant. For 95 percent service level, z is 1.65.

$$ROP = D \cdot L + z \cdot \sigma_d \cdot \sqrt{LT} = 20 \cdot 25 + 1.65 \cdot 3 \cdot \sqrt{25} = 500 + 24.75 = 524.75$$

(Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

141. A product has a reorder point of 110 units, and is ordered four times a year. The following table shows the historical distribution of demand values observed during the reorder period.

Demand	Probability
100	.3
110	.4
120	.2
130	.1

Managers have noted that stockouts occur 30 percent of the time with this policy, and question whether a change in inventory policy, to include some safety stock, might be an improvement. The managers realize that any safety stock would increase the service level, but are worried about the increased costs of carrying the safety stock. Currently, stockouts are valued at $20 per unit per occurrence, while inventory carrying costs are $10 per unit per year. What is your advice? Do higher levels of safety stock add to total costs, or not? What level of safety stock is best?

Action	Safety stock cost		Stockout cost		Total cost
ROP=110 (SS=0)	**0 =**	**$0**	**.2 x 10 x 20 x 4 =**	**$160**	
			.1 x 20 x 20 x 4 =	**$160**	
		$0		**$320**	**$320**
ROP=120 (SS=10)	**10 x $10 =**	**$100**	**.1 x 10 x 20 x 4 =**	**$80**	
		$100		**$80**	**$180**
ROP=130 (SS=20)	**20 x $10 =**	**$200**	**0 =**	**$0**	
		$200		**$0**	**$200**

The cheapest inventory policy has 10 units of safety stock. The managers should not be concerned about carrying cost only, but should consider that, while carrying costs rise, stockout costs fall. (Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

142. Demand for a product is approximately normal, averaging 5 units per day with a standard deviation of 1 unit per day. Lead time for this product is approximately normal, averaging 10 days with a standard deviation of 3 days. What reorder point provides a service level of 90 percent?
This problem requires formula (12-17), since both demand and lead time are variable. The value of z that corresponds to 90 percent service is 1.29.

$$\sigma_{DLT} = \sqrt{10 \cdot 1^2 + 5^2 \cdot 3^2} = \sqrt{235} = 15.33$$

$$ROP = 5 \cdot 10 + 1.29 \cdot 15.33 = 50 + 19.78 = 69.78$$

(Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

143. A product has a reorder point of 260 units, and is ordered ten times a year. The following table shows the historical distribution of demand values observed during the reorder period.

Demand	Probability
240	.1
250	.2
260	.4
270	.2
280	.1

Currently, stockouts are valued at $5 per unit per occurrence, while inventory carrying costs are $2 per unit per year. Should the firm add safety stock? If so, how much safety stock should be added?

Action	Safety stock cost		Stockout cost		Total cost
ROP=260 (SS=0)	**0 =**	**$0**	**.2 x 10 x 5 x 10 =**	**$100**	
			.1 x 20 x 5 x 10 =	**$100**	
		$0		**$200**	**$200**
ROP=270 (SS=10)	**10 x $2 =**	**$20**	**.1 x 10 x 5 x 10 =**	**$50**	
		$20		**$50**	**$70**
ROP=280 (SS=20)	**20 x $2 =**	**$40**	**0 =**	**$0**	
		$40		**$0**	**$40**

The current policy is not the cheapest inventory policy for this product. The cheapest inventory policy has a reorder point of 280, so the firm should add 20 units of safety stock. (Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

144. Demand for a product is relatively constant at five units per day. Lead time for this product is normally distributed with a mean of ten days and a standard deviation of three days.

a. What reorder point provides a 50 percent service level?
b. What reorder point provides a 90 percent service level?
c. If the lead time standard deviation can be reduced from 3 days to 1, what reorder point now provides 90 percent service? How much is safety stock reduced by this change?

This problem requires formula 12-16 since demand is constant but lead time is variable.
(a) There is no safety stock; the reorder point is 5 x 10 = 50 units;
(b) The value of z corresponding to 90 percent service is 1.29.

$$ROP = D \cdot L + z \cdot D \cdot \sigma_{LT} = 5 \cdot 10 + 1.29 \cdot 5 \cdot 3 = 50 + 19.35 = 69.35$$

(c) $ROP = 5 \cdot 10 + 1.29 \cdot 5 \cdot 1 = 50 + 6.45 = 56.45$**; safety stock has decreased by 12.9 units. (Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}**

145. A product has variable demand and constant lead time. Currently this product is managed by a fixed-period inventory system, for which the review period is one week. Lead time is four weeks. Annually about 5,200 units of this product are sold. The current target inventory is 500 units. Today is review day; 75 units are on the shelves, and orders placed at previous reviews in the amount of 110, 60, and 30 have not yet been received. There are no backorders.
a. How much is the firm allowing for safety stock in this case?
b. What should be the order amount this week?
(a) Since demand averages 100 units per week, expected demand is 4 x 100 = 400 units. The target value of 500 implies that safety stock is 100 units.
(b) Q = Target – On-hand – Pending + Backorders = 500 - 75 – (110 + 60 + 30) + 0 = 225
(Probabilistic models and safety stock, moderate) {AACSB: Analytic Skills}

146. Clement Bait and Tackle has been buying a chemical water conditioner for its bait (to help keep its baitfish alive) in an optimal fashion using EOQ analysis. The supplier has now offered Clement a discount of $0.50 off all units if the firm will make its purchases monthly or $1.00 off if the firm will make its purchases quarterly. Current data for the problem are: D = 720 units per year; S = $6.00, I = 20% per year; P = $25.
a. What is the EOQ at the current behavior?
b. What is the annual total cost, including product cost, of continuing their current behavior?
c. What are the annual total costs, if they accept either of the proposed discounts?
d. At the cheapest of the total costs, are carrying costs equal to ordering costs? Explain.

(a) $Q^* = \sqrt{\frac{2 \cdot 720 \cdot 6}{.2 \cdot 25}} = 41.57$ **or 42 units at a time.**

(b) $TC = 720 \cdot 25 + \frac{720}{41.57} \cdot 6 + \frac{41.57}{2} \cdot .2 \cdot 25 = 18000 + 103.92 + 103.92 = \$18{,}207.85$

(c) Placing orders on a monthly basis implies twelve orders per year where Q = 720 / 12 = 60. Placing orders on a quarterly basis implies four orders per year where Q = 720/4 = 180.
(d) They are not; accepting the discount requires an order quantity that is not EOQ. Purchasing 42 units at a time led to setup costs and holding costs of $104 each. With the more favorable discount, setup costs are $24 while holding costs are $432.

	Range 1	Range 2	Range 3
Quantity	**1-59**	**60-179**	**179+**
Unit Price, P	**$25**	**$24.5**	**$24**
Q* (Square root formula)	**41.57**	**41.99**	**42.43**
Order Quantity	**41.57**	**60**	**180**
Holding cost	**103.92**	**72**	**24**
Setup cost	**103.93**	**147**	**432**
Product cost	**18,000.00**	**17,640**	**17,280**
Total cost, T_c	**$18,207.85**	**$17,859**	**$17,736**

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

147. The annual demand for an item is 10,000 units. The cost to process an order is $75 and the annual inventory holding cost is 20% of item cost. What is the optimal order quantity, given the following price breaks for purchasing the item? What price should the firm pay per unit? What is the total annual cost at the optimal behavior?

Quantity	Price
1-9	$2.95 per unit
10 - 999	$2.50 per unit
1,000 - 4,999	$2.30 per unit
5,000 or more	$1.85 per unit

Range 1 and Range 2 are irrelevant, because the EOQ is larger than the upper end of each range. The firm should pay $1.85 per unit by ordering 5000 units at a time. This is above the 2014 EOQ of the next higher price break. Since the firm is not ordering an EOQ amount, ordering costs and carrying costs will not be equal, but total costs are still minimized.

	Range 3	Range 4
Q* (Square root formula)	**1805.788**	**2013.468**
Order Quantity	**1805.788**	**5000**
Holding cost	**$415.33**	**$925.00**
Setup cost	**$415.33**	**$150.00**
Unit costs	**$23,000.00**	**$18,500.00**
Total cost, T_c	**$23,830.66**	**$19,575.00**

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

148. A local artisan uses supplies purchased from an overseas supplier. The owner believes the assumptions of the EOQ model are met reasonably well. Minimization of inventory costs is her objective. Relevant data, from the files of the craft firm, are annual demand (D) =150 units, ordering cost (S) = $42 per order, and holding cost (H) = $4 per unit per year

a. How many should she order at one time?
b. How many times per year will she replenish her inventory of this material?
c. What will be the total annual inventory costs associated with this material?
d. If she discovered that the carrying cost had been overstated, and was in reality only $1 per unit per year, what is the corrected value of EOQ?

a. $Q^* = \sqrt{\frac{2 \cdot 150 \cdot 42}{4}} = 56.12$ **. She should order 56 units at a time.**

b. $N = \frac{150}{56.12} = 2.67$ **She should place about 2.67 orders per year.**

c. The inventory costs are $112 for holding and $112 for ordering, or $224 total.

d. At the lower value for H, the EOQ will be doubled to 112.25.

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

149. The annual demand for an item is 40,000 units. The cost to process an order is $40 and the annual inventory holding cost is $3 per item per year. What is the optimal order quantity, given the following price breaks for purchasing the item?

Quantity	Price
1-1,499	$2.50 per unit
1,500 - 4,999	$2.30 per unit
5,000 or more	$2.25 per unit

a. What is the optimal behavior?
b. Does the firm take advantage of the lowest price available? Explain.

a. Purchase 1500 units at a time, paying $2.30 each.

b. It is not advantageous to pay $2.25 if that requires ordering 5000 units. The annual cost is $97,820.00 at the $2.25 price versus $95,316.67 annual cost at the $2.30 price.

	Range 1	Range 2	Range 3
Q* (Square root formula)	**1032.796**	**1032.796**	**1032.796**
Order Quantity	**1032.796**	**1500**	**5000**
Holding cost	**$1,549.19**	**$2,250.00**	**$7,500.00**
Setup cost	**$1,549.19**	**$1,066.67**	**$320.00**
Unit costs	**$100,000.00**	**$92,000.00**	**$90,000.00**
Total cost, T_c	**$103,098.39**	**$95,316.67**	**$97,820.00**

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

150. Groundz Coffee Shop uses 4 pounds of a specialty tea weekly; each pound costs $16. Carrying costs are $1 per pound per week because space is very scarce. It costs the firm $8 to prepare an order. Assume the basic EOQ model with no shortages applies. Assume 52 weeks per year, closed on Mondays.

a. How many pounds should Groundz order at a time?
b. What is total annual cost (excluding item cost) of managing this item on a cost-minimizing basis?
c. In pursuing lowest annual total cost, how many orders should Groundz place annually?
d. How many days will there be between orders (assume 310 operating days) if Groundz practices EOQ behavior?

a. $Q^* = \sqrt{\frac{2 \cdot 4 \cdot 52 \cdot 8}{1 \cdot 52}} = 8$ **. Groundz should order 8 pounds per order.**

b. $TC = \frac{4 \cdot 52}{8} \cdot 8 + \frac{8}{2} \cdot 1 \cdot 52 = 208 + 208 = 416$ **. The firm will spend $416 annually.**

c. $N = \frac{4 \cdot 52}{8} = 26$ **. Groundz should order 26 times per year.**

d. Days between orders will be 310/26 or approximately every 12 working days.

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

151. Pointe au Chien Containers, Inc., manufactures in batches; the manufactured items are placed in stock. Specifically, the firm is questioning how best to manage a specific wooden crate for shipping live seafood, which is sold primarily by the mail/phone order marketing division of the firm. The firm has estimated that carrying cost is $4 per unit per year. Other data for the crate are: annual demand 60,000 units; setup cost $300. The firm currently plans to satisfy all customer demand from stock on hand. Demand is known and constant.
a. What is the cost minimizing size of the manufacturing batch?
b. What is the total cost of this solution?

The cost-minimizing batch size is $Q^* = \sqrt{\frac{2 \cdot 60000 \cdot 300}{4}} = 3000$ **crates. This will cost**

$\frac{60000}{3000} \cdot 300 + \frac{3000}{2} \cdot 4 = 6000 + 6000 = \$12{,}000$ **per year in inventory management costs.**

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

152. Holding costs are $35 per unit per year, the ordering cost is $120 per order, and sales are relatively constant at 300 per month. What is the optimal order quantity? What are the annual inventory management costs?

Order size is $Q^* = \sqrt{\frac{2 \cdot 300 \cdot 12 \cdot 120}{35}} = 157.12$ **or 157;**

annual inventory costs are $\frac{300 \cdot 12}{157.12} \cdot 120 + \frac{157.12}{2} \cdot 35 = 2749.55 + 2749.55 = \$5{,}499.10$.

(Inventory models for independent demand, moderate) {AACSB: Analytic Skills}

153. An organization has had a policy of ordering 70 units at a time. Their annual demand is 340 units, and the item has an annual carrying cost of $2. The assumptions of the EOQ are thought to apply. For what value of ordering cost would this order size be optimal?

Start with the economic order quantity model, and solve for S.

$70 = \sqrt{\frac{2(340)S}{2}}$ **becomes** $S = \frac{70^2 \cdot 2}{2 \cdot 340} = \$14.41$

(Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

154. Joe's Camera shop has a favorite model that has annual sales of 145. The cost to place an order to replenish inventory is $25 per order, and annual inventory costs are $20. Assume the store is open 350 days per year.
a. What is the optimal order size?
b. What is the optimal number of orders per year?
c. What is the optimal number of days between orders?
d. What is the annual inventory cost?

a. The optimal order size is $Q^* = \sqrt{\frac{2 \cdot 145 \cdot 25}{20}} = 19.04$**, or approximately 19 units.**

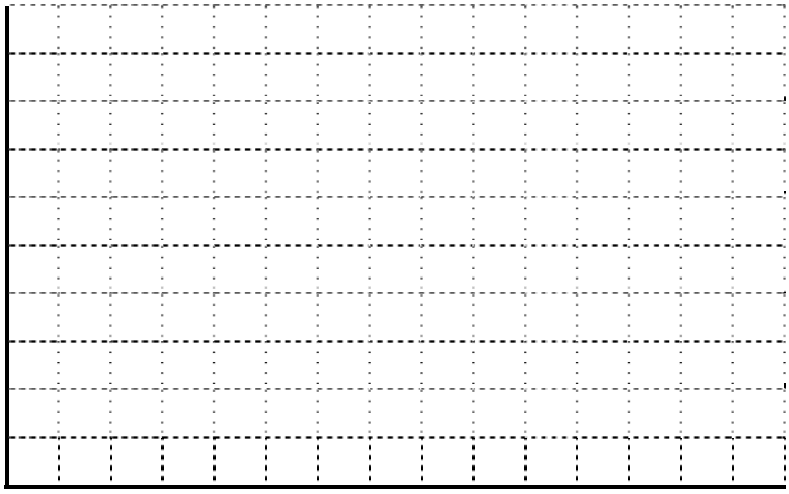
b. The optimal number of orders per year is N = 145 / 19.04 = 7.62 or 8 orders.

c. The optimal number of days between orders is 350/7.62 = 45.9 days.

d. The annual inventory cost is $\frac{145}{19.04} \cdot 25 + \frac{19.04}{2} \cdot 20 = 190.39 + 190.39 = \$380.78$.

(Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

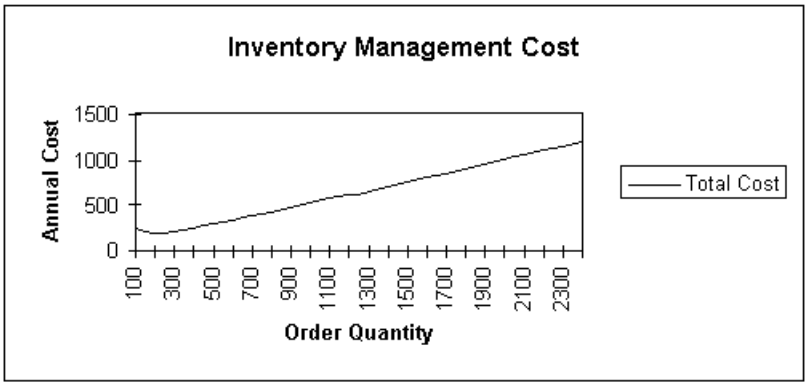
155. The inventory management costs for a certain product are S=$8 to order, and H=$1 to hold for a year. Annual demand is 2400 units. Consider the following ordering plans: (a) order all 2400 at one time, (b) order 600 once each quarter, and (c) order 200 once each month. Calculate the annual costs associated with each plan. Plot these values. Is there another plan, cheaper than any of these? Calculate this, and plot it (plot at least five points) on the grid below. Label your graph carefully.



$$TC_{2400} = 8 \cdot 1 + 1 \cdot \frac{2400}{2} = 1208; TC_{600} = 8 \cdot 4 + 1 \cdot \frac{600}{2} = 322; TC_{200} = 8 \cdot 12 + 1 \cdot \frac{200}{2} = 196$$

$$Q^* = \sqrt{\frac{2 \cdot 2400 \cdot 8}{1}} = 196 \text{ is the cheapest solution.}$$

The graph cannot easily show the difference between Q = 196 and Q = 200, but the increase in cost for Q = 600 and Q = 2400 are dramatic.



(Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

156. Consider a product with a daily demand of 400 units, a setup cost per production run of $100, a monthly holding cost per unit of $2.00, and an annual production rate of 292,000 units. The firm operates and experiences demand 365 days per year. Suppose that management mistakenly used the basic EOQ model to calculate the batch size instead of using the POQ model. How much money per year has that mistake cost the company?

d = 400 units
D = 400(365) = 146,000 units
S = $100
H = $2.00(12) = $24
p = 292,000 / 365 = 800 units

The firm actually ordered EOQ = $\{[2(146,000)100] / 24\}^{1/2}$ = 1103 units.

The firm should have ordered POQ = $\{[2(146,000)100] / [24(1-400/800)]\}^{1/2}$ = 1560 units.

The annual cost of the wrong policy is
(146,000/1103)($100) + (1103/2)($24)(1-400/800) = $13,237 + $6,618 = $19,855.

The annual cost of the correct policy is
(146,000/1560)($100) + (1560/2)($24)(1-400/800) = $9,359 + $9,360 = $18,719.

Thus, the mistake cost $19,855 - $18,719 = $1,136 per year.
(Inventory models for independent demand, difficult) {AACSB: Analytic Skills}

CHAPTER 13: AGGREGATE PLANNING

TRUE/FALSE

1. High levels of efficiency at Anheuser-Busch are the result of excellence in aggregate planning and in high facility utilization.
True (Global company profile, easy)

2. Aggregate planning occurs over the medium or intermediate future of 3 to 18 months.
True (Introduction, easy)

3. The only objective of aggregate planning is to minimize the cost of matching capacity to demand over the planning period.
False (Introduction, easy)

4. Aggregate planning in manufacturing ties organizational strategic goals to a production plan.
True (Introduction, moderate)

5. One of the four things needed for aggregate planning is a logical overall unit for measuring sales and output.
True (Introduction, moderate)

6. Plans for new product development generally fall within the scope of aggregate planning.
False (The planning process, moderate)

7. The aggregate planning process usually includes expediting and dispatching of individual products.
False (The planning process, moderate)

8. Disaggregation is the process of breaking the aggregate plan into greater detail; one example of this detail is the Master Production Schedule.
True (The nature of aggregate planning, Moderate)

9. One question that operations managers must ask when generating an aggregate plan is what factors are likely to influence demand and by how much.
True (Aggregate planning strategies, easy)

10. One of the demand options of aggregate planning is to vary the workforce by hiring or firing.
False (Aggregate planning strategies, moderate)

11. The strategies of aggregate planning are broadly divided into demand options and capacity options.
True (Aggregate planning strategies, easy)

12. In aggregate planning, the amount of overtime and the size of the work force are both adjustable elements of capacity.
True (Aggregate planning strategies, easy)

13. In aggregate planning, one of the adjustable elements of capacity is the extent of subcontracting.
True (Aggregate planning strategies, easy)

14. One motive for using demand-influencing aggregate planning options is to create uses for excess capacity within an organization.
True (Aggregate planning strategies, moderate)

15. The use of part-time workers as an aggregate planning option may be less costly than using full-time workers, but may also reduce quality levels.
True (Aggregate planning strategies, moderate)

16. Advertising and promotion are methods of manipulating product or service supply in aggregate planning.
False (Aggregate planning strategies, moderate)

17. Because service firms do not inventory their output, pure chase strategy is not appropriate.
False (Aggregate planning strategies, moderate)

18. The level scheduling strategy allows lower inventories than the pure chase strategy.
False (Aggregate planning strategies, moderate)

19. Mixed strategies in aggregate planning utilize inventory, work force, and production rate changes over the planning horizon.
True (Methods for aggregate planning, moderate)

20. Finding an ideal mixed strategy is complicated by the huge number of possible strategies.
True (Aggregate planning strategies, moderate)

21. Graphical techniques are easy to understand and use, but are not well-suited for generating optimal strategies.
True (Methods for aggregate planning, moderate)

22. The transportation method of linear programming is an optimizing approach to aggregate planning.
True (Methods for aggregate planning, easy)

23. The management coefficients model is a formal planning model built around a manager's experience and performance.
True (Methods for aggregate planning, moderate)

24. Controlling the cost of labor in services involves quick response to consumer demand, on-call labor for unexpected demand, flexibility of labor for reallocation, and flexibility of hours or rate of output of individual workers.
True (Aggregate planning in services, moderate)

25. Aggregate planning for fast food restaurants is very similar to aggregate planning in manufacturing, but with much smaller units of time.
True (Aggregate planning in services, moderate)

26. A hotel room that goes unrented and an airline seat that goes unsold are both examples of perishability of services inventory.
True (Aggregate planning in services, moderate)

MULTIPLE CHOICE

27. Which of the following statements regarding Anheuser-Busch is **false**?
    a. Aggregate planning is a major part of its competitive edge.
    b. All four stages of beer production are integrated into the aggregate plan.
    c. High facility utilization complements its successful aggregate planning.
    d. Its aggregate planning focuses entirely on facilities, ignoring employee issues.
    e. Even with excellent aggregate planning, its plants need to have high utilization.
    d (Global company profile, easy)

28. The typical time horizon for aggregate planning is
    a. less than a month
    b. up to 3 months
    c. 3 to 18 months
    d. over one year
    e. over 5 years
    c (Introduction, easy)

29. Which of the following is the term used for medium range capacity planning with a time horizon of three to eighteen months?
    a. material requirements planning
    b. short-range planning
    c. strategic planning
    d. aggregate planning
    e. none of the above
    d (Introduction, easy)

30. Aggregate planning is capacity planning for
    a. the long range
    b. the intermediate range
    c. the short range
    d. typically one to three months
    e. typically three or more years
    b (Introduction, easy)

31. Which of the following is **not** one of the four things needed for aggregate planning?
    a. a logical overall unit for measuring sales and output
    b. a method for determining costs, such as hiring, firing, and inventory costs, associated with production schedules
    c. a mathematical model that will minimize costs over the intermediate planning period
    d. an aggregate demand forecast for an intermediate planning period
    e. All of these are needed for aggregate planning.
    c (Introduction, easy)

32. Planning tasks associated with loading, sequencing, expediting, and dispatching typically fall under
    a. short-range plans
    b. intermediate-range plans
    c. long-range plans
    d. mission-related planning
    e. strategic planning
    a (The planning process, moderate)

33. The planning tasks associated with staffing, production, inventory, and sub-contracting levels typically fall under
    a. short-range plans
    b. intermediate-range plans
    c. long-range plans
    d. demand options
    e. strategic planning
    b (The planning process, easy)

34. Which of the following statements about aggregate planning is **true**?
    a. Advertising/promotion is a way of manipulating product or service supply.
    b. Work station loading and job assignments are examples of aggregate planning.
    c. Overtime/idle time is a way of manipulating product or service demand.
    d. Aggregate planning uses the adjustable part of capacity to meet production requirements.
    e. All of the above are true.
    d (The planning process, moderate)

35. Which of the following statements about aggregate planning is **false**?
    a. Hiring, layoffs, overtime, and subcontracting are methods of manipulating capacity.
    b. Aggregate planning produces a plan detailing which products are made and in what quantities.
    c. Yield management is a way of manipulating product or service demand.
    d. Aggregate planning uses the adjustable part of capacity to meet production requirements.
    e. The transportation method is an optimizing technique for aggregate planning.
    b (The planning process, moderate)

36. Disaggregation
    a. breaks the aggregate plan into greater detail
    b. transforms the master production schedule into an aggregate plan
    c. calculates the optimal price points for yield management
    d. converts product schedules and labor assignments to a facility-wide plan
    e. is an assumption required for the use of the transportation model in aggregate planning
    a (The nature of aggregate planning, easy)

37. Dependence on an external source of supply is found in which of the following aggregate planning strategies?
    a. varying production rates through overtime or idle time
    b. subcontracting
    c. using part-time workers
    d. back ordering during high demand periods
    e. hiring and laying off
    b (Aggregate planning strategies, moderate)

38. Which of these is among the **demand** options of aggregate planning?
    a. subcontracting
    b. back-ordering during high-demand periods
    c. changing inventory levels
    d. varying workforce size
    e. All of the above are demand options.
    b (Aggregate planning strategies, moderate)

39. Which of the following aggregate planning strategies might direct your client to a competitor?
    a. using part-time workers
    b. subcontracting
    c. changing inventory level
    d. varying production rates through overtime or idle time
    e. varying work force size by hiring or layoffs
    b (Aggregate planning strategies, moderate)

40. Which of the following aggregate planning strategies is a "capacity option"?
    a. influencing demand by changing price
    b. counterseasonal product mixing
    c. influencing demand by extending lead times
    d. changing inventory levels
    e. influencing demand by back ordering
    d (Aggregate planning strategies, moderate)

41. Which of these aggregate planning strategies adjusts capacity to match demand?
    a. back ordering
    b. using part-time workers
    c. counterseasonal product mixing
    d. changing price
    e. None of the above is a capacity option.
    b (Aggregate planning strategies, moderate)

42. Which of the following aggregate planning strategies is known to lower employee morale?
    a. yield management
    b. counterseasonal product and service mixing
    c. changing inventory levels
    d. varying work force size by hiring or layoffs
    e. back ordering during high demand periods
    d (Aggregate planning strategies, moderate)

43. Which of the following is **not** associated with manipulation of product or service demand?
    a. price cuts or discounts
    b. promotion
    c. subcontracting
    d. counterseasonal products or services
    e. advertising
    c (Aggregate planning strategies, moderate)

44. Which of the following attempts to manipulate product or service demand?
    a. inventories
    b. part-time workers
    c. subcontracting
    d. overtime/idle time
    e. price cuts
    e (Aggregate planning strategies, moderate)

45. Which of the following aggregate planning strategies is a "demand option"?
    a. changing price
    b. subcontracting
    c. varying production levels
    d. changing inventory levels
    e. using part-time workers
    a (Aggregate planning strategies, moderate)

46. In aggregate planning, which one of the following is **not** a basic option for altering demand?
    a. promotion
    b. subcontracting
    c. back ordering
    d. pricing
    e. All are demand options.
    b (Aggregate planning strategies, moderate)

47. Which choice below best describes the **counterseasonal** demand option?
    a. producing such products as lawnmowers and sunglasses during the winter
    b. developing a mix of products that smoothes out their demands
    c. lowering prices when demand is slack
    d. using subcontractors only when demand is excessive
    e. the breaking of the aggregate plan into finer levels of detail
    b (Aggregate planning strategies, easy)

48. Which of the following statements about aggregate planning is **true**?
    a. The development of mathematical models has allowed aggregate planners to discontinue use of trial-and-error methods.
    b. In aggregate planning, back orders are a means of manipulating supply while part-time workers are a way of manipulating product or service demand.
    c. A pure chase strategy allows lower inventories when compared to pure level scheduling.
    d. Disaggregation turns the master production schedule into an intermediate term master plan.
    e. All of the above are true.
    c (Aggregate planning strategies, moderate)

49. Which choice best describes **level scheduling**?
    a. Daily production is variable from period to period.
    b. Subcontracting, hiring, and firing manipulate supply.
    c. Price points are calculated to match demand to capacity.
    d. Inventory goes up or down to buffer the difference between demand and production.
    e. Seasonal demand fluctuations are matched without hirings or layoffs.
    d (Aggregate planning strategies, easy)

50. Which of the following statements regarding aggregate planning is **true**?
    a. In a pure level strategy, production rates or work force levels are adjusted to match demand requirements over the planning horizon.
    b. A pure level strategy allows lower inventories when compared to pure chase and hybrid strategies.
    c. In a mixed strategy, there are changes in both inventory and in work force and production rate over the planning horizon.
    d. Because service firms have no inventory, the pure chase strategy does not apply.
    e. All of the above are true.
    c (Aggregate planning strategies, moderate)

51. In level scheduling, what is kept uniform from month to month?
    a. product mix
    b. inventory levels
    c. production/workforce levels
    d. demand levels
    e. sub-contracting levels
    c (Aggregate planning strategies, moderate)

52. Which of the following is **not** consistent with a pure level strategy?
    a. varying the use of subcontracting
    b. variable work force levels
    c. little or no use of inventory to meet demand requirements
    d. varying production levels and/or work force to meet demand requirements
    e. All of the above are inconsistent with the pure level strategy.
    e (Aggregate planning strategies, moderate)

53. Which of the following is consistent with a pure chase strategy?
    a. vary production levels to meet demand requirements
    b. vary work force to meet demand requirements
    c. vary production levels and work force to meet demand requirements
    d. little or no use of inventory to meet demand requirements
    e. All of the above are consistent with a pure chase strategy.
    e (Aggregate planning strategies, moderate)

54. Which of the following is **not** an advantage of level scheduling?
    a. stable employment
    b. lower absenteeism
    c. matching production exactly with sales
    d. lower turnover
    e. more employee commitment
    c (Aggregate planning strategies, moderate)

55. A firm uses the pure chase strategy of aggregate planning. It produced 1000 units in the last period. Demand in the next period is estimated at 800, and demand over the next six periods (its aggregate planning horizon) is estimated to average 900 units. In following the chase strategy, the firm will
    a. add 100 units to inventory in the next period
    b. add 200 units to inventory in the next period
    c. hire workers to make up the 100 unit difference
    d. fire workers to make up the 200 unit difference
    e. implement a lower price point to increase demand
    d (Aggregate planning strategies, moderate) {AACSB: Analytic Skills}

56. A firm's demand in the next four quarters (its aggregate planning horizon) is forecast to be 80, 50, 40, and 90 units. Last quarter, the firm produced 60 units. If it uses level scheduling, the firm will.
    a. hire workers to permit production of 65 units per quarter for the next four quarters
    b. hire 20 workers
    c. have an increase in inventory of 20 units in the next quarter
    d. have a decrease in inventory of 5 units in the next quarter
    e. change its workforce each quarter so that inventory does not change
    a (Aggregate planning strategies, moderate) {AACSB: Analytic Skills}

57. Which of the following actions is consistent with the use of pure level strategy?
    a. use inventory to meet demand requirements
    b. vary the amount of subcontracting to meet demand requirements
    c. vary production levels to meet demand requirements
    d. vary work force to meet demand requirements
    e. none of the above
    a (Aggregate planning strategies, moderate)

58. "An optimal plan for minimizing the cost of allocating capacity to meet demand over several planning periods" best describes
    a. the linear decision rule
    b. simulation
    c. the management coefficients model
    d. the transportation method
    e. graphical methods
    d (Methods for aggregate planning, moderate)

59. A firm uses graphical techniques in its aggregate planning efforts. Over the next twelve months (its intermediate period) it estimates the sum of demands to be 105,000 units. The firm has 250 production days per year. In January, which has 22 production days, demand is estimated to be 11,000 units. A graph of demand versus level production will show that
    a. the January requirement is below level production of 420 units
    b. level production is approximately 1000 units per day
    c. level production of 420 units per day is below the January requirement
    d. level production is approximately 420 units per month
    e. the firm must hire workers between December and January
    c (Aggregate planning strategies, easy) {AACSB: Analytic Skills}

60. A firm practices the pure chase strategy. Production last quarter was 1000. Demand over the next four quarters is estimated to be 900, 700, 1000, and 1000. Hiring cost is $20 per unit, and firing cost is $5 per unit. Over the next year, the sum of hiring and firing costs will be
    a. $500
    b. $2,500
    c. $7,500
    d. $7,000
    e. $12,500
    c (Aggregate planning strategies, moderate) {AACSB: Analytic Skills}

61. Which of the following aggregate planning models is based primarily upon a manager's past experience?
    a. the linear decision rule
    b. simulation
    c. the management coefficients model
    d. the transportation method
    e. graphical methods
    c (Methods for aggregate planning, moderate)

62. Which of the following aggregate planning methods does not work if hiring and layoffs are possible?
    a. the linear decision rule
    b. simulation
    c. the management coefficients model
    d. the transportation method
    e. graphical methods
    d (Methods for aggregate planning, moderate)

63. Which of the following uses regression to incorporate historical managerial performance into aggregate planning?
    a. transportation method
    b. simulation
    c. linear decision rule
    d. management coefficients model
    e. keiretsu
    d (Methods for aggregate planning, moderate)

64. Which of the following is **not** an ingredient for controlling labor cost in services?
    a. accurate scheduling of labor-hours to assure quick response to customer demand
    b. an on-call labor resource that can be added or deleted to meet unexpected demand
    c. contract overseas labor to obtain a lower wage scale
    d. flexibility of individual worker skills that permits reallocation of available labor
    e. flexibility in rate of output or hours of work to meet changing demand
    c (Aggregate planning in services, moderate)

65. Which of the following statements regarding aggregate planning in services is **false**?
    a. When outputs are intangible, aggregate planning deals mainly with human resources requirements and managing demand.
    b. Perishability of inventory is an important consideration of planning.
    c. Aggregate planning in some service industries can be simpler than in manufacturing.
    d. Labor is the primary aggregate planning vehicle.
    e. Level scheduling is far more common than chase.
    e (Aggregate planning in services, easy)

66. Aggregate planning for service firms that provide intangible output deals mainly with
    a. smoothing the production rate and finding the optimal size of the workforce
    b. yield management
    c. centralized purchasing
    d. centralized production
    e. planning for human resource requirements and managing demand
    e (Aggregate planning in services, moderate)

67. Yield management is most likely to be used in which one of the following situations?
    a. a fast food restaurant with wide demand fluctuations during the day
    b. a dental clinic that wants to fill its appointment book
    c. a firm with a good counterseasonal product mix
    d. a shipping company that can change its fleet size easily
    e. an airline attempting to fill "perishable" seats at maximum revenue
    e (Yield management, difficult)

68. "Yield management" is best described as
    a. a situation where management yields to labor demands
    b. a situation where the labor union yields to management demands
    c. a process designed to increase the rate of output
    d. capacity allocation to different classes of customers in order to maximize profits
    e. management's selection of a product mix yielding maximum profits
    d (Yield management, moderate)

69. Which of these is **not** a characteristic that makes yield management attractive?
    a. demand can be segmented
    b. service can be sold in advance of consumption
    c. capacity is easily changed
    d. variable costs are low and fixed costs are high
    e. demand fluctuates
    c (Aggregate planning in services, easy)

FILL-IN-THE BLANK

70. _____ is an approach to determine the quantity and timing of production for the intermediate future.
    Aggregate planning (Introduction, easy)

71. _____ is the process of breaking the aggregate plan into greater detail.
    Disaggregation (The nature of aggregate planning, moderate)

72. A(n) _____ is the result of the disaggregation of the aggregate plan.
master production schedule (The nature of aggregate planning, moderate)

73. _____ is a capacity option that works especially well in the service sector where labor needs are relatively unskilled.
Using part-time workers (Aggregate planning strategies, moderate)

74. Developing a mix of _____ products is a widely used demand smoothing technique.
counterseasonal (Aggregate planning strategies, moderate)

75. The _____ strategy sets production equal to forecasted demand.
chase (Aggregate planning strategies, easy)

76. The _____ strategy maintains a constant output rate, or work force level, over the planning horizon.
level (Aggregate planning strategies, easy)

77. _____ work with a few variables at a time and are easy to understand and use.
Graphical methods (Methods for aggregate planning, moderate)

78. Among the mathematical approaches to aggregate planning, _____is good at working with inventories, holding costs, overtime, and subcontracting, but not with hiring and firing.
the transportation method or linear programming (section, moderate)

79. The _____ is a formal planning model built around a manager's experience and performance.
management coefficients model (Methods for aggregate planning, moderate)

80. _____ is a complex aggregate planning technique, using models that may be difficult to build and for managers to understand.
Simulation (Methods for aggregate planning, moderate)

81. A hotel room that goes unrented, a dental appointment that no patient booked, and an airline seat that went unsold, are all examples of _____ in services inventory.
perishability (Aggregate planning in services, moderate)

82. _____ involves capacity decisions that determine the allocation of classes of resources in order to maximize profit or yield.
Yield management (Yield management, moderate)

SHORT ANSWERS

83. What four things are needed to develop an aggregate plan?
To develop an aggregate plan, you need a logical overall unit for measuring sales and output, a forecast of demand for reasonable intermediate planning period in aggregate planning terms, a method for determining the cost associated with an aggregate plan, and a model that combines forecasts and costs so that scheduling decisions can be made for the planning period. (Introduction, moderate)

84. What is the typical planning horizon for aggregate planning?
The typical planning horizon is intermediate--3 to 18 months ahead. (Introduction, easy)

85. Why do some firms have longer planning horizons than others?
Aggregate planning is usually considered to encompass several production cycles. Some products, large ships or nuclear reactors, for example, have very long production cycles (years or tens of years). Other products, such as lawn mowers or jewelry, have production cycles measured in days. (The planning process, moderate)

86. What is disaggregation?
Disaggregation is the process of breaking the aggregate plan into greater detail. (The nature of aggregate planning, easy)

87. Identify (a) the demand options for aggregate planning; and (b) the capacity (supply) options for aggregate planning.
Demand options are: influencing demand (through price, promotion, advertising, selling), back ordering during high-demand periods, and counterseasonal product and service mixing. Capacity options are: changing inventory levels, varying workforce size by hiring or layoffs, varying production rates through overtime or idle time, subcontracting, and using part-time workers. (Aggregate planning strategies, moderate)

88. Explain the fundamental difference between the "capacity options" and the "demand options" of aggregate planning strategies.
Capacity options do not try to change the demand but attempt to absorb the demand fluctuations; capacity options deal with supply, not demand. Demand options try to smooth the demand pattern, but do not impact supply or capacity. (Aggregate planning strategies, moderate)

89. Compare the chase versus level strategy options.
The chase strategy sets production equal to forecasted demand, using varying workforce levels, overtime, idle time, part-time employees, or subcontracting. Its main advantage is low inventory levels. The level strategy maintains a constant output rate, production rate, or workforce level over the planning horizon. A stable workforce generally leads to better quality, less turnover and absenteeism, and more employee commitment to corporate goals. (Aggregate planning strategies, moderate)

90. The textbook illustrates demand management in the form of price cuts or discounts. Can demand manipulation for aggregate planning involve price increases? Explain; provide an example.
The text did allude to price increases when it stated that air conditioners are "least expensive in winter"—they must be more expensive when demand is high. Lower prices for one circumstance imply higher prices (or lower discounts) in other circumstances. Student examples may build from text examples, or come from experience, such as: energy companies can use peak load pricing; transit systems have higher rush hour fares. (Aggregate planning strategies, moderate) {AACSB: Reflective Thinking}

91. If a service firm were to attempt a pure level strategy for aggregate planning, should its level of output be at average demand, peak demand, or minimum demand?
This is a critical-thinking item for students. The answer depends on the ability of customers to reschedule or reserve service times, and upon the organization's view toward lost sales. Level = average if customers can reserve or reschedule. Level = maximum if the organization wishes to prevent lost sales. (Aggregate planning strategies, difficult) {AACSB: Reflective Thinking}

92. Most people would argue that a service firm must follow chase or mixed strategies. On the other hand, most state agencies, which are clearly service-oriented, are not at all able to "chase" demand. Discuss how they manipulate demand to allow the level strategy to be used.
This is a critical-thinking item for students. Most will recognize that state agencies (driver's license, tax, etc.) are often level because of restrictions on their ability to hire and fire at will. Some students will liken these agencies to high-volume quasi-manufacturing organizations. Most students will uncover examples from personal experience, such as: demand is forced to meet level capacity by queues, waiting lines, processing delays (back orders), and ultimately by lost "sales." (Aggregate planning strategies, difficult) {AACSB: Reflective Thinking}

93. What is the primary management challenge when implementing yield management?
Identifying differences in customers' willingness to pay and pricing accordingly. (Yield management, difficult)

94. What are the disadvantages common to the following two strategies: (1) varying inventory levels and (2) back ordering during periods of high demand?
Varying inventory levels and back ordering have this disadvantage in common: customers may go elsewhere. (Aggregate planning strategies, moderate)

95. What is the purpose of aggregate planning? Describe some demand and capacity options for implementing plans.
Aggregate planning is the determination of the quantity and timing of production for the intermediate future (often from 3 to 18 months ahead). Demand options attempt to smooth out changes in the demand pattern and include influencing demand through advertising, promotion, personal selling, price cuts, etc.; back order during high demand periods; and counterseasonal product mixing such as production of lawn mowers and snow blowers. Capacity options attempt to absorb fluctuations in demand and include changing inventory levels; varying size of work force by hiring and firing; varying production rate through use of overtime or idle time; subcontracting; and using part-time workers. (Aggregate planning strategies, moderate)

96. The text states that trial-and-error methods continue to be widely used, in spite of the development of various models. Using your knowledge from earlier in this course or from other quantitative courses you might have taken, speculate on why managers continue to use "primitive" devices when such sophistication is available.
Ease of use is preferred to sophistication; simpler models are superior in dynamic decision environments. (Methods for aggregate planning, moderate) {AACSB: Reflective Thinking}

97. Normally, the transportation model is used to solve problems involving several physical sources of product and several physical uses of the product, as in factories and warehouses. How is it possible to use the transportation model where the "routes" are from one time period to another? Describe how this provides aggregate planners with a usable mathematical model.
Time travel is not involved. "From" regular time March "To" demand May simply describes when production took place to provide the units sold in May. "From" April production "To" March demand simply describes back orders – demand in one month is met by production in a later period. The algorithm is optimizing – it minimizes cost over the planning period; the algorithm balances supply and demand by combinations of capacity options and demand options. (Methods for aggregate planning, moderate) {AACSB: Reflective Thinking}

98. Describe the advantages and limitations of the graphical method of aggregate planning.
Advantages include that it is easy to understand and use. Limitations include: (1) it's a trial-and error approach, (2) there is no guarantee that it will provide an optimal solution, and (3) it works with only a few variables at a time.
(Methods for aggregate planning, moderate)

99. List, in order, the five steps of the graphical method of aggregate planning. Is it possible that these steps can be properly followed and the solution properly implemented without using a graph? Explain.
The steps are:
1. Determine the demand in each period.
2. Determine what the capacity is for regular time, overtime, and subcontracting each period.
3. Find the labor costs, hiring and layoff costs, and inventory holding costs.
4. Consider company policy that may apply to the workers or to stock levels.
5. Develop alternative plans and examine their total costs.
The steps can be followed and the solution implemented with tables of values, not graphs.
(Methods for aggregate planning, moderate)

100. Describe the advantages and limitations of the transportation method for aggregate planning.
Advantages include that it provides optimal solutions and it is flexible by allowing overtime, subcontracting, extra shifts, and inventory carryover options. However, it does not work when more factors such as hiring and layoffs are introduced.
(Methods for aggregate planning, moderate)

101. Identify some firms that provide yield management software.
NCR's Teradata, SPS, DemandTec, and Oracle with Profit Logic.
(Yield management, difficult)

102. Identify some mathematical approaches to aggregate planning. Which are optimizing? Which are heuristic?
Some mathematical approaches to aggregate planning are the transportation method of linear programming, the management coefficients model, the linear decision rule, and simulation. Linear programming and linear decision rule techniques generate "optimal" solutions. The management coefficients model and simulation techniques generate "good," but not necessarily "optimal," solutions. (Methods for aggregate planning, moderate)

103. What are successful techniques of controlling the cost of labor involved in service firms?
Successful techniques include:
1. accurate scheduling of labor-hours to assure quick response to customer demand;
2. an on-call labor resource that can be added or deleted to meet unexpected demand;
3. flexibility of individual worker skills that permits reallocation of available labor;
4. flexibility in rate of output or hours of work to meet changing demand.
(Aggregate planning in services, moderate)

104. What conditions make yield management of interest?
The following conditions make yield management an appropriate tool: service or product can be sold in advance of consumption; demand fluctuates; capacity is relatively fixed; demand can be segmented, and variable costs are low and fixed costs are high. (Aggregate planning in services, moderate)

105. How does aggregate planning in services differ from aggregate planning in manufacturing?
Aggregate planning in services differs from aggregate planning in manufacturing in the following ways:

- **Most services are perishable and cannot be inventoried. It is virtually impossible to produce the service early in anticipation of higher demand at a later time.**
- **Demand for services is often difficult to predict. Demand variations are typically more severe and more frequent.**
- **Services are more customized than manufactured goods and can be offered in many different forms. This variability makes it difficult to allocate capacity. Units of capacity may also be hard to define.**
- **Because most services cannot be transported, service capacity must be available at the appropriate place as well as at the appropriate time.**
- **Service capacity is generally altered by changes in labor, rather than by equipment or space, and labor is a highly flexible resource.**

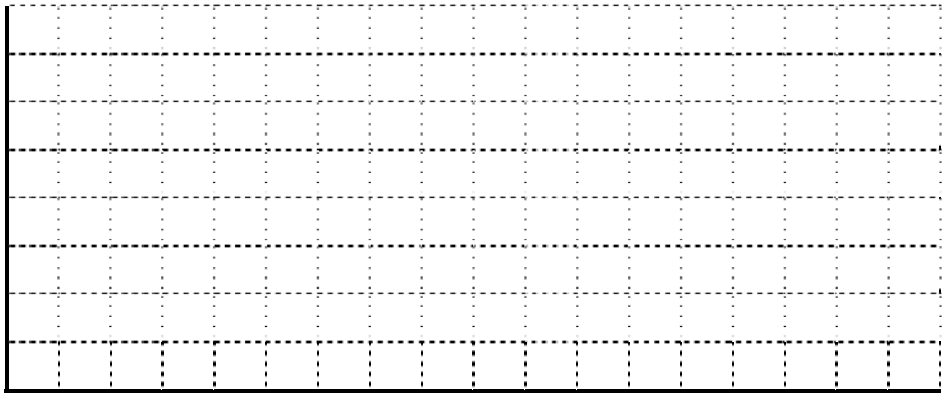
(Aggregate planning in services, moderate)

106. How does "yield management" impact the aggregate plan?
Yield management adds another set of decisions to the aggregate plan, to capacity planning, and to scheduling. However, of these yield management issues, the aggregate plan may be the one least affected. Auto rental companies, airlines, and hotels now all vary "inventory" (autos, seats, rooms) and prices to reflect ways to maximize their yield (profit). Lead time (vacationers price shop more and are willing to do so earlier), days of the week, seasons, holidays, and conventions all impact the yield. In many cases, the aggregate supply is the least affected. (Yield management, moderate)

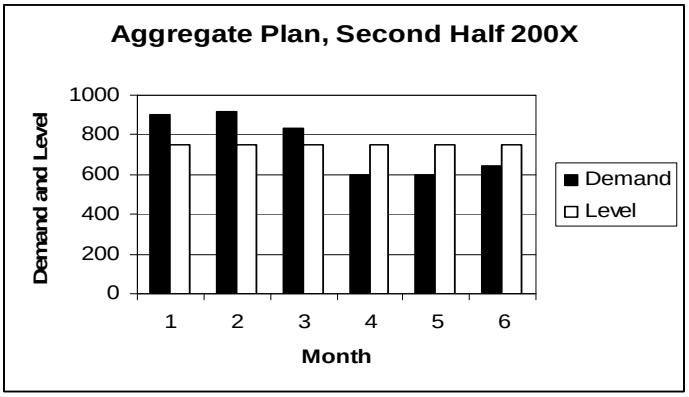
PROBLEMS

107. Fairview Industries is preparing its aggregate plan for the second half of the year. The table below contains monthly demand estimates and working days per month. Complete the table by computing total demand, demand per day (for each month), and the average requirement (in units per day) over the six-month planning horizon. Prepare a graph of forecast demand and level production, by months, for the planning period. Label your graph carefully.

Month	Expected Demand	Production Days	Demand per Day
July	18,000	20	
August	21,000	23	
September	17,500	21	
October	12,500	21	
November	12,000	20	
December	13,500	21	
TOTAL			



Month	**Expected Demand**	**Production Days**	**Demand per Day**
July	**18,000**	**20**	**900.00**
August	**21,000**	**23**	**913.04**
September	**17,500**	**21**	**833.33**
October	**12,500**	**21**	**595.24**
November	**12,000**	**20**	**600.00**
December	**13,500**	**21**	**642.86**
TOTAL	**94,500**	**126**	**Average = 750**



(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

108. Eagle Fabrication has the following aggregate demand requirements and other data for the upcoming four quarters.

Quarter	Demand
1	1300
2	1400
3	1500
4	1300

Previous quarter's output	1500 units
Beginning inventory	200 units
Stockout cost	$50 per unit
Inventory holding cost	$10 per unit at end of quarter
Hiring workers	$4 per unit
Firing workers	$8 per unit
Unit cost	$30 per unit
Overtime	$10 extra per unit

Which of the following production plans is better: Plan A—chase demand by hiring and firing; or Plan B—produce at a constant rate of 1200 and obtain the remainder from overtime?

Plan A would cost $165,400, while Plan B would cost $167,400. In this case it is cheaper to vary work force than to use overtime.

Plan A

Eagle Fabrication Solution					
	Demand	Regular time Capacity	Regular time production	Units increase	Units decrease
Initial Inventory					
Period 1	1,300.	1,100.	1,100.	0.	400.
Period 2	1,400.	1,400.	1,400.	300.	0.
Period 3	1,500.	1,500.	1,500.	100.	0.
Period 4	1,300.	1,300.	1,300.	0.	200.
Total(units)	5,500.	5,300.	5,300.	400.	600.
			@$30 /unit	@$4 /unit	@$8 /unit
Subtotal Costs			159,000.	1,600.	4,800.
Total Cost	165,400.				

Plan B

Eagle Fabrication Solution							
	Demand	Regular time Capacity	Overtime Capacity	Regular time production	Overtime production	Inventory (end PD)	Units decrease
Initial Inventory						200.	
Period 1	1,300.	1,200.	400.	1,200.	0.	100.	300.
Period 2	1,400.	1,200.	400.	1,200.	100.	0.	0.
Period 3	1,500.	1,200.	400.	1,200.	300.	0.	0.
Period 4	1,300.	1,200.	400.	1,200.	100.	0.	0.
Total(units)	5,500.	4,800.	1,600.	4,800.	500.	100.	300.
				@$30 /unit	@$40 /unit	@$10 /unit	@$8 /unit
Subtotal Costs				144,000.	20,000.	1,000.	2,400.
Total Cost	167,400.						

(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

109. Osprey Fabrication has the following aggregate demand requirements and other data for the upcoming four quarters.

Quarter	Demand
1	1400
2	1200
3	1600
4	1500

Previous quarter's output	1300 units
Beginning inventory	0 units
Stockout cost	$50 per unit
Inventory holding cost	$10 per unit at end of quarter
Hiring workers	$40 per unit
Firing workers	$80 per unit
Subcontracting cost	$60 per unit
Unit cost	$30 per unit
Overtime	$15 extra per unit

Which of the following production plans is better: Plan A—chase demand by hiring and firing; Plan B—pure level strategy, or Plan C—1350 level with the remainder by subcontracting?

SEE NEXT PAGE FOR SOLUTION.

Plan A will cost $215,000, Plan B will cost $179,500, and Plan C will cost $183,500. Plan B is the cheapest, by a small margin.

Plan A

	Osprey Fabrication Solution				
	Demand	Regular time Capacity	Regular time production	Units increase	Units decrease
Initial Inventory					
Period 1	1,400.	1,400.	1,400.	100.	0.
Period 2	1,200.	1,200.	1,200.	0.	200.
Period 3	1,600.	1,600.	1,600.	400.	0.
Period 4	1,500.	1,500.	1,500.	0.	100.
Total(units)	5,700.	5,700.	5,700.	500.	300.
			@$30 /unit	@$40 /unit	@$80 /unit
Subtotal Costs			171,000.	20,000.	24,000.
Total Cost	215,000.				

Plan B

	Osprey Fabrication Solution				
	Demand	Regular time Capacity	Regular time production	Inventory (end PD)	Units increase
Initial Inventory				0.	
Period 1	1,400.	1,425.	1,425.	25.	125.
Period 2	1,200.	1,425.	1,425.	250.	0.
Period 3	1,600.	1,425.	1,425.	75.	0.
Period 4	1,500.	1,425.	1,425.	0.	0.
Total(units)	5,700.	5,700.	5,700.	350.	125.
			@$30 /unit	@$10 /unit	@$40 /unit
Subtotal Costs			171,000.	3,500.	5,000.
Total Cost	179,500.				

Plan C

	Osprey Fabrication Solution						
	Demand	Regular time Capacity	Subcontract Capacity	Regular time production	Subcontracting	Inventory (end PD)	Units increase
Initial Inventory						0.	
Period 1	1,400.	1,350.	300.	1,350.	50.	0.	50.
Period 2	1,200.	1,350.	300.	1,350.	0.	150.	0.
Period 3	1,600.	1,350.	300.	1,350.	100.	0.	0.
Period 4	1,500.	1,350.	300.	1,350.	150.	0.	0.
Total(units)	5,700.	5,400.	1,200.	5,400.	300.	150.	50.
				@$30 /unit	@$60 /unit	@$10 /unit	@$40 /unit
Subtotal Costs				162,000.	18,000.	1,500.	2,000.
Total Cost	183,500.						

(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

110. A manufacturer of industrial seafood processing equipment wants you to develop an aggregate plan for the four quarters of the upcoming year using the following data on demand and capacity.

Quarter	Units	Regular Time	Over-time	Sub-contract
1	200	400	80	100
2	750	400	80	100
3	1200	800	160	100
4	450	400	80	100

Initial inventory	250 units
Regular time cost	$1.25/unit
Overtime cost	$1.50/unit
Subcontracting cost	2.00/unit
Carrying cost	$0.50/unit/quarter
No back ordering is allowed	

a. Find the optimal plan using the transportation method.
b. What is the cost of the plan?
c. Does any regular time capacity go unused? How much in what periods?
d. What capacity went unused in this solution (list in detail)?

The optimal plan appears in the table below. A cost of 100 is assigned to "impossible" cells (no back orders are allowed.) Cost increases 0.50 for each period past the current period (carrying cost). The minimum cost solution is $3,360. Forty units of regular time capacity went unused in period 1. Other unused capacity includes OT-1, 80; Sub-1, 100; Sub-2, 100; and OT-4, 30; and Sub-4, 100.

	Period 1	Period 2	Period 3	Period 4	Excess Capacity	Row Total
Beginning inventory	190	0	60	0	0	250
Period 1 reg time	10	350	0	0	40	400
Period 1 overtime	0	0	0	0	80	80
Period 1 subcontracting	0	0	0	0	100	100
Period 2 reg time	0	400	0	0	0	400
Period 2 overtime	0	0	80	0	0	80
Period 2 subcontracting	0	0	0	0	100	100
Period 3 reg time	0	0	800	0	0	800
Period 3 overtime	0	0	160	0	0	160
Period 3 subcontracting	0	0	100	0	0	100
Period 4 reg time	0	0	0	400	0	400
Period 4 overtime	0	0	0	50	30	80
Period 4 subcontracting	0	0	0	0	100	100
Column Total	200	750	1200	450	450	3050

(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

111. Washington Laundry Products, Inc., makes commercial and industrial laundry machines (the kinds hotels use), and has these aggregate demand requirements for the next six months. The firm has regular capacity for 200 units, and overtime capacity for 40 more. Currently, subcontracting can supply up to 100 units per month, but the subcontracting firm may soon be unavailable.

Month	Demand
1	220
2	160
3	200
4	210
5	200
6	190

Costs and other data	
Previous output level	150 units
Beginning inventory	100 units
Stockout cost	$250 per unit
Inventory holding cost	$100 per unit at end of month
Unit Cost, regular time	$1,200 per unit
Subcontracting	$2,000 per unit
Unit Cost, overtime	$1,500 per unit
Hiring workers	$200 per unit
Firing workers	$500 per unit

Which is cheaper: to produce level, incurring back orders and inventory charges; or to produce a base quantity of 120, using first, overtime, then subcontracting, to meet demand?

SEE SOLUTION ON FOLLOWING PAGE.

The cost of the level strategy is $1,326,000. The cost of the mixed strategy is $1,499,000. The added holding costs of the level strategy are far cheaper than the added overtime and subcontracting costs of the mixed strategy.

Level Strategy

Washington Laundry Products Solution					
	Demand	Regular time Capacity	Regular time production	Inventory (end PD)	Units increase
Initial Inventory				100.	
Period 1	220.	180.	180.	60.	30.
Period 2	160.	180.	180.	80.	0.
Period 3	200.	180.	180.	60.	0.
Period 4	210.	180.	180.	30.	0.
Period 5	200.	180.	180.	10.	0.
Period 6	190.	180.	180.	0.	0.
Total(units)	1,180.	1,080.	1,080.	240.	30.
			@$1200 /unit	@$100 /unit	@$200 /unit
Subtotal Costs			1,296,000.	24,000.	6,000.
Total Cost	1,326,000.				

Mixed strategy

Washington Laundry Products Solution								
	Demand	Regular time Capacity	Overtime Capacity	Subcontract Capacity	Regular time production	Overtime production	Subcontracting	Units decrease
Initial Inventory								
Period 1	220.	120.	40.	100.	120.	0.	0.	30.
Period 2	160.	120.	40.	100.	120.	40.	0.	0.
Period 3	200.	120.	40.	100.	120.	40.	40.	0.
Period 4	210.	120.	40.	100.	120.	40.	50.	0.
Period 5	200.	120.	40.	100.	120.	40.	40.	0.
Period 6	190.	120.	40.	100.	120.	40.	30.	0.
Total(units)	1,180.	720.	240.	600.	720.	200.	160.	30.
					@$1200 /unit	@$1500 /unit	@$2000 /unit	@$500
Subtotal Costs					864,000.	300,000.	320,000.	15,000.
Total Cost	1,499,000.							

(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

112. Reddick's Specialty Electronics makes weatherproof surveillance systems for parking lots. Demand estimates for the next four quarters are 25, 9, 13, and 17 units. Prepare an aggregate plan that uses inventory, regular time and overtime and back orders. Subcontracting is not allowed. Regular time capacity is 15 units for quarters 1 and 2, 18 units for quarters 3 and 4. Overtime capacity is 3 units per quarter. Regular time cost is $2000 per unit, while overtime cost is $3000 per unit. Back order cost is $300 per unit per quarter; inventory holding cost is $100 per unit per quarter. Beginning inventory is zero.

The data inputs for this problem, and the optimal solution, generated by microcomputer software, appear below. Answer the following questions based on the scenario and the solution.

a. How many total units will be produced in quarter 1 for delivery in quarter 1?
b. How many units in total will be used to fill back orders over the four quarters?
c. What is the cost to produce one unit in Quarter 4 using overtime to deliver in quarter 1 (filling a back order)?
d. At the end of quarter 3, what is the ending inventory of finished systems?
e. What is the total cost of the solution?
f. What is the average cost per unit?

Reddick's Specialty Electronics					
	Period 1	Period 2	Period 3	Period 4	SUPPLY
RT 1	2,000	2,100	2,200	2,300	15
OT 1	3,000	3,100	3,200	3,300	3
RT 2	2,300	2,000	2,100	2,200	15
OT 2	3,300	3,000	3,100	3,200	3
RT 3	2,600	2,300	2,000	2,100	18
OT 3	3,600	3,300	3,000	3,100	3
RT 4	2,900	2,600	2,300	2,000	18
OT 4	3,900	3,600	3,300	3,000	3
DEMAND	25	9	13	17	

Reddick's Specialty Electronics Solution					
Optimal cost = $132,200	Period 1	Period 2	Period 3	Period 4	Dummy
RT 1	15.				
OT 1					3.
RT 2	6.	9.			
OT 2					3.
RT 3	4.		13.		1.
OT 3					3.
RT 4				17.	1.
OT 4					3.

a. 15; b. 10; c. $3,900; d. 0; e. $132,200; f. 132200 / 64 = $2,066.
(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

113. Osprey Machine Works has the following demand requirements and other data for the upcoming four quarters.

Quarter	Demand
1	2300
2	2400
3	2600
4	2100

Previous quarter's output	2500 units
Beginning inventory	200 units
Stockout (backorder) cost	$50 per unit
Inventory holding cost	$10 per unit at end of quarter
Hiring workers	$4 per unit
Firing workers	$8 per unit
Unit cost	$30 per unit
Overtime	$10 extra per unit

What is the total cost of pursuing a level aggregate plan over the coming year?
Requirements total 9400 units, of which 200 are already in stock. A level rate of 2300 units will meet demand while using up beginning inventory. Costs associated with this plan are:

Cost element	Detail	Extension
Firing	**$8 x 200 units for the reduction from 2500 units to 2300 units**	**$1,600**
Holding	**There will be 200 units ending inventory at end of Q1 and 100 units at end of Q2, creating an inventory holding cost of $10 x 300 units**	**$3,000**
Stockout	**In Q3, 200 units go unfilled until Q4, for a stockout cost of $50 x 200**	**$10,000**
Unit cost	**$30 x 9,200**	**$276,000**
TOTAL		**$290,600.00**

(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

114. Golden Eagle Machine Works has the following demand requirements and other data for the upcoming four quarters.

Quarter	Demand
1	2300
2	2400
3	2600
4	2100

Previous quarter's output	2500 units
Beginning inventory	200 units
Stockout (backorder) cost	$50 per unit
Inventory holding cost	$10 per unit at end of quarter
Hiring workers	$4 per unit
Firing workers	$8 per unit
Unit cost	$30 per unit

What is the total cost of pursuing a chase aggregate plan over the coming year?
For a chase strategy, quarterly production should be Q1: 2100; Q2: 2400; Q3: 2600; and Q4: 2100. Costs associated with this plan are:

Cost element	Detail	Extension
Firing	**Reductions are 400 units in Q1 and 500 units in Q4. Costs are 900 x $8**	**$7,200**
Hiring	**Increases are 300 units in Q2 and 200 units in Q3. Costs are 500 x $4**	**$2,000**
Unit cost	**$30 x 9,200**	**$276,000**
TOTAL		**$285,200.00**

(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

115. An electronics manufacturer makes video security systems for parking lots. Demand estimates for the next four quarters are 15, 9, 23, and 17 units. Prepare an aggregate plan that uses inventory, regular time, overtime, and back orders. Subcontracting is not allowed. Regular time capacity is 12 units for quarters 1 and 2, 15 units for quarters 3 and 4. Overtime capacity is 6 units per quarter. Regular time cost is $20,000 per system, while overtime cost is $30,000 per unit. Back order cost is $2000 per system per quarter; inventory holding cost is $500 per unit per quarter. Beginning inventory is zero.

Complete the table of data inputs for solving this aggregate planning problem with the transportation method. Specifically, how many sources are there, and how many destinations? What is the supply from each source, and the demand of each destination? What is the cost of each source-destination pair?

There are eight sources: regular time and overtime for each quarter. There are four destinations, one for each quarter. The four demands are the quarterly demand estimates. The eight supplies are the regular time and overtime capacities of each quarter. The cell costs for regular time begin at $20,000, and increase rightward by the carrying cost increment, and increase downward by the backorder increment. The data table appears below.

				Video Security	
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	SUPPLY
Regular time quarter 1	20,000	20,500	21,000	21,500	12
Overtime quarter 1	30,000	30,500	31,000	31,500	6
Regular time quarter 2	22,000	20,000	20,500	21,000	12
Overtime quarter 2	32,000	30,000	30,500	31,000	6
Regular time quarter 3	24,000	22,000	20,000	20,500	15
Overtime quarter 3	34,000	32,000	30,000	30,500	6
Regular time quarter 4	26,000	24,000	22,000	20,000	15
Overtime quarter 4	36,000	34,000	32,000	30,000	6
DEMAND	15	9	23	17	

(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

116. Houma Containers, Inc., makes industrial fiberglass tanks that are used on offshore oil platforms. Demand for the next four months and capacities of the plant are shown in the table below. Unit cost on regular time is $400. Overtime cost is 150% of regular time cost. Subcontracting is available in substantial quantity but at a very high cost, $1100 per unit. Holding costs are $200 per tank per month; back orders cost the firm $1000 per unit per month. Houma's management believes that the transportation algorithm can be used to optimize this scheduling problem. The firm has no beginning inventory and anticipates no ending inventory.

	March	April	May	June
Demand	300	500	300	350
Regular capacity	200	200	250	250
Overtime capacity	50	50	50	50
Subcontract cap.	150	100	100	150

a. How many units will be produced on regular time in June?
b. How many units will be produced by subcontracting over the four-month period?
c. What will be the inventory at the end of April?
d. What will be total production from all sources in April?
e. What will be the total cost of the optimum solution?
f. Does the firm utilize the expensive options of subcontracting and back ordering? When; why?

SEE NEXT PAGE FOR SOLUTION

(a) 250; (b) 350; (c) 0, and 50 units are back ordered; (d) 350; (e) $935,000; (f) they use subcontracting every month; there are back orders in April filled with May production. The firm has so little excess capacity, even with the short-term options, that it must utilize almost every unit available, which forces the use of the more expensive options. The data table and solution table appear below.

			Houma Containers		
	March	April	May	June	SUPPLY
March regular time	400	600	800	1,000	200
March overtime	600	800	1,000	1,200	50
March subcontracting	1,100	1,300	1,500	1,700	150
April regular time	1,400	400	600	800	200
April overtime	1,600	600	800	1,000	50
April subcontracting	2,100	1,100	1,300	1,500	100
May regular time	2,400	1,400	400	600	250
May overtime	2,600	1,600	600	800	50
May subcontracting	3,100	2,100	1,100	1,300	100
June regular time	3,400	2,400	1,400	400	250
June overtime	3,600	2,600	1,600	600	50
June subcontracting	4,100	3,100	2,100	1,100	150
DEMAND	300	500	300	350	

			Houma Containers Solution		
Optimal cost = $935,000	March	April	May	June	Dummy
March regular time	100.	100.			
March overtime	50.				
March subcontracting	150.				
April regular time		200.			
April overtime		50.			
April subcontracting		100.			
May regular time			250.		
May overtime			50.		
May subcontracting		50.	0.		50.
June regular time				250.	
June overtime				50.	
June subcontracting				50.	100.

(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

117. Fred's Fabrication has the following aggregate demand requirements and other data for the upcoming four quarters.

Quarter	Demand
1	700
2	900
3	1200
4	600

Previous quarter's output	800 units
Beginning inventory	0 units
Stockout cost	$100 per unit
Inventory holding cost	$10 per unit at end of quarter
Hiring workers	$20 per unit
Firing workers	$40 per unit
Subcontracting cost	$200 per unit
Unit cost	$100 per unit
Overtime	$50 extra per unit

Which of the following production plans is better: Plan A—chase demand by hiring and firing; Plan B—pure level strategy, or Plan C—700 level with the remainder by subcontracting?

SEE NEXT PAGE FOR SOLUTION

Plan A has cost of $378,000, plan B has cost of $368,500, and plan C has cost of $425,000. Plan B has the lowest cost. Note that Plan C has an ending inventory of 100 units, which is the result of level production which exceeds demand in the last quarter.

Plan A -- Chase strategy

					Fred's Fabrication Solution
	Demand	Regular time Capacity	Regular time production	Units increase	Units decrease
Initial Inventory					
Period 1	700.	1,200.	700.	0.	100.
Period 2	900.	1,200.	900.	200.	0.
Period 3	1,200.	1,200.	1,200.	300.	0.
Period 4	600.	1,200.	600.	0.	600.
Total(units)	3,400.	4,800.	3,400.	500.	700.
			@$100 /unit	@$20 /unit	@$40 /unit
Subtotal Costs			340,000.	10,000.	28,000.
Total Cost	378,000.				

Plan B -- Level production, 850 per quarter

				Fred's Fabrication Solution		
	Demand	Regular time Capacity	Regular time production	Inventory (end PD)	Shortage (end PD)	Units increase
Initial Inventory				0.		
Period 1	700.	1,200.	850.	150.	0.	50.
Period 2	900.	1,200.	850.	100.	0.	0.
Period 3	1,200.	1,200.	850.	0.	250.	0.
Period 4	600.	1,200.	850.	0.	0.	0.
Total(units)	3,400.	4,800.	3,400.	250.	250.	50.
			@$100 /unit	@$10 /unit	@$100 /unit	@$20 /unit
Subtotal Costs			340,000.	2,500.	25,000.	1,000.
Total Cost	368,500.					

Plan C -- 700 units level, with subcontracting

					Fred's Fabrication Solution		
	Demand	Regular time production	Subcontracting production	Regular time production	Subcontracting	Inventory (end PD)	Units decrease
Initial Inventory						0.	
Period 1	700.	700.	0.	700.	0.	0.	100.
Period 2	900.	700.	200.	700.	200.	0.	0.
Period 3	1,200.	700.	500.	700.	500.	0.	0.
Period 4	600.	700.	0.	700.	0.	100.	0.
Total(units)	3,400.	2,800.	700.	2,800.	700.	100.	100.
				@$100 /unit	@$200 /unit	@$10 /unit	@$40 /unit
Subtotal Costs				280,000.	140,000.	1,000.	4,000.
Total Cost	425,000.						

(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

118. Byron's Manufacturing makes tables. Demand for the next four months and capacities of the plant are shown in the table below. Unit cost on regular time is $40. Overtime cost is 150% of regular time cost. Subcontracting is available in substantial quantity at $75 per unit. Holding costs are $5 per table per month; back orders cost the firm $10 per unit per month. Byron's management believes that the transportation algorithm can be used to optimize this scheduling problem. The firm has 50 units of beginning inventory and anticipates no ending inventory.

	March	April	May	June
Demand	400	600	600	700
Regular capacity	400	400	400	400
Overtime capacity	100	100	100	100
Subcontract cap.	150	50	50	50

a. How many units will be produced on regular time in June?
b. How many units will be produced by subcontracting over the four-month period?
c. What will be the inventory at the end of April?
d. What will be total production from all sources in April?
e. What will be the total cost of the optimum solution?
f. Does the firm utilize the expensive options of subcontracting and back ordering? When; why?

SEE NEXT PAGE FOR SOLUTION

(a) 400; (b) 250; (c) 0; (d) 600; (e) Total Cost = $109,750; (f) The firm uses subcontracting, but not backordering; there is no production in one month for "delivery" in an earlier month. Subcontracted quantities are 100 in March, 50 each in April, May, and June. The data and solution tables appear below.

			Byron's Manufacturing		
	March	April	May	June	SUPPLY
Beginning Inventory	0	5	10	15	50
March regular time	40	45	50	55	400
March overtime	60	65	70	75	100
March subcontracting	75	80	85	90	150
April regular time	50	40	45	50	400
April overtime	70	60	65	70	100
April subcontracting	85	75	80	85	50
May regular time	60	50	40	45	400
May overtime	80	70	60	65	100
May subcontracting	95	85	75	80	50
June regular time	70	60	50	40	400
June overtime	90	80	70	60	100
June subcontracting	105	90	85	75	50
DEMAND	400	600	600	700	

			Byron's Manufacturing Solution		
Optimal cost = $109,750	March	April	May	June	Dummy
Beginning Inventory	50.				
March regular time	350.	50.			
March overtime		100.			
March subcontracting			100.		50.
April regular time		400.			
April overtime		50.	50.		
April subcontracting				50.	
May regular time			400.		
May overtime			50.	50.	
May subcontracting				50.	
June regular time				400.	
June overtime				100.	
June subcontracting				50.	

(Methods for aggregate planning, moderate) {AACSB: Analytic Skills}

119. A small private university normally charges the same price —$200—per credit-hour for all courses and for all students. While the university is pretty near capacity in the fall and spring, it finds that its classrooms are only about 60 percent occupied during the summer session. A student of operations management (who has recently read this chapter) wonders if yield management might be useful to both the university and its students alike. This student, with help from some economics majors, estimates a demand curve for summer course enrollment. Points on this demand curve include 9000 credit-hours at the current rate of $200, 12,000 credit hours at $180, 15,000 credit-hours at $160, and 18,000 credit-hours at $140. Based on this demand curve, what price point would best serve the university, if its objective is the greatest revenue for the summer session?
The student must consider that since 9000 hours is 60 percent of capacity there is a classroom capacity of 15,000 credit-hours during the summer session. The lowest price generates the most revenue, but it is based on 18,000 credit-hours, which is beyond capacity. At $200 per credit hour, revenues would be $1,800,000; at $180, revenues would be $2,160,000; at $160, revenues would be $2,400,000; and at $140, demand exceeds capacity. The $160 price point yields the most revenue of the feasible price points.
(Yield management, moderate) {AACSB: Analytic Skills}

120. A professional services firm is investigating yield management as a means of taking advantage of unused capacity. Analysts for this firm estimate a demand curve for the firm's service, which is sold by the hour. Points on this demand curve include 9000 hours at the current rate of $60 per hour, 9500 hours at $55, 10,000 hours at $50, and 10,500 hours at $45. Based on this demand curve, what price point would be best for the firm, if its objective is maximum revenue?
The yields of these price points are as follows: at $60 per hour, revenue is $540,000; at $55, revenue is $522,500; at $50, revenue is $500,000; and at $45, revenue is $472,500. The firm would be well advised not to lower its price, since that will not raise revenue. The lower prices will generate more demand, and utilize some unused capacity, but the firm's revenues will fall. (Demand in this case is pretty inelastic).
(Yield management, moderate) {AACSB: Analytic Skills}

CHAPTER 14: MATERIAL REQUIREMENTS PLANNING (MRP) AND ERP

TRUE/FALSE

1. Wheeled Coach obtains competitive advantage through MRP in part because of their excellent record integrity and insistence on record accuracy.
True (Global company profile, easy)

2. MRP is generally practiced on items with dependent demand.
True (Dependent demand, easy)

3. Reduced inventory levels and faster response to market changes are both benefits of MRP.
True (Introduction, easy)

4. A dependent demand item is so called because its demand is dependent on customer preferences.
False (Dependent demand, moderate)

5. The quantity required of a dependent demand item is computed from the demand for the final products in which the item is used.
True (Dependent demand, moderate)

6. Since MRP is quite detailed in nature, it has no influence on the longer-range, less detailed aggregate planning.
False (Dependent inventory model requirements, moderate)

7. The master production schedule is a forecast of demand for families of products.
False (Dependent inventory model requirements, easy)

8. Lead times, inventory availability, and purchase orders outstanding are among the five things operations managers must know for effective use of MRP.
True (Dependent inventory model requirements, easy)

9. A bill of material lists all components, ingredients, and materials needed to produce one unit of an end item.
True (Dependent inventory model requirements, moderate)

10. "Phantom bills" are bills of material for subassemblies that do not exist in reality.
False (Dependent inventory model requirements, easy)

11. Planning bills of material are bills of material for "kits" of inexpensive items such as washers, nuts, and bolts.
True (Dependent inventory model requirements, moderate)

12. The Aggregate Plan, derived from the Master Production Schedule, specifies in more detail how much of which products is to be made at what times.
False (Dependent inventory model requirements, moderate)

13. The time phased product structure, unlike the bill of material, adds the concept of lead times.
True (Dependent inventory model requirements, moderate)

14. If X consists of one A and one B, and each A consists of one F and two Gs, then A is the "parent" component of G.
True (Dependent inventory model requirements, moderate)

15. If 100 units of Q are needed and 10 are already in stock, then the gross requirement is 100 and the net requirement is 90.
True (MRP structure, easy)

16. Gross material requirements do not take into account the amount of inventory on hand.
True (MRP structure, easy)

17. In MRP, a "bucket" refers to a fixed order quantity, such as an EOQ.
False (MRP management, moderate)

18. Time fences divide that segment of the MPS that can be revised from that section that is "frozen."
True (MRP management, easy)

19. MRP is an excellent tool for scheduling products with variable lead times.
False (MRP management, easy)

20. Finite capacity scheduling, unlike MRP, recognizes the capacity limitations of departments and machines when building schedules.
True (MRP management, easy)

21. If parts and subassemblies common to a variety of products are managed through the *supermarket* concept, formal order releases for such parts are not necessary.
True (MRP management, easy)

22. The lot-for-lot lot-sizing technique is particularly appropriate when demand is not very smooth and set up cost is small compared to holding cost.
True (Lot-sizing techniques, moderate)

23. In general, the lot-for-lot approach should be used whenever economical.
True (Lot-sizing techniques, moderate)

24. The economic part period is a fraction of a time bucket.
False (Lot-sizing techniques, easy)

25. The Wagner-Whitin algorithm is the most widely used MRP lot-sizing technique.
False (Lot-sizing techniques, moderate)

26. MRP can be effective only if very accurate lot sizes are calculated in advance.
False (Lot-sizing techniques, easy)

27. Smoothing a resource requirements profile to stay within capacity limits may increase setup costs.
True (Extensions of MRP, moderate)

28. Closed-loop MRP systems allow production planners to move work between time periods to smooth the load or to at least bring it within capacity.
True (Extensions of MRP, moderate)

29. Operations splitting sends pieces to the next operation before the entire lot is completed on the previous operation.
False (Extensions of MRP, moderate)

30. When safety stock is deemed absolutely necessary, the usual policy is to build it into the projected on-hand inventory of the MRP logic.
True (MRP structure, moderate)

31. By convention, the top level in a bill of material is designated level 1.
False (Dependent inventory model requirements, moderate)

32. DRP is a time-phased stock-replenishment plan for all levels of a distribution network.
True (MRP in services, moderate)

33. While ERP may provide a strategic advantage over competitors, it is so complex that many companies cannot adjust to it.
True (Enterprise resource planning (ERP), moderate)

34. Firms may discover that, rather than adapting ERP to the way they do business, they have to adapt the way they do business to accommodate the ERP software.
True (Enterprise resource planning, moderate)

35. The supply chain systems that result from using ERP in the grocery industry are called efficient consumer response (ECR) systems.
True (Enterprise resource planning (ERP), easy)

MULTIPLE CHOICE

36. Which of the following statements regarding Wheeled Coach is **false**?
    a. Wheeled Coach has found competitive advantage through MRP.
    b. Wheeled Coach builds ambulances in a repetitive process.
    c. Wheeled Coach's MRP system allowed the company to meet tight schedules, but caused inventory to rise.
    d. Wheeled Coach's MRP system maintains excellent record integrity.
    e. Low inventory and high quality are two positive outcomes of Wheeled Coach's use of MRP.
    c (Global company profile, easy)

37. Demand for a given item is said to be dependent if
    a. it originates from the external customer
    b. there is a deep bill of material
    c. the finished products are mostly services (rather than goods)
    d. there is a clearly identifiable parent
    e. the item has several children
    d (Dependent demand, easy)

38. The phrase "demand related to the demand for other products" describes
    a. a dependent variable
    b. dependent demand
    c. recursive demand
    d. regression analysis
    e. independent demand
    b (Dependent demand, easy)

39. Dependent demand and independent demand items differ in that
    a. for any product, all components are dependent-demand items
    b. the need for independent-demand items is forecast
    c. the need for dependent-demand items is calculated
    d. All of the above are true.
    e. None of the above is true.
    d (Dependent demand, moderate)

40. A master production schedule specifies
    a. the raw materials required to complete the product
    b. what component is to be made, and when
    c. what product is to be made, and when
    d. the labor hours required for production
    e. the financial resources required for production
    c (Dependent inventory model requirements, moderate)

41. The _____ is (are) the MRP input detailing which end items are to be produced, when they are needed, and in what quantities.
    a. master production schedule
    b. gross requirements
    c. inventory records
    d. assembly time chart
    e. bill of material
    a (Dependent inventory model requirements, moderate)

42. A master production schedule contains information about
    a. quantities and required delivery dates of all subassemblies
    b. quantities and required delivery dates of final products
    c. inventory on hand for each subassembly
    d. inventory on hand for each final product
    e. scheduled receipts for each final product
    b (Dependent inventory model requirements, moderate)

43. The aggregate plan gets input or feedback from which of the following areas?
    a. engineering
    b. finance, marketing, and human resources
    c. the master production schedule
    d. procurement, production, and general management
    e. all of the above
    e (Dependent inventory model requirements, easy)

44. In continuous (make-to-stock) operations, the master production schedule is usually expressed in terms of
    a. end items
    b. modules
    c. kits
    d. customer orders
    e. warehouse orders
    a (Dependent inventory model requirements, moderate)

45. In job shop (make-to-order) operations, the master production schedule is usually expressed in
    a. end items
    b. modules
    c. kits
    d. customer orders
    e. warehouse orders
    d (Dependent inventory model requirements, moderate)

46. The following table is an example of a(n)

	Week 1	Week 2	Week 3	Week 4	Week 5
Clothes Washer		200		100	
Clothes Dryer	300	100	100		100
Upright Freezer			200	500	

    a. aggregate plan
    b. load report
    c. master production schedule
    d. capacity plan
    e. inventory record
    c (Dependent inventory model requirements, moderate)

47. A document calls for the production of 50 small garden tractors in week 1; 50 small garden tractors and 100 riding mowers in week 2; 100 riding mowers and 200 garden utility carts in week 3; and 100 riding mowers in week 4. This document is most likely a(n)
    a. net requirements document
    b. resource requirements profile
    c. aggregate plan
    d. master production schedule
    e. Wagner-Whitin finite capacity document
    d (Dependent inventory model requirements, moderate)

48. The _____ is the input to material requirements planning which lists the assemblies, subassemblies, parts, and raw materials needed to produce one unit of finished product.
    a. bill of material
    b. master production schedule
    c. inventory records
    d. assembly time chart
    e. net requirements chart
    a (Dependent inventory model requirements, moderate)

49. A bill of material lists the
    a. times needed to perform all phases of production
    b. production schedules for all products
    c. components, ingredients, and materials required to produce an item
    d. operations required to produce an item
    e. components, ingredients, materials, and assembly operations required to produce an item
    c (Dependent inventory model requirements, moderate)

50. Firms making many different final products use _____ to facilitate production scheduling.
    a. planning bills
    b. modular bills
    c. phantom bills
    d. overdue bills
    e. none of the above
    b (Dependent inventory model requirements, moderate)

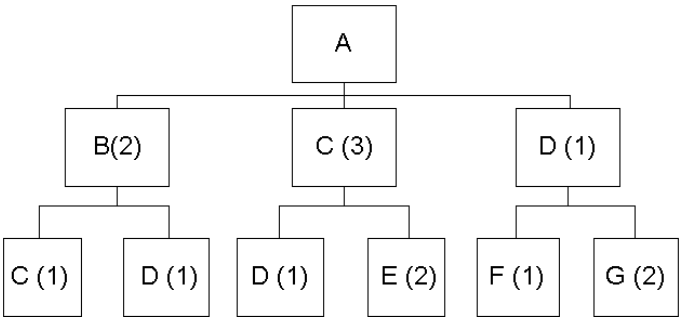
51. A bill of material must be updated with the corrected dimensions of a part. The document that details this change is a(n)
    a. modular bill
    b. engineering change notice
    c. resource requirements profile
    d. lead time-offset product structure document
    e. planning bill
    b (Dependent inventory model requirements, easy)

52. The bill of material contains information necessary to
    a. place an order to replenish the item
    b. calculate quantities on hand and on order
    c. convert net requirements into higher level gross requirements
    d. convert gross requirements into net requirements
    e. convert (explode) net requirements at one level into gross requirements at the next level
    e (Dependent inventory model requirements, moderate)

53. Which of the following statements best compares modular bills and phantom bills?
    a. Both pertain to assemblies that are not inventoried.
    b. There is no difference between the two.
    c. Both pertain to assemblies that are inventoried.
    d. Modular bills are used for assemblies that are not inventoried, unlike phantom bills.
    e. Modular bills represent subassemblies that actually exist and are inventoried, while phantom bills represent subassemblies that exist only temporarily and are not inventoried.
    e (Dependent inventory model requirements, moderate)

54. The minimum record accuracy required for successful MRP is approximately
    a. lower than 90%
    b. 90%
    c. 95%
    d. 97%
    e. 99%
    e (Dependent inventory model requirements, moderate)

55. Given the following bill of material

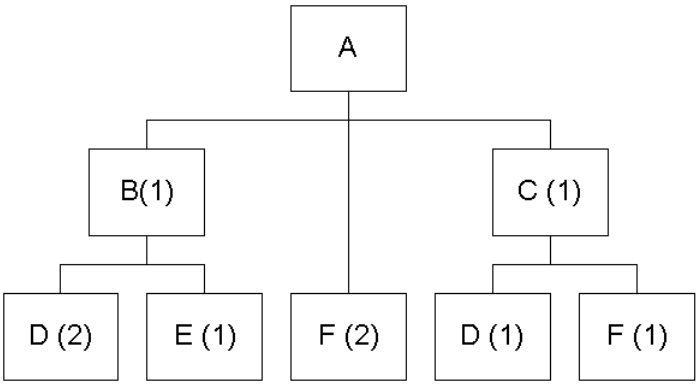


If the demand for product A is 50 units, what will be the gross requirement for component E?

a. 4
b. 100
c. 200
d. 250
e. 300

e (Dependent inventory model requirements, moderate) {AACSB: Analytic Skills}

56. Given the following bill of material



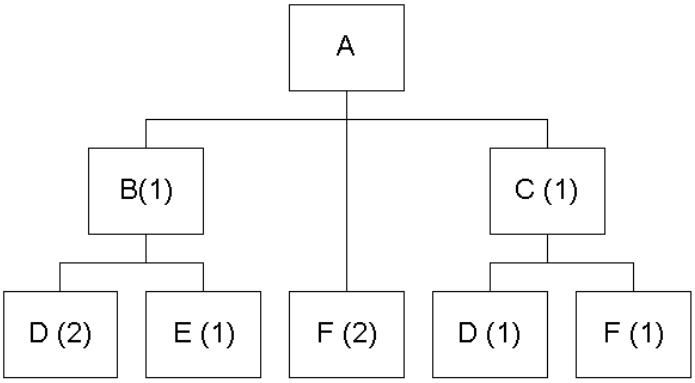
If the demand for product A is 50 units, what will be the gross requirement for component E?

a. 50
b. 100
c. 150
d. 200
e. 300

a (Dependent inventory model requirements, moderate) {AACSB: Analytic Skills}

57. When safety stock is deemed absolutely necessary, the usual policy is to build it into which category of the MRP logic?
    a. Gross Requirements
    b. Scheduled Receipts
    c. Projected On Hand
    d. Net Requirements
    e. Planned Order Receipts
    c (MRP structure, moderate)

58. Given the following bill of material



    If the demand for product A is 30 units, and there are 10 units of B on hand and none of C, how many units of part D will be needed?
    a. 3
    b. 40
    c. 70
    d. 90
    e. 110
    c (Dependent inventory model requirements, difficult) {AACSB: Analytic Skills}

59. Low level coding means that
    a. a final item has only a few levels in the BOM structure
    b. it is the code for the lowest level in the BOM structure
    c. a component item is coded at the lowest level at which it appears in the BOM structure
    d. the top level of the BOM is below level zero and that BOMs are not organized around the finished product
    e. none of the above
    c (Dependent inventory model requirements, moderate)

60. Each X requires 2 of component Y; each Y requires 4 of part Z. The lead time for assembly of X is 1 week. The lead time for the manufacture of Y is 1 week. The lead time for the procurement of Z is 6 weeks. The cumulative lead time for X is _____ weeks.
    a. 6
    b. 7
    c. 8
    d. 10
    e. cannot be determined
    c (MRP structure, moderate) {AACSB: Analytic Skills}

61. A material requirements plan contains information with regard to all of the following **except**
    a. quantities and required delivery dates of all subassemblies
    b. quantities and required delivery dates of final products
    c. the capacity needed to provide the projected output rate
    d. inventory on hand for each final product
    e. inventory on hand for each subassembly
    c (MRP structure, moderate)

62. Each R requires 2 of component S and 1 of part T. The lead time for assembly of R is 3 days. The lead time for the manufacture of S is 5 days. The lead time for the manufacture of T is 10 days. The cumulative lead time for R is _____ days.
    a. 6
    b. 9
    c. 13
    d. 17
    e. cannot be determined
    c (MRP structure, moderate) {AACSB: Analytic Skills}

63. Each R requires 4 of component S; each S requires 3 of part T. The lead time for assembly of R is 1 week. The lead time for the manufacture of S is 2 weeks. The lead time for the procurement of T is 6 weeks. The cumulative lead time for R is _____ weeks.
    a. 6
    b. 9
    c. 12
    d. 18
    e. 28
    b (MRP structure, moderate) {AACSB: Analytic Skills}

64. Which of the following best describes a gross material requirements plan?
    a. a schedule that shows total demand for an item, and when it must be ordered from a supplier or when production must be started
    b. an intermediate range plan for the scheduling of families of products
    c. a chart illustrating whether capacity has been exceeded
    d. a table that corrects scheduled quantities for inventory on hand
    e. a schedule showing which products are to be manufactured and in what quantities
    a (MRP structure, moderate)

65. Which of the following statements regarding the gross material requirements plan is **true**?
    a. It shows total demand for an item.
    b. It shows when an item must be ordered from a supplier or when production must be started.
    c. It combines a master production schedule with the time-phased schedule.
    d. It requires several inputs, including an accurate bill of material.
    e. All of the above are true.
    e (MRP structure, moderate)

66. The MPS calls for 110 units of Product M. There are currently 30 of Product M on hand. Each M requires 4 of Component N. There are 20 units of N on hand. The net requirements for N are
    a. 150
    b. 170
    c. 300
    d. 320
    e. 440
    c (MRP structure, moderate) {AACSB: Analytic Skills}

67. The MPS calls for 50 units of Product A and 60 of B. There are currently 25 of Product B on hand. Each A requires 2 of Part C; each B requires 5 of C. There are 160 units of C available. The net requirements for C are
    a. 115
    b. 175
    c. 240
    d. 690
    e. 700
    a (MRP structure, difficult) {AACSB: Analytic Skills}

68. The MPS calls for 110 units of Product A. There are currently 60 of Product A on hand. Each A requires 4 of Part B. There are 20 units of B available. The net requirements for B are
    a. 20
    b. 120
    c. 180
    d. 240
    e. 440
    c (MRP structure, moderate) {AACSB: Analytic Skills}

69. In MRP record calculations, the appearance of a negative value for the gross requirements of an end item in a specific time bucket
    a. signals the need to purchase that end item in that period
    b. implies that value was scheduled by the MPS
    c. signals the need for a negative planned order receipt in that period
    d. is impossible
    e. All of the above are true.
    d (MRP structure, moderate)

70. The number of units projected to be available at the end of each time period refers to
    a. net requirements
    b. scheduled receipts
    c. the projected usage of the item
    d. the amount projected to be on hand
    e. the amount necessary to cover a shortage
    d (MRP structure, moderate)

71. Linking a part requirement with the parent component that caused the requirement is referred to as
    a. net requirements planning
    b. a time fence
    c. pegging
    d. kanban
    e. leveling
    c (MRP management, moderate)

72. In MRP, system nervousness is caused by
    a. management's attempt to continually respond to minor changes in production requirements
    b. the use of the lot-for-lot approach
    c. management's marking part of the master production schedule as "not to be rescheduled"
    d. the use of phantom bills of material
    e. management's attempt to evaluate alternative plans before making a decision
    a (MRP management, moderate)

73. One of the tools that is particularly useful in reducing the system nervousness in the MRP system is (are)
    a. modular bills
    b. time phasing
    c. time fences
    d. lot sizing
    e. closed loop system
    c (MRP management, moderate)

74. Distortion in MRP systems can be minimized when safety stock is held at the
    a. purchased component or raw material level
    b. work-in-process level
    c. finished goods level
    d. a and b
    e. a and c
    e (MRP structure, difficult)

75. Material requirements plans specify
    a. the quantities of the product families that need to be produced
    b. the quantity and timing of planned order releases
    c. the capacity needed to provide the projected output rate
    d. the costs associated with alternative plans
    e. whether one should use phantom bills of material or not
    b (MRP structure, moderate)

76. Which of the following best differentiates material requirements planning (MRP) from finite capacity scheduling (FCS)?
    a. FCS recognizes the finite nature of capacity while MRP does not.
    b. FCS works in services while MRP does not.
    c. MRP requires time buckets while FCS does not.
    d. FCS is an input into traditional MRP systems.
    e. FCS uses the Wagner-Whitin algorithm while MRP uses lot-for-lot and EOQ.
    a (MRP management, moderate)

77. Which of the following lot-sizing techniques results in the lowest holding costs?
    a. lot-for-lot
    b. EOQ
    c. part-period balancing
    d. Wagner-Whitin algorithm
    e. the quantity discount model
    a (Lot-sizing techniques, moderate)

78. Which of the following statements is **true** about the MRP plan when using lot-for-lot ordering?
    a. The quantity of gross requirements for a child item is always equal to the quantity of planned order releases for its parent.
    b. The quantity of gross requirements for a child item is equal to the quantity of planned order release(s) multiplied by the number of child items used in the parent assembly.
    c. The quantity of gross requirements for a child item is always equal to the quantity of gross requirements for its parent.
    d. The quantity and gross requirements for a child item is always equal to the quantity of net requirements for its parent.
    e. All of the above are true.
    b (MRP structure, moderate)

79. What lot-sizing technique is generally preferred when inventory holding costs are extremely high?
    a. lot-for-lot
    b. EOQ
    c. part-period balancing
    d. the Wagner-Whitin algorithm
    e. All of the above are appropriate for the situation.
    a (Lot-sizing techniques, moderate)

80. For the lot-sizing technique known as lot-for-lot to be appropriate
    a. future demand should be known for several weeks
    b. setup cost should be relatively small
    c. annual volume should be rather low
    d. item unit cost should be relatively small
    e. the independent demand rate should be very stable
    b (Lot-sizing techniques, moderate)

81. An item's holding cost is 60 cents per week. Each setup costs $120. Lead time is 2 weeks. EPP is
    a. .005
    b. 60
    c. 72
    d. 100
    e. 200
    e (Lot-sizing techniques, moderate) {AACSB: Analytic Skills}

82. Which of the following statements regarding lot-sizing is **true**?
    a. EOQ principles should be followed whenever economical.
    b. Too much concern with lot-sizing results in false accuracy.
    c. Lot-for-lot cannot be modified for scrap allowance or process constraints.
    d. The Wagner-Whitin algorithm simplifies lot size calculations.
    e. All of the above are true.
    b (Lot-sizing techniques, moderate)

83. A firm makes numerous models of mowers, garden tractors, and gasoline powered utility vehicles. Some assemblies and parts are common to many end items. To relieve the MPS of performing order releases on these common parts, the firm might choose to use the _____ technique.
    a. Wagner-Whitin
    b. economic part period
    c. supermarket
    d. gross material requirements
    e. resource requirements profile
    c (MRP management, moderate)

84. Capacity planning in closed-loop MRP
    a. utilizes feedback about workload from each work center
    b. may make use of resource requirements profiles (load reports)
    c. may smooth work center loads with such tactics as overlapping and lot splitting
    d. does not add capacity, but rather seeks effective use of existing capacity
    e. All of the above are true.
    e (Extensions of MRP, moderate)

85. If a load report (resource requirements profile) shows a work center scheduled beyond capacity
    a. the company must add capacity by enlarging the facility
    b. the company must add capacity by such tactics as overtime and subcontracting
    c. the work center's load may be smoothed by such tactics as operations splitting or lot splitting
    d. the aggregate plan must be revised
    e. the Wagner-Whitin algorithm should be used to rebalance the load
    c (Extensions of MRP, moderate)

86. MRP II is accurately described as
    a. MRP software designed for services
    b. MRP with a new set of computer programs that execute on microcomputers
    c. MRP augmented by other resource variables
    d. an enhancement of MRP that plans for all levels of the supply chain
    e. a new generation of MRP software that extends MRP to planning and scheduling functions
    c (Extensions of MRP, moderate)

87. The extension of MRP which extends to resources such as labor hours and machine hours, as well as to order entry, purchasing, and direct interface with customers and suppliers is
    a. MRP II
    b. enterprise resource planning
    c. the master production schedule
    d. closed-loop MRP
    e. not yet technically possible
    b (Extensions of MRP, moderate)

88. Which of the following statements regarding MRP in services is **true**?
    a. MRP is for manufacturing only, and is not applicable to services.
    b. MRP can be used in services, but only those that offer very limited customization.
    c. MRP does not work in services because there is no dependent demand.
    d. Services such as restaurant meals illustrate dependent demand, and require product structure trees, bills-of-material, and scheduling.
    e. None of the above is true.
    d (MRP in services, moderate)

89. Distribution resource planning (DRP) is
    a. a transportation plan to ship materials to warehouses
    b. a time-phased stock replenishment plan for all levels of a distribution network
    c. a shipping plan from a central warehouse to retail warehouses
    d. material requirements planning with feedback loop from distribution centers
    e. a material requirements planning package used exclusively by warehouses
    b (MRP in services, moderate)

90. By convention, the top level in a bill of material is
    a. level 0
    b. level 1
    c. level T
    d. level 10
    e. level 100
    a (Dependent inventory model requirements, moderate)

91. Enterprise resource planning (ERP)
    a. seldom requires software upgrade or enhancement
    b. does not integrate well with functional areas other than operations
    c. is inexpensive to implement
    d. automates and integrates the majority of business processes
    e. all of the above
    d (Enterprise resource planning (ERP), moderate)

92. Enterprise resource planning (ERP)
    a. has been made possible because of advances in hardware and software
    b. uses client/server networks
    c. creates commonality of databases
    d. uses business application-programming interfaces (BAPI) to access their database
    e. All of the above are true of ERP.
    e (Enterprise resource planning (ERP), moderate) {AACSB: Use of IT}

93. Which of the following is **false** concerning enterprise resource planning (ERP)?
    a. It attempts to automate and integrate the majority of business processes.
    b. It shares common data and practices across the enterprise.
    c. It is inexpensive to implement.
    d. It provides and accesses information in a real-time environment.
    e. All of the above are true.
    c (Enterprise resource planning (ERP), moderate)

94. Which of the following regarding enterprise resource planning (ERP) is **true**?
    a. It involves an ongoing process for implementation.
    b. It can incorporate improved, reengineered "best processes."
    c. It has a software database that is off-the-shelf coding.
    d. ERP systems usually include MRP, financial and human resource information.
    e. All of the above are true.
    e (Enterprise resource planning (ERP), moderate)

95. All of the following are advantages of enterprise resource planning (ERP) **except** it
    a. creates commonality of databases
    b. increases communications and collaboration worldwide
    c. helps integrate multiple sites and business units
    d. requires major changes in the company and its processes to implement
    e. can provide a strategic advantage over competitors
    d (Enterprise resource planning (ERP), moderate) {AACSB: Communication}

FILL-IN-THE BLANK

96. Wheeled Coach uses _____ as the catalyst for low inventory, high quality, tight schedules, and accurate records.
    material requirements planning or MRP (Global company profile, easy)

97. _____ is a dependent demand technique that uses a bill of material, inventory, expected receipts, and a master production schedule to determine material requirements.
    Material requirements planning or MRP (Dependent demand, easy)

98. A(n) _____ is a timetable that specifies what is to be made and when.
    master production schedule or MPS (Dependent inventory model requirements, easy)

99. A(n) _____ is a listing of the components, their description, and the quantity of each required to make one unit of a product.
    bill of material or BOM (Dependent inventory model requirements, moderate)

100. A process focus facility (for example, a print shop) will likely schedule _____ as the focus of its master production schedule.
     orders (Dependent inventory model requirements, easy)

101. Bills of material organized by major subassemblies or by product options are called _____.
     modular bills (Dependent inventory model requirements, moderate)

102. The _____ is used to correct an erroneous dimension, quantity, or other specification in a bill of material.
engineering change notice (Dependent inventory model requirements, easy)

103. _____ is a bill of material for components, usually assemblies that exist only temporarily; they are never inventoried.
Phantom bill of material (Dependent inventory model requirements, moderate)

104. _____ are the result of adjusting gross requirements for inventory on hand and scheduled receipts.
Net material requirements (MRP structure, moderate)

105. _____ are a way of allowing a segment of the master schedule to be designated as "not to be rescheduled."
Time fences (MRP management, moderate)

106. _____, unlike MRP, recognizes that departments and machines have limitations on their capacity that must be observed if the schedule is to be realistic.
Finite capacity scheduling or FCS (MRP management, easy)

107. _____ refers to the time units in a material requirements planning (MRP) system.
Buckets (MRP management, easy)

108. _____ is a lot-sizing technique that generates exactly what was required to meet the plan.
Lot-for-lot (Lot-sizing techniques, moderate)

109. The _____ technique may be applicable where a firm's parts and subassemblies are common to a variety of its products.
supermarket (MRP management, easy)

110. A(n) _____ provides feedback to the capacity plan, master production schedule, and production plan so planning can be kept valid at all times.
closed-loop MRP system (Extensions of MRP, moderate)

111. A(n) _____ can illustrate whether a work center has been scheduled beyond its capacity.
load report or resource requirement profile (Extensions of MRP, easy)

112. _____ is a system that allows, with MRP in place, inventory data to be augmented by other resource variables.
Material requirements planning II or material resource planning or MRP II (Extensions of MRP, moderate)

113. A(n) _____ system is packaged business software that automates and integrates the majority of their business processes, shares common data and practices across the entire enterprise, and produces and accesses information in a real-time environment.
enterprise resource planning or ERP (Enterprise Resource Planning (ERP), moderate) {AACSB: Use of IT}

SHORT ANSWERS

114. Describe the role of record accuracy in Wheeled Coach's successful use of MRP. Is this company's experience the exception or the rule? Answer in a well-developed paragraph.
Wheeled Coach's record integrity is excellent. They have accurate bills of material and of inventory; they use cycle counters for material audits and error detection. Record accuracy is recognized as a fundamental ingredient of successful MRP implementation. Thus Wheeled Coach's excellent record integrity is expected; they would not have successful use of MRP without it. (Global company profile, easy)

115. What is MRP? Identify four benefits from its use.
MRP or material requirements planning is a dependent demand technique that uses a bill of material, inventory expected receipts, and a master production schedule to determine material requirements. The benefits of MRP include better response to customer orders, faster response to market changes, improved utilization of facilities and labor, and reduced inventory levels. (Introduction and Dependent demand, easy)

116. How does the process choice of an organization affect the basis of its master production schedule?
In a continuous focus (make-to-stock) company, the MPS will likely be expressed in end items; in a process focus (make-to-order) company, customer orders will likely be the basis of the MPS; and in a repetitive process (assemble-to-stock) company, the basis will be its modules. (Dependent inventory model requirements, moderate)

117. If the explosion of the bill of material tells MRP **how much** of each part is needed, how does MRP learn **when** each of these parts is needed?
Timing is established with the time-phased product structure, which factors item quantities with item lead times. The lead times are cumulative, in the sense that the lead time for a child part is the sum of its lead time and that of all of its parent components. (Dependent inventory model requirements, moderate)

118. Explain the difference between a gross requirements plan and a net requirements plan.
A gross requirements plan multiplies each part quantity in the bill of material by the number of top level parents needed. This ignores any inventory on hand, whether of parents or children. A net requirements plan starts with the top level requirements from the bill of material, then subtracts inventory of that item on hand. This net requirement becomes the gross requirement to the next level of the product structure. (MRP structure, easy)

119. Describe briefly the information requirements of basic and extended MRP systems. Comment on the challenge of maintaining timely, accurate information for a large manufacturing operation based on MRP.
MRP requires very high accuracy of inventory data file. MRP needs inputs from the master production schedule, bills of material, inventory records, and expected receipts. As MRP is extended to MRP II and ERP, the information needs are intensified. (MRP structure and Extensions of MRP, moderate)

120. What information is necessary for an operations manager to make effective use of a dependent inventory demand model?
The information necessary for an operations manager to make effective use of a dependent inventory demand model are the master production schedule (what is to be made, and when); specifications or bills of material (how to make the product); inventory availability (what is in stock); purchase orders outstanding (what is on order); and lead times (how long does it take to get or make each component). (MRP structure, moderate)

121. A working MRP system allows a firm to react to even minor changes in production requirements. Discuss both the advantages and disadvantages of having such ability.
The advantages are it allows the firm to react quickly and, conceivably, to minimize costs. The disadvantages are the reaction to a large number of minor changes may introduce instability (nervousness) into the purchasing and production departments. (MRP structure, moderate)

122. An error has been detected in the technical drawing of a product about to be placed on a master production schedule. The part should be 9" by 12", not 9 cm by 12 cm; further, the part should be stainless steel, not ordinary steel. What document transmits the needed change? Where is the corrected information recorded? Why is this important to the master production schedule?
An engineering change notice or ECN is the document that corrects the error; the correction is made on the bill of material for that product. Accurate records are a necessity for successful use of MRP. In this case, the wrong part would be made or purchased, then sent to assembly. The product could not be correctly made, the schedule could not be met, and the customer's order could not be delivered. (Dependent inventory model requirements, moderate)

123. What are time fences? Why are they used?
Time fences allow a segment of the master schedule to be designated as "not to be rescheduled." They are used to reduce system nervousness in MRP environments. (MRP management, moderate)

124. Explain what is meant by "nervousness" of the MRP schedule. Provide an example. Name two tools that are particularly useful in reducing system nervousness in MRP systems.
Nervousness is the reaction to a large number of minor changes that may introduce instability into the purchasing and production departments. Two tools for reducing system nervousness are time fences and pegging. (MRP management, moderate)

125. Describe finite capacity scheduling. How is it more realistic than MRP?
FCS provides the precise scheduling needed for rapid material movement. MRP schedules work without regard to capacity. Finite capacity scheduling factors department and machine capacity into its scheduling, and is thus more realistic than MRP. (MRP and JIT, easy)

126. What is the "supermarket" as it is used in MRP? How does it alter the responsibility for dealing with lead-time offsets?
The supermarket concept applies when parts and assemblies are common to various end items. These items are inventoried in the supermarket so that the master production scheduler does not issue order releases for them. These parts can simply be picked up, and have no lead time. Maintaining the supermarket is done through kanban methods, not MRP. (MRP management, moderate)

127. You have seen several methods for lot sizing in MRP. Why is lot sizing important in MRP? Can too much concern be given lot sizing? Answer in a well-developed paragraph.
Lot sizing is important because, at the very least, it impacts costs. But too much attention can be paid to lot sizing, which can result in false accuracy. Also, several lot-sizing methods may all produce satisfactory results. Finally, proper lot size is often not possible to determine until after actual requirements are known. (Lot-sizing techniques, moderate)

128. What does the part-period balancing lot-sizing technique attempt to do in deciding the lot sizes?
It balances the setup and holding costs. PPB uses additional information by changing the lot size to reflect requirements of the next lot size in the future. (Lot-sizing techniques, moderate)

129. Describe how MRP II differs from MRP.
MRP II is MRP in which inventory data are augmented by labor hours, material cost, capital cost, or by virtually any resource. (Extensions of MRP, moderate)

130. How can MRP and JIT be effectively integrated?
One approach is the small bucket approach that involves the following steps:
1. Reduce the MRP buckets from weekly to daily to perhaps hourly.
2. The planned receipts that are part of a firm's planned orders in an MRP system are communicated to the work areas and are used to sequence production.
3. Inventory is moved through the plant on a JIT basis.
4. As products are completed, they are moved into inventory in the normal way.
5. A back flush is used to reduce inventory balances.
Another approach is the balanced flow. In this system, execution is achieved by maintaining a carefully balanced flow of materials to assembly areas with small lot sizes.
(MRP management, difficult)

131. Identify the several lot-sizing algorithms used in MRP. Provide at least one advantage and one disadvantage of each.

Algorithm	Advantage	Disadvantage
Lot-for-lot	no inventory; use whenever economical	expensive when setup costs are significant
Wagner-Whitin	good results	complexity
Part period balancing	Lot size varies with needs; good when setup cost is significant	not always optimal
Economic order quantity (EOQ)	use when the demand is constant and setup costs are high	lot size fixed; incurs holding costs; works best with independent demand

(Lot-sizing techniques, moderate)

132. Describe the tactics for load smoothing in MRP.
Overlapping - send pieces to the second operation before the entire lot is completed on the first operation; operations splitting - send the lot to two different machines for the same operation; and lot splitting - break up the order and run part of it ahead of schedule. (Extensions of MRP, moderate)

133. What do we mean by closed-loop MRP?
Closed-loop MRP indicates that (a) there is both a planning and execution phase, and (b) information from the execution phase is fed back to the planning phase. Once planning is complete, an attempt is made to execute the "planned" schedule. Information is fed back from the execution of this schedule to the planning phase so the plans can be modified as necessary. (Extensions of MRP, moderate)

134. What types of resources might be scheduled via an MRP II system?
Virtually all resources can be evaluated via MRP II. This includes material, labor, cash, and facilities. (Extensions of MRP, moderate)

135. What is DRP?
DRP is a time-phased stock replenishment plan for all levels of a distribution network. (MRP in services, moderate)

136. Compare MRP in services to MRP in manufacturing. Utilize a simple example in your comparison.
Services can exhibit dependent demand, just like parts and assemblies in manufacturing. Such services can require product structure trees, bills of material, bills of labor, and scheduling. These are the same features that make MRP attractive to manufacturers. Examples will vary, but here is a sample drawn from food service. One can construct a product structure tree and bill of material for a restaurant meal; lead time offsets are vital; otherwise the elements of the meal would not be served in the right order or at the proper temperature. (MRP in services, moderate)

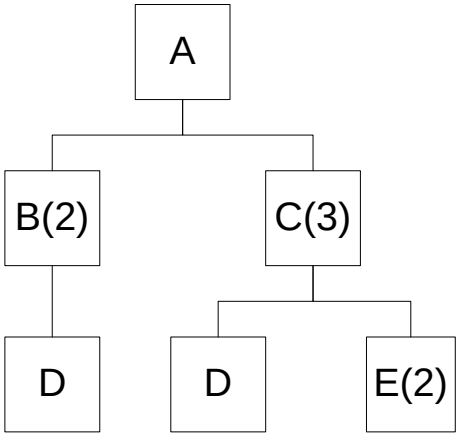
137. What does enterprise resource planning (ERP) allow an organization to do?
It allows them to automate and integrate the majority of their business processes, to share common data and practices across the entire enterprise, and to produce and access information in a real-time environment. (Enterprise resource planning (ERP), moderate) {AACSB: Use of IT}

138. What are the advantages of enterprise resource planning (ERP)?
ERP provides integration of the supply chain, production, and administrative processes; creates commonality of databases; incorporates improved, redesigned, or "best" practices; increases communication and collaboration worldwide; helps integrate multiple sites and business units; comes with software core that is off-the-shelf coding; and provides a strategic advantage over competitors. (Enterprise resource planning (ERP), moderate) {AACSB: Use of IT}

139. What are the disadvantages of enterprise resource planning (ERP)?
ERP is very expensive to purchase, and even more costly to customize; requires major changes in the company and processes to implement; is such a complex program that many companies cannot adjust to it; involves an ongoing process for implementation, often never completed; and expertise in ERP is limited, with staffing an ongoing problem. (Enterprise resource planning (ERP), moderate) {AACSB: Use of IT}

PROBLEMS

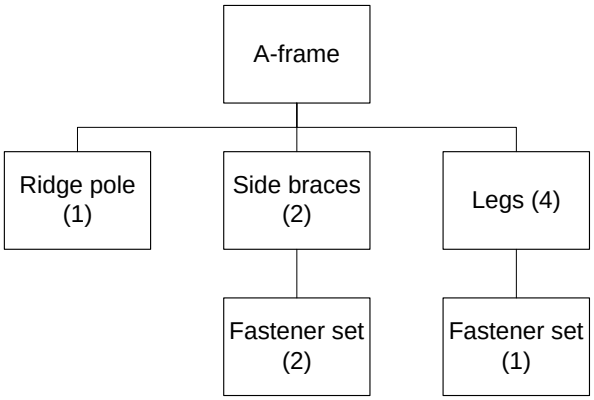
140. Consider the following bill of material. Fifty units of Product A are needed. Assuming no on-hand inventory, and no scheduled receipts, explode the bill of material.



Item A: 50 units; Item B: 50 * 2 = 100 units; Item C: (50 * 3) = 150 units; Item D: (50 * 2 * 1) + (50 * 3 * 1) = 250 units; Item E: (50 *3 * 2) = 300 units.
(MRP structure, moderate) {AACSB: Analytic Skills}

141. The large parts of a playground A-frame (from which to hang a swing or glider) consist of a ridge pole, four legs, and two side braces. Each pair of legs fastens to the ridge with one fastener set. Each side brace requires two fastener sets for attachment to the legs. Each fastener set includes one zinc-plated bolt, one lock-washer, and one nut.

There is one order outstanding, to make 80 frame kits. There are 200 legs in inventory. There are no other large items in inventory, and no scheduled receipts. Fasteners are available from the small parts area.
a. Draw the product structure tree
b. Calculate the net requirements to fulfill the outstanding order.
Solution:



Part	GR	OH	NR
A-frame	**80**		**80**
Ridge pole	**80**		**80**
Side braces	**160**		**160**
Legs	**320**	**200**	**120**
Fastener set	**440**		**440**

(MRP structure, easy) {AACSB: Analytic Skills}

142. A very simple product (A) consists of a base (B) and a casting (C). The base consists of a plate (P) and three fasteners (F). There are currently 30 castings and 100 bases on hand. Final assembly takes one week. The casting has a lead time of three weeks. All other parts have one week lead times. There are no scheduled receipts. All components are lot for lot. The MPS requires 80 units of product A in week 5 and 120 in week 8. Produce the MRP for the upcoming eight weeks. Produce a list of all planned order releases.

Indented Bill of Material

Item name	Level	Number per parent	Indented BOM
A	0	1	A
B	1	1	B
P	2	1	P
F	2	3	F
C	1	1	C
Distinct items		5	

A		Lead time	1	Safety Stock	0	Lot size	1	Minimum quantity	0
	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Gross requirements		0	0	0	0	80	0	0	120
Scheduled receipts									
On Hand Inventory		0	0	0	0	0	0	0	0
NET POQ Req		0	0	0	0	80	0	0	120
Planned receipts		0	0	0	0	80	0	0	120
Planned orders		0	0	0	80	0	0	120	0

B		Lead time	1	Safety Stock	0	Lot size	1	Minimum quantity	0
	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Gross requirements		0	0	0	80	0	0	120	0
Scheduled receipts									
On Hand Inventory	100	100	100	100	100	20	20	20	0
NET POQ Req		0	0	0	0	0	0	100	0
Planned receipts		0	0	0	0	0	0	100	0
Planned orders		0	0	0	0	0	100	0	0

C		Lead time	3	Safety Stock	0	Lot size	1	Minimum quantity	0
	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Gross requirements		0	0	0	80	0	0	120	0
Scheduled receipts									
On Hand Inventory	30	30	30	30	30	0	0	0	0
NET POQ Req		0	0	0	50	0	0	120	0
Planned receipts		0	0	0	50	0	0	120	0
Planned orders		50	0	0	120	0	0	0	0

P		Lead time	1	Safety Stock	0	Lot size	1	Minimum quantity	0
	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Gross requirements		0	0	0	0	0	100	0	0
Scheduled receipts									
On Hand Inventory		0	0	0	0	0	0	0	0
NET POQ Req		0	0	0	0	0	100	0	0
Planned receipts		0	0	0	0	0	100	0	0
Planned orders		0	0	0	0	100	0	0	0

F		Lead time	1	Safety Stock	0	Lot size	1	Minimum quantity	0
	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Gross requirements		0	0	0	0	0	300	0	0
Scheduled receipts									
On Hand Inventory		0	0	0	0	0	0	0	0
NET POQ Req		0	0	0	0	0	300	0	0
Planned receipts		0	0	0	0	0	300	0	0
Planned orders		0	0	0	0	300	0	0	0

(MRP structure, moderate) {AACSB: Analytic Skills}

143. Consider the following requirements for a certain product.

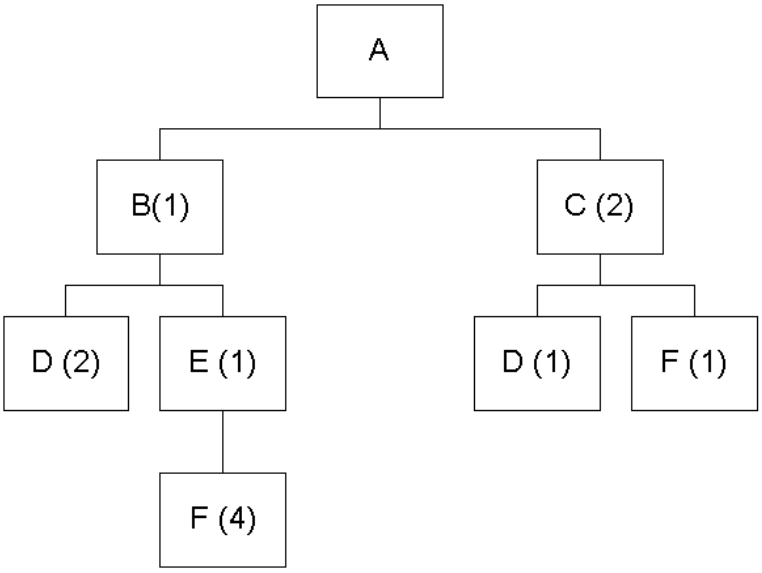
Period	1	2	3	4	5	6	7	8
Gross requirements	0	200	200	500	0	400	0	400

Beginning inventory = 500 units
Setup cost = $500 per setup
Lead time = 1 week
Holding cost = $3 per unit per week
a. Develop the lot-for-lot MRP table.
b. Calculate the total relevant cost.
There are three setups at $500 each, totaling $1,500. There are 500 units held in period 1 and 2, and 300 in period 3. The holding costs are 1300 units x $3 per unit, for a total of $3,900. Total relevant costs are $5,400.

A		Lead time	1	Safety Stock	0	Lot size	1	Minimum quantity	0
	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Gross requirements		0	200	200	500	0	400	0	400
Scheduled receipts									
On Hand Inventory	500	500	500	300	100	0	0	0	0
NET POQ Req		0	0	0	400	0	400	0	400
Planned receipts		0	0	0	400	0	400	0	400
Planned orders		0	0	400	0	400	0	400	0

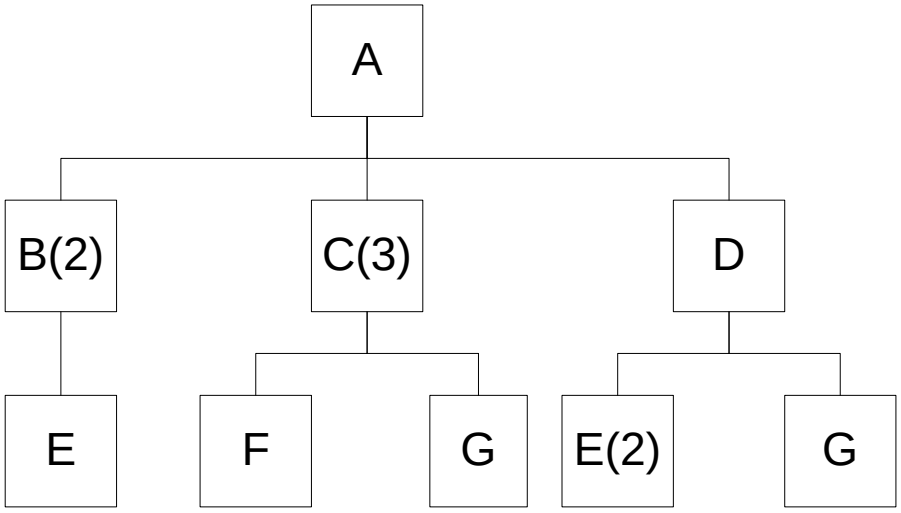
(Lot-sizing techniques, easy) {AACSB: Analytic Skills}

144. Consider the following bill of material. Fifty units of Product A are needed. Assuming no on-hand inventory, explode the bill of material.



Item A: 50 units; Item B: 50 * 1 = 50 units; Item C: (50 * 2) = 100 units; Item D: (50 * 2 * 1) + (100 * 1) = 200 units; Item E: (50 * 1 * 1) = 50 units; Item F: (50 * 1 * 1 * 4) + (50 * 2 * 1) = 300 units. (MRP structure, moderate) {AACSB: Analytic Skills}

145. Consider the following bill of material. Forty units of Product A are needed. Assuming no on-hand inventory, and no scheduled receipts, explode the bill of material.



Item A: 40 units; Item B: 40 * 2 = 80 units; Item C: (40 * 3) = 120 units; Item D: (40 * 1) = 40 units; Item E: (80 * 1) + (40 * 2) = 160 units; Item F: (120 * 1) = 120 units; Item G: 120 + 40 160 units. (MRP structure, moderate) {AACSB: Analytic Skills}

146. Clancy's Motors has the following demand to meet for custom manufactured fuel injector parts. The holding cost for that item is $.75 per month and each setup costs $150. Calculate the order quantity by use of the part-period algorithm. Lead time is 2 months.

Month	1	2	3	4	5	6	7
Requirement	100	150	200	150	100	150	250

$$EPP = \frac{\textbf{Setup cost}}{\textbf{Holding cost}} = \frac{\$150}{\$0.75} = \textbf{200 units}$$

In Period 1, an order for 250 units should be received; in Period 3, an order for 350 units should be received; in Period 5, an order for 250 units should be received, and in Period 7, an order for 250 should be received, as per the table below.

Period	Order size	# of Units	# period	PP	CumPP
1	100	0			
1, 2	250	150	1	150	150*
1, 2, 3	450	200	2	400	550
3	200	0			
3, 4	350	150	1	150	150*
3, 4, 5	450	100	2	200	350
5	100	0			
5,6	250	150	1	150	150*
5,6,7	500	250	2	500	650
7	250				

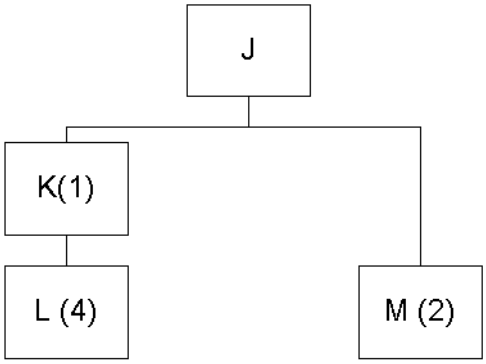
(Lot-sizing techniques, moderate) {AACSB: Analytic Skills}

147. The MPS calls for 120 units of Product M. There are currently 30 of Product M on hand. Each M requires 4 of Component N. There are 20 units of N on hand.
a. Calculate the net requirements for M.
b. Calculate the gross requirements for N.
c. Calculate the net requirements for N.
(a) 120 - 30 = 90; (b) 90 x 4 = 360; 360 - 20 = 340
(MRP structure, easy) {AACSB: Analytic Skills}

148. The MPS calls for 110 units of Product A. There are currently 60 of Product A on hand. Each A requires 2 of Part B. There are 30 units of B available.
a. Calculate the net requirements for A.
b. Calculate the gross requirements for B.
c. Calculate the net requirements for B.
(a) 110 - 60 = 50; (b) 50 x 2 = 100; (c) 100 - 30 = 70
(MRP structure, easy) {AACSB: Analytic Skills}

149. The MPS calls for 50 units of Product A and 60 of B. There are currently 35 of Product B on hand. Each A requires 2 of Part C; each B requires 5 of C. There are 160 units of C available.
a. Calculate the net requirements for B.
b. Calculate the gross requirements for C.
c. Calculate the net requirements for C.
(a) 60 - 35 = 25; (b) 50 x 2 + 25 x 5 = 225; (c) 225 - 160 = 65
(MRP structure, easy) {AACSB: Analytic Skills}

150. Consider the bill of material for Product J and the data given in the following table. The gross requirements for J are 200 units in week 6 and 250 units in week 8. Develop the MRP tables for each item for an 8-week planning period. Use the lot-for-lot lot-sizing rule.



Item	Lead Time	Quantity on Hand	Scheduled receipts
J	1	0	
K	2	20	30 in week 2
L	2	0	
M	1	20	10 in week 1

SEE NEXT PAGE FOR SOLUTION.

Item name	Level	Number per parent	Indented BOM
J	0	1	J
K	1	1	K
L	2	4	L
M	1	2	M

J		Lead time	1	Safety Stock	0	Lot size	1	Minimum quantity	0
	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Gross requirements		0	0	0	0	0	200	0	250
Scheduled receipts									
On Hand Inventory		0	0	0	0	0	0	0	0
NET POQ Req		0	0	0	0	0	200	0	250
Planned receipts		0	0	0	0	0	200	0	250
Planned orders		0	0	0	0	200	0	250	0

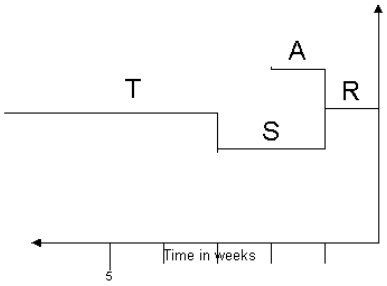
K		Lead time	2	Safety Stock	0	Lot size	1	Minimum quantity	0
	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Gross requirements		0	0	0	0	200	0	250	0
Scheduled receipts			30						
On Hand Inventory	20	20	20	50	50	50	0	0	0
NET POQ Req		0	0	0	0	150	0	250	0
Planned receipts		0	0	0	0	150	0	250	0
Planned orders		0	0	150	0	250	0	0	0

M		Lead time	1	Safety Stock	0	Lot size	1	Minimum quantity	0
	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Gross requirements		0	0	0	0	400	0	500	0
Scheduled receipts		10							
On Hand Inventory	20	20	30	30	30	30	0	0	0
NET POQ Req		0	0	0	0	370	0	500	0
Planned receipts		0	0	0	0	370	0	500	0
Planned orders		0	0	0	370	0	500	0	0

L		Lead time	2	Safety Stock	0	Lot size	1	Minimum quantity	0
	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Gross requirements		0	0	600	0	1000	0	0	0
Scheduled receipts									
On Hand Inventory		0	0	0	0	0	0	0	0
NET POQ Req		0	0	600	0	1000	0	0	0
Planned receipts		0	0	600	0	1000	0	0	0
Planned orders		600	0	1000	0	0	0	0	0

(MRP structure, moderate) {AACSB: Analytic Skills}

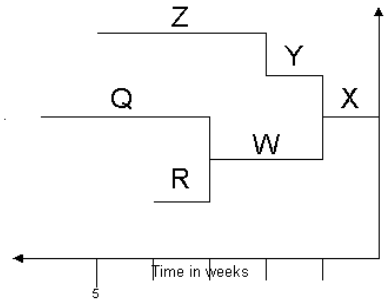
151. Each R requires 3 of component S and 3 of material A; each S requires 3 of part T. The lead time for assembly of R is 1 week. The lead time for the manufacture of S is 2 weeks. The lead time for material A is 1 week. The lead time for the procurement of T is 4 weeks.
a. Construct the time-phased product structure.
b. Construct the bill of material.
Solution:



Bill of Material			
Item			**Quantity**
R			**1**
	S(3)		**3**
		T(3)	**9**
	A(3)		**3**

(MRP structure, moderate) {AACSB: Analytic Skills}

152. Each X requires 2 of component Y and 1 of part W. Each Y requires 10 of Z. Each W requires 3 of Q and 2 of R. Lead times are X = 1 week, Y = 1 week, W = 2 weeks, R = 1 week, Z = 3 weeks, and Q = 3 weeks.
a. Construct the time-phased product structure.
b. Construct the bill of material.
Solution:



Bill of Material			
Item			**Quantity**
X			**1**
	Y(2)		**2**
		Z(10)	**20**
	W(1)		**1**
		Q(3)	**3**
		R(2)	**2**

(MRP structure, moderate) {AACSB: Analytic Skills}

153. A product has the following gross requirements. Which is cheaper—lot-for-lot, part period balance, or EOQ lot sizing?

Week	1	2	3	4	5	6
Requirements	50	80	90	50	30	60

Other data for this scenario include: setup cost = $250, inventory holding cost $2 per unit per week. There is no beginning inventory; there are no scheduled receipts. The usage pattern is expected to continue for the remainder of the year.

Lot-for-lot will cost $250 x 6 = $1,500 for the six periods.

EOQ is based on 60 units per week demand: $\sqrt{\frac{2 \cdot 60 \cdot 52 \cdot 250}{2 \cdot 52}} = 122$

Annual setup costs = $\frac{60 \cdot 52}{122} \cdot 250 = \$6{,}393;$

Annual holding costs = $\frac{122}{2} \cdot 2 \cdot 52 = \$6{,}344$

Total annual costs = $12,737; Cost for six weeks = $12{,}737 \cdot \frac{6}{52} = \$1{,}469$

For part-period balancing, the EPP=250/2 = 125. Total cost for PPB over the six periods is $1,210.

Period	Order size	# of Units	CumPP	Setup cost	Holding cost
1	70	0	0		
1, 2	150	80	80*	250	160
1, 2, 3	240	90 * 2	260		
3	90	0	0		
3, 4	160	70	70		
3, 4, 5	200	40 * 2	150*	250	300
3, 4, 5, 6	270	70 * 3	360		
6	70	0	0	250	0
			Total	750	460

Summary of costs: LFL = $1,500; EOQ = $1,469; PPB = $1,210. PPB is cheapest lot-sizing model for this problem. (Lot-sizing techniques, moderate) {AACSB: Analytic Skills}

154. A product has the following gross requirements. Which is cheaper—lot-for-lot or EOQ lot-sizing?

Week	1	2	3	4
Requirements	50	30	40	80

Other data for this scenario include: setup cost = $1000, inventory holding cost $1 per unit per week. There is no beginning inventory; there are no scheduled receipts. The usage pattern is expected to continue for the remainder of the year.

Lot-for-lot will cost $1000 x 4 = $4,000 for the four periods.

EOQ is based on 50 units per week demand: $\sqrt{\frac{2 \cdot 50 \cdot 52 \cdot 1000}{1 \cdot 52}} = 316$

Annual setup costs = $\frac{50 \cdot 52}{316} \cdot 1000 = \$8{,}228;$

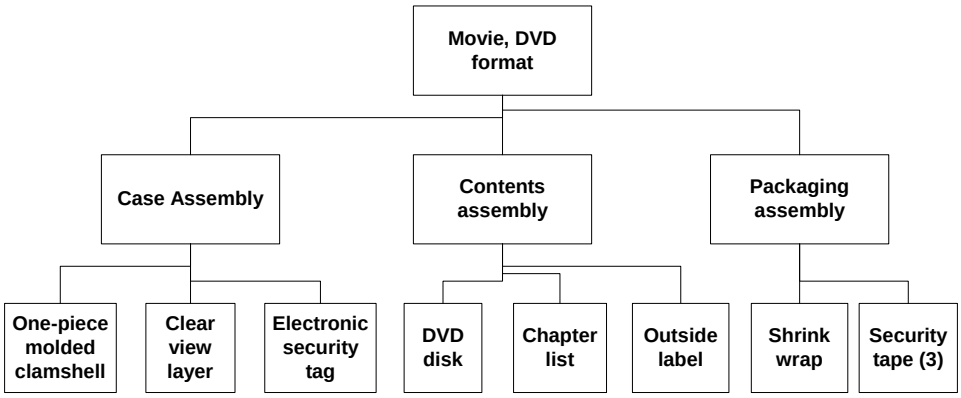
Annual holding costs = $\frac{316}{2} \cdot 1 \cdot 52 = \$8{,}216$

Total annual costs = $16,444; Cost for four weeks = $16{,}444 \cdot \frac{4}{52} = \$1{,}265$

Summary of costs: LFL = $4,000; EOQ = $1,265. EOQ is cheaper lot-sizing model for this problem. (Lot-sizing techniques, moderate) {AACSB: Analytic Skills}

155. Construct a product structure tree for a movie purchased in DVD format. Assume that it contains a single DVD disk. Don't be concerned with artwork—you may use labeled boxes for your parts and assemblies.

Not all DVDs are alike in their construction, so student answers will vary. Here is a fairly generic version. Note that the primary container is a one-piece molded plastic "clamshell." There are three layers, 0, 1, and 2.



(Dependent inventory model requirements, moderate) {AACSB: Analytic Skills}

156. Construct an indented bill of material for a common 3-ring view binder (the kind that lets you slip your own cover sheet into the front panel). Assume the rings to be 1 inch diameter. Don't worry about other dimensions—pay attention to accounting for all of the parts.

Not all such binders are identical, and student answers will vary, but here is a fairly generic version. The main components are the cover assembly and the ring assembly. Students will need to include some form of locking mechanism and/or spring.

Indented bill of material, Three-ring binder

Cover assembly
- **Front cover**
  - **Chipboard interior**
  - **Vinyl exterior, inside and outside of front cover**
  - **Clear "view" layer, outside**
  - **Vinyl pocket, inside**
- **Spine**
  - **Chipboard interior**
  - **Vinyl exterior, inside and outside of front cover**
  - **Clear "view" layer, outside**
- **Back cover**
  - **Chipboard interior**
  - **Vinyl exterior, inside and outside of front cover**
  - **Clear "view" layer, outside**
  - **Vinyl pocket, inside**

Ring Assembly
- **Spine**
  - **Main spine (holds the three sets of rings and the tabs)**
  - **Spring (runs the length of the spine)**
- **Rings (3)**
  - **Left ring half**
  - **Right ring half**
- **Spacer and tensioner (2)**
- **Clasps (2) (holds the locking tabs in)**
- **Rivets (2)**
- **Locking tabs (2)**

Paperwork
- **Front insert**
- **Spine insert**
- **UPC tag**

(Dependent inventory model requirements, moderate) {AACSB: Analytic Skills}

157. Jacquie Welkener, operations manager for ABC Technologies, must schedule work for the next five days. Each unit takes 30 minutes to process. Available capacity is 8 hours per day. The production order quantities are 12, 18, 20, 13, and 17 for Monday through Friday, respectively. What should be the production plan?

Sixteen units should be produced each day. Thus, 4 units should be moved from Tuesday to Monday, 2 units should be moved from Wednesday to Tuesday, 2 units should be moved from Wednesday to Thursday, and 1 unit should be moved from Friday to Thursday. (Extensions of MRP, easy) {AACSB: Analytic Skills}

CHAPTER 15: SHORT-TERM SCHEDULING

TRUE/FALSE

1. Delta uses mathematical short-term scheduling techniques and a high-tech nerve center to manage the rapid rescheduling necessary to cope with weather delays and similar disruptions.
True (Global company profile, moderate)

2. Short-term scheduling is important to efficiency and to cost reduction, but its impact is not of strategic importance.
False (The strategic importance of short-term scheduling, moderate)

3. The benefits of effective scheduling include lower cost, faster delivery, and dependable delivery.
True (The strategic importance of short-term scheduling, moderate)

4. In forward scheduling, jobs are scheduled as late as possible within the time allowed by the customer due dates.
False (Scheduling issues, moderate)

5. One criterion for developing effective schedules is minimizing completion time.
True (Scheduling issues, easy)

6. Scheduling optimization systems used in retail stores typically track customer traffic in 4-hour time increments.
False (Scheduling services, difficult) {AACSB: Use of IT}

7. Process-focused facilities and repetitive facilities generate forward-looking schedules, but process-focused facilities do this with JIT and kanban while repetitive facilities generally use MRP.
False (Scheduling issues, moderate)

8. The work center master file contains data such as capacity and efficiency.
True (Scheduling process-focused facilities, moderate)

9. The constant work-in-process (ConWIP) card aids input-output control by limiting the amount of work in a work center.
True (Loading jobs, easy)

10. A Gantt load chart shows the loading and idle time of several departments, machines, or facilities.
True (Loading jobs, moderate)

11. Gantt charts are useful for scheduling jobs, but not for loading them.
False (Loading jobs, easy)

12. The assignment method provides an optimum, one-to-one assignment of jobs to resources.
True (Loading jobs, easy)

13. Earliest due date is a shop floor dispatching (sequencing) rule that relates the time available to complete a job to the amount of work left to be completed.
False (Sequencing jobs, moderate)

14. The critical ratio sequencing rule prioritizes the jobs based on the importance or value of the customers who have placed the orders.
False (Sequencing jobs, moderate)

15. Dispatching rules are typically judged by four effectiveness criteria: average completion time, utilization, average number of jobs in the system, and average job lateness.
True (Sequencing jobs, moderate)

16. Johnson's rule (and its extensions) sequences a set of jobs through a set of operations where the operations must be performed in a specific order.
True (Sequencing jobs, moderate)

17. Finite capacity scheduling allows virtually instantaneous changes by operators, which is the technique's primary advantage over rule-based scheduling.
True (Finite capacity scheduling, moderate)

18. The word "finite" in finite capacity scheduling refers to the use of finite or limited capacity rather than unlimited capacity.
True (Finite capacity scheduling, moderate)

19. The theory of constraints is fundamental to proper use of the assignment method of loading jobs.
False (Theory of constraints, moderate)

20. The theory of constraints is a body of knowledge that deals with anything that limits an organization's ability to meet its goals.
True (Theory of constraints, easy)

21. Substantial research has proved that the only successful method of dealing with bottlenecks is to increase the bottleneck's capacity.
False (Theory of constraints, moderate)

22. The first step in level material use is to combine orders into a few large batches in order to utilize economies of scale.
False (Scheduling repetitive facilities, easy)

23. In services, the scheduling emphasis is usually on staffing levels, not materials.
True (Scheduling services, easy)

24. Because of the significance of labor in the scheduling of services, behavioral and social issues, wage and hour law, and union contracts all complicate the scheduling process.
True (Scheduling services, moderate)

25. In manufacturing scheduling, physical inventories of goods can buffer variations in demand, but service scheduling normally lacks that buffer because services are generally consumed at the same time they are delivered.
True (Scheduling services, moderate)

26. Some firms have developed arrangements to literally “swap” employees with each other during their respective peak demand times.
True (Scheduling services, moderate)

MULTIPLE CHOICE

27. Which of the following statements regarding scheduling at Delta Airlines is **false**?
    a. About one flight in twenty is disrupted by weather events.
    b. Schedule changes at one airport have a ripple effect that may have impacts in many others.
    c. Delta's high-tech computer and communications system is located in Atlanta.
    d. Delta's rapid rescheduling uses mathematical scheduling models.
    e. Delta's rapid rescheduling promotes air safety and limits traveler inconvenience, but has not resulted in money savings for Delta.
    e (Global company profile, moderate)

28. Which of the following best describes the strategic importance of short-term scheduling?
    a. Effective scheduling, through lower costs, faster delivery, and more dependable schedules, can provide a competitive advantage.
    b. Effective scheduling is a tactical tool for increasing demand to meet production.
    c. Forward scheduling looks to future demand levels in order to increase customer satisfaction.
    d. Aggregate planning is a tactical action, but short-term scheduling is strategic because of its immense impact on costs.
    e. Short-term scheduling matches capacity to demand during the short term, three to eighteen months into the future.
    a (The strategic importance of short-term scheduling, moderate)

29. The three components that can lead to competitive advantage through effective scheduling are
    a. aggregate planning, intermediate scheduling, and medium-term planning
    b. forward scheduling, real-time scheduling, and backward scheduling
    c. the item master file, the routing file, and the work-center master file
    d. lower costs, faster delivery, and more dependable schedules
    e. Gantt charts, Johnson's rule and the Pareto principle
    d (The strategic importance of short-term scheduling, moderate)

30. The sequence of decisions that affect scheduling is
    a. short term→intermediate term→long term
    b. capacity planning→aggregate planning→master schedule→short-term schedules
    c. strategic decisions→tactical decisions→operational decisions
    d. forward decisions→current decisions→backward decisions
    e. none of the above
    b (Scheduling issues, moderate)

31. Forward scheduling is the scheduling of
    a. the end items or finished products
    b. jobs as soon as the requirements are known
    c. the start items or component parts
    d. the final operation first beginning with the due date
    e. jobs according to their profit contributions
    b (Scheduling issues, moderate)

32. Short-term schedules are prepared
    a. directly from the aggregate plans
    b. directly from the capacity plans
    c. from inventory records for items that have been used up
    d. from master schedules which are derived from aggregate plans
    e. from the purchasing plans
    d (Scheduling issues, moderate)

33. Which scheduling technique should be employed when due dates are important for a job order?
    a. forward scheduling
    b. loading
    c. dispatching
    d. backward scheduling
    e. master scheduling
    d (Scheduling issues, moderate)

34. Which of the following is **not** an effectiveness criterion for scheduling?
    a. minimizing customer waiting time
    b. minimizing completion time
    c. minimizing WIP inventory
    d. maximizing utilization
    e. maximizing flow time
    e (Scheduling issues, moderate)

35. The scheduling criterion *minimize work-in-process inventory*
    a. results in the smallest flowtime of all scheduling criteria
    b. is especially useful in problems solved with Johnson's rule
    c. uses the average number of jobs in the system as the indicator of the level of inventory
    d. is identical to the *maximize utilization* criterion
    e. All of the above are true.
    c (Scheduling issues, moderate)

36. The four criteria for short-term scheduling
    a. are of equal importance
    b. include maximize completion time and minimize utilization
    c. are applied simultaneously
    d. may have different levels of importance, depending on circumstances
    e. All of the above are true.
    d (Scheduling issues, moderate)

37. Scheduling is rather straightforward in product-focused facilities because
    a. kanban automates the scheduling of the assembly line
    b. demand is reasonably stable, and capacities, set-up times, and run times are generally known
    c. assembly line balancing assures the highest possible production efficiency
    d. finite capacity scheduling has made MRP much more realistic
    e. All of the above are true.
    b (Scheduling issues, moderate)

38. Forward scheduling
    a. begins with a delivery date, then offsets each operation one at a time, in reverse order
    b. is well suited where the supplier is usually able to meet precise delivery dates
    c. tends to minimize work-in-process inventory
    d. assumes that procurement of material and operations start as soon as requirements are known
    e. produces a schedule only if it meets the due date
    d (Scheduling issues, moderate)

39. Which file contains important information regarding an item's flow through the shop?
    a. item master file
    b. work center master file
    c. control files
    d. routing file
    e. None of the above provides information regarding an item's flow through the shop.
    d (Scheduling process-focused facilities, moderate)

40. Which of these is **not** part of the planning files of a production planning and control system?
    a. a progress file
    b. a work center master file
    c. an item master file
    d. a routing file
    e. They are all part of the planning files.
    a (Scheduling process-focused facilities, moderate)

41. Which of the following files tracks work order progress?
    a. work center master files
    b. routing files
    c. item master files
    d. control files
    e. None of the above tracks work order progress.
    d (Scheduling process-focused facilities, moderate)

42. The production database containing information about each of the components that a firm produces or purchases is the
    a. routing file
    b. work center master file
    c. control file
    d. item master file
    e. none of the above
    d (Scheduling process-focused facilities, moderate)

43. The short-term scheduling activity called **loading**
    a. assigns dates to specific jobs or operations steps
    b. specifies the order in which jobs should be done at each center
    c. assigns jobs to work centers
    d. assigns workers to jobs
    e. assigns workers to machines
    c (Loading jobs, easy)

44. The assignment method is
    a. a method to highlight overloads in a given work center
    b. a computerized method of determining appropriate tasks for an operation
    c. a form of linear programming for optimally assigning tasks or jobs to resources
    d. the same thing as the Gantt schedule chart
    e. a method for achieving a balance between forward and backward scheduling
    c (Loading jobs, moderate)

45. A scheduling technique used to achieve optimum, one-to-one matching of tasks and resources is
    a. the assignment method
    b. Johnson's rule
    c. the CDS algorithm
    d. the appointment method
    e. the reservation method
    a (Loading jobs, moderate)

46. Which of the following is an aid used to monitor jobs in process?
    a. a Gantt load chart
    b. the assignment method
    c. a Gantt schedule chart
    d. Johnson's rule
    e. none of the above
    c (Loading jobs, moderate)

47. A method of input-output control that uses a system of cards to limit the amount of work at a work center and also to control lead time and monitor backlog is
    a. the assignment method
    b. backward scheduling
    c. forward scheduling
    d. constant work-in-process or ConWIP
    e. level material use
    d (Loading jobs, easy)

48. If an assignment problem consists of 6 workers and 7 projects,
    a. one worker will not get a project assignment
    b. one worker will be assigned two projects
    c. each worker will contribute work toward the seventh project
    d. one project will not get a worker assigned
    e. The problem cannot be solved by assignment method.
    d (Loading jobs, moderate)

49. If an assignment problem consists of 5 workers and 4 projects,
    a. one worker will not get a project assignment
    b. one project will be assigned two workers
    c. the fifth worker will split time among the four projects
    d. one project will not get a worker assigned
    e. The problem cannot be solved by assignment method.
    a (Loading jobs, moderate)

50. Three jobs are to be assigned to three machines. Cost for each job-machine combination appears in the table below. Perform the first two steps of the assignment method (subtract the smallest number in each row and subtract the smallest number in each column; then cover with straight lines). At this point in the problem-solving process

	Machine A	Machine B	Machine C
Job 1	11	14	6
Job 2	8	10	11
Job 3	9	12	7

a. the row for Job 1 contains the values 5, 6, and 0
b. calculations are complete, and the problem is ready for an optimal set of assignments
c. the column for Machine B indicates that it should be retired
d. Job 1 should be performed on Machine B
e. Job 1 should be performed on Machine A

a (Loading jobs, difficult) {AACSB: Analytic Skills}

51. Orders are processed in the sequence in which they arrive if (the) _____ rule sequences the jobs.
a. earliest due date
b. slack time remaining
c. first come, first served
d. critical ratio
e. Johnson's

c (Scheduling jobs, moderate)

52. Which of the following dispatching rules ordinarily gives the best results when the criterion is lowest time for completion of the full sequence of jobs?
a. shortest processing time (SPT)
b. critical ratio (CR)
c. first in, first out (FIFO)
d. first come, first served (FCFS)
e. longest processing time

a (Scheduling jobs, moderate)

53. Five jobs are waiting to be processed. Their processing times and due dates are given below. Using the **shortest processing time** dispatching rule, in which order should the jobs be processed?

Job	Processing Time (days)	Job due date (days)
A	4	7
B	7	4
C	8	11
D	3	5
E	5	8

a. A, B, C, D, E
b. C, E, A, D, B
c. B, D, A, E, C
d. D, A, E, B, C
e. C, E, A, D, B

d (Scheduling jobs, moderate) {AACSB: Analytic Skills}

54. Sequencing (or dispatching)
    a. assigns dates to specific jobs or operations steps
    b. assigns jobs to work centers
    c. specifies the order in which jobs should be done at each center
    d. assigns workers to jobs
    e. assigns workers to machines
    c (Scheduling jobs, moderate)

55. Five jobs are waiting to be processed. Their processing times and due dates are given below. Using the **earliest due date** dispatching rule, in which order should the jobs be processed?

Job	Processing Time (days)	Job due date (days)
A	4	7
B	2	4
C	8	11
D	3	5
E	5	8

    a. C, E, A, D, B
    b. A, B, C, D, E
    c. B, D, A, E, C
    d. C, B, A, E, D
    e. none of the above
    c (Scheduling jobs, moderate) {AACSB: Analytic Skills}

56. Flow time represents the time
    a. an order spends waiting for processing at a work center
    b. an order spends being processed at a work center
    c. an order spends moving from one work center to another
    d. to complete an order, including time spent in processing and in waiting
    e. none of the above
    d (Scheduling jobs, moderate)

57. Which of the following dispatching rules tends to minimize job flow time?
    a. FCFS: first come, first served
    b. SPT: shortest processing time
    c. EDD: earliest due date
    d. LPT: longest processing time
    e. FCLS: first come, last served
    b (Scheduling jobs, moderate)

58. Average completion time for a schedule sequence at a work center is the ratio of
    a. total processing time to the number of jobs
    b. total flow time to total processing time
    c. total flow time to the number of jobs
    d. total processing time plus total late time to the number of jobs
    e. total flow time plus total late time to the number of jobs
    c (Scheduling jobs, moderate)

59. Eight jobs have been sequenced at a single work center. Total processing time for the eight jobs is 34 hours and total flow time for the sequence is 85 hours. For this schedule, utilization is _____ and average jobs in the system is _____.
a. 100 percent; 10.625
b. low; .0941
c. 0.400 or 40 percent; 2.5
d. 0.235 or 23.5 percent; 4.25
e. maximized; minimized
c (Sequencing jobs, moderate) {AACSB: Analytic Skills}

60. Five welding jobs are waiting to be processed. Their processing times and due dates are given below. Using the **critical ratio** dispatching rule, in which order should the jobs be processed?

Job	Processing Time (days)	Job due date (days)
A	4	7
B	2	4
C	8	11
D	3	5
E	5	11

a. B, D, A, E, C
b. C, D, A, B, E
c. C, E, A, D, B
d. E, B, A, D, C
e. none of the above
b (Scheduling jobs, moderate) {AACSB: Analytic Skills}

61. Which critical ratio value implies that a job is already late?
a. more than 100
b. 1
c. less than 1
d. 10
e. none of the above
c (Scheduling jobs, moderate)

62. The priority rule which sequences jobs using the smallest ratio of due date to processing time is
a. critical ratio
b. earliest due date
c. first come, first served
d. longest processing time
e. shortest processing time
a (Scheduling jobs, moderate)

63. Which of the following is an advantage of the FCFS dispatching rule when used in services?
a. FCFS is easy to update.
b. FCFS minimizes the average number of jobs in the system.
c. FCFS minimizes the average lateness of all jobs.
d. FCFS maximizes the number of jobs completed on time.
e. FCFS seems fair to customers.
e (Scheduling jobs, moderate)

64. The most appropriate sequencing rule to use if the goal is to dynamically track the progress of jobs and establish relative priority on a common basis is
    a. shortest processing time
    b. earliest due date
    c. critical ratio
    d. longest processing time
    e. Johnson's rule
    c (Scheduling jobs, moderate)

65. Use of the shortest processing time sequencing rule generally results in
    a. maximum average lateness
    b. maximum utilization
    c. maximum effectiveness
    d. minimum average flow time
    e. none of the above
    d (Scheduling jobs, moderate)

66. Which of the following dispatching rules is typically the best technique for taking first those jobs with the most urgent needs?
    a. shortest processing time
    b. critical ratio
    c. earliest due date
    d. longest processing time
    e. none of the above
    e (Scheduling jobs, moderate)

67. When a set of jobs must pass through two workstations whose sequence is fixed, _____ is the rule most commonly applied.
    a. critical ratio
    b. earliest due date
    c. first come, first served
    d. slack time remaining
    e. Johnson's rule
    e (Scheduling jobs, moderate)

68. A recent advance in short-term scheduling that makes use of expert systems and simulation in solving dynamic scheduling problems is
    a. forward scheduling
    b. backward scheduling
    c. infinite scheduling
    d. finite capacity scheduling
    e. progressive scheduling
    d (Finite capacity scheduling (FCS), moderate)

69. Five jobs are waiting for processing through two work centers. Their processing time (in minutes) at each work center is contained in the table below. Each job requires work center Alpha before work center Beta. According to Johnson's rule, which job should be scheduled first?

Job	Alpha	Beta
R	20	10
S	25	35
T	50	20
U	15	35
V	55	75

a. R
b. S
c. T
d. U
e. V

d (Scheduling jobs, moderate) {AACSB: Analytic Skills}

70. Five jobs are waiting for processing through two work centers. Their processing time (in minutes) at each work center is contained in the table below. Each job requires work center Sigma before work center Delta. According to Johnson's rule, what sequence of jobs will minimize the completion time for all jobs?

Job	Sigma	Delta
R	40	10
S	25	30
T	50	20
U	35	35
V	55	15

a. R-S-T-U-V
b. S-V-T-R-U
c. S-U-T-V-R
d. V-R-U-S-T
e. none of the above

c (Scheduling jobs, moderate) {AACSB: Analytic Skills}

71. Which of the following are limitations of rules-based dispatching systems?
a. Rules need to be revised to adjust to changes in orders, product mix, and so forth.
b. Rules may not recognize idle resources.
c. Rules may not recognize bottleneck resources
d. Rules may not be able to prioritize two jobs with identical due dates.
e. All of the above are limitations.

e (Scheduling jobs, moderate)

72. Five jobs are waiting for processing through two work centers. Their processing time (in minutes) at each work center is contained in the table below. Each job requires work center Alpha before work center Beta. According to Johnson's rule, what is the optimum sequence of jobs and the minimum time for completion of all jobs?

Job	Alpha	Beta
R	20	10
S	25	35
T	50	20
U	15	35
V	55	75

a. V-T-S-U-R; 225
b. U-R-T-S-V; 175
c. R-S-T-U-V; 240
d. U-S-V-T-R; 200
e. none of the above

d (Scheduling jobs, moderate) {AACSB: Analytic Skills}

73. Conventional MRP uses time buckets that do not recognize capacity limits, and in fact ignores capacity issues. A more realistic scheduling system that includes work center capacities and other resource availabilities is
a. aggregate planning
b. the master production schedule
c. finite capacity scheduling
d. the assignment method
e. level material use

c (Finite capacity scheduling (FCS), moderate) {AACSB: Use of IT}

74. Which of the following statements regarding finite capacity scheduling (FCS) is **false**?
a. Finite capacity scheduling allows delivery needs to be balanced against efficiency.
b. Finite capacity scheduling overcomes the disadvantages of systems based exclusively on rules.
c. Finite capacity scheduling allows virtually instantaneous change by operators.
d. Finite capacity scheduling software formalizes the same data needed in any manual system.
e. None; all of the above are true.

e (Finite capacity scheduling (FCS), moderate) {AACSB: Use of IT}

75. Which of the following statements regarding finite capacity scheduling (FCS) is **false**?
a. Finite capacity scheduling is well suited for dynamic scheduling environments.
b. Finite capacity scheduling overcomes the disadvantages of systems based exclusively on rules.
c. Finite capacity scheduling is very powerful, but does not allow for rapid changes.
d. Finite capacity scheduling often gets its data from the output of an MRP system.
e. None; all of the above are true.

c (Finite capacity scheduling (FCS), moderate) {AACSB: Use of IT}

76. The theory of constraints has its origins in
    a. linear programming theory
    b. the theory of economies of scale
    c. material requirements planning
    d. the theory of finite capacity planning
    e. Goldratt and Cox's book, *The Goal: A Process of Ongoing Improvement*
    e (Theory of constraints, easy)

77. Which of the following techniques is **not** a technique for dealing with a bottleneck?
    a. Schedule throughput to match capacity of the bottleneck.
    b. Increase capacity of the constraint.
    c. Have cross-trained employees available to keep the constraint at full operation.
    d. Develop alternate routings.
    e. All are tools for dealing with bottlenecks.
    e (Theory of constraints, easy)

78. An appliance manufacturer assembles icemakers in large batches. The operations manager would like to significantly reduce the batch size. What would you suggest?
    a. Use the SPT rule.
    b. Use forward scheduling.
    c. Use Gantt charts.
    d. Use finite scheduling.
    e. Develop level material use schedules.
    e (Repetitive facilities, moderate)

79. Which of the following is **not** tracked by scheduling optimization systems used in retail stores?
    a. cars parked in the parking lot
    b. individual store sales
    c. transactions
    d. units sold
    e. customer traffic
    e (Scheduling services, moderate)

80. In “drum, buffer, rope,” what provides the schedule, i.e. the pace of production?
    a. drum
    b. buffer
    c. rope
    d. all three of the above in combination
    e. none of the above
    a (Scheduling services, moderate)

81. Which of the following is **true** regarding services scheduling?
    a. The critical ratio sequencing rule is widely used for fairness to customers.
    b. The emphasis is on staffing levels, not materials.
    c. Reservations and appointments are often used to manipulate the supply of services.
    d. Labor use can be intensive, and labor demand is usually stable.
    e. All of the above are true.
    b (Scheduling services, moderate)

FILL-IN-THE BLANK

82. _____ scheduling begins with the due date and schedules the final operation first and the other job steps in reverse order.
Backward (Scheduling issues, moderate)

83. In the sequence of decisions that affect scheduling, _____ is (are) the immediate follower of the master schedule (or master production schedule).
short-term schedules (Scheduling issues, moderate)

84. Because facility capacity, set-up time, and run time are usually known, scheduling is often straightforward in _____ facilities.
product-focused or continuous (Scheduling issues, easy)

85. _____ is the assignment of jobs to work or processing centers.
Loading (Loading jobs, easy)

86. _____ is an input-output control system that uses cards to manage the amount of work in a work center.
ConWIP or continuous work-in-process (Scheduling process-focused facilities, moderate)

87. _____ are used to schedule resources and allocate time.
Gantt charts (Loading jobs, moderate)

88. The _____ is a special class of linear programming models that involves assigning tasks or jobs to resources.
assignment method (Loading jobs, moderate)

89. _____ determines the order in which jobs should be done at each work center.
Sequencing (Sequencing jobs, easy)

90. _____ determine the sequence of jobs in process-oriented facilities.
Priority rules (Sequencing jobs, easy)

91. The priority rule that appears fair to customers in service systems is _____.
first come, first served (Sequencing jobs, easy)

92. An approach to sequencing that can handle the situation where jobs must pass through two or more work centers in a fixed sequence is _____.
Johnson's rule (Sequencing jobs in work centers, moderate)

93. _____ uses computerized short-term scheduling to overcome the disadvantages of rule-based systems by providing the user with interactive computing and graphical output.
Finite capacity scheduling (Finite capacity scheduling (FCS), moderate) {AACSB: Use of IT}

94. The _____ is a body of knowledge that deals with anything that limits an organization's ability to achieve its goals.
theory of constraints (Theory of constraints, moderate)

95. Rerouting work, changing work sequence, and accepting idleness at other workstations are some techniques for dealing with a _____.
bottleneck (Theory of constraints, moderate)

96. In "drum, buffer, rope,"_____ is the resource, usually inventory, necessary to keep the constraint operating at capacity.
buffer (Theory of constraints, moderate)

97. _____ means frequent, high-quality, small lot sizes that contribute to just-in-time production.
Level material use (Repetitive facilities, moderate)

98. In “drum, buffer, rope,” the _____ acts like kanban signals.
rope (Theory of constraints, moderate)

SHORT ANSWERS

99. Briefly describe how "the unexpected" makes short-term scheduling at Delta Airlines a challenge. Also describe how Delta meets that challenge, and achieves competitive advantage through short-term scheduling.
The unexpected refers to delays and cancellations that are largely weather-related. These events require rapid rescheduling in order to keep operations going and to keep passengers from becoming too inconvenienced. Delta's solution involves a high-tech nerve center of computers and communications gear, and uses mathematical models to reroute and reschedule as quickly as possible. (Global company profile, easy)

100. What makes short-term scheduling of strategic importance?
Effective scheduling lowers cost by making greater use of facilities. Faster throughput leads to faster delivery to customers. Good scheduling contributes to realistic schedules and therefore to more dependable delivery. These three elements can create competitive advantage, and therefore make short-term scheduling of strategic importance. (The strategic importance of short-term scheduling, moderate)

101. Explain, in your own words, how backward scheduling and forward scheduling differ.
Forward scheduling starts the schedule as soon as the requirements are known. Backward scheduling begins with the due date, scheduling the final operation first and proceeding in the reverse order. (Scheduling issues, moderate)

102. How does short-term scheduling vary among the different process choices? Specifically, compare short-term scheduling at process-oriented, work cells, repetitive, and product-focused facilities.
All three process choices produce forward-looking schedules. Process-focused facilities and work cells use MRP; their scheduling problems are ongoing because their product mix is so variable. Repetitive facilities schedule with line balancing and pull techniques; their scheduling problems are most challenging when assembly lines are new or when models change. Continuous processes have rather straightforward scheduling because they make relatively few products, and facility capacity and setup times and run times are usually known. (Scheduling issues, moderate)

103. Identify the types of planning files used in scheduling decisions. Which are used in manual systems, and which are used in automated systems?
The three types are item master files, routing files, and work center master files. All three are used in both manual and in automated systems. (Scheduling issues, moderate)

104. What is input-output control?
Input-output control is a technique that allows operations personnel to manage facility work flow by tracking work added to a work center and its completed work. (Loading jobs, moderate)

105. What are the options available to operations personnel to manage facility work flow?
Options available to manage facility work flow include correcting performances, increasing capacity, and increasing or reducing input to the work center by routing work to or from other work centers, increasing or decreasing subcontracting, and producing less or more. (Loading jobs, moderate)

106. What is the assignment method?
The assignment method is a special class of linear programming models that involves assigning tasks or jobs to resources. (Loading jobs, moderate)

107. Identify the disadvantages of the Gantt load chart.
It does not account for production variability, such as unexpected breakdowns or human errors that require reworking a job, and it must be updated regularly to account for new jobs and revised time estimates. (Loading jobs, moderate)

108. What is the difference between a Gantt load chart and a Gantt scheduling chart?
The Gantt load chart indicates a planned allocation of capacity—the allocation of the capacity of a department or work center to a particular job or order. The Gantt schedule chart indicates, for each job or order, the relative adherence to the particular time schedule, i.e., what fraction of total time to be expended on an order has been expended. (Loading jobs, moderate)

109. What does Johnson's rule do?
Johnson's rule is an approach that minimizes processing time for sequencing a group of jobs through two work centers while minimizing total idle time in the work centers. (Sequencing jobs, moderate)

110. In retail outlets, customers are usually processed on a first come, first served basis. Why? Is the express lane in the supermarket an exception? Craft a sequencing rule to explain express lane behavior.
All customers are considered equally important, and not one should be given a higher priority than another. Most students will write a rule like "FCFS, except for very short processing times"; "8 items or less" is a proxy for processing time. (Sequencing jobs, moderate) {AACSB: Reflective Thinking}

111. What is the primary disadvantage of the shortest processing time dispatch rule? Is this a problem if there can be no new jobs arriving after the sequence is set?
As new jobs arrive, new short-duration jobs will push back existing long-duration jobs in priority in favor of short-duration jobs. If newly arriving jobs must wait for a new sequence to be built, this is less problematic. (Sequencing jobs, moderate)

112. Consider the arrival of patients into a public health clinic. Some patients are ill; some are injured; some are elderly; and some are very young. Some cases may be life-threatening, while others are inconsequential. How do the basic dispatch rules fall short in this situation? Design a dispatch rule for scheduling these patients.
First come, first served is inappropriate because it ignores the urgency of treating the most serious cases. There is no "due date" on which to base lateness or critical ratio sequences. Most students will write a "priority" rule that behaves like triage—assigning an urgency code to each patient, and taking highest urgency cases first. Student rules may have more than one part; for example, patients may be sorted by urgency code, and by treatment time within urgency code. They may also create a separate code for contagious cases. (Sequencing jobs, moderate) {AACSB: Reflective Thinking}

113. What are the criteria by which we evaluate sequencing rules?
There are a number of criteria for evaluating job sequencing rules. Criteria discussed in the text include average job completion time, average number of jobs in the system, and average job lateness. Additional criteria include: average wait time, average total completion time, and variance in completion times. (Sequencing jobs, moderate)

114. What are some limitations of rule-based scheduling systems? What alternatives are there to rules-based scheduling systems?
Three limitations are (1) Rules need to be revised to adjust to changes in process, equipment, product mix, etc.; (2) Rules do not look at upstream or downstream, and (3) Rules do not look beyond due dates. Finite capacity scheduling is one recently developed option. (Sequencing jobs, easy)

115. Describe finite capacity scheduling in a sentence or two. What is its role in short-term scheduling?
Finite capacity scheduling (FCS) removes a shortcoming of MRP, which is that it ignores the capacity of time buckets. FCS makes short-term scheduling more realistic because it accounts for the finite capacity of time buckets. FCS can allow almost instantaneous change, and may involve an expert system or simulation system as planning tools. Short-term scheduling is evolving into finite capacity scheduling. (Finite capacity scheduling (FCS), moderate) {AACSB: Use of IT}

116. Describe the theory of constraints in a sentence.
The theory of constraints is the body of knowledge that deals with anything that limits an organization's ability to achieve its goals. (Theory of constraints, easy)

117. Identify, in proper sequence, the steps in the process of recognizing and managing constraints.
The five-step process of the theory of constraints includes:
Step 1: Identify the constraints.
Step 2: Develop a plan for overcoming them.
Step 3: Focus resources on accomplishing step 2.
Step 4: Off-load work from the constraint or expand capability at the constraint.
Step 5: Once one set of constraints is overcome, go back to step 1 and identify new constraints. (Theory of constraints, moderate)

118. Explain the importance of a bottleneck operation in a production sequence.
A bottleneck operation is one that limits output in the production sequence. Consequently, to increase throughput of the facility, the bottleneck operations must be maximized. (Theory of constraints, moderate)

119. What techniques exist for dealing with bottlenecks? Which of these leads to increased capacity? Which of these leads to more throughput without adding capacity? Do any of these techniques fail to increase throughput?
Five techniques are available to deal with the constraint. They are:
1. Increase the capacity of the constraint. This obviously increases capacity.
2. Have well-trained and cross-trained employees keep the bottleneck at full operation. This increases capacity.
3. Develop alternate routings. This makes better use of existing capacity.
4. Move inspection and testing points to positions that precede the bottleneck, to avoid wasting bottleneck capacity on bad items. This makes better use of existing capacity.
5. Schedule throughput to match the bottleneck's capacity. There's no more throughput, but there may be lower costs at other work centers. (Theory of constraints, difficult)

120. In repetitive manufacturing, what are the advantages of level material use? Does level material use have any role in intermittent process facilities?
The five advantages are:
1. Lower inventory levels to release capital for other uses.
2. Increase the rate of product throughput.
3. Improve component quality and hence improve product quality.
4. Reduce floor-space requirements.
5. Move employees closer together to improve communication.
6. The production process is smoothed because large lots have not "hidden" the problems.
Intermittent (job shop) facilities have so many additional sources of variation (materials, requirements, work center order, etc.) that there is little role for level material use.
(Repetitive facilities, moderate)

121. Explain, in your own words, what is meant by "level material use." In what types of facilities is it appropriate? Explain.
It means frequent, high quality, small lot sizes that contribute to just-in-time production. It is appropriate in repetitive processing, not in intermittent processing, because repetitive processing has much more predictable material and processing needs. (Repetitive facilities, moderate)

122. In what ways does the problem of scheduling service systems differ from that of scheduling manufacturing systems?
Scheduling services differs from scheduling manufacturing systems in five ways:
1. In manufacturing, emphasis is on materials, whereas in services it is on staffing levels.
2. Service systems do not store inventories of services.
3. Services are labor intensive, and demand for this labor can be highly variable.
4. Legal considerations constrain scheduling decisions.
5. Behavioral, social, seniority, and status issues occur in service scheduling.
(Scheduling services, moderate)

123. Identify some scheduling optimization systems that are used at retail stores. Describe what these systems do.
Workbrain, Cybershift, and Kronos. These systems track individual store sales, transactions, units sold, and customer traffic in 15-minute increments to create work schedules.
(Scheduling services, difficult) {AACSB: Use of IT}

PROBLEMS

124. A practitioner of family medicine begins her day with five patients needing urgent care. She does a very brief assessment of what each patient appears to need and estimates the time required of each. None of the cases is life-threatening, and so she determines to take the five in the order that they arrived at the clinic. The data for these patients, in the order they arrived, is Patient A, 30 minutes; Patient B, 40 minutes; Patient C; 10 minutes; Patient D, 50 minutes; and Patient E, 15 minutes.

a. If it is now 8:00 a.m., at what time will the doctor be finished with all five of these emergencies?
b. How much time will the five patients have collectively spent waiting?
c. How much less time would have been spent waiting if the doctor had taken the patients according to shortest processing time?

(a) Using first come, first served, all five patients will be finished in 145 minutes, or at 10:25 a.m. (b)Total flow time is 455 minutes, of which 145 is for processing, and the remaining 310 is waiting time. (c) If the doctor had used shortest processing time, the total flow time would have been 330 minutes, of which 185 is waiting time. In both cases, the doctor finished all patients at 10:25 a.m. A supporting table for each rule appears below.

	Machine 1	Due Date	# Opns	Order	Flow time
A	30.	0.	0.	first	30.
B	40.	0.	0.	second	70.
C	10.	0.	0.	third	80.
D	50.	0.	0.	fourth	130.
E	15.	0.	0.	fifth	145.
TOTAL					455.
AVERAGE					91.
Average # jobs in	3.1379				
Sequence: A, B, C, D, E					

	Machine 1	Due Date	# Opns	Order	Flow time
A	30.	0.	0.	third	55.
B	40.	0.	0.	fourth	95.
C	10.	0.	0.	first	10.
D	50.	0.	0.	fifth	145.
E	15.	0.	0.	second	25.
TOTAL					330.
AVERAGE					66.
Average # jobs in	2.2759				
Sequence: C, E, A, B, D					

(Sequencing jobs, moderate) {AACSB: Analytic Skills}

125. The emergency room at a hospital estimates the following requirements for registered nurses (RNs) for the late night shift each week. Nurses work four consecutive days, then have off three days.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
3	4	2	2	3	6	4

Perform cyclical scheduling on the data. (Note that you must identify three-day patterns of minimum requirements). How many RNs are required? How much extra capacity is required?

	Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
RN-1	**3**	**4**	**②**	**②**	**③**	**6**	**4**
RN-2	**2**	**③**	**②**	**②**	**3**	**5**	**3**
RN-3	**1**	**3**	**②**	**②**	**②**	**4**	**2**
RN-4	**⓪**	**②**	**2**	**2**	**2**	**3**	**①**
RN-5	**-**	**2**	**①**	**①**	**①**	**2**	**1**
RN-6	**-**	**1**	**1**	**1**	**1**	**①**	**⓪**
RN-7	**-**	**0**	**⓪**	**⓪**	**⓪**	**1**	**-**
RN-8						**1**	
Capacity	**5**	**5**	**2**	**2**	**3**	**7**	**5**

Days off are shaded. Seven full-time RNs are needed; an eighth works Friday only. A total of 29 shifts are used, while only 24 are required; thus 5 shifts represent excess capacity. This solution is not unique, as there are two instances where an arbitrary set of days was selected for minimum sum. (Scheduling services, moderate) {AACSB: Analytic Skills}

126. Jack's Refrigeration Repair is under contract to repair, recondition, and/or refurbish commercial and industrial icemakers from restaurants, seafood processors, and similar organizations. Jack currently has five jobs to be scheduled, shown in the order in which they arrived.

Job	Processing Time (hours)	Due (hours)
V	20	50
W	10	35
X	50	90
Y	15	35
Z	55	75

a. Complete the following table. (Show your supporting calculations below).
b. Which dispatching rule has the best score for flow time?
c. Which dispatching rule has the best score for work-in-process (jobs in the system)?
d. Which dispatching rule has the best score for lateness?
e. What dispatching rule would **you** select? Support your decision.

Dispatching Rule	Job Sequence	Average Flow Time	Average Number of Jobs	Average Lateness
FCFS				
SPT				
EDD				
CR				

(a) A summary of calculations appears in the table below.

Dispatching Rule	**Job Sequence**	**Average Flow Time**	**Average Number of Jobs**	**Average Lateness**
FCFS	**V, W, X, Y, Z**	**75**	**2.50**	**27**
SPT	**W, Y, V, X, Z**	**65**	**2.17**	**16**
EDD	**W, Y, V, Z, X**	**66**	**2.23**	**17**
CR	**Z, X, Y, V, W**	**114**	**3.80**	**61**

(b,c,d) SPT is best on all three criteria: flow time, work-in-process, and lateness. (e) Most students will select SPT as quite obvious, but EDD is a close second in all criteria. Supporting calculations for each priority rule appear in the tables below.

SPT	**Machine1**	**Due Date**	**Flow Time**	**Late**
W	**10**	**35**	**10**	**0**
Y	**15**	**35**	**25**	**0**
V	**20**	**50**	**45**	**0**
X	**50**	**90**	**95**	**5**
Z	**55**	**75**	**150**	**75**
Total			**325**	**80**
Average			**65**	**16**

Average # jobs in system = 2.17

FCFS	Machine1	Due Date	Flow Time	Late
V	20	50	20	0
W	10	35	30	0
X	50	90	80	0
Y	15	35	95	60
Z	55	75	150	75
Total			375	135
Average			75	27

Average # jobs in system = 2.5

EDD	Machine1	Due Date	Flow Time	Late
W	10	35	10	0
Y	15	35	25	0
V	20	50	45	0
Z	55	75	100	25
X	50	90	150	60
Total			330	85
Average			66	17

Average # jobs in system = 2.23

CR	Machine1	Due Date	CR	Flow Time	Late
Z	55	75	1.36	55	0
X	50	90	1.8	105	15
Y	15	35	2.33	120	85
V	20	50	2.5	140	90
W	10	35	3.5	150	115
Total				570	305
Average				114	61

Average # jobs in system = 3.80

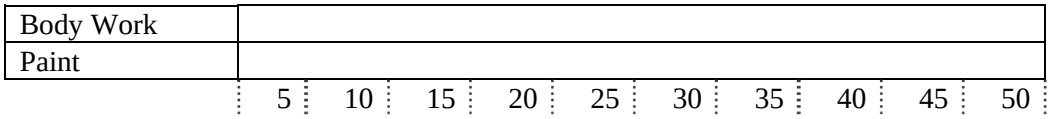
(Sequencing jobs, moderate) {AACSB: Analytic Skills}

127. The operations manager of a body and paint shop has five cars to schedule for repair. He would like to minimize the throughput time (makespan) to complete all work on these cars. Each car requires body work prior to painting. The estimates of the times required to do the body and paint work on each are as follows:

Car	Body Work (Hours)	Paint (Hours)
A	8	7
B	9	4
C	7	9
D	3	4
E	12	5

a. Chart the progress of these five jobs through the two centers on the basis of the arbitrary order A →B→C→D→E.

b. After how many hours will all jobs be completed?



c. Use Johnson's rule to sequence these five jobs for minimum total duration. Show your work in determining the job sequence.

d. The optimal sequence is _____.

e. Chart the progress of the five jobs in this optimal sequence.

f. After how many hours will all jobs be completed?

SEE NEXT PAGE FOR SOLUTION.

(a,b) Arbitrary order:

Body Work	**A**		**B**		**C**		**D**		**E**	
Paint			**A**		**B**		**C**		**D**	**E**
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**

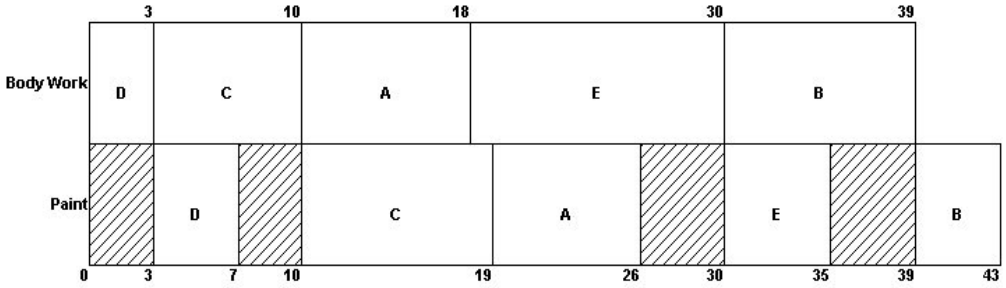
(c,d) The sequence of jobs is Car E, Car D, Car A, Car C, Car B. Makespan = 43 as per the POM for Windows solution below.

	Body Work	Paint	Order	Done 1	Done 2 (flow time)
A	8.	7.	third	18.	26.
B	9.	4.	fifth	39.	43.
C	7.	9.	second	10.	19.
D	3.	4.	first	3.	7.
E	12.	5.	fourth	30.	35.
Makespan					43.
Sequence: D, C, A, E, B					

(c) Johnson's method sequence of steps

Step	Job	Position
1	D	1.
2	B	5.
3	E	4.
4	A	3.
5	C	2.

(e,f)



(Sequencing jobs, moderate) {AACSB: Analytic Skills}

128. The president of a consulting firm wants to minimize the total number of hours it will take to complete four projects for a new client. Accordingly, she has estimated the time it should take for each of her top consultants -- Charlie, Gerald, Johnny, and Rick -- to complete any of the four projects, as follows:

	Project (hours)			
Consultant	A	B	C	D
Charlie	13	16	11	18
Gerald	13	15	10	12
Johnny	15	11	20	15
Rick	17	17	12	22

a. In how many different ways can she assign these consultants to these projects?
b. What is the total number of hours required by the following arbitrary assignment?
Charlie→B; Gerald→A; Johnny→D; Rick→C
c. What is the optimal assignment of consultants to projects? (Use the assignment method; **SHOW YOUR WORK!**)
d. For the optimal schedule, what is the total number of hours it will take these consultants to complete these projects?
e. What is the significance, if any, of the fact that Gerald is the best performer at all four projects?
(a) 4!, or 24 ways. (b) 16+13+15+12=56 hours. (c) Table appears below. (d) 48 hours. (e) Each person must get exactly one assignment. Note that Gerald does not get the assignment at which he is absolutely most productive (Project C). The optimum assignment is about opportunity cost, not absolute high or low values.

	Project A	**Project B**	**Project C**	**Project D**
Charlie	**1**	**0**	**0**	**0**
Gerald	**0**	**0**	**0**	**1**
Johnny	**0**	**1**	**0**	**0**
Rick	**0**	**0**	**1**	**0**

(Loading jobs, moderate) {AACSB: Analytic Skills}

129. The following jobs are waiting to be processed at your work center, which cleans valve body castings. Job numbers are assigned sequentially upon arrival in the facility (a missing number means that job does not require your work center). All dates are specified as days from present.

Job	Due Date	Duration (days)
101	43	10
102	34	12
104	37	11
107	32	7
108	37	15

a. In what sequence should the jobs be processed according to the FCFS scheduling rule?
b. In what sequence should the jobs be processed according to the EDD scheduling rule?
c. In what sequence should the jobs be processed according to the SPT scheduling rule?
d. In what sequence should the jobs be processed according to the LPT scheduling rule?
e. In what sequence should the jobs be processed according to the critical ratio scheduling rule?
FCFS: 101, 102, 104, 107, 108
EDD: 107, 102, 104 and 108 (tie), 101
SPT: 107, 101, 104, 102, 108
LPT: 108, 102, 104, 101, 107
CR: 108 (2.47), 102 (2.67), 104 (3.36), 101 (3.40), 107 (6.14)
(Sequencing jobs, moderate) {AACSB: Analytic Skills}

130. Lockport Marine Services, Inc. wishes to assign a set of jobs to a set of machines. The following table provides data on the cost of production of each job when performed on a specific machine.
a. Determine the set of assignments that maximizes production value.
b. What is the total production value of your assignments?

	Machine			
Job	A	B	C	D
1	27	29	28	30
2	30	29	27	26
3	31	25	29	26
4	29	31	25	28

(a) The optimal set of assignments is Job 1→Machine A, Job 2→Machine D, Job 3→Machine B, and Job 4→Machine C. (b) The total production value is 103.

	Machine A	**Machine B**	**Machine C**	**Machine D**	**Row Total**
Job 1	**1**	**0**	**0**	**0**	**1**
Job 2	**0**	**0**	**0**	**1**	**1**
Job 3	**0**	**1**	**0**	**0**	**1**
Job 4	**0**	**0**	**1**	**0**	**1**
Column Total	**1**	**1**	**1**	**1**	**4**
Total Cost	**103**				

(Loading jobs, moderate) {AACSB: Analytic Skills}

131. At Morgan's Transformer Rebuilding, a set of five jobs is ready for dispatching to a machine center. The processing times and due dates for the jobs are given in the table below. Use **shortest processing time** to sequence the jobs, and calculate the average completion time, the average job lateness, and the average number of jobs in the machine center.

Job	Work Time (days)	Due Date (days)
A	15	38
B	13	28
C	7	20
D	18	50
E	9	15

The optimal sequence is C-E-B-A-D. The average completion time is 31.6 days. The average lateness is 4 days. The average jobs in system is 2.548. Details appear in the table below.

SPT	Time	Due Date	Slack	Flow time	Late days
C	**7**	**20**	**13**	**7**	**0**
E	**9**	**15**	**6**	**16**	**1**
B	**13**	**28**	**15**	**29**	**1**
A	**15**	**38**	**23**	**44**	**6**
D	**18**	**50**	**32**	**62**	**12**
			Total	**158**	**20**
			Average	**31.6**	**4**

Average number of jobs in system 2.548
(Sequencing jobs, moderate) {AACSB: Analytic Skills}

132. At Morgan's Transformer Rebuilding, five jobs are ready now for dispatching to a machine center. The processing times and due dates for the jobs are given below. Use **earliest due date** to sequence the jobs, and calculate the average completion time, the average job lateness, and the average number of jobs in the machine center.

Job	Work Time (days)	Due Date (days)
A	15	38
B	13	28
C	7	20
D	18	50
E	9	15

The EDD sequence is E-C-B-A-D. Average completion time is 32 days. Average lateness is 3.8 days. Average number of jobs is 2.58

EDD	Time	Due Date	Slack	Flow time	Late days
E	**9**	**15**	**6**	**9**	**0**
C	**7**	**20**	**13**	**16**	**0**
B	**13**	**28**	**15**	**29**	**1**
A	**15**	**38**	**23**	**44**	**6**
D	**18**	**50**	**32**	**62**	**12**
			Total	**160**	**19**
			Average	**32**	**3.8**

Average number of jobs in system 2.58
(Sequencing jobs, moderate) {AACSB: Analytic Skills}

133. Use Johnson's rule to determine the optimal sequencing for the five jobs to be processed on two machines in a fixed order (Machine 1 before Machine 2). The processing times are given in the table below.
a. What is the optimal sequence?
b. What is the total flow time for this sequence?

Job	Machine 1	Machine 2
L	10	11
M	8	17
N	14	9
O	13	7
P	10	8

(a,b) The optimal sequence is M-L-N-P-O, and the total flow time is 62. Details are contained in the solution table below.

	Machine 1	Machine 2	Order	Done 1	Done 2 (flow time)
L	10.	11.	second	18.	36.
M	8.	17.	first	8.	25.
N	14.	9.	third	32.	45.
O	13.	7.	fifth	55.	62.
P	10.	8.	fourth	42.	53.
Makespan					62.
Sequence: M, L, N, P, O					

(Sequencing jobs, moderate) {AACSB: Analytic Skills}

134. A manufacturer has the following jobs waiting on a single work center. The firm has not decided which dispatching rule to apply in order to prioritize the jobs and fix them into the schedule. Processing time in 15-minute time blocks and due date for each job are in the table below.

	Time	Due Date
Job 1	5	17
Job 2	4	20
Job 3	3	16
Job 4	7	9
Job 5	3	6
Job 6	5	7

a. Complete the following table. Show your supporting calculations below.
b. Which dispatching rule has the best score for flow time? for work in process (jobs in the system)? for lateness?
c. Is there ANY sequence that can avoid all lateness? Explain or provide an example.

Dispatching Rule	Job Sequence	Average Flow Time	Average Number of Jobs	Average Lateness
EDD				
SPT				
LPT				

SEE NEXT PAGE FOR SOLUTION.

(a) The results appear in the table below. A supporting table for each dispatch rule also follows.

Dispatching Rule	Job Sequence	Average Flow Time	Average Number of Jobs	Average Lateness
EDD	5-6-4-3-1-2	15.67	3.48	3.67
SPT	3-5-2-1-6-4	13.50	3.00	5.17
LPT	4-6-1-2-5-3	18.00	4.00	5.83

(b,c,d) SPT is best for flow time, and for average jobs in system; EDD is best for lateness.
(e) Lateness is unavoidable with any dispatch rule; the sum of processing times is 27 but the longest due date is only 20 days away.

EDD	Time	Due Date	Slack	Flow time	Late days
Job 5	3	6	3	3	0
Job 6	5	7	2	8	1
Job 4	7	9	2	15	6
Job 3	3	16	13	18	2
Job 1	5	17	12	23	6
Job 2	4	20	16	27	7
			Total	94	22
			Average	15.67	3.667
Average number of jobs in system				3.481	

SPT	Time	Due Date	Slack	Flow time	Late days
Job 3	3	16	13	3	0
Job 5	3	6	3	6	0
Job 2	4	20	16	10	0
Job 1	5	17	12	15	0
Job 6	5	7	2	20	13
Job 4	7	9	2	27	18
			Total	81	31
			Average	13.5	5.167
Average number of jobs in system				3	

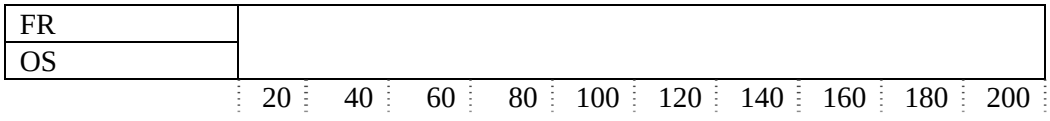
LPT	Time	Due Date	Slack	Flow time	Late days
Job 4	7	9	2	7	0
Job 6	5	7	2	12	5
Job 1	5	17	12	17	0
Job 2	4	20	16	21	1
Job 5	3	6	3	24	18
Job 3	3	16	13	27	11
			Total	108	35
			Average	18	5.83
Average number of jobs in system				4	

(Sequencing jobs in work centers, moderate) {AACSB: Analytic Skills}

135. Bob Dresser operates a major appliance warranty service center. His operation has two check stations that are required at the end of every repair task performed by his appliance repair staff. These are the Functionality Review (FR) and the Overall Scan (OS). The FR must be performed successfully before the OS is begun. On Friday morning, six repair jobs are completed, awaiting these two inspection activities. Processing times are given in minutes.

Job	FR	OS
A	50	30
B	35	55
C	25	20
D	20	35
E	15	10
F	10	25

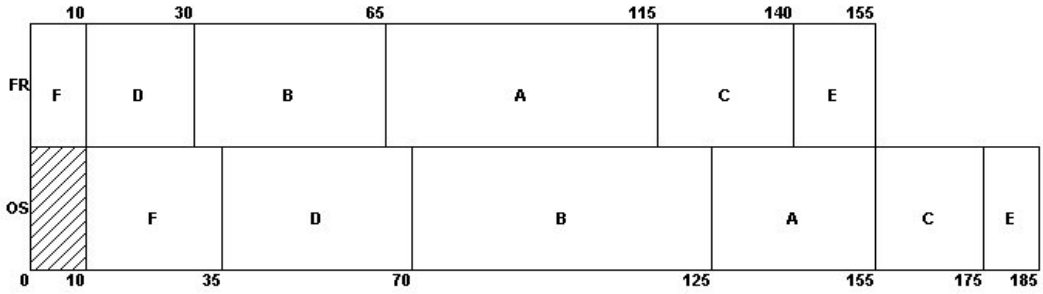
a. What is the optimal sequence of jobs for the objective of minimizing the total flow time?
b. Show your work, and document the sequence.
c. Chart the solution to this problem.
d. What jobs are being processed at time period 90?
e. What is the total flow time of this problem?



(a) The optimal sequence is F-D-B-A-C-E. (b) Supporting work appears in the table below.

	FR	OS	Order	Done 1	Done 2 (flow time)
A	50.	30.	fourth	115.	155.
B	35.	55.	third	65.	125.
C	25.	20.	fifth	140.	175.
D	20.	35.	second	30.	70.
E	15.	10.	sixth	155.	185.
F	10.	25.	first	10.	35.
Makespan					185.
Sequence: F, D, B, A, C, E					

(c) The schedule appears in the chart below. (d) At hour 50, B is in the first center, and D is in the second. (e) Total flow time for the schedule is 185.



d) Job A is being processed at FR (Machine 1), while Job B is being processed at OS (Machine 2) (Sequencing jobs, moderate) {AACSB: Analytic Skills}

136. Machines A, B, C, and D have been in use for several years, while machine E is new. The following table provides data on the value of production of each job when performed on a specific machine.
a. Determine the set of assignments that maximizes production value.
b. What is the total production value of your assignments?
c. Which machine should be retired (i.e., gets no assignment)?
d. If they do retire one machine, will they be as profitable without it as with it? Explain.

	Machine				
Job	A	B	C	D	E
1	27	29	28	30	40
2	30	32	31	34	46
3	33	25	29	26	37
4	29	31	24	28	28

(a) The optimal assignment is Job 1→D, Job 2→E, Job 3→A, and Job 4→B. (b) The cost of this assignment is 140. (c) C gets no assignment, and should be the machine retired.

	A	B	C	D	E	Row Total
Job 1	**0**	**0**	**0**	**1**	**0**	**1**
Job 2	**0**	**0**	**0**	**0**	**1**	**1**
Job 3	**1**	**0**	**0**	**0**	**0**	**1**
Job 4	**0**	**1**	**0**	**0**	**0**	**1**
Job 5	**0**	**0**	**1**	**0**	**0**	**1**
Column Total	**1**	**1**	**1**	**1**	**1**	**5**
Total Cost	**140**					

(d) Taking away what was arguably the least productive machine still reduces the options of the firm, and alters the opportunity costs. They cannot be better off without the machine.

	Assignments				
Shipments	**A**	**B**	**D**	**E**	**Row Total**
Job 1	**0**	**0**	**1**	**0**	**1**
Job 2	**0**	**0**	**0**	**1**	**1**
Job 3	**1**	**0**	**0**	**0**	**1**
Job 4	**0**	**1**	**0**	**0**	**1**
Column Total	**1**	**1**	**1**	**1**	**4**
Total Cost	**140**				

(Loading jobs, moderate) {AACSB: Analytic Skills}

137. A firm that specializes in desktop publishing for local charities has agreed to take on the following jobs. The firm has not decided which dispatching rule to apply in order to prioritize the jobs and fix them into the schedule.

	Time	Due Date
Job 1	20	25
Job 2	15	20
Job 3	7	16
Job 4	25	50
Job 5	31	33
Job 6	43	55

a. Complete the following table. Show your supporting calculations below.
b. Which dispatching rule has the best score for flow time?
c. Which dispatching rule has the best score for work-in-process (jobs in the system)?
d. Which dispatching rule has the best score for lateness?

Dispatching Rule	Job Sequence	Average Flow Time	Average Number of Jobs	Average Lateness
FCFS				
EDD				
SPT				
LPT				

(a) The table of results appears below. A supporting table for each dispatch rule also follows.

Dispatching Rule	**Job sequence**	**Average Flow Time**	**Average Number of Jobs**	**Average Lateness**
FCFS	**1-2-3-4-5-6**	**67.2**	**2.86**	**34.8**
EDD	**3-2-1-5-4-6**	**63.8**	**2.71**	**32.2**
SPT	**3-2-1-4-5-6**	**62.8**	**2.67**	**31.2**
LPT	**6-5-4-1-2-3**	**101.7**	**4.33**	**70.5**

(b,c,d) The SPT rule is best for flow time, for average jobs in system, and for lateness.

FCFS	**Time**	**Due Date**	**Slack**	**Flow time**	**Late days**
Job 1	**20**	**25**	**5**	**20**	**0**
Job 2	**15**	**20**	**5**	**35**	**15**
Job 3	**7**	**16**	**9**	**42**	**26**
Job 4	**25**	**50**	**25**	**67**	**17**
Job 5	**31**	**33**	**2**	**98**	**65**
Job 6	**43**	**55**	**12**	**141**	**86**
			Total	**403**	**209**
			Average	**67.17**	**34.83**
Average jobs in system				**2.858**	

EDD	Time	Due Date	Slack	Flow time	Late days
Job 3	7	16	9	7	0
Job 2	15	20	5	22	2
Job 1	20	25	5	42	17
Job 5	31	33	2	73	40
Job 4	25	50	25	98	48
Job 6	43	55	12	141	86
			Total	383	193
			Average	63.83	32.17

Average number of jobs in system 2.716

SPT	Time	Due Date	Slack	Flow time	Late days
Job 3	7	16	9	7	0
Job 2	15	20	5	22	2
Job 1	20	25	5	42	17
Job 4	25	50	25	67	17
Job 5	31	33	2	98	65
Job 6	43	55	12	141	86
			Total	377	187
			Average	62.83	31.17

Average number of jobs in system 2.674

LPT	Time	Due Date	Slack	Flow time	Late days
Job 6	43	55	12	43	0
Job 5	31	33	2	74	41
Job 4	25	50	25	99	49
Job 1	20	25	5	119	94
Job 2	15	20	5	134	114
Job 3	7	16	9	141	125
			Total	610	423
			Average	101.67	70.5

Average number of jobs in system 4.326

(Sequencing jobs, moderate) {AACSB: Analytic Skills}

138. Use Johnson's rule to determine the optimal sequencing for the five jobs to be processed on two machines in a fixed order (Machine 1 before Machine 2). The processing times in hours are given in the table below.
a. What is the optimal sequence?
b. What is the total flow time for this sequence?
c. Which job is the first to be scheduled? Is it scheduled to be the first job or the last? Explain.

Job	Machine 1	Machine 2
A	10	11
B	8	17
C	14	10
D	13	7
E	10	8
F	25	9
G	6	15

(a,b) The optimal sequence is G-B-A-C-F-E-D, and the total flow time is 93 hours, as shown in the software solution below.

	Machine 1	Machine 2	Order	Done 1	Done 2 (flow time)
A	10.	11.	third	24.	49.
B	8.	17.	second	14.	38.
C	14.	10.	fourth	38.	59.
D	13.	7.	seventh	86.	93.
E	10.	8.	sixth	73.	81.
F	25.	9.	fifth	63.	72.
G	6.	15.	first	6.	21.
Makespan					93.
Sequence: G, B, A, C, F, E, D					

(c) Job G is the first job to be scheduled. The smallest of all processing times is 6 hours, for Job G. Because this occurs at Machine 1, Job G is scheduled into the first position.
(Sequencing jobs, moderate) {AACSB: Analytic Skills}

CHAPTER 16: JUST-IN-TIME AND LEAN PRODUCTION SYSTEMS

TRUE/FALSE

1. TPS stands for Toyota Production System.
True (Just-in-time, the Toyota production system, and lean operations; easy)

2. TPS stands for Total Production Streamlining.
False (Just-in-time, the Toyota production system, and lean operations; easy)

3. Product storage is an example of waste, in the sense that no value is added.
True (Just-in-time, the Toyota production system, and lean operations; moderate)

4. In a JIT system, product inspection adds value by identifying defective items.
False (Just-in-time, the Toyota production system, and lean operations; moderate)

5. Customer demand will always remain an unknown, so it is not considered a source of variation.
False (Just-in-time, the Toyota production system, and lean operations; moderate)

6. Variability in manufacturing can occur because engineering drawings or specifications are incomplete or inaccurate.
True (Just-in-time, the Toyota production system, and lean operations; moderate)

7. A push system means providing the next station with exactly what is needed when it is needed.
False (Just-in-time, the Toyota production system, and lean operations; moderate)

8. Waste is anything that does not add value, such as storage or inspection of items; waste also includes any activity that does not add value from the consumer's perspective.
True (Just-in-time, the Toyota production system, and lean operations; moderate)

9. Increasing inventory exposes variability in production processes.
False (Just-in-time, the Toyota production system, and lean operations; moderate)

10. JIT brings about competitive advantage by faster response to the customer regardless of cost.
False (Just-in-time (JIT), moderate)

11. One goal of JIT partnerships is the removal of in-plant inventory by delivery in small lots directly to the using department as needed.
True (Just-in-time (JIT), easy)

12. Many suppliers feel that having a variety of customers is better than being tied to long-term contracts with one customer.
True (Just-in-time (JIT), moderate)

13. JIT suppliers have concerns that the JIT firm's demands for small lot sizes are simply a way of transferring holding cost from manufacturer firm to the supplier firm.
True (Just-in-time (JIT), moderate)

14. Reducing distance is a common JIT goal.
True (JIT layout, moderate)

15. Cross-training is a common JIT tactic to improve flexibility.
True (JIT layout, moderate)

16. JIT systems carry inventory just in case something goes wrong.
False (JIT inventory, moderate)

17. Hidden problems are generally uncovered during the process of reducing inventory.
True (JIT inventory, moderate)

18. Lower average inventory is feasible only if setup times are short.
True (JIT inventory, moderate)

19. If setup times and costs can be reduced enough, the JIT ideal of "Lot Size = 1" can be achieved.
True (JIT inventory, moderate)

20. A scheduler may find that freezing the portion of the schedule closest to the due dates allows the production system to function and the schedule to be met.
True (JIT scheduling, moderate)

21. The first step in reducing setup times is the separation of setup into preparation activities and actual setup, so that as much work as possible can be done while the machine or process is operating.
True (JIT inventory, easy)

22. Level scheduling means producing at a constant rate, regardless of customer demands.
False (JIT scheduling, easy)

23. With level schedules, a few large batches, rather than frequent small batches, are processed.
False (JIT scheduling, moderate)

24. The number of kanbans decreases as safety stock is increased.
False (JIT scheduling, easy) {AACSB: Communication}

25. A kanban system requires little variability in lead time because shortages have their impact on the entire productive system.
True (JIT scheduling, moderate) {AACSB: Communication}

26. Inventory has only one positive aspect, which is availability; inventory has several negatives, including increased material handling, obsolescence, and damage.
True (JIT scheduling, moderate)

27. The quality management tool called poka-yoke is not relevant to JIT systems.
False (JIT Quality, moderate)

28. Employee empowerment is unnecessary in the Toyota Production System, because automation and powerful information systems reduce the need for employee creativity and decision making.
False (Toyota production system, easy)

29. The Toyota Production System requires that activities have built-in, automatic tests so that gaps between expectations and actuality are immediately evident.
True (Toyota production system, easy)

30. The 5S's—sort/segregate, simplify/straighten, shine/sweep, standardize, and sustain/self discipline—are important to lean production because they act as a means to reduce waste.
True (Just-in-time, the Toyota production system, and lean operations; easy)

31. When implemented as a comprehensive manufacturing strategy, JIT, TPS, and lean systems sustain competitive advantage and result in increased overall returns.
True (Just-in-time, the Toyota production system, and lean operations; moderate)

32. Because most services cannot be inventoried, there is little place for JIT to help service organizations achieve competitive advantage.
False (Lean operations in services, moderate)

MULTIPLE CHOICE

33. What does TPS stand for?
    a. Total Production Streamlining
    b. Toyota Production System
    c. Taguchi's Production S's
    d. Total Process Simplification
    e. None of the above
    b (Just-in-time, the Toyota production system, and lean operations; easy)

34. Which of the following is generally found in most JIT environments?
    a. a push or pull system, depending upon the rate of demand
    b. a push system for high margin items and a pull system for low margin items
    c. a push system for purchased parts and a pull system for manufactured parts
    d. push systems
    e. pull systems
    e (Just-in-time, the Toyota production system, and lean operations; moderate)

35. Which one of the following is **not** a benefit of the implementation of JIT?
    a. cost reduction
    b. variability increase
    c. rapid throughput
    d. quality improvement
    e. rework reduction
    b (Just-in-time (JIT), easy)

36. Which of the following is **not** a reason for variability?
    a. Employees, machines, and suppliers produce units late.
    b. Customer demand is unknown.
    c. Employees, machines, and suppliers produce units that conform to standards.
    d. Engineering drawings are inaccurate.
    e. Drawings or specifications are incomplete.
    c (Just-in-time, the Toyota production system, and lean operations; easy)

37. Which of the following is specifically characterized by a focus on continuous improvement, respect for people, and standard work practices?
    a. Just-in-time (JIT)
    b. Toyota Production System (TPS)
    c. Lean operations
    d. Material requirements planning (MRP)
    e. kanban
    b (Just-in-time, the Toyota production system, and lean operations; moderate)

38. Which of the following is specifically characterized by continuous and forced problem solving via a focus on throughput and reduced inventory?
    a. Just-in-time (JIT)
    b. Toyota Production System (TPS)
    c. Lean operations
    d. Material requirements planning (MRP)
    e. kanban
    a (Just-in-time, the Toyota production system, and lean operations; moderate)

39. Which of the following statements regarding a pull system is **true**?
    a. Large lots are pulled from upstream stations.
    b. Work is pulled to the downstream stations before it is actually needed.
    c. Manufacturing cycle time is increased.
    d. Problems become more obvious.
    e. None of the above is true of a pull system.
    d (Just-in-time, the Toyota production system, and lean operations; moderate)

40. Manufacturing cycle time is best defined as the
    a. length of the work shift, expressed in minutes per day
    b. time it takes a unit to move from one workstation to the next
    c. time between the start of one unit and the start of the next unit
    d. sum of all the task times to make one unit of a product
    e. time from raw materials receipt to finished product exit
    e (Just-in-time, the Toyota production system, and lean operations; moderate)

41. If the goals of JIT partnerships are met, which of the following is a result?
    a. For incoming goods, receiving activity and inspection are outsourced.
    b. In-transit inventory falls as suppliers are located closer to facilities.
    c. The number of suppliers increases.
    d. In-plant inventory replaces in-transit inventory.
    e. All of the above are consequences of meeting the JIT partnership goals.
    b (Just-in-time (JIT), moderate)

42. Which one of the following is a characteristic of a JIT partnership?
    a. large number of suppliers
    b. maximal product specifications imposed on supplier
    c. active pursuit of vertical integration
    d. removal of incoming inspection
    e. frequent deliveries in large lot quantities
    d (Just-in-time (JIT), moderate)

43. Which of the following is specifically characterized by the elimination of waste through a focus on exactly what the customer wants?
    a. Just-in-time (JIT)
    b. Toyota Production System (TPS)
    c. Lean operations
    d. Material requirements planning (MRP)
    e. kanban
    c (Just-in-time, the Toyota production system, and lean operations; moderate)

44. Characteristics of JIT partnerships with respect to suppliers include
    a. competitive bidding encouraged
    b. buyer plant pursues vertical integration to reduce the number of suppliers
    c. support suppliers so they become or remain price competitive
    d. most suppliers at considerable distance from purchasing organization
    e. All of the above are characteristics of JIT partnerships.
    c (Just-in-time (JIT), moderate)

45. Characteristics of just-in-time partnerships do **not** include
    a. removal of in-transit inventory
    b. large lot sizes to save on setup costs and to gain quantity discounts
    c. long-term contracts
    d. few suppliers
    e. buyer helps supplier to meet the quality requirements
    b (Just-in-time (JIT), moderate)

46. What is the time required to move orders through the production process, from receipt to delivery?
    a. throughput
    b. manufacturing cycle time
    c. pull time
    d. push time
    e. queuing time
    a (Just-in-time, the Toyota production system, and lean operations; moderate)

47. Which of the following is **not** a goal of JIT partnerships?
    a. removal of unnecessary activities
    b. removal of in-plant inventory
    c. removal of in-transit inventory
    d. removal of engineering changes
    e. All of the above are goals of JIT partnerships.
    d (Just-in-time (JIT), moderate)

48. A characteristic of JIT partnerships with respect to quality is to
    a. help suppliers meet quality requirement
    b. inspect all incoming parts
    c. maintain a steady output rate
    d. impose maximum product specifications on the supplier
    e. draw up strict contracts ensuring that all defectives will be immediately replaced
    a (Just-in-time (JIT), moderate)

49. Which of the following is **not** a goal of JIT partnerships?
    a. removal of unnecessary activities
    b. removal of in-plant inventory
    c. removal of in-transit inventory
    d. obtain improved quality and reliability
    e. All of the above are goals of JIT partnerships.
    e (Just-in-time (JIT), moderate)

50. Which one of the following is a concern expressed by suppliers?
    a. elimination of in-plant inventory
    b. delivery to the point of use
    c. production with zero defects
    d. large lot sizes
    e. customers' infrequent engineering changes
    c (Just-in-time (JIT), moderate)

51. Reduction of in-transit inventory can be encouraged through use of
    a. supplier location near plants
    b. low setup costs
    c. low carrying costs
    d. use of trains, not trucks
    e. low-cost, global suppliers
    a (Just-in-time (JIT), moderate)

52. In JIT partnerships, suppliers have several concerns. Which of the following is **not** such a concern?
    a. desire for diversification
    b. poor customer scheduling
    c. small lot sizes
    d. producing high enough quality levels
    e. customers' infrequent engineering changes
    e (Just-in-time (JIT), easy)

53. Which of the following is **not** a concern of suppliers as they prepare to enter into JIT partnerships?
    a. Suppliers feel that they would be less at risk if they contracted with more than one customer.
    b. Suppliers are concerned that customers will present frequent engineering changes with inadequate lead time to deal with them.
    c. Suppliers feel that their processes are suited for larger lot sizes than the customer wants.
    d. Suppliers are concerned that frequent delivery of small quantities is economically prohibitive.
    e. All of the above represent JIT supplier concerns.
    e (Just-in-time (JIT), moderate)

54. Just-in-time systems make demands on layouts, including
    a. distance reduction
    b. increased flexibility
    c. reduced space and inventory
    d. cross-trained, flexible employees
    e. All of the above are JIT influences on layout.
    e (JIT layout, moderate)

55. Which one of the following is **not** a layout tactic in a JIT environment?
    a. work cells for families of products
    b. fixed equipment
    c. minimizing distance
    d. little space for inventory
    e. poka-yoke devices
    b (JIT layout, moderate)

56. Which of the following is the author of the phrase "Inventory is evil"?
    a. Poka Yoke
    b. Pat "Keiretsu" Morita
    c. Kanban Polka
    d. Shigeo Shingo
    e. none of the above
    d (JIT inventory, moderate)

57. Which one of the following statements is **true** regarding JIT inventory?
    a. It exists just in case something goes wrong.
    b. It is the minimum inventory necessary to keep a perfect system running.
    c. It hides variability.
    d. It is minimized with large lot production.
    e. It increases if setup costs decrease.
    b (JIT inventory, moderate)

58. A firm wants to develop a level material use schedule based on the following data. What should be the setup cost?

Desired lot size:	60
Annual demand:	40,000
Holding cost:	$20 per unit per year
Daily production rate:	320
Work days per year:	250

    a. $0.45
    b. $4.50
    c. $45
    d. $450
    e. $500
    a (JIT inventory, moderate) {AACSB: Analytic Skills}

59. A product has annual demand of 100,000 units. The plant manager wants production to follow a four-hour cycle. Based on the following data, what setup cost will enable the desired production cycle? d=400 per day (250 days per year), p=4000 units per day, H=$40 per unit per year, and Q=200 (demand for four hours, half a day).
    a. $2.00
    b. $7.20
    c. $18.00
    d. $64.00
    e. $1,036.80
    b (JIT inventory, moderate) {AACSB: Analytic Skills}

60. Throughput measures the time
    a. that it takes to process one unit at a station
    b. between the arrival of raw materials and the shipping of finished products
    c. to produce one whole product through an empty system (i.e., with no waiting)
    d. required to move orders through the production process, from receipt to delivery
    e. none of the above
    d (Just-in-time, the Toyota production system, and lean operations; moderate)

61. Which of the following is **true** regarding the steps to reducing setup times?
    a. The first step involves performing as much setup preparation as possible while the process/machine is operating.
    b. The cycle of steps is repeated until setup time is reduced to under a minute.
    c. Standardize tooling and standardize training are included in the same step.
    d. Improved material handling and move material closer are done before operator training.
    e. All of the above are true.
    e (JIT inventory, moderate)

62. Factory X is trying to use level use scheduling. If their first target were to cut the current lot size in half, by what proportion must setup cost change?
    a. Setup cost must be cut to one fourth its current value.
    b. Setup cost must also be cut in half from its current value.
    c. Setup cost must double from its current value.
    d. cannot be determined
    e. none of the above
    a (JIT inventory, moderate)

63. The technique known as level schedules
    a. requires that schedules be met without variation
    b. processes many small batches rather than one large one
    c. is known as "jelly bean" scheduling
    d. is based on meeting one day's demand with that day's production
    e. All of the above are true regarding level scheduling.
    e (JIT scheduling, moderate)

64. Which one of the following statements is **true** about the kanban system?
    a. The quantities in the containers are usually large to reduce setup costs.
    b. It is associated with a push system.
    c. It is useful to smooth operations when numerous quality problems occur.
    d. The supplier workstation signals the customer workstation as soon as a batch is completed.
    e. The customer workstation signals to the supplier workstation when production is needed.
    e (JIT scheduling, moderate) {AACSB: Communication}

65. Kanban is associated with all of the following **except**
    a. small lot sizes
    b. signals, such as cards, lights, or flags
    c. moving inventory only as needed
    d. increased material handling
    e. reductions in inventory
    d (JIT scheduling, moderate) {AACSB: Communication}

66. The word "kanban" means
    a. low inventory
    b. employee empowerment
    c. card
    d. continuous improvement
    e. lot size of one
    c (JIT scheduling, easy) {AACSB: Communication}

67. Which one of the following scenarios represents the use of a kanban to reduce inventories?
    a. A supervisor tells the operators to stay busy and start producing parts for next month.
    b. A "supplier" work center signals the downstream workstation that a batch has been completed.
    c. A supervisor signals to several work centers that the production rate should be changed.
    d. A "customer" work center signals to the "supplier" workstation that more parts are needed.
    e. An operator asks the next station's operator to help him fix his machine.
    d (JIT scheduling, moderate) {AACSB: Communication}

68. If a casual-dining restaurant is attempting to practice JIT and lean operations, which of the following would **not** be present?
    a. close relationship with the restaurant's suppliers of food, utensils, and equipment
    b. food preparation in large batches
    c. a kitchen set up to minimize wasteful movements
    d. lean inventories of food
    e. All of the above should be present.
    b (JIT scheduling, moderate)

69. The number of kanbans is
    a. one
    b. the ratio of the reorder point to container size
    c. the same as EOQ
    d. one full day's production
    e. none of the above
    b (JIT scheduling, moderate) {AACSB: Communication}

70. Which of the following is **false** regarding the links between JIT and quality?
    a. Inventory hides bad quality; JIT immediately exposes it.
    b. JIT reduces the number of potential sources of error by shrinking queues and lead times.
    c. As quality improves, fewer inventory buffers are needed; in turn, JIT performs better.
    d. If consistent quality exists, JIT allows firms to reduce all costs associated with inventory.
    e. All of the above are true.
    e (JIT Quality, moderate)

71. Which of the following is an illustration of employee empowerment?
    a. UPS drivers are trained to perform several motions smoothly and efficiently.
    b. Unionization of the work place brings better morale and therefore better quality.
    c. "No one knows the job better than those who do it."
    d. all of the above
    e. none of the above
    c (Toyota production system, moderate)

72. Which of the following is **not** an attribute of lean operators?
    a. eliminating almost all inventory through just-in-time techniques
    b. minimizing space requirements by reducing the distance a part travels
    c. pushing responsibility to the highest level possible through centralized decision making
    d. educating suppliers to accept responsibility for helping meet customer needs
    e. All of the above are attributes of lean producers.
    c (Lean operations, easy)

73. The 5S's
    a. have the "flavor" of a housekeeping list
    b. are a checklist for lean operations
    c. have become a list of seven items in American practice
    d. can be used to assist with necessary changes in organizational culture
    e. All of these are true.
    e (Just-in-time, the Toyota production system, and lean operations; moderate)

74. The list of 5S's, although it looks like a housekeeping directive, supports lean production by
    a. identifying non-value items and removing them, in the "sort/segregate" item
    b. reducing inventory, in the "standardize" item
    c. increasing variability through standardized procedures, in the "standardize" item
    d. eliminating wasted motion through ergonomic studies, in the "support" item
    e. building good safety practices, in the "shine/sweep" item
    a (Just-in-time, the Toyota production system, and lean operations; moderate)

75. In the quest for competitive advantage, which of the following is a JIT requirement?
    a. small number of job classifications
    b. reduced number of vendors
    c. reduced space for inventory
    d. quality by suppliers
    e. All of the above are JIT requirements.
    e (Multiple sections, moderate)

76. Which one of the following does **not** exemplify JIT used for competitive advantage?
    a. Acme Foods decides to decrease the number of its suppliers to just a few.
    b. Ajax, Inc. is proud to announce that incoming goods are delivered directly to the point of use.
    c. Ardoyne Builders has a scheduled preventive maintenance program.
    d. Cheramie Trucking trains workers to specialize and become very efficient in one job.
    e. Cajun Contractors has reduced the amount of space for inventory.
    d (Multiple sections, moderate)

77. Which one of the following is **not** a requirement of JIT systems?
    a. quality deliveries on time
    b. low setup time
    c. training support
    d. strong job specialization
    e. employee empowerment
    d (Multiple sections, moderate)

78. Great Lakes Barge and Baggage Company makes, among other things, battery-operated bilge pumps. Which of the following activities is **not** part of JIT? They
    a. communicate their schedules to suppliers
    b. produce in long production runs to reduce the impact of setup costs
    c. use a pull system to move inventory
    d. continuously work on reducing setup time
    e. produce in small lots
    b (Multiple sections, moderate)

79. Which one of the following is an example of JIT being used for competitive advantage?
    a. Jones Company has decreased the number of job classifications to just a few.
    b. Lafourche Metals increases the number of its suppliers to be less dependent on just a few.
    c. Houma Fabricators is proud to announce that incoming goods are inspected.
    d. Acme Company tells its maintenance department to intervene only if a machine breaks down.
    e. Caro Specialty Metals, Inc. has built a new, huge warehouse to store inventory.
    a (Multiple sections, moderate)

80. A manufacturer took the following actions to reduce inventory. Which of these is generally **not** accepted as a JIT action?
    a. It used a pull system to move inventory.
    b. It produced in ever smaller lots.
    c. It required deliveries directly to the point of use.
    d. It picked the supplier that offered the lowest price based on quantity discounts.
    e. It worked to reduce the company's in-transit inventory.
    d (Multiple sections, moderate)

81. Which of the following is **not** one of the Seven Wastes?
    a. overproduction
    b. transportation
    c. assignment
    d. defective product
    e. motion
    c (Just-in-time, the Toyota production system, and lean operations; easy)

82. Concerning relationships with suppliers, which of the following combinations is critical to the success of JIT?
    a. close relationships with trust
    b. close relationships with skepticism
    c. distant relationships with trust
    d. distant relationships with skepticism
    e. none of the above
    a (Just-in-time (JIT), easy)

83. Which of the following statements regarding JIT in services is **true**?
    a. Restaurants do not use JIT layouts because they interfere with creation of a good servicescape.
    b. Excess customer demand in services such as air travel is met by dipping into safety stocks.
    c. All of the JIT techniques for dealing with suppliers, layout, inventory, and scheduling are used in services.
    d. Scheduling is not relevant to effective use of JIT in services.
    e. All of the above are false.
    c (Lean operations in services, moderate)

FILL-IN-THE-BLANK

84. _____ is the minimum inventory necessary to keep a perfect system running.
    Just-in-time inventory (Just-in-time, the Toyota production system, and lean operations; moderate)

85. _____ is the Japanese word for card that has come to mean "signal."
    Kanban (JIT scheduling, moderate) {AACSB: Communication}

86. When suppliers are encouraged to locate near manufacturing plants, the goal of the JIT partnership is to reduce _____ inventory.
    in-transit (Just-in-time (JIT), easy)

87. _____ is any deviation from the optimum process that delivers perfect product on time, every time.
    Variability (Just-in-time, the Toyota production system, and lean operations; moderate)

88. A(n) _____ is a JIT concept that results in material being produced only when requested and moved to where it is needed just as it is needed.
    pull system (Just-in-time, the Toyota production system, and lean operations; moderate)

89. The _____ is the time between the arrival of raw materials and the shipping of finished products.
    manufacturing cycle time (Just-in-time, the Toyota production system, and lean operations; moderate)

90. _____ allows manufacturing work cells and offices to be easily rearranged.
    Layout flexibility (JIT layout, easy)

91. The main focus of JIT efforts to reduce investment in inventory requires _____.
    small lot sizes or reduction of lot size (JIT inventory, easy)

92. _____ gets suppliers to accept responsibility for satisfying end customer needs.
Educating suppliers (Lean operations, easy)

93. _____ involves scheduling products so that each day's production meets the demand for that day.
Level scheduling (JIT scheduling, moderate)

94. TPS stands for _____.
Toyota Production System (Just-in-time, the Toyota production system, and lean operations; easy)

95. The 5S term _____ includes analysis to improve workflow and reduce wasted motion.
simplify/straighten or simplify (Just-in-time, the Toyota production system, and lean operations; easy)

96. Handling material more than once is an example of the waste called _____.
transportation (Just-in-time, the Toyota production system, and lean operations; easy)

SHORT ANSWERS

97. What does TPS stand for?
Toyota Production System (Just-in-time, the Toyota production system, and lean operations; easy)

98. Define variability within the context of JIT.
Variability is any deviation from the optimum process that delivers perfect products on time every time. (Just-in-time, the Toyota production system, and lean operations; moderate)

99. Differentiate between a push and a pull system.
A push system pushes material into downstream workstations regardless of the resources available. A pull system uses signals to request delivery from upstream stations to the station that has production facilities available. In a pull system, materials or parts are pulled where they are needed when they are needed. (Just-in-time, the Toyota production system, and lean operations; moderate)

100. Define *manufacturing cycle time* in the context of JIT systems.
Manufacturing cycle time is the time between receipt of raw materials and shipment of the finished product. (Just-in-time, the Toyota production system, and lean operations; moderate)

101. Identify sources of variability.
1. Incomplete or inaccurate drawings or specifications
2. Late or non-comforming units
3. Unknown customer demands
(Just-in-time, the Toyota production system, and lean operations; moderate)

102. What three things does the Toyota Production System (TPS) emphasize?
Focus on continuous improvement, respect for people, and standard work practices. (Just-in-time, the Toyota production system, and lean operations; moderate)

103. What are the goals of JIT partnerships?
1. *Removal of unnecessary activities*, such as receiving, incoming inspection, and paperwork related to bidding, invoicing, and payment.
2. *Removal of in-plant inventory* by delivery in small lots directly to the using department as needed.
3. *Removal of in-transit inventory* by encouraging suppliers to locate nearby and provide frequent small shipments.
4. *Obtain improved quality and reliability* through long-term commitments, communication, and cooperation.
(Just-in-time (JIT), moderate)

104. Compare and contrast *throughput* with *manufacturing cycle time*.
Throughput is a measure (in units or time) that it takes to move an order from receipt to delivery. Each minute that products remain on the books, costs accumulate and competitive advantage is lost. On the other hand, the time that an order is actually in the shop is called manufacturing cycle time. This is the time between the arrival of raw materials and the shipping of finished product. Driving down manufacturing cycle time can make a major improvement in throughput. (Just-in-time, the Toyota production system, and lean operations; moderate)

105. What are the five reasons given by suppliers for their reluctance to enter into JIT systems? Elaborate on one of these, of your choosing.
The five reasons are desire for diversification, poor customer scheduling, engineering changes, quality assurance, and small lot sizes. (Just-in-time (JIT), moderate)

106. Identify the layout tactics appropriate for a JIT environment.
Layout tactics for a JIT environment include build work cells for families of products, include a large number of operations in a small area, minimize distance, design little space for inventory, improve employee communication, use poka-yoke devices, build flexible or movable equipment, and cross-train workers to add flexibility. (JIT layout, moderate)

107. Identify the inventory tactics appropriate for a JIT environment.
Inventory tactics for a JIT environment include a pull system to move inventory, ever smaller lots, just-in-time deliveries from suppliers, deliveries directly to point of use, performance to schedule, setup reduction, and group technology. (JIT inventory, moderate)

108. What is a kanban?
Kanban is the Japanese word for card that has come to mean "signal." A kanban system moves parts through production via a "pull" from a signal. (JIT scheduling, easy) {AACSB: Communication}

109. Describe level schedules. What purpose do they serve?
Level schedules act on frequent small batches rather than a few large batches; the small batches are always changing. The practice matches one day's demand to one day's work. (JIT scheduling, moderate)

110. Identify JIT scheduling tactics.
JIT scheduling tactics include communicate schedules to suppliers; make level schedules; freeze part of the schedule; perform to schedule; seek one-piece-make and one-piece-move; eliminate waste; produce in small lots; use kanbans; and make each operation produce a perfect part. (JIT scheduling, moderate)

111. Identify some of the signals that kanban systems use.
Kanban systems use a wide variety of signals. These include cards, lights, an empty position, an empty tote tray, a rag over a rack adjacent to a storage area, or a post that indicates how high the inventory should be in the storage area. (JIT scheduling, easy) {AACSB: Communication}

112. Explain how JIT works in services. After all, how does "small lot size" and "reduce setup cost" make sense in services? Supply examples to support your work.
In services, JIT works more on scheduling than on inventory, but is otherwise quite applicable. Furthermore, many services, such as restaurants, have significant inventories to deal with. (JIT in services, moderate)

113. How are lean operations and the Toyota Production System (TPS) alike? How are they different?
Lean operations and TPS are basically synonymous, and the two terms are often used interchangeably. The approach we call lean operations was begun by two employees at Toyota. Lean operations places more emphasis on understanding the customer; TPS places more emphasis on employee empowerment. (Lean operations, easy)

114. What are the 5S's? Why does the list of the 5S's sometimes have seven elements?
The five terms are sort/segregate, simplify/straighten, shine/sweep, standardize, and sustain/self discipline. American practice often adds safety and support/maintenance. (Just-in-time, the Toyota production system, and lean operations; moderate)

115. Identify Ohno's Seven Wastes. Which one of these deals most directly with distance reductions?
The seven are overproduction, queues, transportation, inventory, motion, overprocessing, and defective product. Transportation is the obvious choice, but motion may also be appropriate. (Just-in-time, the Toyota production system, and lean operations; moderate)

116. Identify JIT policies for and expectations of suppliers.
Few vendors; supportive supplier relationships; and quality deliveries on time, directly to work areas. (Just-in-time (JIT), easy)

PROBLEMS

117. Weekly usage of a product is 8 units. Since the plant operates 50 weeks per year, this leads to annual usage of 400 units. Setup cost is $40 and annualized carrying cost is $80. Weekly production of this product is 12 units. Lead time is four weeks, and safety stock is one week's production. What is optimal kanban size? What is the optimal number of kanbans?
35; 44/35→2 (JIT scheduling, moderate) {AACSB: Analytic Skills}

118. You have read that in JIT and lean production the optimum lot size is one, with some exceptions for packaging and physical limitations. If a product currently has a lot size of 25, what must happen to setup time for the lot size to truly fall to one? Data for this problem are D=100 units, S=$75 based on setup time of 50 minutes at $1.50 per minute, and H=$40 per unit per year.
Students may try ever smaller values for S, and find S =$0.12 by trial and error. Or they may solve the economic production quantity model for S, which also yields $0.12. Or they may recognize that the reduction in Q by a factor of 25 requires a reduction in S by that factor squared; in this case $75 / (25*25) = 0.12. (JIT inventory, moderate) {AACSB: Analytic Skills}

119. Daily usage of a product is 10 in a facility that operates every day of the year. Setup cost is $68 and annualized carrying cost is $100. Daily production of this product is 20. Lead time is 14 days; safety stock is one day's production. What is the optimum kanban size, and number of kanbans?
100; 160/100→2 (JIT scheduling, moderate) {AACSB: Analytic Skills}

120. Daily usage of an assembly is 100 in a facility that operates 300 days of the year. Setup cost is $5 and annualized carrying cost is $160. Production of this assembly occurs at the rate of 400 per day when production of the assembly is underway. Lead time is 3 days; safety stock is 1/2 day's production. What is the optimum kanban size, and number of kanbans?
50; 500/50=10 (JIT scheduling, moderate) {AACSB: Analytic Skills}

121. Daily usage of a part is 20 in a facility that operates 250 days of the year. Setup cost is $20 and annualized carrying cost is $210. Production of this part occurs at the rate of 50 per day when production of the part is underway. Lead time is 1 day; safety stock is 1/2 day's production. What is the optimum kanban size, and number of kanbans?
40; 45/40→2 (JIT scheduling, moderate) {AACSB: Analytic Skills}

122. A certain product has been effectively managed in the past, according to its managers. The previous technique used the economic production quantity model, and resulted in an optimum lot size of 100. For this product, setup time is directly proportional to setup cost, and setup time is currently 40 minutes per batch. How much must setup time decline in order for the lot size to fall to 50 units? 25 units? 10 units?
Complete data for the problem is not necessary. To cut the lot size in half, S must be cut to 25 percent of its pervious value, or from 40 minutes to 10 minutes. The reduction of lot size to 25 units requires another reduction by a factor of four, to 2.5 minutes. Reducing the lot size by a factor of ten requires the reduction in setup time by a factor of 100, the equivalent of 0.4 minutes. (JIT inventory, moderate) {AACSB: Analytic Skills}

123. A repetitive manufacturing firm is planning on level material use. The following information has been collected. Currently, the firm operates 250 days per year.

Annual demand	22,000
Daily demand	88
Daily production	250
Desired lot size (2 hours of production)	63
Holding cost per unit per year	$50

a. What is the setup cost, based on the desired lot size?
b. What is the setup time, based on $40 per hour setup labor?

(a) $S = \frac{Q^2 * H * (1 - d/p)}{2D}$ **leads to** $= \frac{63^2 * 50 * (1 - 88/250)}{2 * 22000}$ **and S = $2.92**

(b) Setup time = 4.38 min
(JIT inventory, moderate) {AACSB: Analytic Skills}

CHAPTER 17: MAINTENANCE AND RELIABILITY

TRUE/FALSE

1. Orlando Utilities Commission uses a computerized maintenance management program, and devotes significant dollar and labor resources to power plant maintenance, because the costs of unexpected failure are incredibly high.
True (Global company profile, easy) {AACSB: Use of IT}

2. Maintenance includes all activities involved in keeping a system's equipment in working order.
True (The strategic importance of maintenance and reliability, easy)

3. Reliability is the probability that a machine part or product will function properly for a specified time regardless of conditions.
False (The strategic importance of maintenance and reliability, easy)

4. The product failure rate is the percentage of failures among the total number of products tested.
True (Reliability, moderate)

5. The MTBF (mean time between failures) is calculated as the reciprocal of the number of failures during a period of time.
True (Reliability, moderate)

6. If the mean time between failures has been calculated to be 2,000 hours, then the number of unit failures per 2,000 hours must be one.
False (Reliability, moderate)

7. The reliability of a system in which each individual component must function in order for the entire system to function, and in which each component has its own unique reliability, independent of other components, is the product of the probabilities of each of those components.
True (Reliability, moderate)

8. Adding an additional part to a component or product ordinarily reduces reliability by introducing an additional source of failure.
True (Reliability, moderate)

9. A redundant part or component increases reliability because it is connected in parallel, not in series.
True (Reliability, moderate)

10. A redundant part decreases reliability if the reliability of the redundant part is lower than that of the part it is backing up.
False (Reliability, moderate)

11. Preventive maintenance is reactive.
False (Maintenance, moderate)

12. Preventive maintenance is nothing more than keeping the equipment and machinery running.
False (Maintenance, moderate)

13. Preventive maintenance implies that we can determine when a system needs service or will need repair.
True (Maintenance, moderate)

14. Infant mortality refers to the high failure rate often encountered in the very early stages of the lifetime of a product.
True (Maintenance, moderate)

15. The failure distributions of products, machines, or processes that have "settled in," or gone beyond the infant mortality phase, often follow the normal distribution.
True (Maintenance, easy)

16. Recording the maintenance history of processes, machines, or equipment is important for preventive maintenance, but largely irrelevant for breakdown maintenance.
False (Maintenance, easy)

17. The "full cost view of maintenance" results in more firms choosing a policy of breakdown maintenance, when compared to the "traditional view of maintenance."
False (Maintenance, easy)

18. Failures are tolerable as long as their results are not catastrophic.
False (Maintenance, moderate)

19. Small standard deviations in the MTBF distribution of a machine tend to support a policy of breakdown maintenance for that machine.
False (Maintenance, moderate)

20. When identifying the optimal maintenance policy, the cost of inventory maintained to compensate for the downtime is a cost often ignored.
True (Maintenance, moderate)

21. An optimal maintenance policy strikes a balance between the costs of breakdown and preventive maintenance so that the total cost of maintenance is at a minimum.
True (Maintenance, moderate)

22. While breakdowns occur randomly, their frequency is somewhat predictable through such tools as the product failure rate, MTBF, and the breakdown costs model.
True (Maintenance, moderate)

23. The objective of maintenance and reliability is to maintain the capability of the system.
True (The strategic importance of maintenance and reliability, moderate)

24. TPM (total productive maintenance) is an application of TQM (total quality management) principles to the area of maintenance.
True (Total productive maintenance, moderate)

25. Simulation models and expert systems are useful tools for determining maintenance policies.
True (Techniques for enhancing maintenance, moderate) {AACSB: Use of IT}

MULTIPLE CHOICE

26. Which of the following statements about maintenance at Orlando Utilities Commission is **false**?
    a. There are at least two types of preventive maintenance, including an annual maintenance and a less frequent overhaul schedule.
    b. Its preventive maintenance program has earned the company top rankings and its competitive advantage.
    c. Each power-generating unit is taken off-line every three years for a complete overhaul.
    d. Each of its power-generating units is taken off-line for maintenance every one to three weeks.
    e. Costs associated with breakdowns are several times higher than costs arising from preventive maintenance.

    d (Global company profile, moderate)

27. The objective of maintenance and reliability is to
    a. ensure that breakdowns do not affect the quality of the products
    b. ensure that no breakdowns will ever occur
    c. ensure that preventive maintenance costs are kept as low as possible
    d. maintain the capability of the system
    e. ensure that maintenance employees are fully utilized

    d (The strategic importance of maintenance and reliability, moderate)

28. The probability that a product will function properly for a specified time under stated conditions is
    a. functionality
    b. maintenance
    c. durability
    d. reliability
    e. fitness for use

    d (The strategic importance of maintenance and reliability, moderate)

29. Which of the following best illustrates the importance of employee involvement in achieving successful maintenance and reliability?
    a. Operator, machine, and mechanic are independent of one another.
    b. Small standard deviations tend to favor preventive maintenance over breakdown maintenance.
    c. Infant mortality in products can be decreased through improved owner's manuals and after-sales service and customer training.
    d. Employee involvement through such elements as reward systems and power sharing combine with good maintenance and reliability procedures to improve capacity and reduce variability.
    e. Empowered operators have higher competence at repairs than field service or depot service.

    d (The strategic importance of maintenance and reliability, moderate)

30. What is the reliability of a four-component product, with components in series, and component reliabilities of .90, .95, .98, and .99?
    a. under 0.83
    b. at most 0.90
    c. 0.955
    d. no less than .99
    e. none of the above

    a (Reliability, moderate) {AACSB: Analytic Skills}

31. A system is composed of three components A, B, and C. All three must function for the system to function. There are currently no backups in place. The system has a reliability of 0.966. If a backup is installed for component A, the new system reliability will be
    a. unchanged
    b. less than 0.966
    c. less than 0.998
    d. greater than 0.966
    e. none of the above
    d (Reliability, moderate) {AACSB: Analytic Skills}

32. A system has three components *in series* with reliabilities 0.9, 0.7, and 0.5. System reliability is
    a. 0.315
    b. 0.500
    c. 0.700
    d. 0.900
    e. 2.100
    a (Reliability, moderate) {AACSB: Analytic Skills}

33. A system has three components *in parallel* with reliabilities 0.9, 0.7, and 0.5. System reliability is
    a. 0.315
    b. 0.700
    c. 0.900
    d. 0.985
    e. 2.100
    d (Reliability, moderate) {AACSB: Analytic Skills}

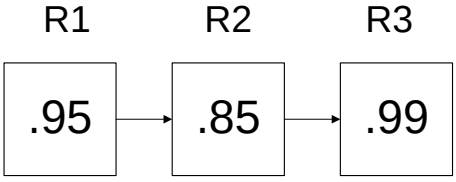
34. Components A, B, and C are connected in series. Component D is connected in parallel to component B. Which of the following statements is **true**?
    a. The system works only if A works, B or C works, and D works.
    b. Component B must work for the system to work.
    c. The system works when A works, C, works, and either B or D works.
    d. Components B and C are backups to A.
    e. The system works if D works, and any of A, B, or C works.
    c (Reliability, moderate) {AACSB: Analytic Skills}

35. A job consists of a series of three tasks. Task 1 is performed correctly 98% of the time, task 2 is performed correctly 99% of the time, and task 3 is performed correctly 97% of the time. The reliability of this job is
    a. 91.27%
    b. 94.11%
    c. 97.00%
    d. 98.00%
    e. 99.00%
    b (Reliability, moderate) {AACSB: Analytic Skills}

36. As the number of components in a system connected *in a series* decreases, all other things being equal, the reliability of the system usually
    a. increases
    b. stays the same
    c. decreases
    d. increases, then decreases
    e. decreases, then increases
    a (Reliability, moderate) {AACSB: Analytic Skills}

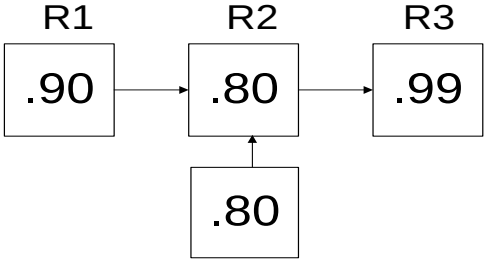
37. A product has three components, A, B, and C, with reliabilities of 0.95, 0.98, and 0.995. Engineers intend to put a redundant component A that has reliability 0.70. With this change, system reliability will
    a. fall by 20%
    b. fall by 10% or less
    c. rise
    d. cannot determine from the information provided
    e. none of the above
    c (Reliability, moderate) {AACSB: Analytic Skills}

38. What is the reliability of the three components connected in series shown below?



    a. 0.799425
    b. at least 0.85
    c. 0.91333
    d. 0.95000
    e. 2.79
    a (Reliability, moderate) {AACSB: Analytic Skills}

39. For the system shown below, the reliability is



    a. 0.50000
    b. 0.71280
    c. 0.80000
    d. 0.85536
    e. 3.49000
    d (Reliability, moderate) {AACSB: Analytic Skills}

40. Ten high-technology batteries are tested for 200 hours each. One failed at 20 hours; all others completed the test. FR(%) is _____ and MTBF is _____.
    a. 10%; 1/1820
    b. 90%; 1/1820
    c. 10%; 1820 hours
    d. 10%; 1980 hours
    e. cannot calculate from information provided
    c (Reliability, moderate) {AACSB: Analytic Skills}

41. Ten high-technology batteries are tested for 200 hours each. One failed at 50 hours; all others completed the test. FR(%) is _____ and FR(N) is _____.
    a. 10%; 1/1850
    b. 10%; 1/2000
    c. 25%; 1850 hours
    d. 90%; 1/2000
    e. indeterminate; no standard deviation is given
    a (Reliability, moderate) {AACSB: Analytic Skills}

42. Ten high-technology batteries are tested for 200 hours each. One failed at 20 hours; another failed at 140 hours; all others completed the test. FR(%) is _____ and MTBF is _____.
    a. 20%; 880 hours
    b. 10%; 1980 hours
    c. 20%; 1760 hours
    d. cannot calculate from information provided
    e. 80%; 920 hours
    a (Reliability, moderate) {AACSB: Analytic Skills}

43. MTBF measures the average
    a. calendar time between failures
    b. operating time between failures
    c. number of failures per unit time
    d. number of operations between failures
    e. downtime per breakdown
    b (Reliability, moderate)

44. A system is composed of four parts, J, K, L, and M. All four must function for the system to function. The four component reliabilities are .99, .98, .992, and .998. The designers are considering putting a .80 reliable backup at K. This backup will change the system reliability from _____ to _____.
    a. 0.9762 to 0.9605
    b. 0.9605 to 0.9762
    c. 0.9605 to some smaller value
    d. cannot be determined
    e. none of the above
    b (Reliability, moderate) {AACSB: Analytic Skills}

45. The normal distribution is an appropriate model of
    a. the high initial failure rates of product, machine, or processes
    b. system reliability where components are connected in series
    c. system reliability where components are connected in parallel
    d. failures of products, machines, or processes that have "settled in"
    e. the full cost view of maintenance
    d (Maintenance, moderate)

46. Infant mortality refers to which one of the following examples?
    a. high frequency on the left side of the MTBF distribution
    b. failure of items used in the nursery ward of a hospital
    c. failure of products with a very short life cycle
    d. market failure of brand new products
    e. high failure rate often encountered in the very early stages of the lifetime of a product
    e (Maintenance, moderate)

47. How is MTBF related to FR(N)?
    a. MTBF is measured in hours, while FR(N) is measured in years.
    b. MTBF is normally distributed, with FR(%) as its mean and FR(N) as its standard deviation.
    c. MTBF is the reciprocal of FR(N).
    d. Both MTBF and FR(N) increase when breakdown maintenance is replaced by preventive maintenance.
    e. MTBF and FR(N) are unrelated concepts.
    c (Reliability, moderate)

48. A machine that has passed the phase of early failures exhibits a normal distribution of failures. The smaller the standard deviation of this distribution
    a. the more expensive is preventive maintenance
    b. the more likely this machine is a candidate for preventive maintenance
    c. the shorter is the time interval between breakdowns
    d. the more likely this machine will break down
    e. the more likely this machine will be maintained by a breakdown maintenance policy
    b (Maintenance, moderate)

49. Which one of the following statements about maintenance is **true**?
    a. The optimal degree of preventive maintenance is associated with zero breakdowns.
    b. Breakdown maintenance is proactive.
    c. Preventive maintenance is reactive.
    d. Preventive maintenance is limited to keeping machinery and equipment running.
    e. Human resources are a major component of effective maintenance management.
    e (Maintenance, moderate)

50. The process that involves repair on an emergency or priority basis is known as
    a. breakdown maintenance
    b. emergency maintenance
    c. failure maintenance
    d. preventive maintenance
    e. priority maintenance
    a (Maintenance, moderate)

51. As a firm's maintenance commitment increases,
    a. the breakdown maintenance costs increase and the preventive maintenance costs decrease
    b. both the breakdown maintenance costs and the preventive maintenance costs decrease
    c. the breakdown maintenance costs decrease and the preventive maintenance costs increase
    d. both the breakdown maintenance costs and the preventive maintenance costs increase
    e. None of the above is true.
    c (Maintenance, moderate)

52. As far as maintenance costs are concerned,
    a. for low levels of maintenance commitment, breakdown maintenance costs exceed preventive maintenance costs
    b. for low levels of maintenance commitment, preventive maintenance costs exceed breakdown maintenance costs
    c. for high levels of maintenance commitment, breakdown maintenance costs exceed preventive maintenance costs
    d. preventive maintenance is always more economical than breakdown maintenance
    e. All of the above are true.
    a (Maintenance, moderate)

53. For a machine to be a good candidate for preventive maintenance
    a. the consequences of failure must exceed the cost of preventive maintenance and the MTBF distribution must have a large standard deviation
    b. the consequences of failure must exceed the cost of preventive maintenance and the MTBF must be relatively low
    c. the consequences of failure must exceed the cost of preventive maintenance and the MTBF distribution must have a relatively low standard deviation
    d. the consequences of failure must exceed the cost of preventive maintenance and the MTBF must be relatively high
    e. the consequences of failure must be relatively unknown and, therefore, risky
    c (Maintenance, moderate)

54. Which one of the following is **not** necessary to identify the optimal maintenance policy?
    a. historical data on maintenance costs
    b. cost of performing the analysis
    c. breakdown probabilities
    d. breakdown occurrences
    e. repair times
    b (Maintenance, moderate)

55. Which of the following costs tend to be ignored in determining the optimal maintenance policy?
    a. expected breakdown costs
    b. preventive maintenance costs
    c. the costs associated with various levels of commitment to maintenance
    d. cost of low morale
    e. all of the above
    d (Maintenance, moderate)

56. DuLarge Marine manufactures diesel engines for shrimp trawlers and other small commercial boats. One of their CNC machines has caused several problems. Over the past 30 weeks, the machine has broken down as indicated below.

Number of breakdowns per week	0	1	2	3	4
Frequency (Number of weeks that breakdowns occurred)	8	3	5	9	5

What is the expected number of breakdowns per week?
a. 1
b. 2
c. 6
d. 10
e. 30
b (Maintenance, moderate) {AACSB: Analytic Skills}

57. DuLarge Marine manufactures diesel engines for shrimp trawlers and other small commercial boats. One of their CNC machines has caused several problems. Over the past 30 weeks, the machine has broken down as indicated below. Each time the machine breaks down, the firm loses an average of $3,000 in time and repair expenses.

Number of breakdowns per week	0	1	2	3	4
Frequency (Number of weeks that breakdowns occurred)	8	3	5	9	5

What is the expected breakdown cost per week?
a. $1,000
b. $2,000
c. $6,000
d. $10,000
e. $60,000
c (Maintenance, moderate) {AACSB: Analytic Skills}

58. DuLarge Marine manufactures diesel engines for shrimp trawlers and other small commercial boats. One of their CNC machines has caused several problems. Over the past 30 weeks, the machine has broken down as indicated below. Each time the machine breaks down, the firm loses an average of $3,000 in time and repair expenses. If preventive maintenance were implemented, it is estimated that an average of only one breakdown per week would occur. The cost of preventive maintenance is $1,000 per week.

Number of breakdowns per week	0	1	2	3	4
Frequency (Number of weeks that breakdowns occurred)	8	3	5	9	5

What is the weekly total maintenance cost of this program?
a. $1,000
b. $3,000
c. $4,000
d. $6,000
e. $8,000
c (Maintenance, moderate) {AACSB: Analytic Skills}

59. When depot service is compared to operator maintenance,
    a. operator maintenance is slower than depot service
    b. competence is higher, but costs may also be higher, with depot service
    c. depot service is often the weak link in the chain because of the lack of specific training
    d. depot service occurs on-site, while operator maintenance occurs off-site
    e. depot service is better for systems connected in parallel, while operator maintenance is preferred for systems connected in series

    b (Maintenance, moderate)

60. Which of the following is **true** regarding total productive maintenance (TPM)?
    a. TPM is concerned with machine operation, not machine design.
    b. Field service and depot service perform virtually all maintenance and repair activities.
    c. Operators run their machines, but maintenance departments maintain them.
    d. TPM reduces variability through employee empowerment and excellent maintenance records.
    e. TPM views maintenance and repair as tactical issues, not strategic ones.

    d (Total productive maintenance, moderate)

FILL-IN-THE BLANK

61. _____ consists of all activities involved in keeping a system's equipment in working order.
    Maintenance (The strategic importance of maintenance and reliability, easy)

62. _____ is the probability that a machine part or product will function properly for a specified time under stated conditions.
    Reliability (The strategic importance of maintenance and reliability, easy)

63. _____ is the expected time between a repair and the next failure of a component, machine, process, or product.
    Mean time between failures or MTBF (Reliability, moderate)

64. The inverse of the mean time between failures is the _____.
    number of failures during a period of time or FR(N) (Reliability, moderate)

65. _____ is the use of a component in parallel to raise reliabilities.
    Redundancy (Reliability, moderate)

66. _____ is a plan that involves routine inspections, servicing, and keeping facilities in good repair to prevent failure.
    Preventive maintenance (Maintenance, moderate)

67. _____ is the failure rate early in the life of a product or process.
    Infant mortality (Maintenance, moderate)

68. The _____ takes into account such costs as deteriorated customer relations and lost sales.
    full cost view of maintenance (Maintenance, moderate)

69. _____ combines total quality management with a strategic view of maintenance from process equipment design to preventive maintenance.
    Total preventive maintenance or TPM (Increasing repair capabilities, moderate)

SHORT ANSWERS

70. Describe how Orlando Utilities Commission obtains competitive advantage through its maintenance practices.
The company recognizes the importance of preventive maintenance to the business it is in; this is driven in part by the very large cost of forced power outages. Their maintenance plan involves annual checkups for each plant and complete overhauls every three years. The firm has well-developed and highly detailed preventive maintenance procedures. Maintenance work orders are computerized for efficiency. (Global company profile, moderate)

71. What is the role of people, especially empowered employees, in an effective maintenance strategy?
The interdependency of operator, machine, and mechanic is a hallmark of successful maintenance. Good maintenance and reliability procedures are incomplete without the involvement of employees. A good case can be made for operators, as empowered employees, maintaining their own equipment; after all, who knows the equipment better? (The strategic importance of maintenance and reliability, and Maintenance, moderate)

72. Identify the two reliability tactics and the two maintenance tactics.
Reliability tactics are improving individual components and providing redundancy. Maintenance tactics are implementing or improving preventive maintenance and increasing repair capabilities or speed. (The strategic importance of maintenance and reliability, moderate)

73. Define reliability.
Reliability is the probability that a machine part or product will function properly for a specified time under stated conditions. (The strategic importance of maintenance and reliability, moderate)

74. Define maintenance.
Maintenance is all activities involved in keeping a system's equipment in working order. (The strategic importance of maintenance and reliability, moderate)

75. What is the impact on system reliability of adding parts or components in parallel?
This will increase the reliability of the system by introducing redundancy. (Reliability, easy)

76. Increasing the number of parts or components in a product tends to reduce its reliability. Why is this true only when adding components in series?
Adding parts in series involves an additional multiplication by a value less than one, so that reliability must fall. Adding parts in parallel (the redundancy concept) increases reliability because only one part of the parallel system must function. (Reliability, moderate)

77. Explain carefully how redundancy improves product reliability.
A redundant part or component is connected in parallel with the primary part or component. "In parallel" means that either the original part or its backup needs to work, not that both must work at the same time. Redundancy increases reliability by providing an additional path (through the redundant part) to provide system reliability. (Reliability, moderate)

78. Why is it that many cases of infant mortality of products are not due to product failure?
In many cases the failure is not of the product, but of its improper use. Thus there is a need for good after-sales service that might include installation and training, and good instructions for use. (Maintenance, moderate)

79. "High reliability can be achieved in a product without having high reliability in the component parts. In fact, any reliability target, no matter how high, can be achieved with only mediocre parts, so long as enough of them are present." Discuss; an example may help.
This carries the redundancy concept one step beyond the textbook, to having multiple redundancies on the same component. If only one part in a parallel system needs to work to provide reliability of that part of the system, then several parts in parallel should offer very high reliability. Example: four parts in parallel, each with only 0.50 reliability, provide reliability of .50+.25+.125+.0625=.9375. Additional parts in parallel continue to improve reliability. (Reliability, moderate)

80. What is FR(N)? How is it calculated? How are FR(N) and MTBF related?
FR(N) is the product failure number; it is the ratio of failed units to total operating hours. MTBF is the reciprocal of FR(N). (Reliability, moderate)

81. What is breakdown maintenance?
Breakdown maintenance is the remedial maintenance that occurs when equipment fails and must be repaired on an emergency or priority basis. (Maintenance, easy)

82. Explain why a small standard deviation of the MTBF distribution makes a product, machine, or process a good candidate for preventive maintenance while a large standard deviation does not.
A small standard deviation means that there is a relatively narrow range for breakdowns. With this narrow range, it is easier to predict when failure might occur and, therefore, take preventive action in advance of failure. A large standard deviation implies a wider range of values over which failure might occur, making failure less predictable and preventive maintenance less advantageous. (Maintenance, moderate)

83. Why is it that many cost curves associated with maintenance rarely consider the full cost of a breakdown?
Many costs are ignored because they are not directly related to the immediate breakdown. For example, some of these costs include the cost of inventory, employee morale, and impact on delivery schedules and customer relations. (Maintenance, moderate)

84. Is there an optimal amount of preventive maintenance? What caution should be exercised before calculating this optimal amount?
Too little preventive maintenance causes breakdown costs to rise sharply, adding more to cost than is saved by less preventive maintenance; too much preventive maintenance reduces breakdowns, but by an amount insufficient to offset the added cost of preventive maintenance. Operations managers should assure that all costs of breakdowns have been properly included in the calculations. There is a history of not including indirect and subjective breakdown cost elements, which leads to performing too little preventive maintenance. (Maintenance, moderate)

85. How do many electronic firms deal with infant mortality in their products?
They "burn in" their products prior to shipment; they execute a variety of tests to detect start-up problems prior to shipment. (Maintenance, moderate)

86. Under what conditions is preventive maintenance likely to be appropriate?
Preventive maintenance is appropriate when the variance in the MTBF curve is relatively small, the cost of a breakdown occurring (both repair *and* lost production) is higher than the cost of the preventive maintenance, and a sensing system is available to provide indication of a possible breakdown. (Maintenance, moderate)

87. What is the primary concept of total productive maintenance (TPM)? List the other elements of total productive maintenance.
TPM's primary concept is reducing variability through employee involvement and excellent maintenance records. Four other ingredients of TPM are
1. Designing machines that are reliable, easy to operate, and easy to maintain
2. Emphasizing total cost of ownership when purchasing machines
3. Developing preventive maintenance plans that utilize best practices of operators, maintenance departments, and depot service, and
4. Training workers to operate and maintain their own machines
(Total productive maintenance, moderate)

88. How do expert systems improve maintenance systems?
Expert systems can be (and are) very helpful in diagnosing maintenance problems. For instance, they are used in GE's locomotive maintenance shop, and medical doctors also use them to diagnose necessary maintenance for people. (Techniques for enhancing maintenance, moderate) {AACSB: Use of IT}

PROBLEMS

89. Ten high-intensity bulbs are tested for 100 hours each. One failed at 40 hours; all others completed the test. Calculate FR(%) and FR(N).
FR(%) = 1/10 or 10%; operating hours = 9x100+40=940; FR(N)=1/940 or 0.00106 (Reliability, moderate) {AACSB: Analytic Skills}

90. Ten high-intensity bulbs are tested for 100 hours each. One failed at 10 hours; all others completed the test. Calculate FR(%), FR(N) and MTBF.
FR(%)=1/10 or 10%; operating hours = 9x100+10 = 910; FR(N)=1/910 or .0011, and MTBF = 910 hours (Reliability, moderate) {AACSB: Analytic Skills}

91. Ten high-intensity bulbs are tested for 100 hours each. One failed at 40 hours; another failed at 70 hours; all others completed the test. Calculate FR(%), FR(N), and MTBF.
FR(%)=2/10 or 20%; FR(N)=2/910 or .0022; MTBF = 455 hours (Reliability, moderate) {AACSB: Analytic Skills}

92. A product is composed of a series connection of four components with the following reliabilities. What is the reliability of the system?

Component	1	2	3	4
Reliability	.90	.95	.97	.88

The reliability of the system is R = 0.90 * 0.95 * 0.97 * 0.88 = 0.73 (Reliability, moderate) {AACSB: Analytic Skills}

93. Given the following data, find the expected breakdown cost. The cost per breakdown is $200.

Number of breakdowns per week	0	1	2	3	4
Weekly frequency	5	12	10	18	5

Number of breakdowns per week	**0**	**1**	**2**	**3**	**4**	**Total**
Weekly Probability	**.10**	**.24**	**.20**	**.36**	**.10**	**1.00**

Expected number of breakdowns = (0 * .10) + (1 * .24) + (2 * .20) + (3 * .36) + (4 * .10) = 2.12
Expected cost of breakdowns = 2.12 * $200 = $424. (Maintenance, moderate) {AACSB: Analytic Skills}

94. Given the following data, find the expected breakdown cost. The cost per breakdown is $100.

Number of breakdowns	0	1	2	3
Monthly frequency	5	20	23	2

Number of breakdowns	**0**	**1**	**2**	**3**	**Total**
Monthly probability	**.10**	**.40**	**.46**	**.04**	**1.000**

Expected number of breakdowns per month = (0 * .10) + (1 * .40) + (2 * .46) + (3 * .04) = 1.44; Expected cost of breakdowns = 1.44 * $100 = $144 (Maintenance, moderate) {AACSB: Analytic Skills}

95. Great Southern Consultants Group's computer system has been down several times over the past few months, as shown below.

Number of breakdowns	0	1	2	3	4
Monthly frequency	9	2	4	4	1

Each time the system is down, the firm loses an average of $400 in time and service expenses. They are considering signing a contract for preventive maintenance. With preventive maintenance, the system would be down on average only 0.5 per month. The monthly cost of preventive maintenance would be $200 a month. Which is cheaper, breakdown or preventive maintenance?

Number of breakdowns	**0**	**1**	**2**	**3**	**4**	**Total**
Monthly probability	**0.45**	**0.10**	**0.20**	**0.20**	**0.05**	**1.00**

Expected number of breakdowns per month = (0 * .45) + (1 * .10) + (2 * .20) + (3 * .20) + (4 * .05) = 1.30; Expected cost of breakdowns per month = 1.30 * $400 = $520
Preventive maintenance cost per month = (.5 * $400) + $200 = $400; Preventive maintenance is more cost-effective. (Maintenance, moderate) {AACSB: Analytic Skills}

96. A system has four components in a series. What is the reliability of the system?

Component	1	2	3	4
Reliability	.90	.95	.90	.99

0.90 * 0.95 * 0.90 * 0.99 = .7618 (Reliability, moderate) {AACSB: Analytic Skills}

97. A system consists of four components in series. The reliability of each component is 0.96. What is the reliability of the system?
The reliability of the system is $R = (0.96)^4 = 0.8493$ (Reliability, moderate) {AACSB: Analytic Skills}

98. A system has six components in series. Each component has a reliability of 0.99. What is the reliability of the system?
$(0.99)^6 = 0.9415$ (Reliability, moderate) {AACSB: Analytic Skills}

99. Tiger Island Fabricators, which builds offshore oil platforms, has been experiencing problems with its profiling machine, a computer-driven device that cuts the ends of pipe so that it can be welded to another pipe, as shown in the data below.

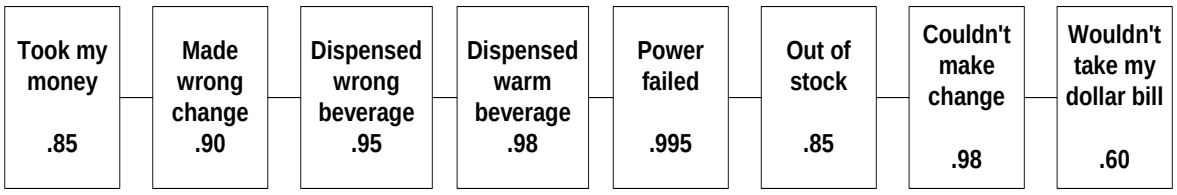
Number of breakdowns	0	1	2	3	4	5
Breakdown frequency	2	2	2	6	7	1

Each time a machine breaks down, the company loses about $3,000. If the company implements preventive maintenance, it will be able to reduce the number of breakdowns to one per month. Preventive maintenance costs would be $500 a month. Is preventive maintenance a cost-effective option?

Number of breakdowns	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
Breakdown frequency	**.10**	**.10**	**.10**	**.30**	**.35**	**.05**	**1.00**

Expected number of breakdowns = (0 * .10) + (1 * .10) + (2 * .10) + (3 * .30) + (4 * .35) + (5 * .05) = 2.85; Expected cost of breakdowns per month = 2.85 * $3,000 = $8,550; Cost of preventive maintenance = (1 * $3,000) + $500 = $3,500. It is about three times more expensive to suffer breakdowns than to perform preventive maintenance. (Maintenance, moderate) {AACSB: Analytic Skills}

100. The diagram below identifies the elements of service as provided by a soft drink vending machine. Each element has an estimate of its own reliability, independent of the others. What is the reliability of the "system"?



Reliability = .85 * .90 * .95 * .98 * .995 * .85 * .98 * .60=0.3542 (Reliability, moderate) {AACSB: Analytic Skills}

101. Century Digital Phone advertises phone battery life (on standby) of up to three days. The standard deviation is thought to be five hours. Tina Talbot, an employee at CDP, tested 10 of these batteries for 72 hours. One failed at 40 hours; one failed at 62 hours; one failed at 70 hours. All others completed the test. Calculate FR(%), FR(N), and MTBF.
FR(%) = 3/10 or 30%. FR(N) = 3/[(72*10)-32-10-2] = 3/676 = .00444. MTBF is 1/FR(N) = 225.3 hours. (Reliability, moderate) {AACSB: Analytic Skills}

102. The Everstart is a battery with an intended design life of 72 months. Stephanie Bradley recently put five of these batteries through accelerated testing (the company couldn't wait six years) to simulate failure patterns. The test results had one failure at 26 months, one failure at 32 months, one failure at 50 months, and one failure at 62 months. Calculate FR(%), FR(N), and MTBF.
FR(%) = 4/5 or 80%. FR(N) = 4/(72+26+32+50+62) =4/242 = .0165. The MTBF is 1/FR(N) = 60.5 (Reliability, moderate) {AACSB: Analytic Skills}

103. The academic service commonly referred to as "registration" consists of several smaller components: advising, registration for courses, fee assessment, financial aid calculations, and fee payment. Each of these modules operates independently and has some probability of failure for each student. If the five probabilities which accompany these services are 95%, 90%, 99%, 98%, and 99%, what is the "reliability" of the entire product from the student's perspective—the probability that all five will work according to plan?
Reliability is .95 * .90 * .99 * .98 * .99 = .82123 (Reliability, moderate) {AACSB: Analytic Skills}

104. A simple electrical motor has three components: windings, armature, and housing. These three components have reliabilities of .9998, .9992, and .9999. There is no possibility of redundant parts. What is the reliability of the motor? Round your answer to four decimal places.
0.9998 * 0.9992 * 0.9999 = 0.9989 (Reliability, moderate) {AACSB: Analytic Skills}

105. A simple electrical motor has three components: windings, armature, and housing. These three components have reliabilities of .97, .992, and .999. There is no possibility of redundant parts. The motor must have an overall reliability of 0.980, according to the product line manager who will use the motor as an input. What would you do to redesign the motor to meet this specification? Discuss, including a recalculation to meet the standard.
Since no backup is possible, individual components must be redesigned. The windings represent the weak link, and are the obvious choice. If only the windings are improved, their new reliability must be at least 0.980 / (0.992* 0.999) = 0.98889 (Reliability, moderate) {AACSB: Analytic Skills}

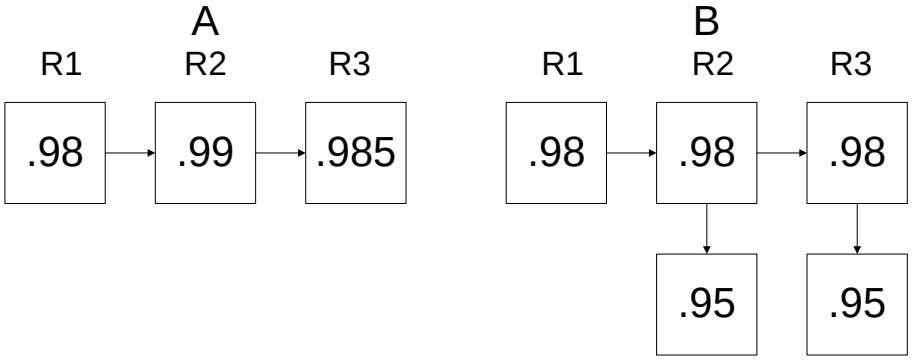
106. A product has four components A, B, C, and D. The finished product must have a reliability of .95. The first three components come from a supplier, and have reliabilities of .99, .98, and .995. The fourth component is being designed now. What must the reliability of component D be in order to meet the product reliability condition?
System reliability must be at least .99 x .98 x .995 x D = .95. Component D's reliability must be at least 0.95 / (0.99 * 0.98 * 0.995) = 0.9841 (Reliability, moderate) {AACSB: Analytic Skills}

107. A product has three components X, Y, and Z. X has reliability of 0.991; Y has reliability of 0.993. If Z has reliability of 0.991, what is the reliability of the entire product? Can Z be redesigned to be reliable enough for the entire product to have reliability of 0.99? Explain.
The product has reliability 0.991 * 0.993 * 0.991 = 0.9752; No: the required component reliability is impossible. 0.99 / (0.991 * 0.993) = 1.006 (Reliability, moderate) {AACSB: Analytic Skills}

108. A component must have reliability of .9925. Two technologies are available for this component: one produces a component with .999 reliability at a cost of $2000. Another produces a component with .73 reliability at a cost of $450. Which is cheaper: one high quality component or a parallel set of inferior components?
First determine how many of the 0.73 reliable components are needed: 2: 0.9271 3: 0.980317 4: 0.994686 Four are needed, which will cost $1800. This is cheaper than the $2000 single high-quality component. (Reliability, difficult) {AACSB: Analytic Skills}

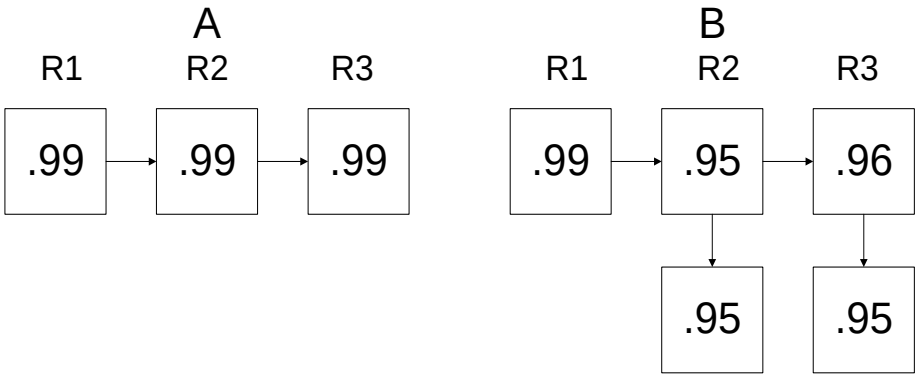
109. General Grant must send orders to General Butler. Carrier pigeons are the medium of choice. A single pigeon has a .7 probability of arriving at the proper destination in a timely fashion. How many pigeons, each carrying an identical set of orders, must Grant send in order for him to have 98% confidence that the orders reached General Butler?
2: 0.91 3: 0.973 4: 0.9919 One, two, or three is not enough; four will easily achieve the .98 reliability. (Reliability, difficult) {AACSB: Analytic Skills}

110. Which product design below has the higher system reliability?



A's reliability is .98 * .99 * .985 = .9556. B's reliability is .98 * (.98 + .02 * .95) * (.98 + .02 * .95) = .9780. B has a higher reliability. (Reliability, moderate) {AACSB: Analytic Skills}

111. Which product design below has the higher system reliability?



A's reliability is .99 * .99 * .99 = .9703. B's reliability is .99 * (.95 + .05 * .95) * (.96 + .04 * .95) = .9856. B has a higher reliability. (Reliability, moderate) {AACSB: Analytic Skills}

112. Consider a product that is "settled in." Its MTBF distribution has been found to be normal with a mean of 10,000 hours and a standard deviation of 100 hours. What is the probability of a breakdown before 8,000 hours? Before 9,000 hours? Would you prefer a policy of preventive maintenance, or a policy of breakdown maintenance, on this product? Explain your choice.
Both of the specified times are far below the mean: 8,000 hours is twenty standard deviations away, and 9,000 hours is ten standard deviations away. In both instances, the normal areas table computes the probability of failure to be approximately zero. Most students will opt for preventive maintenance; the standard deviation is quite small compared to the mean, so that preventive maintenance can pretty reliably be used. (Maintenance, moderate) {AACSB: Analytic Skills}

113. A product design team is preparing to build a new doohickey. A doohickey consists of one A module, one B module, and one C module. There are different versions of these modules available in the company's design library. For example, there are two choices for A: A1 is .99 reliable, while A2 is .975 reliable. The table below details the choices available, along with the cost of each choice.

Module variation	Reliability	Cost, each
A1	.99	$17
A2	.975	$10
B1	.995	$4
B2	.992	$3
C1	.98	$2
C2	.90	$0.50
C3	.60	$0.25

Help the design team by selecting the least costly version of a doohickey that has system reliability of at least .96. Draw a schematic of your finished design.

Students will need to solve this problem by trial and error. Here are some possible designs.

(I) $A1_{0.99} * B1_{0.995} * C1_{0.98} = 0.96535$ meets the reliability specification but costs $23.

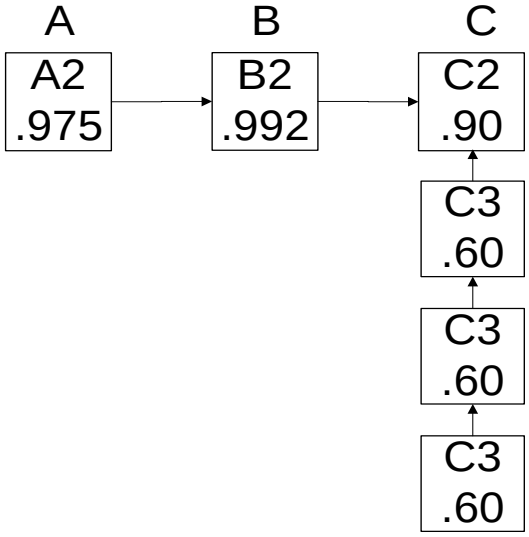
(II) $A2_{0.975} * B2_{0.992} * C1_{0.98} = 0.947856$ costs $15 but does not meet the specification.

There are a dozen design alternatives which have no redundant parts. There are many more choices with one or more redundancies built in. The reliability of A2 + B2 is 0.975 * 0.992 = 0.9672, which means that redundancies at C are an option.

(III) $A2_{0.975} * B2_{0.992} * C2+C2_{0.99} = 0.957528$ costs $16 but does not meet the test.

(IV) $A2_{0.975} * B2_{0.992} * C1+C3_{0.992} = 0.95946$ costs $15.25 but does not meet the test.

(V) $A2_{0.975} * B2_{0.992} * C2+C3+C3+C3_{0.9936} = 0.96101$ costs $14.25 and meets the test. It is possible that even cheaper solutions exist. The schematic for this design appears below.



(Reliability, difficult) {AACSB: Analytic Skills}

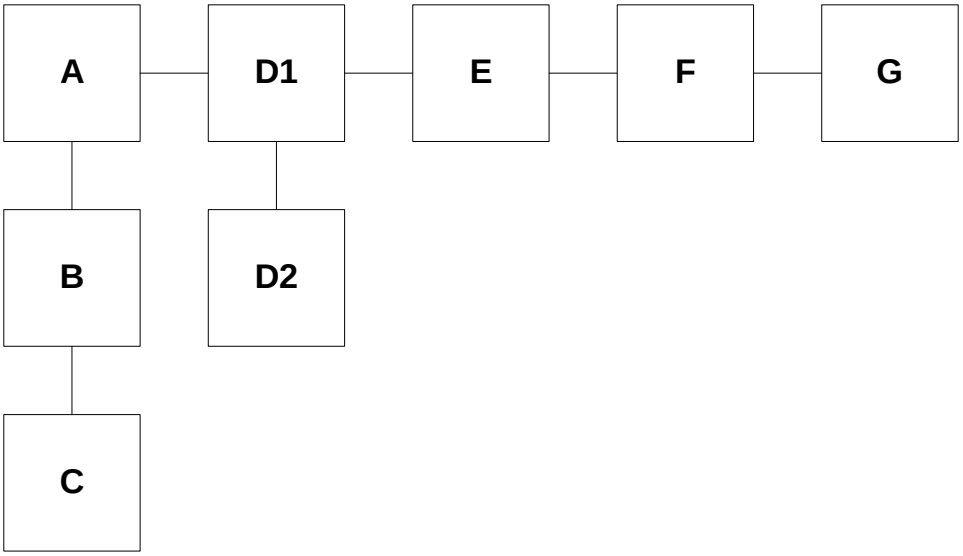
114. Consider a product that is "settled in." Its MTBF distribution has been found to be normal with a mean of 1,000 hours and a standard deviation of 250 hours. What is the probability of a breakdown before 750 hours? Before 500 hours? Would you prefer a policy of preventive maintenance, or a policy of breakdown maintenance, on this product? Explain your choice.
Failure probabilities are not negligible. The value 750 hours is one standard deviation away from the mean, and the area under the normal curve left of that point is 0.15866. The value 500 hours is two standard deviations away, and the area representing failure is 0.02275. Most students will opt for breakdown maintenance. The standard deviation is relatively large compared to the mean; preventive maintenance would have to be performed relatively early and often. (Maintenance, moderate) {AACSB: Analytic Skills}

115. A high school senior is seeking admission into her state's flagship university. The admission requirements are as follows. The student must meet at least ONE of the criteria A, B, C. The student must meet criterion D. These criteria are detailed below. And the student must file a complete application, file a medical form, and pay an application fee by a stated date.

A: score a composite 28 on the ACT exam
B: have a high school GPA of 3.0 or greater
C: place in the top ten percent of the high school class
D: complete all courses in the state-mandated "core college preparatory" curriculum (CCPC); OR complete all but one course in CCPC with a 3.5 GPA on all CCPC courses taken.

Using the tools of reliability analysis with redundancy, translate these conditions into the appropriate reliability schematic.

The connection to reliability is clear: each element in the system has some chance of failure, and the probability of system success is driven by the probability of success of individual components. Students must treat the "or" conditions as redundancies, or parallel items; and they must treat "and" items as items in series. Criterion D is really two items in parallel, which might be labeled D1 and D2. The elements of application, medical, and payment are each separate events, and might be labeled E, F, and G. A possible solution appears below.



(Reliability, moderate) {AACSB: Analytic Skills}

MODULE A: DECISION-MAKING TOOLS

TRUE/FALSE

1. Analytic decision making is based on logic and considers all available data and possible alternatives.
True (The decision process in operations, easy) {AACSB: Analytic Skills}

2. The last step in the analytic decision process clearly defines the problem and the factors that influence it.
False (The decision process in operations, easy) {AACSB: Analytic Skills}

3. A state of nature is an occurrence of a situation over which the decision maker has little or no control.
True (Fundamentals of decision making, easy)

4. In a decision tree, a square symbol represents a state of nature node.
False (Fundamentals of decision making, moderate)

5. If a decision maker can assign probabilities of occurrence to the states of nature, then the decision is being made under conditions of uncertainty.
False (Types of decision-making environments, moderate)

6. An example of a conditional value would be the payoff from selecting a particular alternative when a particular state of nature occurs.
True (Types of decision-making environments, moderate)

7. The maximax criterion of decision making requires that all decision alternatives have an equal probability of occurrence.
False (Types of decision-making environments, easy)

8. The maximin criterion is pessimistic, while the maximax criterion is optimistic.
True (Types of decision-making environments, easy)

9. If a decision maker knows for sure which state of nature will occur, he/she is making a decision under certainty.
True (Types of decision-making environments, moderate)

10. The expected value with perfect information assumes that all states of nature are equally likely.
False (Types of decision-making environments, easy)

11. An example of expected monetary value would be the payoff from selecting a particular alternative when a particular state of nature occurs.
False (Decision tables, moderate)

12. The expected monetary value of a decision alternative is the sum of all possible payoffs from the alternative, each weighted by the probability of that payoff occurring.
True (Types of decision-making environments, easy)

13. If a decision maker has to make a certain decision only once, expected monetary value is a good indication of the payoff associated with the decision.
False (Types of decision-making environments, moderate)

14. The expected value of perfect information is the same as the expected value with perfect information.
False (Decision tables, moderate)

15. Decision trees and decision tables can both solve problems requiring a single decision, but decision tables are the preferred method when a sequence of decisions is involved.
False (Decision trees, easy)

16. In a decision tree, the expected monetary values are computed by working from right to left.
True (Decision trees, moderate)

MULTIPLE CHOICE

17. Which of the following is **not** considered a step in the decision-making process?
a. Clearly identify the problem.
c. Develop objectives.
d. Evaluate alternatives.
b. Select the best alternative.
e. Minimize costs whenever possible.
e (The decision process in operations, moderate)

18. The first step, and a key element, in the decision-making process is to
a. consult a specialist
b. clearly define the problem
c. develop objectives
d. monitor the results
e. select the best alternative
b (The decision process in operations, easy)

19. In terms of decision theory, an occurrence or situation over which the decision maker has no control is called a(n)
a. decision under uncertainty
b. decision tree
c. state of nature
d. alternative
e. none of the above
c (Fundamentals of decision making, easy)

20. A tabular presentation that shows the outcome for each decision alternative under the various possible states of nature is called a(n)
    a. isoquant table
    b. payback period matrix
    c. payoff table
    d. feasible region
    e. decision tree
    c (Decision tables, easy)

21. The decision criterion that would be used by an optimistic decision maker solving a problem under conditions of uncertainty would be the
    a. expected monetary value criterion
    b. equally likely criterion
    c. maximax criterion
    d. maximin criterion
    e. minimin criterion
    c (Types of decision-making environments, moderate)

22. A decision maker who uses the maximin criterion when solving a problem under conditions of uncertainty is
    a. an optimist
    b. a pessimist
    c. an economist
    d. an optometrist
    e. making a serious mistake; maximin is not appropriate for conditions of uncertainty
    b (Types of decision-making environments, moderate)

23. Expected monetary value is most appropriate for problem solving that takes place
    a. when conditions are average
    b. when all states of nature are equally likely
    c. when all alternatives are equally likely
    d. under conditions of uncertainty
    e. under conditions of risk
    e (Types of decision-making environments, moderate)

24. The expected value with perfect information
    a. is appropriate when solving problems under conditions of certainty
    b. requires that each decision alternative have a known probability of occurrence
    c. is an input into the calculation of the expected value of perfect information
    d. is the average of the maximax and the maximin
    e. none of the above
    c (Types of decision-making environments, moderate)

25. The difference between the expected payoff under perfect information and the maximum expected payoff under risk is
    a. expected monetary value
    b. economic order quantity
    c. expected value of perfect information
    d. PERT
    e. expected monetary payoff
    c (Types of decision-making environments, moderate)

26. The outcome of an alternative/state of nature combination is a(n)
    a. price
    b. conditional value
    c. expected value
    d. conditional probability
    e. All of the above are correct.
    b (Decision tables, moderate)

27. The likelihood that a decision maker will ever receive a payoff precisely equal to the EMV when making any one decision is
    a. low (near 0%)
    b. high (near 100%)
    c. dependent upon the number of alternatives
    d. dependent upon the number of states of nature
    e. none of the above
    a (Types of decision-making environments, moderate)

28. The expected value of perfect information (EVPI) is the
    a. payoff for a decision made under perfect information
    b. payoff under minimum risk
    c. average expected payoff
    d. difference between the payoff under perfect information and the payoff under risk
    e. none of the above
    d (Types of decision-making environments, moderate)

29. A decision-maker using the maximax criterion on the problem below would choose Alternative _____ because the maximum of the row maximums is _____.

	States of nature		
	1	2	3
Alternative A	50	55	60
Alternative B	30	50	80
Alternative C	70	80	70
Alternative D	-100	-10	140

a. A; 60
b. B; 80
c. C; 70
d. D; -100
e. D; 140

e (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

30. A decision-maker using the maximin criterion on the problem below would choose Alternative _____ because the maximum of the row minimums is _____.

	States of nature		
	1	2	3
Alternative A	50	55	60
Alternative B	30	50	80
Alternative C	70	80	70
Alternative D	-100	-10	140

a. A; 55
b. B; 30
c. C; 70
d. D; 140
e. D; 10

c (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

31. The highest value for the equally likely criterion is _____; this occurs with alternative__ ____.

	States of nature	
Alternatives	S_1	S_2
Option 1	$10,000	$30,000
Option 2	$5,000	$45,000
Option 3	$-4,000	$60,000

a. $20,000; Option 1
b. $25,000; Option 2
c. $28,000; Option 3
d. $32,000; Option 3
e. $60,000; Option 3

c (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

32. What is the EMV for Option 1 in the following decision table?

	States of nature	
Alternatives	S_1	S_2
p	.3	.7
Option 1	15,000	20,000
Option 2	10,000	30,000

a. 15,000
b. 17,000
c. 17,500
d. 18,500
e. 20,000

d (Types of decision-making environments, easy) {AACSB: Analytic Skills}

33. The expected value with perfect information is
a. the maximum EMV for a set of alternatives
b. the same as the expected value of perfect information
c. valuable in situations involving risk
d. the average return obtained when the decision maker knows which state of nature is going to occur before the decision is made
e. obtained using conditional probabilities

d (Types of decision-making environments, moderate)

34. What is the EMV for Option 2 in the following decision table?

	States of nature	
Alternatives	S_1	S_2
p	.3	.7
Option 1	15,000	20,000
Option 2	10,000	30,000

a. 10,000
b. 16,000
c. 20,000
d. 24,000
e. 30,000

d (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

35. What is the EMV for Option 1 in the following decision table?

States of nature

Alternatives	S_1	S_2
p	.4	.6
Option 1	10,000	30,000
Option 2	5,000	45,000
Option 3	-4,000	60,000

a. 10,000
b. 18,000
c. 20,000
d. 22,000
e. 30,000

d (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

36. What is the EMV for Option 2 in the following decision table?

States of nature

Alternatives	S_1	S_2
p	.4	.6
Option 1	10,000	30,000
Option 2	5,000	45,000
Option 3	-4,000	60,000

a. 5,000
b. 21,000
c. 25,000
d. 29,000
e. 45,000

d (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

37. What is the expected value with perfect information of the following decision table?

States of nature

Alternatives	S_1	S_2
p	.4	.6
Option 1	10,000	30,000
Option 2	5,000	45,000
Option 3	-4,000	60,000

a. 5,000
b. 10,000
c. 40,000
d. 60,000
e. 70,000

c (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

38. What is the EMV for Option 1 in the following decision table?

States of nature

Alternatives	S_1	S_2
p	.6	.4
Option 1	200	300
Option 2	50	350

a. 200
b. 240
c. 250
d. 260
e. 300

b (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

39. What is the EMV for Option 2 in the following decision table?

States of nature

Alternatives	S_1	S_2
p	.6	.4
Option 1	200	300
Option 2	50	350

a. 50
b. 100
c. 170
d. 200
e. 350

c (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

40. What is the expected value with perfect information in the following decision table?

States of nature

Alternatives	S_1	S_2
p	.6	.4
Option 1	200	300
Option 2	50	350

a. 50
b. 200
c. 260
d. 300
e. 350

c (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

41. What is the expected value of perfect information of the following decision table?

States of nature

Alternatives	S_1	S_2
p	.6	.4
Option 1	200	300
Option 2	50	350

a. 0
b. 20
c. 50
d. 150
e. 200
b (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

42. A retailer is deciding how many of a certain product to stock. The historical probability distribution of sales for this product is 0 units, 0.2; 1 unit, 0.3; 2 units, 0.4, and 3 units, 0.1. The product costs $8 per unit and sells for $25 per unit. The conditional value for the decision alternative "Stock 3" and state of nature "Sell 1" is
a. 1.4 units
b. $1 profit
c. $25 profit
d. $-8 profit
e. none of the above
b (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

43. A retailer is deciding how many of a certain product to stock. The historical probability distribution of sales for this product is 0 units, 0.2; 1 unit, 0.3; 2 units, 0.4, and 3 units, 0.1. The product costs $8 per unit and sells for $25 per unit. The largest conditional value (profit) in the entire payoff table for this scenario is
a. $-24 profit
b. $-8 profit
c. $17 profit
d. $51 profit
e. $75 profit
d (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

44. Decision trees
a. give more accurate solutions than decision tables
b. give less accurate solutions than decision tables
c. are especially powerful when a sequence of decisions must be made
d. are rarely used because one needs specialized software to graph them
e. are too complex to be used by decision makers
c (Decision trees, moderate)

45. A decision tree is a(n)
    a. algebraic representation of alternatives and states of nature
    b. behavioral representation of alternatives and states of nature
    c. matrix representation of alternatives and states of nature
    d. schematic representation of alternatives and states of nature
    e. tabular representation of alternatives and states of nature
    d (Decision trees, moderate)

46. All of the following steps are taken to analyze problems with decision trees **except**
    a. define the problem
    b. structure or draw a decision tree
    c. assign probabilities to the alternatives
    d. estimate payoffs for each possible alternative/state of nature combination
    e. solve the problem by computing expected monetary values for each state of nature node
    c (Decision trees, moderate)

47. A problem that involves a sequence of decisions
    a. cannot be analyzed with expected monetary value
    b. can be better analyzed with a decision tree than by a decision table
    c. must be analyzed in the same order that the decisions are made
    d. cannot be analyzed with decision tree software
    e. can only be analyzed using decision making under certainty
    b (Decision trees, moderate)

FILL-IN-THE BLANK

48. A(n) _____ is a tabular means of analyzing decision alternatives and states of nature.
    decision table (Decision tables, easy)

49. _____ is the criterion for decision making under uncertainty that finds an alternative that maximizes the minimum outcome or consequences.
    Maximin (Decision tables, moderate)

50. _____ is the criterion for decision making under certainty that assigns equal probability to each state of nature.
    Equally likely (Decision tables, moderate)

51. _____ is the expected payout or value of a variable that has different possible states of nature, each with an associated probability.
    Expected monetary value or EMV (Decision tables, moderate)

52. _____ is the difference between the payoff under perfect information and the payoff under risk.
    Expected value of perfect information or EVPI (Decision tables, moderate)

53. A(n) _____ is a graphical means of analyzing decision alternatives and states of nature.
    decision tree (Decision trees, easy)

54. A(n) _____ is an occurrence or situation over which the decision maker has little or no control.
state of nature (Decision trees, easy)

55. The square symbol used in drawing a decision trees represents a _____ node.
decision (Decision trees, easy)

56. A branch of a decision tree that is less favorable than other available options may be _____.
pruned or dropped (Decision trees, easy)

SHORT ANSWER

57. In the context of decision-making, define **state of nature.**
A state of nature is an occurrence or situation over which the decision maker has little or no control. (Fundamentals of decision making, moderate)

58. In the context of decision-making, define **alternative**.
An alternative is a course of action or a strategy that may be chosen by a decision maker. (Fundamentals of decision making, moderate)

59. Identify, in order, the six steps of analytical decision making.
1. Clearly define the problem and factors that influence it.
2. Develop specific and measurable objectives.
3. Develop a model—that is, a relationship between objectives and variables (which are measurable quantities).
4. Evaluate each alternative solution based on its merits and drawbacks.
5. Select the best alternative.
6. Implement the decision and set a timetable for completion.
(The decision process in operations, moderate)

60. Explain the graphical shapes used in decision tree analysis.
A decision node from which one or several alternatives may be selected is represented by a square; a state of nature node out of which states of nature will occur is represented by a circle. (Fundamentals of decision making, moderate)

61. What are decision tables?
Decision tables are a tabular means of analyzing decision alternatives and states of nature. (Decision tables, easy)

62. What is a conditional value?
It is an outcome of a particular alternative/state of nature combination. (Decision tables, moderate)

63. How is the expected value of perfect information (EVPI) found?
It is found by taking the expected value with perfect information and subtracting the maximum expected monetary value (EMV) from it. (Types of decision-making environments, moderate)

64. Identify and describe three methods used for decision making under conditions of uncertainty.
The three decision rules are maximax, maximin, and equally likely. Maximax is a criterion that finds an alternative that maximizes the maximum outcome. Maximin is a criterion that finds an alternative that maximizes the minimum outcome. Equally likely is a criterion that assigns equal likelihood to each state of nature. (Types of decision-making environments, moderate)

65. Which technique results in an optimistic decision? Why?
Maximax is the optimistic criterion. It maximizes the maximum outcome. (Types of decision-making environments, easy)

66. If a decision maker is a pessimist, what decision-making criterion is appropriate? Why?
Maximin is the pessimistic criterion. It assumes that the worst state of nature will happen. The decision making criterion selects the best of all possible worst outcomes. (Types of decision-making environments, easy)

67. What limitation(s) do decision trees overcome compared to decision tables?
Decision trees work better when a sequence of decisions must be made. (Decision trees, moderate)

68. Define expected monetary value (EMV).
EMV is the expected value or return for an alternative if we were to repeat the decision a large number of times, each time choosing that alternative. (Types of decision-making environments, moderate)

69. Describe the meaning of EVPI. Provide an example in which EVPI can help a manager.
EVPI is defined as the expected value of perfect information. It is found by taking the expected value with perfect information and subtracting the maximum expected monetary value (EMV) from it, and it is the maximum amount that we would be willing to pay for additional (perhaps, perfect) information. Determination of EVPI is useful any time the manager has the option of expending additional resources to acquire additional information and making the decision using currently available information. (Decision trees, moderate)

PROBLEMS

70. The construction manager for Acme Construction, Inc. must decide whether to build single family homes, apartments, or condominiums. This is not a product-mix problem, but an all-or nothing decision. He will hire workers and rent equipment appropriate for one action only. He estimates annual profits (in thousands of dollars) will vary with population trends as follows:

Dwelling type	Population steady	Population grows slowly	Population grows rapidly
Single family	$100	$90	$70
Apartments	50	170	90
Condominiums	-20	100	220

a. If he uses the maximin criterion, which type of dwellings will he choose to build? Show your supporting calculations.
b. If he uses the equally likely criterion, which kind of dwellings will he choose to build? Show your supporting calculations.
c. If the construction manager were an optimist, what criterion would he choose? What would be the choice of dwelling for that criterion? Show your supporting calculations.

(a) The pessimistic maximin criterion assumes the worst state of nature will occur and selects the action associated with the best of these worst outcomes. For this problem, the "worsts" for each action are Single family = $70, Apartments = $50, and Condominiums = -20. The best of the worsts is $70, so the manager should choose to build single family homes.
(b) The equally likely criterion calculates the simple average of each action; the results are Single family = $83.3, Apartments = $103.3, and Condominiums = $100. The manager should select the action associated with the largest of these values, and build apartments.
(c) The optimistic criterion is maximax, which assumes that the best outcome will occur for each action. The best outcomes are Single family = $100, Apartments = $170, and Condominiums = $220. The manager chooses the action associated with the best of the bests, or Condominiums. (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

71. An operations manager's staff has compiled the information below for four manufacturing alternatives (A, B, C, and D) that vary by production technology and the capacity of the machinery. All choices enable the same level of total production and have the same lifetime. The four states of nature represent four levels of consumer acceptance of the firm's products. Values in the table are net present value of future profits in millions of dollars.

	States of nature			
	1	2	3	4
Alternative A	50	55	60	65
Alternative B	30	50	80	130
Alternative C	70	80	70	65
Alternative D	-100	-10	150	220

a. Assuming a maximax strategy, which alternative would be chosen?
b. If maximin were used, which would be chosen?
c. If the states of nature were equally likely, which alternative should be chosen?

(a) The maximax strategy selects the best of the best, which is $220. This happens when Alternative D is selected. (b) The maximin strategy selects the best of the worsts; the worsts are A=50, B=30, C=65, and D=-100. The best of these is 65, associated with Alternative C. (c) The averages for the four alternatives are A=57.5, B=72.5, C=71.25, and D=65. The highest of these is 72.5, associated with Alternative B. (Decision tables, moderate) {AACSB: Analytic Skills}

72. An operations manager's staff has compiled the information below for four manufacturing alternatives (E, F, G, and H) that vary by production technology and the capacity of the machinery. All choices enable the same level of total production and have the same lifetime. The four states of nature represent four levels of consumer acceptance of the firm's products. Values in the table are net present value of future profits in millions of dollars. Forecasts indicate that there is a 0.1 probability of acceptance level 1, 0.2 chance of acceptance level 2, 0.4 chance of acceptance level 3, and 0.3 change of acceptance level 4.

	States of nature			
	1	2	3	4
Alternative E	50	50	70	60
Alternative F	30	50	80	130
Alternative G	70	80	70	60
Alternative H	-140	-10	150	220

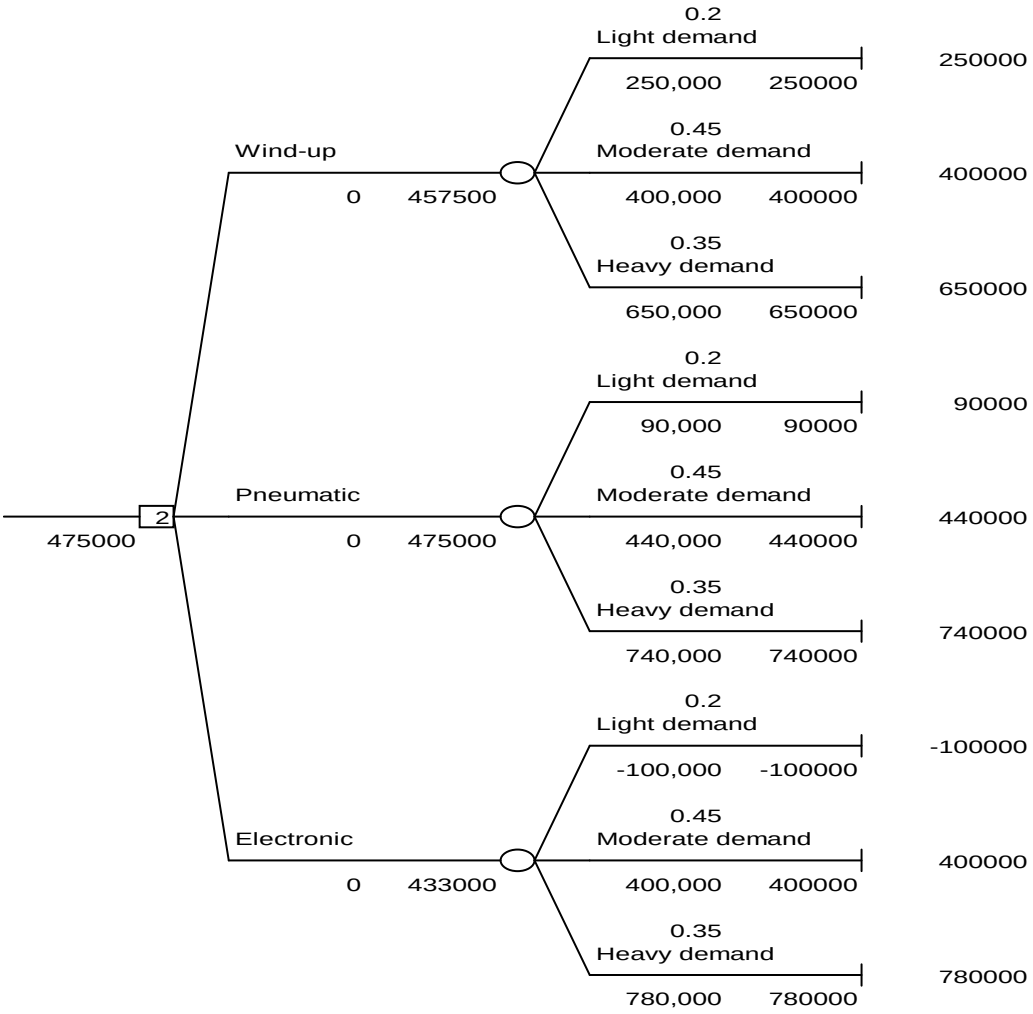
Using the criterion of expected monetary value, which production alternative should be chosen?

The expected values are:
E = .1*50 + .2*50 + .4*70 + .3*60 = 5 + 10 + 28 + 18 = 61
F = .1*30 + .2*50 + .4*80 + .3*130 = 3 + 10 + 32 + 39 = 84
G = .1*70 + .2*80 + .4*70 + .3*60 = 7 + 16 + 28 + 18 = 69
H = .1 *-140 + .2*-10 + .4*150 + .3*220 = -10 -2 + 60 + 66 = 110
The highest of these occurs with production alternative H. (Decision tables, moderate) {AACSB: Analytic Skills}

73. A toy manufacturer makes stuffed kittens and puppies which have relatively lifelike motions. There are three different mechanisms which can be installed in these "pets." These toys will sell for the same price regardless of the mechanism installed, but each mechanism has its own variable cost and setup cost. Profit, therefore, is dependent upon the choice of mechanism and upon the level of demand. The manufacturer has in hand a forecast of demand that suggests a 0.2 probability of light demand, a 0.45 probability of moderate demand, and a probability of 0.35 of heavy demand. Payoffs for each mechanism-demand combination appear in the table below.

Demand	Wind-up action	Pneumatic action	Electronic action
Light	$250,000	$90,000	-$100,000
Moderate	400,000	440,000	400,000
Heavy	650,000	740,000	780,000

Construct the appropriate decision tree to analyze this problem. Use standard symbols for the tree. Analyze the tree to select the optimal decision for the manufacturer.



The best choice is Pneumatic, $475,000. (Decision trees, moderate) {AACSB: Analytic Skills}

74. A toy manufacturer has three different mechanisms that can be installed in a doll that it sells. The different mechanisms have three different setup costs (overheads) and variable costs and, therefore, the profit from the dolls is dependent on the volume of sales. The anticipated payoffs are as follows.

	Light Demand	Moderate Demand	Heavy Demand
Probability	0.25	0.45	0.3
Wind-up action	$325,000	$190,000	$170,000
Pneumatic action	$300,000	$420,000	$400,000
Electrical action	-$400,000	$240,000	$800,000

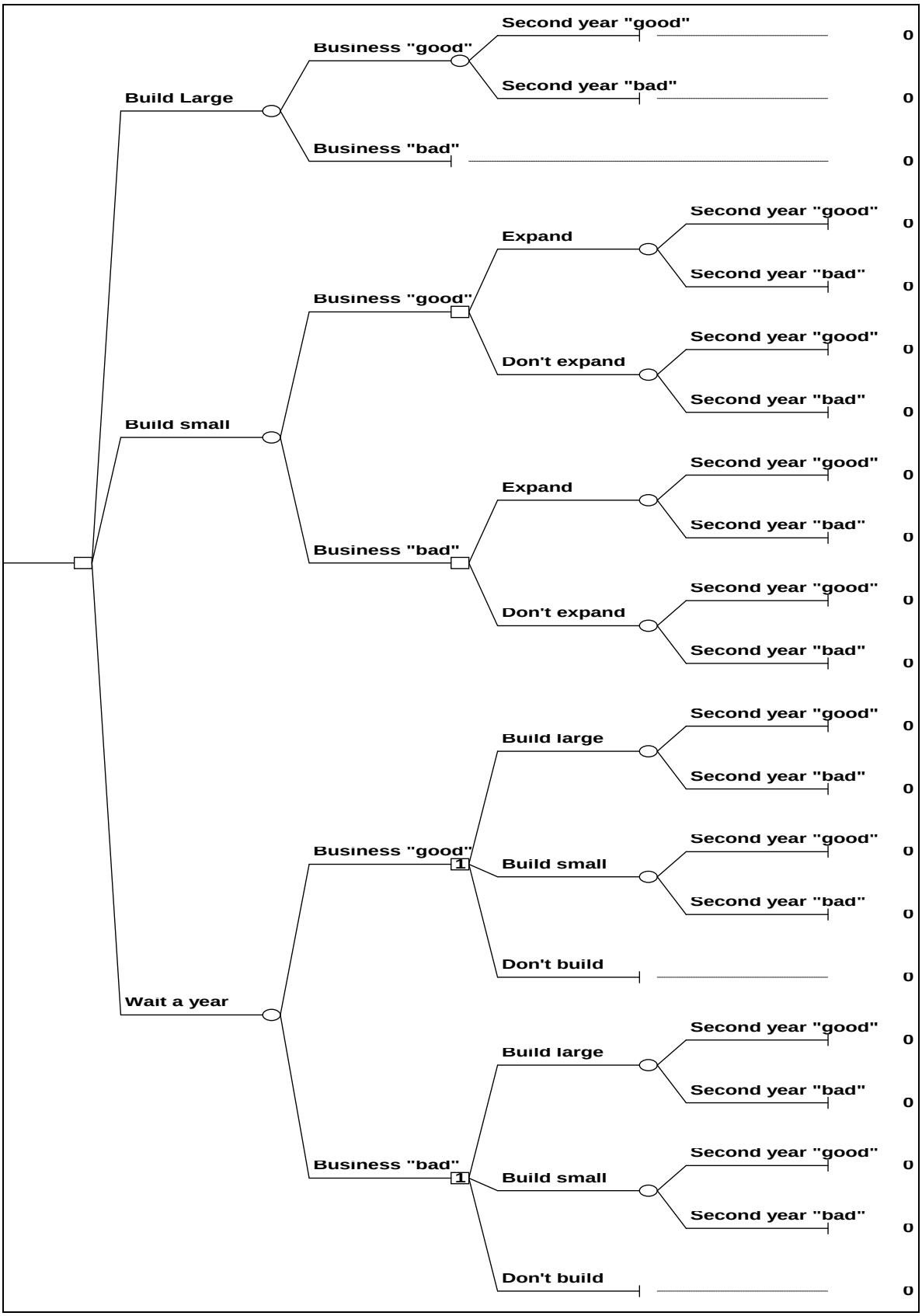
a. What is the EMV of each decision alternative?
b. Which action should be selected?
c. What is the expected value with perfect information?
d. What is the expected value of perfect information?
(a) Wind-up=.25*$325,000 + .45*$190,000 + .3*$170,000 = $217,750; Pneumatic =.25*$300,000 + .45*$420,000 + .3*$400,000 = $384,000; and Electrical = .25*(-$400,000) + .45*$240,000 + .3*$800,000 = $248,000. (b) Pneumatic has the best EMV, at $384,000. (c) EVwPI is .25*$325,000 + .45* $420,000 + .3* $800,000 = $510,250; (d) EVPI =$510,250 - $384,000 = $126,250.
(Types of decision-making environments, moderate) {AACSB: Analytic Skills}

75. A local business owner is a bit uncertain of the demand forecast, and is timidly approaching the capacity decision for a business he is about to open. Here's how he describes the decisions that confront him over the next two years.

"First, I have to choose between building a large plant initially and building a small one that has room to expand. Or I could stay on the sidelines now, and enter with a business next year. That one, too, could be the large version or the small. If I build small, then after one year, I can review how good business was, and decide whether to expand. If I build large, there is no further option to enlarge."

Do not concern yourself with probabilities or payoff values .Simply draw the tree that illustrates the manager's decision alternatives and the chance events that go along with them. Use standard symbols for decision tree construction, and label all parts of your diagram carefully. To simplify, assume that business in the first year, and in the second, can be only "good" or "bad."

SEE SOLUTION ON NEXT PAGE.



(Decision trees, moderate) {AACSB: Analytic Skills}

76. Steve Gentry, the operations manager of Baja Fabricators, wants to purchase a new profiling machine (it cuts compound angles on the ends of large structural pipes used in the fabrication yard). However, because the price of crude oil is depressed, the market for such equipment is down. Steve believes that the market will improve in the near future and that the company should expand its capacity. The table below displays the three equipment options he is currently considering, and the profit he expects each one to yield over a two-year period. The consensus forecast at Baja is that there is about a 30% probability that the market will pick up "soon" (within 3 to 6 months) and a 70% probability that the improvement will come "later" (in 9 to 12 months, perhaps longer).

Profit from Capacity Investment (in Dollars)

Equipment Option	Market picks up "soon" p = 0.30	Market picks up "later" p = 0.70
Manual Machine	-120000	210000
NC Machine	140000	160000
CNC Machine	200000	-200000

a. Calculate the expected monetary value of each decision alternative.
b. Which equipment option should Steve take?
(a) The expected monetary values are: "Manual machine" $111,000, "NC Machine" $154,000, and "CNC Machine" -$80,000. (b) Based upon the EMV criterion, Baja should purchase an NC machine. (Types of decision-making environments, easy) {AACSB: Analytic Skills}

77. Miles is considering buying a new pickup truck for his lawn service firm. The economy in town seems to be growing, and he is wondering whether he should opt for a subcompact, compact, or full-size pickup truck. The smaller truck would have better fuel economy, but would sacrifice capacity and some durability. A friend at the Bureau of Economic Research told him that there is a 30% chance of lower gas prices in his area this year, a 20% chance of higher gas prices, and a 50% chance that gas prices will stay roughly unchanged. Based on this information, Miles has developed a decision table that indicates the profit amount he would end up with after a year for each combination of truck and gas prices.

States of nature

Alternatives	Lower gas prices	Gas prices unchanged	Higher gas prices
probability	.3	.5	.2
Subcompact	16,000	21,000	23,000
Compact	15,000	20,000	22,000
Full size	18,000	19,000	6,000

Calculate the expected monetary value for each decision alternative. Which decision yields the highest EMV?
The expected values are: subcompact $19,900, compact $18,900, and full size $16,100. The highest EMV is that of the subcompact truck. (Types of decision-making environments, moderate) {AACSB: Analytic Skills}

78. Earl Shell owns his own Sno-Cone business and lives 30 miles from a beach resort. The sale of Sno-Cones is highly dependent upon his location and upon the weather. At the resort, he will profit $110 per day in fair weather, $20 per day in foul weather. At home, he will profit $70 in fair weather, $50 in foul weather. Assume that on any particular day, the weather service suggests a 60% chance of fair weather.
a. Construct Earl's payoff table.
b. What decision is recommended by the expected value criterion?
c. What is the EVPI?

(a)The payoff table is

Profit	**Fair weather**	**Foul weather**
	Probability = 0.6	**Probability = .4**
Sell at the resort	**110**	**20**
Sell at home	**70**	**50**

(b) the EMV for sell at the resort = .6*110 + .4*20 = 74; The EMV for sell at home = .6*70 + .3*50 = 62. The better value is $74, so Earl should sell at the resort.
(c) EVwPI = .6*110 + .4*50 = $86; EVPI = $86 - $74 = $12.
(Types of decision-making environments, moderate) {AACSB: Analytic Skills}

79. The campus bookstore sells stadium blankets embroidered with the university crest. The blankets must be purchased in bundles of one dozen each. Each blanket in the bundle costs $65, and will sell for $90. Blankets unsold by homecoming will be clearance priced at $20. The bookstore estimates that demand patterns will follow the table below.
a. Build the decision table.
b. What is the maximum expected value?
c. How many bundles should be purchased?

Demand level	Probability
1 bundle	10 percent
2 bundles	30 percent
3 bundles	50 percent
4 bundles	10 percent

(a) See the table below; (b) the maximum expected value is $516; (c) the bookstore should order 2 cases.

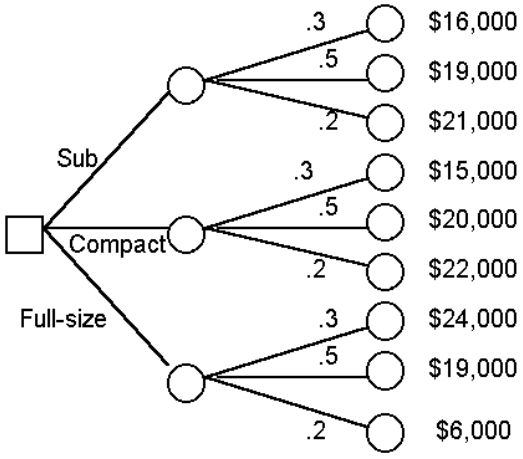
Profit	**Demand 1**	**Demand 2**	**Demand 3**	**Demand 4**		**EMV**
Probability	**0.1**	**0.3**	**0.5**	**0.1**		
Order 1	**300**	**300**	**300**	**300**		**300**
Order 2	**-240**	**600**	**600**	**600**	**Maximum**	**516**
Order 3	**-780**	**60**	**900**	**900**		**480**
Order 4	**-1320**	**-480**	**360**	**1200**		**24**

(Types of decision-making environments, moderate) {AACSB: Analytic Skills}

80. Miles is considering buying a new pickup truck for his lawn service firm. The economy in town seems to be growing, and he is wondering whether he should opt for a subcompact, compact, or full-size pickup truck. The smaller truck would have better fuel economy, but would sacrifice capacity and some durability. A friend at the Bureau of Economic Research told him that there is a 30% chance of lower gas prices in his area this year, a 20% chance of higher gas prices, and a 50% chance that gas prices will stay roughly unchanged. Based on this information, Miles has developed a decision table that indicates the profit amount he would end up with after a year for each combination of truck and gas prices. Develop a decision tree for this situation and indicate which type of truck he should select.

	States of nature		
Alternatives	Lower gas prices	Gas prices unchanged	Higher gas prices
probability	.3	.5	.2
Subcompact	16,000	19,000	21,000
Compact	15,000	20,000	22,000
Full size	24,000	19,000	6,000

The tree appears in the drawing below. The highest expected value decision alternative is the compact truck, at $18,900, as shown in the POM for Windows solution.



Objective
Profits (maximize)
Costs (minimize)

Truck Decision Solution

	Start Node	End Node	Branch Probabili	Profit	Use Branch?	End node	Node Type	Node Value
Start	0.	1.	0.	0.		1.	Decision	18,900.
Branch 1	1.	2.	0.	0.		2.	Chance	18,500.
Branch 2	1.	3.	0.	0.	Yes	3.	Chance	18,900.
Branch 3	1.	4.	0.	0.		4.	Chance	17,900.
Branch 4	2.	5.	0.3	16,000.		5.	Final	16,000.
Branch 5	2.	6.	0.5	19,000.		6.	Final	19,000.
Branch 6	2.	7.	0.2	21,000.		7.	Final	21,000.
Branch 7	3.	8.	0.3	15,000.		8.	Final	15,000.
Branch 9	3.	10.	0.2	22,000.		10.	Final	22,000.
Branch 10	4.	11.	0.3	24,000.		11.	Final	24,000.
Branch 11	4.	12.	0.5	19,000.		12.	Final	19,000.
Branch 12	4.	13.	0.2	6,000.		13.	Final	6,000.

(Decision trees, easy) {AACSB: Analytic Skills}

81. Daily sales of bread by Salvador Monella's Baking Company follow the historical pattern shown in the table below. It costs the bakery 50 cents to produce a loaf of bread, which sells for 95 cents. Any bread unsold at the end of the day is sold to the parish jail for 25 cents per loaf. Construct the decision table of conditional payoffs. How many loaves should Sal bake each day in order to maximize contribution?

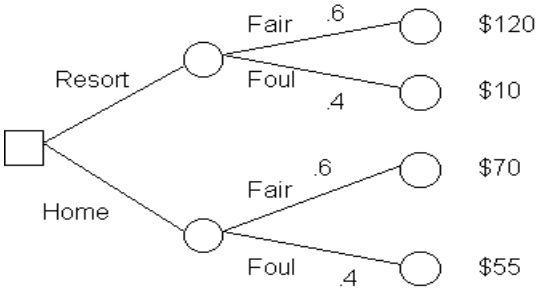
Demand	400	500	600	700	800
Probability	.20	.20	.40	.15	.05

The Excel OM decision table and solution appear below. The best expected value is $228, which occurs with the decision to bake 600 loaves.

Profit	**Sell 400**	**Sell 500**	**Sell 600**	**Sell 700**	**Sell 800**		**EMV**
Probability	**0.2**	**0.2**	**0.4**	**0.15**	**0.05**		
Bake 400	**180**	**180**	**180**	**180**	**180**		**180**
Bake 500	**155**	**225**	**225**	**225**	**225**		**211**
Bake 600	**130**	**200**	**270**	**270**	**270**	**Maximum**	**228**
Bake 700	**105**	**175**	**245**	**315**	**315**		**217**
Bake 800	**80**	**150**	**220**	**290**	**360**		**195.5**

(Types of decision-making environments, moderate) {AACSB: Analytic Skills}

82. Earl Shell owns his own Sno-Cone business and lives 30 miles from a beach resort. The sale of Sno-Cones is highly dependent upon his location and upon the weather. At the resort, he will profit $120 per day in fair weather, $10 per day in bad weather. At home, he will profit $70 in fair weather, $55 in bad weather. Assume that on any particular day, the weather service suggests a 40% chance of foul weather.
a. Construct Earl's decision tree.
b. What decision is recommended by the expected value criterion?
Resort has a higher EMV ($76) than Home



Decision Tree Results

Earl's Truck Solution

	Start Node	End Node	Branch Probabili	Profit	Use Branch?	End node	Node Type	Node Value
Start	0.	1.	0.	0.		1.	Decision	76.
Resort	1.	2.	0.	0.	Yes	2.	Chance	76.
Home	1.	3.	0.	0.		3.	Chance	64.
Fair/Resort	2.	4.	0.6	120.		4.	Final	120.
Foul/Resort	2.	5.	0.4	10.		5.	Final	10.
Fair/Home	3.	6.	0.6	70.		6.	Final	70.
Fair/Home	3.	7.	0.4	55.		7.	Final	55.

(Decision trees, moderate) {AACSB: Analytic Skills}

83. The campus bookstore sells highlighters that it purchases by the case. Cost per case, including shipping and handling, is $200. Revenue per case is $350. Any cases unsold will be discounted and sold at $175. The bookstore has estimated that demand will follow the pattern below

Demand level	Probability
10 cases	20 percent
11 cases	20 percent
12 cases	40 percent
13 cases	15 percent
14 cases	5 percent

a. Construct the bookstore's payoff table.
b. How many cases should the bookstore stock in order to maximize profit?
c. How would your answer differ if the clearance price were not $175 per case but $225 per case? (It is not necessary to re-solve the problem to answer this.)
(a) The Excel OM table is below. (b) The highest EMV is 1705, from stocking 13 cases. (c) If the clearance price exceeds the case cost, there will be no disincentive to stocking the maximum demand level, 14 cases.

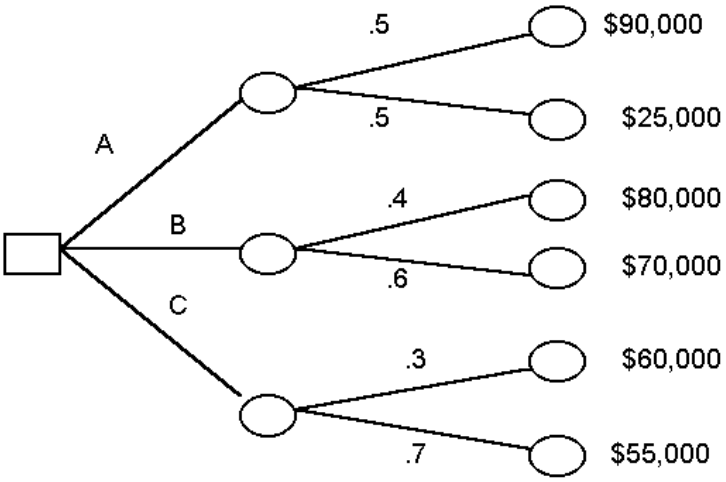
Profit	**Demand 10**	**Demand 11**	**Demand 12**	**Demand 13**	**Demand 14**		**EMV**
Probability	**0.2**	**0.2**	**0.4**	**0.15**	**0.05**		
Stock 10	**1500**	**1500**	**1500**	**1500**	**1500**		**1500**
Stock 11	**1475**	**1650**	**1650**	**1650**	**1650**		**1615**
Stock 12	**1450**	**1625**	**1800**	**1800**	**1800**		**1695**
Stock 13	**1425**	**1600**	**1775**	**1950**	**1950**	**Maximum**	**1705**
Stock 14	**1400**	**1575**	**1750**	**1925**	**2100**		**1688.75**

(Types of decision-making environments, moderate) {AACSB: Analytic Skills}

84. Bratt's Bed and Breakfast, in a small historic New England town, must decide how to subdivide (remodel) the large old home that will become their inn. There are three alternatives: Option A would modernize all baths and combine rooms, leaving the inn with four suites, each suitable for two to four adults. Option B would modernize only the second floor; the results would be six suites, four for two to four adults, and two for two adults only. Option C (the status quo option) leaves all walls intact. In this case, there are eight rooms available, but only two are suitable for four adults, and four rooms will not have private baths. Below are the details of profit and demand patterns that will accompany each option. Which option has the highest expected value?

	Annual profit under various demand patterns			
	Capacity	p	Average	p
A (Modernize all)	$90,000	.5	$25,000	.5
B (Modernize 2nd)	$80,000	.4	$70,000	.6
C (Status Quo)	$60,000	.3	$55,000	.7

Branch 2, which represents Option B-Modernize 2nd floor, has the highest expected value, $74,000. This cannot be done as a decision table. POM for Windows solution follows.



Bratt B and B Solution

	Start Node	End Node	Branch Probabili	Profit	Use Branch?	End node	Node Type	Node Value
Start	0.	1.	0.	0.		1.	Decision	74,000.
Branch 1	1.	2.	0.	0.		2.	Chance	57,500.
Branch 2	1.	3.	0.	0.	Yes	3.	Chance	74,000.
Branch 3	1.	4.	0.	0.		4.	Chance	56,500.
Branch 4	2.	5.	0.5	90,000.		5.	Final	90,000.
Branch 5	2.	6.	0.5	25,000.		6.	Final	25,000.
Branch 6	3.	7.	0.4	80,000.		7.	Final	80,000.
Branch 7	3.	8.	0.6	70,000.		8.	Final	70,000.
Branch 8	4.	9.	0.3	60,000.		9.	Final	60,000.
Branch 9	4	10	0.7	55,000		10	Final	55,000

(Decision trees, moderate) {AACSB: Analytic Skills}

MODULE B: LINEAR PROGRAMMING

TRUE/FALSE

1. Linear programming helps operations managers make decisions necessary to make effective use of resources such as machinery, labor, money, time, and raw materials.
True (Introduction, easy)

2. One requirement of a linear programming problem is that the objective function must be expressed as a linear equation.
True (Introduction, easy)

3. A common form of the product-mix linear programming seeks to find that combination of products and the quantity of each that maximizes profit in the presence of limited resources.
True (Formulating linear programming problems, moderate)

4. Linear programming is an appropriate problem-solving technique for decisions that have no alternative courses of action.
False (Requirements of a linear programming problem, easy)

5. In linear programming, a statement such as "maximize contribution" becomes an objective function when the problem is formulated.
True (Formulating linear programming problems, moderate)

6. Constraints are needed to solve linear programming problems by hand, but not by computer.
False (Graphical solution to a linear programming problem, easy) {AACSB: Use of IT}

7. In terms of linear programming, the fact that the solution is infeasible implies that the "profit" can increase without limit.
False (Graphical solution to a linear programming problem, moderate)

8. The region that satisfies all of the constraints in graphical linear programming is called the region of optimality.
False (Graphical solution to a linear programming problem, moderate)

9. Solving a linear programming problem with the iso-profit line solution method requires that we move the iso-profit line to each corner of the feasible region until the optimum is identified.
False (Graphical solution to a linear programming problem, moderate)

10. The optimal solution to a linear programming problem is within the feasible region.
True (Graphical solution to a linear programming problem, moderate)

11. For a linear programming problem with the constraints $2X + 4Y \leq 100$ and $1X + 8Y \leq 100$, two of its corner points are (0, 0) and (0, 25).
False (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

12. In linear programming, if there are three constraints, each representing a resource that can be used up, the optimal solution must use up all of each of the three resources.
False (Graphical solution to a linear programming problem, moderate)

13. The region that satisfies the constraint $4X + 15Z \geq 1000$ includes the origin of the graph.
False (Graphical solution to a linear programming problem, easy) {AACSB: Analytic Skills}

14. The optimal solution of a linear programming problem that consists of two variables and six constraints will probably not satisfy all six constraints precisely.
True (Graphical solution to a linear programming problem, difficult)

15. Sensitivity analysis of linear programming solutions can use trial and error or the analytic postoptimality method.
True (Sensitivity analysis, easy)

16. In sensitivity analysis, a zero shadow price (or dual value) for a resource ordinarily means that the resource has not been used up.
True (Sensitivity analysis, difficult)

17. The graphical method of solving linear programming can handle only maximizing problems.
False (Solving minimization problems, moderate)

18. In linear programming, statements such as "the blend must consist of at least 10% of ingredient A, at least 30% of ingredient B, and no more than 50% of ingredient C" can be made into valid constraints even though the percentages do not add up to 100 percent.
True (Linear programming applications, difficult) {AACSB: Reflective Thinking}

MULTIPLE CHOICE

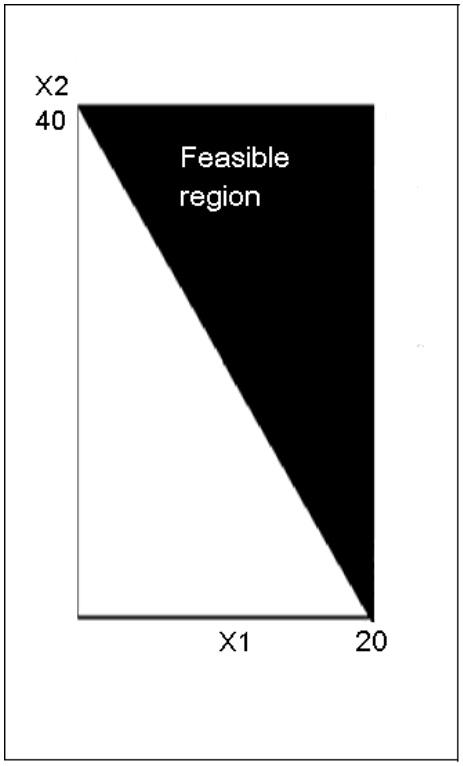
19. Which of the following represents valid constraints in linear programming?
    a. $2X \geq 7X*Y$
    b. $2X * 7Y \geq 500$
    c. $2X + 7Y \geq 100$
    d. $2X^2 + 7Y \geq 50$
    e. All of the above are valid linear programming constraints.
    c (Requirements of a linear programming problem, moderate)

20. Which of the following is **not** a requirement of a linear programming problem?
    a. an objective function, expressed in terms of linear equations
    b. constraint equations, expressed as linear equations
    c. an objective function, to be maximized or minimized
    d. alternative courses of action
    e. for each decision variable, there must be one constraint or resource limit
    e (Requirements of a linear programming problem, moderate)

21. In linear programming, a statement such as "maximize contribution" becomes a(n)
    a. constraint
    b. slack variable
    c. objective function
    d. violation of linearity
    e. decision variable

    c (Formulating linear programming problems, moderate)

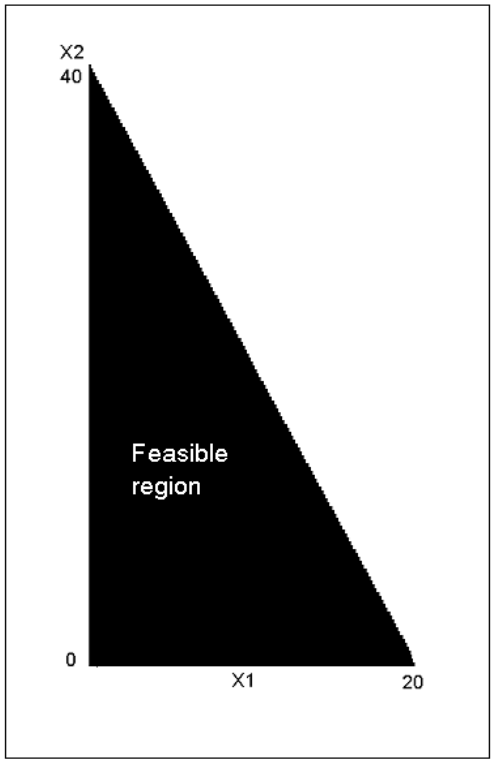
22. The feasible region in the diagram below is consistent with which one of the following constraints?



    a. $8X1 + 4X2 \leq 160$
    b. $8X1 + 4X2 \geq 160$
    c. $4X1 + 8X2 \leq 160$
    d. $8X1 - 4X2 \leq 160$
    e. $4X1 - 8X2 \leq 160$

    b (Graphical solution to a linear programming problem, difficult) {AACSB: Analytic Skills}

23. The feasible region in the diagram below is consistent with which one of the following constraints?



a. $8X1 + 4X2 \geq 160$
b. $4X1 + 8X2 \leq 160$
c. $8X1 - 4X2 \leq 160$
d. $8X1 + 4X2 \leq 160$
e. $4X1 - 8X2 \leq 160$

d (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

24. An iso-profit line
a. can be used to help solve a profit maximizing linear programming problem
b. is parallel to all other iso-profit lines in the same problem
c. is a line with the same profit at all points
d. none of the above
e. all of the above

e (Graphical solution to a linear programming problem, moderate)

25. Which of the following combinations of constraints has no feasible region?
a. $X + Y \geq 15$ and $X - Y \leq 10$
b. $X + Y \geq 5$ and $X \geq 10$
c. $X \geq 10$ and $Y \geq 20$
d. $X + Y \geq 100$ and $X + Y \leq 50$
e. All of the above have a feasible region.

d (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

26. The corner point solution method requires
    a. finding the value of the objective function at the origin
    b. moving the iso-profit line to the highest level that still touches some part of the feasible region
    c. moving the iso-profit line to the lowest level that still touches some part of the feasible region
    d. finding the coordinates at each corner of the feasible solution space
    e. none of the above
    d (Graphical solution to a linear programming problem, moderate)

27. Which of the following sets of constraints results in an unbounded maximizing problem?
    a. $X + Y \geq 100$ and $X + Y \leq 50$
    b. $X + Y \geq 15$ and $X - Y \leq 10$
    c. $X + Y \leq 10$ and $X \geq 5$
    d. $X \leq 10$ and $Y \leq 20$
    e. All of the above have a bounded maximum.
    b (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

28. The region which satisfies all of the constraints in graphical linear programming is called the
    a. area of optimal solutions
    b. area of feasible solutions
    c. profit maximization space
    d. region of optimality
    e. region of non-negativity
    b (Graphical solution to a linear programming problem, moderate)

29. Using the graphical solution method to solve a maximization problem requires that we
    a. find the value of the objective function at the origin
    b. move the iso-profit line to the highest level that still touches some part of the feasible region
    c. move the iso-cost line to the lowest level that still touches some part of the feasible region
    d. apply the method of simultaneous equations to solve for the intersections of constraints
    e. none of the above
    b (Graphical solution to a linear programming problem, moderate)

30. For the two constraints given below, which point is in the feasible region of this maximization problem? (1) $14x + 6y \leq 42$ (2) $x - y \leq 3$
a. $x = 2, y = 1$
b. $x = 1, y = 5$
c. $x = -1, y = 1$
d. $x = 4, y = 4$
e. $x = 2, y = 8$
a (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

31. For the two constraints given below, which point is in the feasible region of this minimization problem? (1) $14x + 6y \geq 42$ (2) $x - y \geq 3$
a. $x = -1, y = 1$
b. $x = 0, y = 4$
c. $x = 2, y = 1$
d. $x = 5, y = 1$
e. $x = 2, y = 0$
d (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

32. What combination of x and y will yield the optimum for this problem?
Maximize $\$3x + \$15y$, subject to (1) $2x + 4y \leq 12$ and (2) $5x + 2y \leq 10$.
a. $x = 2, y = 0$
b. $x = 0, y = 3$
c. $x = 0, y = 0$
d. $x = 1, y = 5$
e. none of the above
b (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

33. What combination of x and y will yield the optimum for this problem?
Minimize $\$3x + \$15y$, subject to (1) $2x + 4y \leq 12$ and (2) $5x + 2y \leq 10$.
a. $x = 2, y = 0$
b. $x = 0, y = 3$
c. $x = 0, y = 0$
d. $x = 1, y = 5$
e. none of the above
c (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

34. What combination of a and b will yield the optimum for this problem?
Maximize $\$6a + \$15b$, subject to (1) $4a + 2b \leq 12$ and (2) $5a + 2b \leq 20$.
a. $a = 0, b = 0$
b. $a = 3, b = 3$
c. $a = 0, b = 6$
d. $a = 6, b = 0$
e. cannot solve without values for a and b
c (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

35. A maximizing linear programming problem has two constraints: $2X + 4Y \leq 100$ and $3X + 10Y \leq 210$, in addition to constraints stating that both X and Y must be nonnegative. The corner points of the feasible region of this problem are
    a. (0, 0), (50, 0), (0, 21), and (20, 15)
    b. (0, 0), (70, 0), (25, 0), and (15, 20)
    c. (20, 15)
    d. (0, 0), (0, 100), and (210, 0)
    e. none of the above

    a (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

36. A linear programming problem has two constraints $2X + 4Y \leq 100$ and $1X + 8Y \leq 100$. Which of the following statements about its feasible region is **true**?
    a. There are four corner points including (50, 0) and (0, 12.5).
    b. The two corner points are (0, 0) and (50, 12.5).
    c. The graphical origin (0, 0) is not in the feasible region.
    d. The feasible region includes all points that satisfy one constraint, the other, or both.
    e. The feasible region cannot be determined without knowing whether the problem is to be minimized or maximized.

    a (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

37. A linear programming problem has two constraints $2X + 4Y \geq 100$ and $1X + 8Y \leq 100$. Which of the following statements about its feasible region is **true**?
    a. There are four corner points including (50, 0) and (0, 12.5).
    b. The two corner points are (0, 0) and (50, 12.5).
    c. The graphical origin (0, 0) is in the feasible region.
    d. The feasible region is triangular in shape, bounded by (50, 0), (33-1/3, 8-1/3), and (100, 0).
    e. The feasible region cannot be determined without knowing whether the problem is to be minimized or maximized.

    d (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

38. A linear programming problem has two constraints $2X + 4Y = 100$ and $1X + 8Y \leq 100$, plus non-negativity constraints on X and Y. Which of the following statements about its feasible region is **true**?
    a. The points (100, 0) and (0, 25) both lie outside the feasible region.
    b. The two corner points are (33-1/3, 8-1/3) and (50, 0).
    c. The graphical origin (0, 0) is not in the feasible region.
    d. The feasible region is a straight line segment, not an area.
    e. All of the above are true.

    e (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

39. A linear programming problem contains a restriction that reads "the quantity of X must be at least three times as large as the quantity of Y." Which of the following inequalities is the proper formulation of this constraint?
    a. $3X \geq Y$
    b. $X \leq 3Y$
    c. $X + Y \geq 3$
    d. $X - 3Y \geq 0$
    e. $3X \leq Y$

    d (Formulating linear programming problems, moderate) {AACSB: Analytic Skills}

40. A linear programming problem contains a restriction that reads "the quantity of Q must be no larger than the sum of R, S, and T." Formulate this as a constraint ready for use in problem solving software.
    a. $Q + R + S + T \leq 4$
    b. $Q \geq R + S + T$
    c. $Q - R - S - T \leq 0$
    d. $Q / (R + S + T) \leq 0$
    e. none of the above
    c (Formulating linear programming problems, moderate) {AACSB: Analytic Skills}

41. A linear programming problem contains a restriction that reads "the quantity of S must be no less than one-fourth as large as T and U combined." Formulate this as a constraint ready for use in problem solving software.
    a. $S / (T + U) \geq 4$
    b. $S - .25T - .25U \geq 0$
    c. $4S \leq T + U$
    d. $S \geq 4T / 4U$
    e. none of the above
    b (Formulating linear programming problems, moderate) {AACSB: Analytic Skills}

42. A firm makes two products, Y and Z. Each unit of Y costs $10 and sells for $40. Each unit of Z costs $5 and sells for $25. If the firm's goal were to maximize sales revenue, the appropriate objective function would be
    a. maximize $40Y = $25Z
    b. maximize $40Y + $25Z
    c. maximize $30Y + $20Z
    d. maximize 0.25Y + 0.20Z
    e. none of the above
    c (Formulating linear programming problems, moderate) {AACSB: Analytic Skills}

43. A linear programming problem has three constraints:
    $2X + 10Y \leq 100$
    $4X + 6Y \leq 120$
    $6X + 3Y \leq 90$
    What is the largest quantity of X that can be made without violating any of these constraints?
    a. 50
    b. 30
    c. 20
    d. 15
    e. 10
    d (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

44. In sensitivity analysis, a zero shadow price (or dual value) for a resource ordinarily means that
    a. the resource is scarce
    b. the resource constraint was redundant
    c. the resource has not been used up
    d. something is wrong with the problem formulation
    e. none of the above
    c (Sensitivity analysis, difficult)

45. A shadow price (or dual value) reflects which of the following in a maximization problem?
    a. the marginal gain in the objective realized by subtracting one unit of a resource
    b. the market price that must be paid to obtain additional resources
    c. the increase in profit that would accompany one added unit of a scarce resource
    d. the reduction in cost that would accompany a one unit decrease in the resource
    e. none of the above
    c (Sensitivity analysis, moderate)

46. A linear programming problem has three constraints:
    $2X + 10Y \leq 100$
    $4X + 6Y \leq 120$
    $6X + 3Y \geq 90$
    What is the largest quantity of X that can be made without violating any of these constraints?
    a. 50
    b. 30
    c. 20
    d. 15
    e. 10
    b (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

47. A maximizing linear programming problem with variables X and Y and constraints C1, C2, and C3 has been solved. The *dual values* (not the solution quantities) associated with the problem are X = 0, Y = 0, C1 = $2, C2 = $0.50, and C3 = $0. Which statement below is **false**?
    a. One more unit of the resource in C1 would add $2 to the objective function value.
    b. One more unit of the resource in C2 would add one more unit each of X and Y.
    c. The resource in C3 has not been used up
    d. The resources in C1 and in C2, but not in C3, are scarce.
    e. All of the above are true.
    b (Sensitivity analysis, difficult) {AACSB: Analytic Skills}

48. A maximizing linear programming problem with variables X and Y and constraints C1, C2, and C3 has been solved. The *dual values* (not the solution quantities) associated with the problem are X = 0, Y = $10, C1 = $2, C2 = $0.50, and C3 = $0. Which statement below is **true**?
    a. One more unit of the resource in C1 would reduce the objective function value by $2.
    b. One more unit of the resource in C2 would add one-half unit each of X and Y.
    c. The resources in C1 and C2 have not been used up.
    d. The optimal solution makes only X; the quantity of Y must be zero.
    e. All of the above are true.
    d (Sensitivity analysis, difficult) {AACSB: Analytic Skills}

49. A linear programming maximization problem has been solved. In the optimal solution, two resources are scarce. If an added amount could be found for only one of these resources, how would the optimal solution be changed?
    a. The shadow price of the added resource will rise.
    b. The solution stays the same; the extra resource can't be used without more of the other scarce resource.
    c. The extra resource will cause the value of the objective to fall.
    d. The optimal mix will be rearranged to use the added resource, and the value of the objective function will rise.
    e. none of the above
    d (Sensitivity analysis, moderate) {AACSB: Analytic Skills}

FILL-IN-THE-BLANK

50. _____ is a mathematical technique designed to help operations managers plan and make decisions relative to the trade-offs necessary to allocate resources.
    Linear programming (Introduction, easy)

51. The requirements of linear programming problems include an objective function, the presence of constraints, objective and constraints expressed in linear equalities or inequalities, and _____.
    alternative courses of action (Requirements of a linear programming problem, easy)

52. The _____ is a mathematical expression in linear programming that maximizes or minimizes some quantity.
    objective function (Requirements of a linear programming problem, easy)

53. _____ are restrictions that limit the degree to which a manager can pursue an objective.
    Constraints (Requirements of a linear programming problem, moderate)

54. The _____ is the set of all feasible combinations of the decision variables.
    feasible region (Graphical solution to a linear programming problem, moderate)

55. Two methods of solving linear programming problems by hand include the corner point method and the_____.
    iso-profit (or iso-cost) line method (Sensitivity analysis, moderate)

56. _____ is an analysis that projects how much a solution might change if there were changes in the variables or input data.
    Sensitivity analysis (Sensitivity analysis, moderate)

57. Two methods of conducting sensitivity analysis on solved linear programming problems are _____ and _____.
    postoptimal analytical method, trial and error (Sensitivity analysis, moderate)

58. A synonym for shadow price is _____.
    dual value (Sensitivity analysis, moderate)

SHORT ANSWERS

59. What is linear programming?
Linear programming is a mathematical technique designed to help operations managers plan and make decisions necessary to allocate resources. (Introduction, easy)

60. Identify three examples of resources that are typically constrained in a linear programming problem.
The textbook gives machinery, labor, money, time, and raw materials. (Introduction, easy)

61. What are the requirements of all linear programming problems?
Linear programming problems require (1) maximization or minimization of an objective function, (2) the presence of restrictions (constraints), (3) alternative courses of action to choose from, and (4) the objective and constraints expressed in linear equations or inequalities. (Requirements of a linear programming problem, easy)

62. In a linear programming problem, what is the relationship between the constraints and the feasible region? Explain with reference to a problem with two variables.
Each constraint appears on a graph as an area or a line segment. Since all constraints must hold simultaneously, the feasible region is formed by the overlapping of all constraints. The straight line segments of the constraints set the boundaries of the feasible region. (Graphical solution to a linear programming problem, moderate)

63. What is the feasible region in a linear programming problem?
The feasible region is the set of all feasible combinations of decision variables. (Graphical solution to a linear programming problem, moderate)

64. What are corner points? What is their relevance to solving linear programming problems?
Corner points are the intersections of the constraints that form the feasible region. While all points in the feasible region are possible, the optimal solution will always be at a corner point. Therefore, one method of solving linear programming problems involves the identification and valuation of all corner points. (Graphical solution to a linear programming problem, moderate)

65. What is the usefulness of a shadow price (or dual value)?
Shadow prices and dual values are found in sensitivity analysis of linear programming solutions. They indicate what changes would take place in a solution if input data were changed. For a constraint, the shadow price indicates how much the objective function would change if more (or less) of that constraint's resource were added. (Sensitivity analysis, moderate)

66. What is sensitivity analysis?
Sensitivity analysis projects how much a solution might change if there were changes in the variables or input data. (Sensitivity analysis, easy)

67. What is the simplex method?
The simplex method is an algorithm for solving linear programming problems of all sizes. (The simplex method of LP, easy)

68. Explain how to use the iso-profit line in a graphical maximization problem.
The iso-profit line is moved up in a maximization problem until it no longer intersects with any constraint equation. The last point in the feasible region that the line touches is the optimal corner point. (Graphical solution to a linear programming problem, moderate)

PROBLEMS

69. A linear programming problem contains a restriction that reads "the quantity of X must be at least twice as large as the quantity of Y." Formulate this as a constraint ready for use in problem solving software.
The quoted sentence translates into the algebraic form $X \geq 2Y$. Linear programming requires that the RHS be a non-negative numeric value, so further rearranging is necessary. This step requires subtracting 2Y from both sides of the inequality. The finished form of the constraint is $X - 2Y \geq 0$. (Formulating linear programming problems, moderate) {AACSB: Analytic Skills}

70. A linear programming problem contains a restriction that reads "the quantity of Q must be at least as large as the sum of R, S, and T." Formulate this as a constraint ready for use in problem solving software.
The quoted sentence translates into the algebraic form $Q \geq R + S + T$. Linear programming requires that the RHS be a non-negative numeric value, so further rearranging is necessary. This step requires subtracting R + S + T from both sides of the inequality. The finished form of the constraint is $Q - R - S - T \geq 0$. (Formulating linear programming problems, moderate) {AACSB: Analytic Skills}

71. A linear programming problem contains a restriction that reads "the quantity of S must be no more than one-fourth as large as T and U combined." Formulate this as a constraint ready for use in problem solving software.
The quoted sentence translates into the algebraic form $S \leq .25 (T + U)$. Linear programming requires that the RHS be a non-negative numeric value, so further rearranging is necessary. This step requires clearing the parentheses and subtracting .25T and .25U from both sides of the inequality. The finished form of the constraint is $S - .25T - .25U \leq 0$. (Formulating linear programming problems, moderate) {AACSB: Analytic Skills}

72. Tom is a habitual shopper at garage sales. Last Saturday he stopped at one where there were several types of used building materials for sale. At the low prices being asked, Tom knew that he could resell the items in another town for a substantial gain. Four things stood in his way: he could only make one round trip to resell the goods; his pickup truck bed would hold only 1000 pounds; the pickup truck bed could hold at most 70 cubic feet of merchandise; and he had only $200 cash with him. He wants to load his truck with the mix of materials that will yield the greatest profit when he resells them.

Item	Cubic feet per unit	Price per unit	Weight per unit	Can resell for
2 x 4 studs	1	$0.10	5 pounds	$0.80
4 x 8 plywood	3	$0.50	20 pounds	$3.00
Concrete blocks	0.5	$0.25	10 pounds	$0.75

State the decision variables (give them labels). State the objective function. Formulate the constraints of this problem. DO NOT SOLVE, but speculate on what might be a good solution for Tom. You must supply a set of quantities for the decision variables. Provide a sentence or two of support for your choice.

Student responses must be feasible, but not necessarily optimal. Students may realize that cash is the least important constraint. Here are some obvious solutions:
Studs only: the maximum quantity is 70. 70 @ .70 each profits $49.00
Plywood only: the maximum quantity is 70/3 = 23-1/3. 23-1/3 x $2.50 = $58.33
Concrete blocks only: 140 blocks fill the truck, but exceed the weight limit. The maximum quantity of these is 100. 100 x 0.50 = $50.00.
There are numerous non-optimal mixtures that may yield more profit than some of these one-product solutions. One of these is 20 plywood and 20 blocks, which profits $60.00. The optimal solution is no studs, 10 sheets of plywood, and 80 concrete blocks, which earns a profit of $65. (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

73. A financial advisor is about to build an investment portfolio for a client who has $100,000 to invest. The four investments available are A, B, C, and D. Investment A will earn 4 percent and has a risk of two "points" per $1,000 invested. B earns 6 percent with 3 risk points; C earns 9 percent with 7 risk points; and D earns 11 percent with a risk of 8. The client has put the following conditions on the investments: A is to be no more than one-half of the total invested. A cannot be less than 20 percent of the total investment. D cannot be less than C. Total risk points must be at or below 1,000.

Identify the decision variables of this problem. Write out the objective function and constraints. Do not solve.

Maximize 0.04A + 0.06B + 0.09C + 0.11D
Subject to
A + B + C + D ≤ $100,000
.5A -.5B -.5C -.5D ≤ 0 (rearranged from A ≤ .5(A + B + C + D))
.8A -.2B -.2C - .2D ≥ 0 (rearranged from A ≥ .2 (A + B + C + D))
-C + D ≤ 0 (rearranged from D ≤ C)
.002A + .003B + .007C + .008C ≤ 1000
(Formulating linear programming problems, moderate) {AACSB: Analytic Skills}

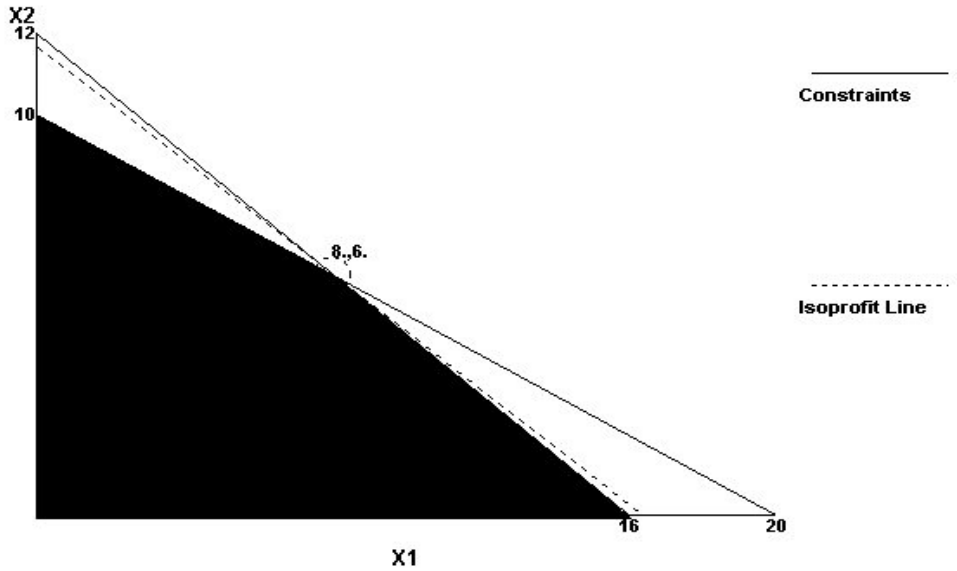
74. A manager must decide on the mix of products to produce for the coming week. Product A requires three minutes per unit for molding, two minutes per unit for painting, and one minute for packing. Product B requires two minutes per unit for molding, four minutes for painting, and three minutes per unit for packing. There will be 600 minutes available for molding, 600 minutes for painting, and 420 minutes for packing. Both products have contributions of $1.50 per unit. Answer the following questions; base your work on the solution panel provided.

	A	B		RHS	Dual
Maximize	1.5	1.5			
Molding	3.	2.	<=	600.	0.375
Painting	2.	4.	<=	600.	0.1875
Packing	1.	3.	<=	420.	0.
Solution->	150.	75.		337.5	

a. What combination of A and B will maximize contribution?
b. What is the maximum possible contribution?
c. Are any resources not fully used up? Explain.

Maximum contribution occurs at A=150, B=75, where contribution=$337.50. Molding time is completely used, as is painting time. Packing time used is 1 x 150 + 3 x 75 = 375, so Packing has 45 hours left over. (Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

75. John's Locomotive Works manufactures a model locomotive. It comes in two versions--a standard (X1), and a deluxe (X2). The standard version generates $250 per locomotive for the standard version, and $350 per locomotive for the deluxe version. One constraint on John's production is labor hours. He only has 40 hours per week for assembly. The standard version requires 250 minutes each, while the deluxe requires 350 minutes. John's milling machine is also a limitation. There are only 20 hours a week available for the milling machine. The standard unit requires 60 minutes, while the deluxe requires 120. Formulate as a linear programming problem, and solve using either the graphical or corner points solution method.



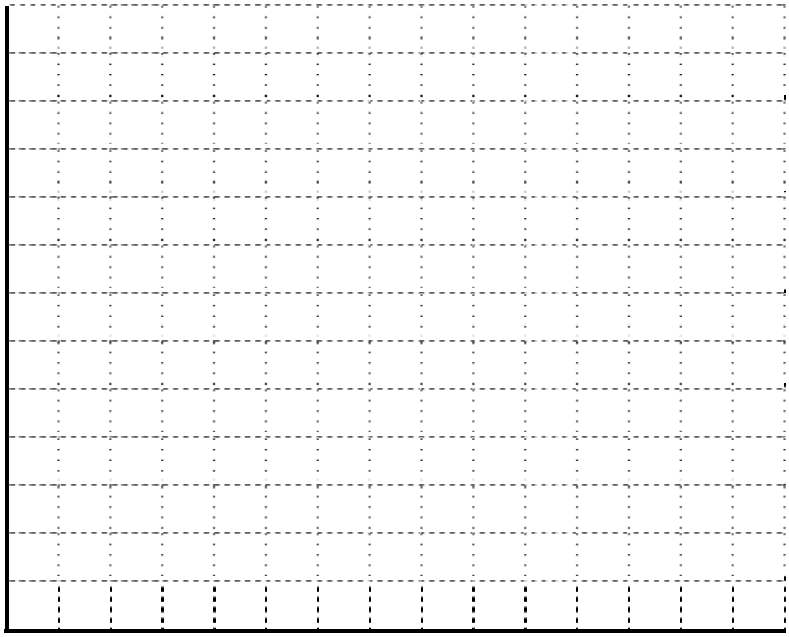
Corner Points		
X1	X2	Z
0	0	0.
16	0	4,000.
0	10	3,500.
8	6	4,100.

(Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

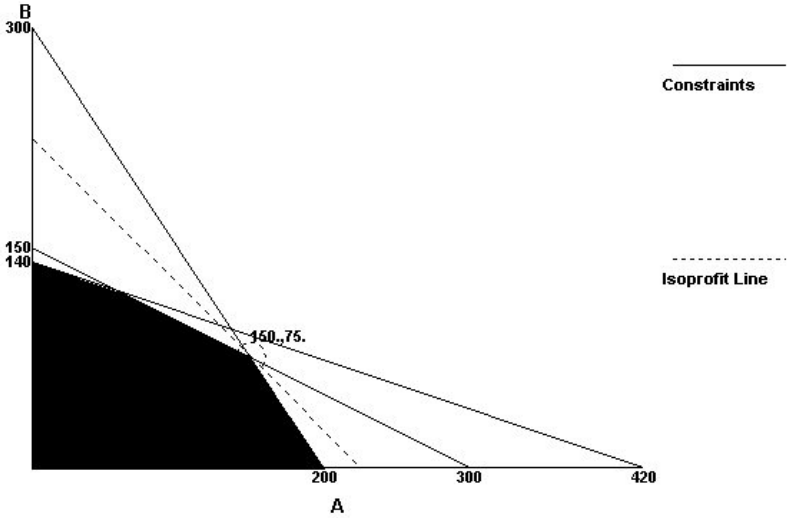
76. Phil Bert's Nuthouse is preparing a new product, a blend of mixed nuts. The product must be at most 50 percent peanuts, must have more almonds than cashews, and must be at least 10 percent pecans. The blend will be sold in one-pound bags. Phil's goal is to mix the nuts in such a manner that all conditions are satisfied and the cost per bag is minimized. Peanuts cost $1 per pound. Cashews cost $3 per pound. Almonds cost $5 per pound and pecans cost $6 per pound. Identify the decision variables of this problem. Write out the objective and the set of constraints for the problem. Do not solve.

Call the variables PN, AL, CA, and PC.
The objective function is to minimize $1PN + $3CA + $5AL + $6PC
subject to these four constraints:
PN + CA + AL + PC ≥ 1 (so that the bag weighs one pound)
.5PN - .5CA -.5AL - .5PC ≤ 0 (an inferior version reads PN ≤ .5)
-CA + AL ≥ 0
-.1PN - .1CA -.1AL +.9PC ≥ 0 (an inferior version reads PC ≥ .1)
(Formulating linear programming problems, difficult) {AACSB: Analytic Skills}

77. A manager must decide on the mix of products to produce for the coming week. Product A requires three minutes per unit for molding, two minutes per unit for painting, and one minute for packing. Product B requires two minutes per unit for molding, four minutes for painting, and three minutes per unit for packing. There will be 600 minutes available for molding, 600 minutes for painting, and 420 minutes for packing. Both products have contributions of $1.50 per unit.
    a. Algebraically state the objective and constraints of this problem.
    b. Plot the constraints on the grid below and identify the feasible region.



The objective of the problem is to maximize 1.50A + 1.50B,
The constraints are 3A + 2B ≤ 600, 2A + 4B ≤ 600, and 1A + 3B ≤ 420. The plot and feasible region appear in the graph below.



(Graphical solution to a linear programming problem, easy) {AACSB: Analytic Skills}

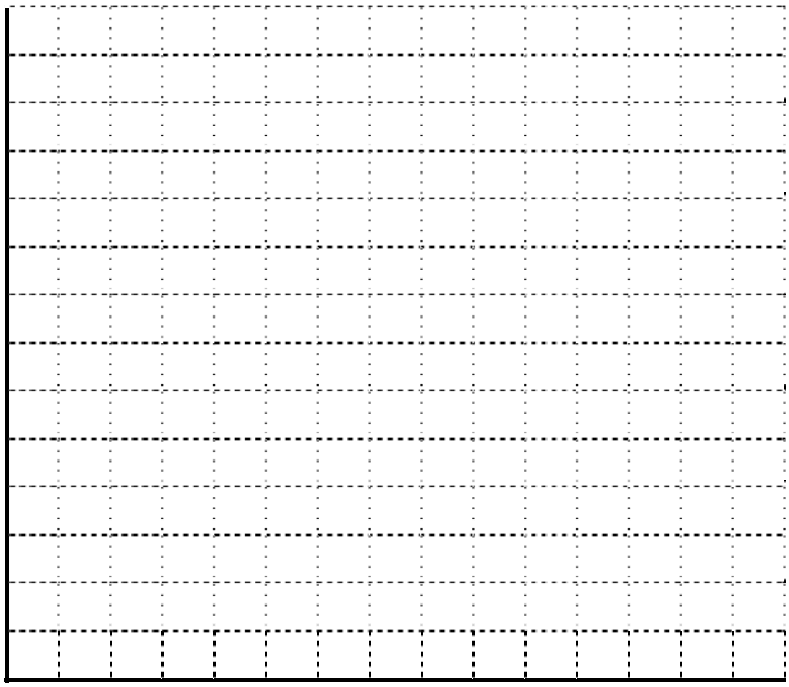
78. A craftsman builds two kinds of birdhouses, one for wrens (X1), and one for bluebirds (X2). Each wren birdhouse takes four hours of labor and four units of lumber. Each bluebird house requires two hours of labor and twelve units of lumber. The craftsman has available 60 hours of labor and 120 units of lumber. Wren houses profit $6 each and bluebird houses profit $15 each.

Use the software output that follows to interpret the problem solution. Include a statement of the solution quantities (how many of which product), a statement of the maximum profit achieved by your product mix, and a statement of "resources unused" and "shadow prices."

Bird Houses Solution					
Variable	Value	Reduced	Original Val	Lower Bound	Upper Bound
X1	12.	0.	6.	5.	30.
X2	6.	0.	15.	3.	18.
Constraint	Dual Value	Slack/Surplus	Original Val	Lower Bound	Upper Bound
Constraint 1	0.3	0.	60.	20.	120.
Constraint 2	1.2	0.	120.	60.	360.

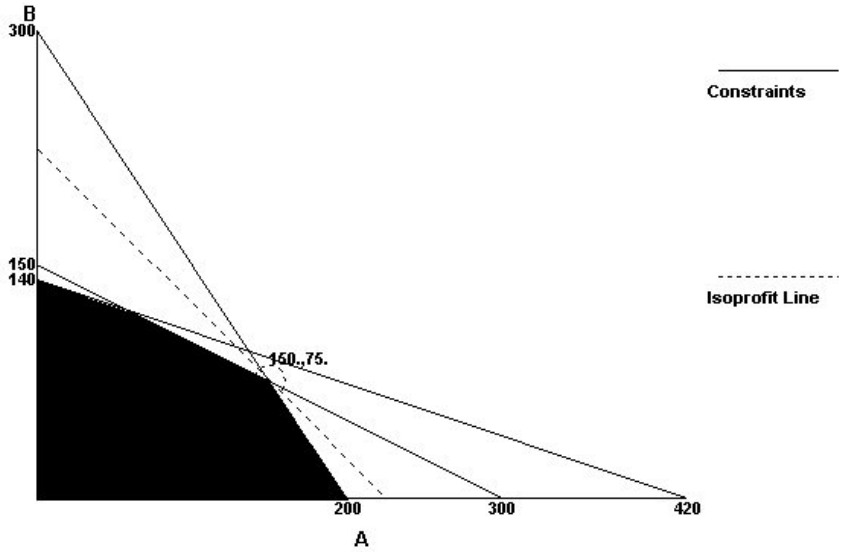
The optimal solution is X1 = 12, X2 = 6, which earns a profit of 12 * 6 + 6 * 15 = $162. Both labor and lumber are used up, so there are no resources unused. Additional labor is worth $0.30 per hour, and additional lumber is worth $1.20 per unit. (Sensitivity analysis, moderate) {AACSB: Analytic Skills}

79. The objective of a linear programming problem is to maximize 1.50A + 1.50B, subject to $3A + 2B \leq 600$, $2A + 4B \leq 600$, and $1A + 3B \leq 420$.
   a. Plot the constraints on the grid below
   c. Identify the feasible region and its corner points. Show your work.
   d. What is the optimal product mix for this problem?



SEE NEXT PAGE FOR SOLUTION.

The objective of the problem is to maximize 1.50A + 1.50B,
The constraints are 3A + 2B ≤ 600, 2A + 4B ≤ 600, and 1A + 3B ≤ 420. The plot and feasible region appear in the graph below. The corner points are (0, 0), (200, 0), (0, 140), and (150, 75). The first three points can be read from the graph axes. The last corner point is the intersection of the equality 2A + 4B = 600 and 3A + 2B = 600. Multiply the first equality by ½ and subtract from the second, leaving 2A = 300 or A = 150. Substituting A = 150 in either equality yields B = 75.



(Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

80. The property manager of a city government issues chairs, desks, and other office furniture to city buildings from a centralized distribution center. Like most government agencies, it operates to minimize its costs of operations. In this distribution center, there are two types of standard office chairs, Model A and Model B. Model A is considerably heavier than Model B, and costs $20 per chair to transport to any city building; each model B costs $14 to transport. The distribution center has on hand 400 chairs—200 each of A and B.

The requirements for shipments to each of the city's buildings are as follows:
Building 1 needs at least 100 of A
Building 2 needs at least 150 of B.
Building 3 needs at least 100 chairs, but they can be of either type, mixed.
Building 4 needs 40 chairs, but at least as many B as A.

Write out the objective function and the constraints for this problem. (Hint: there are eight variables—chairs for building 1 cannot be used to satisfy the demands for another building).
Let the variables be A1, A2, A3, and A4 for the type A chairs sent to each of the four buildings, and B1, B2, B3, and B4 for the type B chairs sent to each of the four buildings.

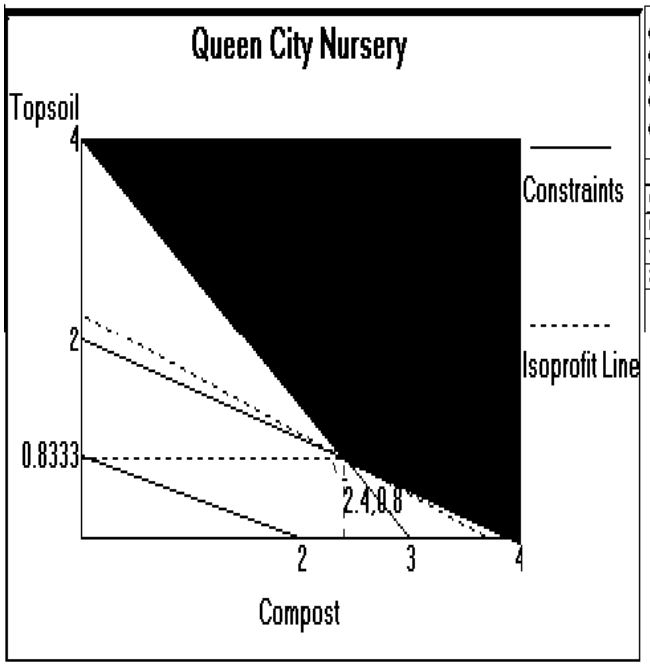
The objective function: minimize 20A1 + 20A2 + 20A3 + 20A4 + 14B1 + 14B2 + 14B3 + 14B4
Subject to these seven constraints:
A1 + A2 + A3 + A4 ≤ 200
B1 + B2 + B3 + B4 ≤ 200
A1 ≥ 100; B2 ≥ 150; A3 + B3 ≥ 100; A4 + B4 ≥ 40; and -A4 + B4 ≥ 0
(Formulating linear programming problems, difficult) {AACSB: Analytic Skills}

81. The Queen City Nursery manufactures bags of potting soil from compost and topsoil. Each cubic foot of compost costs 12 cents and contains 4 pounds of sand, 3 pounds of clay, and 5 pounds of humus. Each cubic foot of topsoil costs 20 cents and contains 3 pounds of sand, 6 pounds of clay, and 12 pounds of humus. Each bag of potting soil must contain at least 12 pounds of sand, 12 pounds of clay, and 10 pounds of humus. Explain how this problem meets the conditions of a linear programming problem. Plot the constraints and identify the feasible region. Graphically or with corner points find the best combination of compost and topsoil that meets the stated conditions at the lowest cost per bag. Identify the lowest cost possible.

The problem formulation appears in the software panel below. The second panel contains the graphical and corner point solutions. The minimum cost per bag is $0.45, and is achieved by using 2.4 cubic feet of compost and 0.8 cubic feet of topsoil.

Queen City Nursery

	Compost	Topsoil		RHS
Minimize	0.12	0.2		
Sand	4.	3.	>=	12
Clay	3.	6.	>=	12
Humus	5.	12.	>=	10



Constraint Display
- Min .12Compost+.2Topsoil
- 4Compost+3Topsoil>=12
- 3Compost+6Topsoil>=12
- 5Compost+12Topsoil>=10
- (•) none

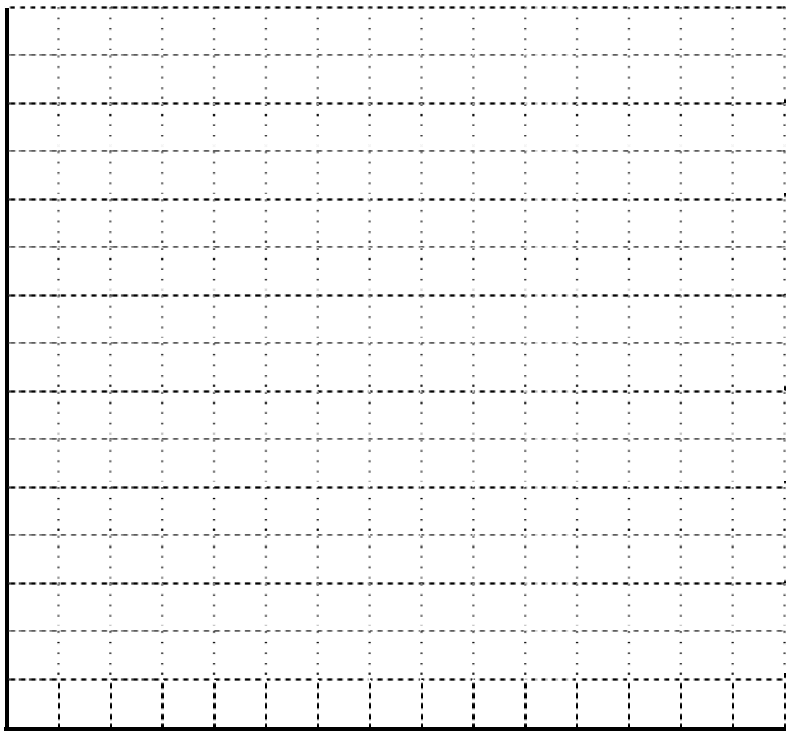
Corner Points

Compost	Topsoil	Z
0	4	.8
4	0	.48
2.4	.8	.448

(Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

82. A stereo mail order center has 8,000 cubic feet available for storage of its private label loudspeakers. The ZAR-3 speakers cost $295 each and require 4 cubic feet of space; the ZAR-2ax speakers cost $110 each and require 3 cubic feet of space; and the ZAR-4 model costs $58 and requires 1 cubic foot of space. The demand for the ZAR-3 is at most 20 units per month. The wholesaler has $100,000 to spend on loudspeakers this month. Each ZAR-3 contributes $105, each ZAR-2ax contributes $50, and each ZAR-4 contributes $28. The objective is to maximize total contribution. Write out the objective and the constraints.
The objective is to maximize 105 ZAR-3 + 50 ZAR-2ax + 28 ZAR-4. There are constraints on storage space, budget, and maximum sales. The space constraint is 4 ZAR-3 + 3 ZAR-2ax + 1 ZAR-4 < 8000. The budget constraint is 295 ZAR-3 + 110 ZAR-2ax + 58 ZAR-4 < $100,000. The marketing constraint is 1 ZAR-3 < 20. (Formulating linear programming problems, moderate) {AACSB: Analytic Skills}

83. Rienzi Farms grows sugar cane and soybeans on its 500 acres of land. An acre of soybeans brings a $1000 contribution to overhead and profit; an acre of sugar cane has a contribution of $2000. Because of a government program no more than 200 acres may be planted in soybeans. During the planting season 1200 hours of planting time will be available. Each acre of soybeans requires 2 hours, while each acre of sugar cane requires 5 hours. The company seeks maximum contribution (profit) from its planting decision.
a. Algebraically state the decision variables, objective and constraints.
b. Plot the constraints
c. Solve graphically, using the corner point method.

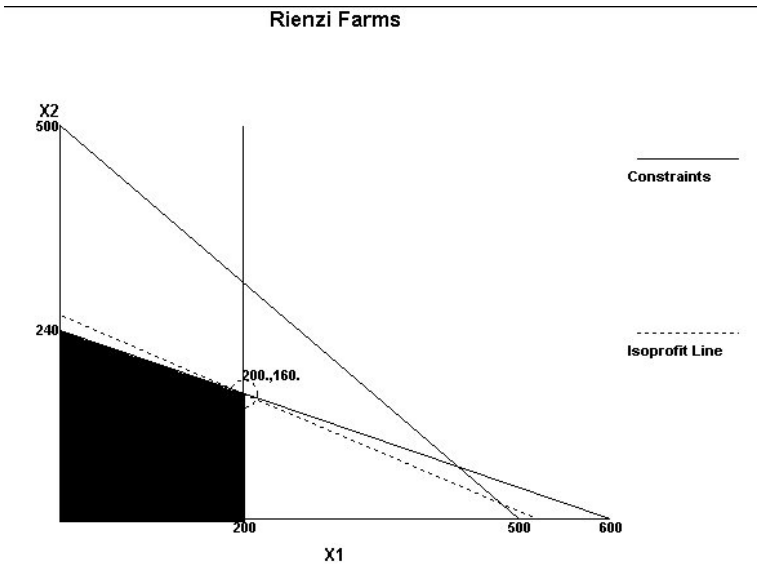


SEE NEXT PAGE FOR SOLUTION.

The problem statement is contained in the software panel below. The graphical and corner point solutions are found in the second and third panels. The optimal solution is 200 acres in soybeans and 160 acres in sugar cane. There's not enough labor to plant all 500 acres when 200 acres is in soybeans.

Rienzi Farms Solution					
	X1	X2		RHS	Dual
Maximize	1,000.	2,000.			
Acres	1.	1.	<=	500.	0.
Soybean restriction	1.	0.	<=	200.	200.
Planting labor	2.	5.	<=	1,200.	400.
Solution->	200.	160.		520,000.	

Corner Points		
X1	X2	Z
0	0	0.
200	0	200,000.
0	240	480,000.
200	160	520,000.



(Graphical solution to a linear programming problem, moderate) {AACSB: Analytic Skills}

84. South Coast Papers wants to mix two lubricating oils (A and B) for its machines in order to minimize cost. It needs no less than 3,000 gallons in order to run its machines during the next month. It has a maximum oil storage capacity of 4,000 gallons. There are 2,000 gallons of Oil A and 4,000 of Oil B available. The mixed fuel must have a viscosity rating of no less than 40.

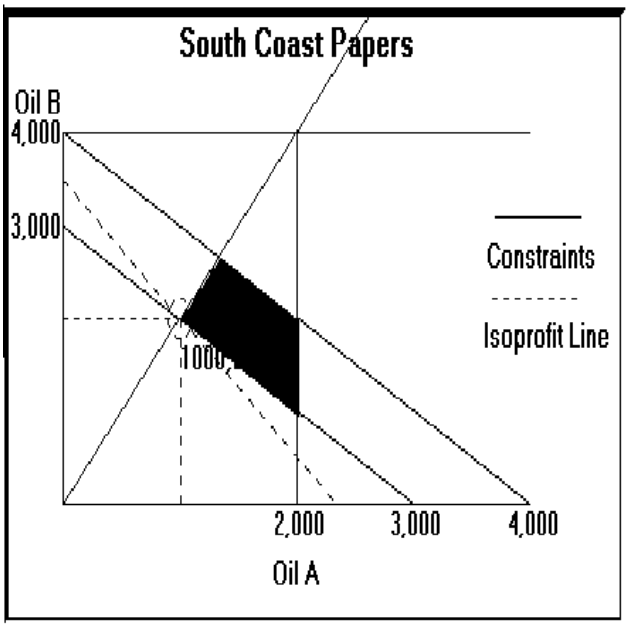
When mixing fuels, the amount of oil obtained is exactly equal to the sum of the amounts put in. The viscosity rating is the weighted average of the individual viscosities, weighted in proportion to their volumes. The following is known: Oil A has a viscosity of 45 and costs 60 cents per gallon; Oil B has a viscosity of 37.5 and costs 40 cents per gallon.

State the objective and the constraints of this problem. Plot all constraints and highlight the feasible region. Use your (by now, well-developed) intuition to suggest a feasible (but not necessarily optimal) solution. Be certain to show that your solution meets all constraints.
The problem formulation appears below. The only unusual constraint is the fifth one. This begins as the viscosity expression: viscosity = (45A + 37.5B) / (A + B) ≥ 40, which becomes 5A > 2.5B. It is not possible to meet the restrictions with only Oil A or only Oil B. Most students will discover that a combination is required. They need to show that their mix has a high enough viscosity by substituting their quantities into the viscosity inequality (as well as showing that their quantities are within the four volume constraints).

Linear Programming Results

South Coast Papers Solution

	Oil A	Oil B		RHS	Dual
Minimize	0.6	0.4			
Constraint 1	1.	1.	>=	3,000.	-0.4667
Constraint 2	1.	1.	<=	4,000.	0.
Constraint 3	1.	0.	<=	2,000.	0.
Constraint 4	0.	1.	<=	4,000.	0.
Constraint 5	5.	-2.5	>=	0.	-0.0267
Solution->	1,000.	2,000.		1,400.	



Constraint Display
- Min .6Oil A+.4Oil B
- 1Oil A+1Oil B>=3000
- 1Oil A+1Oil B<=4000
- 1Oil A<=2000
- 1Oil B<=4000
- 5Oil A-2.5Oil B>=0
- none

Corner Points

Oil A	Oil B	Z
2000	1000	1600
1000	2000	1400
2000	2000	2000

(Graphical solution to a linear programming problem, difficult) {AACSB: Analytic Skills}

85. Lost Maples Winery makes three varieties of contemporary Texas Hill Country wines: Austin Formation (a fine red), Ste. Genevieve (a table white), and Los Alamos (a hearty pink Zinfandel). The raw materials, labor, and contribution per case of each of these wines is summarized below.

	Grapes Variety A bushels	Grapes Variety B bushels	Sugar pounds	Labor (man-hours)	Contrib. per case
Austin Formation	4	0	1	3	$24
Ste. Genevieve	0	4	0	1	$28
Los Alamos	2	2	2	2	$20

The winery has 2800 bushels of Variety A grapes, 2040 bushels of Variety B grapes, 800 pounds of sugar, and 1060 man-hours of labor available during the next week. The firm operates to achieve maximum contribution. Refer to the POM for Windows panels showing the solution to this problem.

Linear Programming Results

Lost Maples Solution

	Austin	Ste. Genevieve	Los Alamos		RHS	Dual
Maximize	24.	28.	20.			
Variety A	4.	0.	2.	<=	2,800.	0.
Variety B	0.	4.	2.	<=	2,040.	5.
Sugar	1.	0.	2.	<=	800.	0.
Labor	3.	1.	2.	<=	1,060.	8.
Solution->	183.3333	510.	0.		18,680.	

Ranging

Lost Maples Solution

Variable	Value	Reduced	Original Val	Lower Bound	Upper Bound
Austin	183.3333	0.	24.	12.	84.
Ste. Genevieve	510.	0.	28.	16.	Infinity
Los Alamos	0.	6.	20.	-Infinity	26.
Constraint	Dual Value	Slack/Surplus	Original Val	Lower Bound	Upper Bound
Variety A	0.	2,066.667	2,800.	733.3333	Infinity
Variety B	5.	0.	2,040.	0.	4,240.
Sugar	0.	616.6667	800.	183.3333	Infinity
Labor	8.	0.	1,060.	510.0001	2,610.

Answer the following questions.

a. For maximum contribution, how much of each wine should be produced?

b. How much contribution will be made by selling the output?

c. Is there any sugar left over? If so, how much? If not, what is its shadow price (dual value)? Explain what this value means to Lost Maples' management.

d. Interpret the meaning of the lower bound to **Labor** in the Ranging analysis. That is, explain how the solution would change if the amount of labor fell below that lower value.

e. Interpret the meaning of the upper bound to Los Alamos wine in the Ranging analysis.

(a) 183 1/3 cases of Austin Formation, 510 cases of Ste. Genevieve; (b) maximum contribution is $18,680; (c) There are 617 pounds of sugar remaining; its dual value is zero, indication that management should not seek out any more sugar; (d) if the amount of labor fell below the 510 hour level, its dual value would rise; (e) Los Alamos is not currently included in the solution; it would enter the solution only if its contribution rose over the ranging limit of $26 per case. (Sensitivity analysis, moderate) {AACSB: Analytic Skills}

MODULE C: TRANSPORTATION MODELS

TRUE/FALSE

1. The transportation model is an excellent tool for minimizing shipping costs among existing facilities, but it is not useful when firms consider new facility locations.
False (Introduction, easy)

2. The transportation model seeks satisfactory, but not necessarily optimal, solutions for shipping goods from several origins to several destinations.
False (Transportation modeling, moderate)

3. The transportation model is a special class of linear programming models.
True (Transportation modeling, easy)

4. A transportation problem requires exactly as many origins as destinations.
False (Transportation modeling, moderate)

5. Neither the northwest corner rule nor the intuitive method considers shipping cost in making initial allocations.
False (Developing an initial solution, moderate)

6. The intuitive method of generating an initial solution has different results for each problem solver because "intuition" varies from person to person.
False (Developing an initial solution, moderate)

7. The stepping-stone method frequently achieves an optimal solution as soon as it calculates an initial feasible solution.
False (Developing an initial solution, easy)

8. A feasible solution in transportation models is one in which all of the supply and demand constraints are satisfied.
True (Developing an initial solution, moderate)

9. The added cost of shipping one unit through an unused cell in a transportation problem without changing the edge requirements is the shipping cost associated with that cell.
False (The stepping-stone method, moderate)

10. In a transportation minimization problem, the negative improvement index associated with a cell indicates that reallocating units to that cell would lower costs.
True (The stepping-stone method, moderate)

11. Degeneracy in a transportation problem is when no closed path exists for evaluating an unused cell.
True (Special issues in modeling, moderate)

12. When using the stepping stone method, the closed path sometimes has the shape of a triangle as diagonal moves are permitted.
False (The stepping-stone method, moderate)

13. When using the stepping stone method for a minimization problem, the number of units that reallocates corresponds to the smallest number found in the cells containing minus signs.
True (The stepping-stone method, moderate)

14. A transportation problem with a total supply of 500 and a total demand of 400 will have an optimal solution that leaves 100 units of supply unused.
True (Special issues in modeling, moderate)

15. A transportation problem with 8 sources and 6 destinations will have an optimal solution that uses at most 13 of the 48 possible routes.
True (Special issues in modeling, moderate) {AACSB: Analytic Skills}

16. To handle degeneracy, a very small quantity is placed in one of the unused squares.
True (Special issues in modeling, moderate)

17. Degeneracy occurs when the number of occupied squares is less than the number of rows plus the number of columns minus one.
True (Special issues in modeling, moderate)

18. If demand exceeds supply in a transportation problem, the problem must be balanced by adding a dummy source with additional supply.
True (Special issues in modeling, moderate)

MULTIPLE CHOICE

19. Which of the following is **not** needed in order to use the transportation model?
    a. the source points and their capacity
    b. the fixed costs of source points
    c. the destination points and their demand
    d. the cost of shipping one unit from each source to each destination
    e. All of these are needed.
    b (Transportation modeling, easy)

20. The information needs of a transportation problem include
    a. the cost of shipping one unit from each origin to each destination
    b. the set of destinations and the demand of each
    c. the set of origins
    d. the supply at each origin
    e. all of the above
    e (Transportation modeling, easy)

21. Which of the following is **not** an information need for a transportation problem?
    a. the cost of shipping one unit from each origin to each destination
    b. the set of destinations and the demand at each
    c. the set of origins and the demand at each origin
    d. the list of sources and the capacity at each
    e. all of the above
    c (Transportation modeling, easy)

22. The purpose of the transportation approach for location analysis is to minimize
    a. total costs
    b. total variable costs
    c. total fixed costs
    d. total shipping costs
    e. the number of shipments
    d (Transportation modeling, moderate)

23. The transportation method is a special case of the family of problems known as
    a. regression problems
    b. decision tree problems
    c. linear programming problems
    d. simulation problems
    e. statistical problems
    c (Transportation modeling, easy)

24. The initial solution to a transportation problem can be generated several ways, so long as
    a. it minimizes cost
    b. it ignores cost
    c. all supply and demand conditions are satisfied
    d. degeneracy does not exist
    e. all cells are filled
    c (Developing an initial solution, moderate)

25. The northwest corner rule is best used
    a. to minimize the total shipping cost from several origins to several destinations
    b. to calculate whether a feasible solution is also an optimal solution
    c. to calculate how much to transfer from one shipping route to another
    d. to generate an initial feasible solution to a transportation problem
    e. to resolve cases of degeneracy in transportation problems
    d (Developing an initial solution, easy)

26. For the problem data set below, what is the northwest corner allocation to the cell Source 1-Destination 1?

COSTS	Dest. 1	Dest. 2	Dest. 3	Supply
Source 1	2	1	3	30
Source 2	4	2	1	40
Source 3	3	8	6	20
Demand	15	50	25	90 \ 90

    a. 0
    b. 2
    c. 15
    d. 30
    e. 90
    c (Developing an initial solution, easy) {AACSB: Analytic Skills}

27. For the problem data set below, what is the northwest corner allocation to the cell Source 1 - Destination 2?

COSTS	Dest. 1	Dest. 2	Dest. 3	Supply
Source 1	2	1	3	30
Source 2	4	2	1	40
Origin 3	3	8	6	20
Demand	15	50	25	90 \ 90

a. 0
b. 15
c. 25
d. 35
e. 45

b (Developing an initial solution, moderate) {AACSB: Analytic Skills}

28. For the problem data set below, what is the northwest corner allocation to the cell Source 3- Destination 3?

COSTS	Dest. 1	Dest. 2	Dest. 3	Supply
Source 1	2	1	3	30
Source 2	4	2	1	40
Source 3	3	8	6	20
Demand	15	50	25	90 \ 90

a. 0
b. 15
c. 20
d. 35
e. 45

c (Developing an initial solution, moderate) {AACSB: Analytic Skills}

29. For the problem below, what is the quantity assigned to the cell Source 1-Destination 2 using the intuitive method for an initial feasible solution?

COSTS	Dest. 1	Dest. 2	Dest. 3	Supply
Source 1	2	1	3	50
Source 2	4	7	5	40
Source 3	3	12	6	30
Demand	50	45	25	120 \ 120

a. 1
b. 5
c. 30
d. 45
e. 50

d (Developing an initial solution, moderate) {AACSB: Analytic Skills}

30. For the problem below, what is the quantity assigned to the cell Source 3-Destination 1 using the intuitive method for an initial feasible solution?

COSTS	Dest. 1	Dest. 2	Dest. 3	Supply
Source 1	2	1	3	50
Source 2	4	7	5	40
Source 3	3	12	6	30
Demand	50	45	25	120 \ 120

a. 3
b. 13.333
c. 30
d. 45
e. 50

c (Developing an initial solution, easy) {AACSB: Analytic Skills}

31. A transportation problem has a feasible solution when
a. all of the improvement indexes are greater than or equal to zero
b. all demand and supply constraints are satisfied
c. the number of filled cells is one less than the number of rows plus the number of columns
d. all the squares are used
e. the solution yields the lowest possible cost

b (The stepping-stone method, moderate)

32. A transportation problem has an optimal solution when
a. all of the improvement indexes are greater than or equal to zero
b. all demand and supply constraints are satisfied
c. the number of filled cells is one less than the number of rows plus the number of columns
d. all the squares are used
e. all origin-destination combinations have been made equally low in cost

a (The stepping-stone method, moderate)

33. In transportation model analysis the stepping-stone method is used to
a. obtain an initial optimum solution
b. obtain an initial feasible solution
c. evaluate empty cells for possible degeneracy
d. balance supply and demand
e. evaluate empty cells for potential solution improvements

e (The stepping-stone method, easy)

34. The total cost of the optimal solution to a transportation problem
a. is calculated by multiplying the total supply (including any dummy values) by the average cost of the cells
b. cannot be calculated from the information given
c. can be calculated based only on the entries in the filled cells of the solution
d. can be calculated from the original northwest corner solution
e. is found by multiplying the amounts in each cell by the cost for that cell for each row and then subtracting the products of the amounts in each cell times the cost of each cell for the columns

c (The stepping-stone method, moderate)

35. Consider the transportation problem and its optimal solution in the tables below. What is the evaluator for the cell Source 2 – Destination 3?

COSTS	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1	12	18	9	11	105
Source 2	19	7	30	15	145
Source 3	8	10	14	16	50
Demand	80	60	70	90	300 \ 300

Shipments	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Row Total
Source 1	30	0	70	5	105
Source 2	0	60	0	85	145
Source 3	50	0	0	0	50
Col. Total	80	60	70	90	300 \ 300

a. 0
b. 13
c. 17
d. 75
e. 150

c (The stepping-stone method, moderate) {AACSB: Analytic Skills}

36. Consider the transportation problem and its optimal solution in the tables below. What is the value of the objective function?

COSTS	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1	12	18	9	11	105
Source 2	19	7	30	15	145
Source 3	8	10	14	16	50
Demand	80	60	70	90	300 \ 300

Shipments	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Row Total
Source 1	30	0	70	5	105
Source 2	0	60	0	85	145
Source 3	50	0	0	0	50
Col. Total	80	60	70	90	300 \ 300

a. 0
b. $169
c. 300 units
d. $2,100
e. $3,140

e (The stepping-stone method, moderate) {AACSB: Analytic Skills}

37. Consider the transportation problem and its optimal solution in the tables below. The cell Source 3 – Destination 3 is currently empty. What would be the change in the objective function if the largest possible amount were shipped using that route, leaving all the supply and demand conditions unchanged?

COSTS	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1	12	18	9	11	105
Source 2	19	7	30	15	145
Source 3	8	10	14	16	50
Demand	80	60	70	90	300 \ 300

Shipments	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Row Total
Source 1	30	0	70	5	105
Source 2	0	60	0	85	145
Source 3	50	0	0	0	50
Col. Total	80	60	70	90	300 \ 300

a. 0
b. fifty units
c. a decrease of $9
d. an increase of $450
e. an increase of $630

d (The stepping-stone method, difficult) {AACSB: Analytic Skills}

38. Consider the transportation problem and its optimal solution in the tables below. The cell Source 3 – Destination 4 is currently empty. What would be the largest possible amount that could be shipped using that route, leaving all the supply and demand conditions unchanged?

COSTS	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1	12	18	9	11	105
Source 2	19	7	30	15	145
Source 3	8	10	14	16	50
Demand	80	60	70	90	300 \ 300

Shipments	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Row Total
Source 1	30	0	70	5	105
Source 2	0	60	0	85	145
Source 3	50	0	0	0	50
Col. Total	80	60	70	90	300 \ 300

a. 0 units
b. 5 units
c. 30 units
d. 50 units
e. 90 units

b (The stepping-stone method, moderate) {AACSB: Analytic Skills}

39. In a minimization problem, a negative improvement index in a cell indicates that the
    a. solution is optimal
    b. total cost will increase if units are reallocated to that cell
    c. current iteration is worse than the previous one
    d. total cost will decrease if units are reallocated to that cell
    e. problem has no feasible solution
    d (The stepping-stone method, moderate)

40. In a minimization problem, a positive improvement index in a cell indicates that
    a. the solution is optimal
    b. the total cost will increase if units are reallocated to that cell
    c. there is degeneracy
    d. the total cost will decrease if units are reallocated to that cell
    e. the problem has no feasible solution
    b (The stepping-stone method, moderate)

41. Consider the transportation problem and its initial solution in the table below. What is the improvement index for the empty cell Source 1 – Destination 3?

COSTS	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1	12	18	9	11	45
Source 2	19	7	30	15	145
Source 3	8	10	14	16	50
Demand	80	30	70	60	240 \240

Shipments	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Row Total
Source 1	45	0	0	0	45
Source 2	35	30	70	10	145
Source 3	0	0	0	50	50
Col. Total	80	30	70	60	240\ 240

    a. 0
    b. -14
    c. -23
    d. -70
    e. 115
    b (The stepping-stone method, moderate) {AACSB: Analytic Skills}

42. The stepping-stone method
    a. is an alternative to using the northwest corner rule
    b. often involves tracing closed paths with a triangular shape
    c. is used to identify the relevant costs in a transportation problem
    d. is used to evaluate the cost effectiveness of shipping goods via transportation routes not currently in the solution
    e. helps determine whether a solution is feasible or not
    d (The stepping-stone method, moderate)

43. A transportation problem has two origins: A can supply 20 units and B can supply 30 units. This problem has two destinations: C requires 25 units and D requires 35 units. Which of the following is **true**?
    a. The problem will require a dummy demand with a capacity of 10 units.
    b. The problem is unbalanced and cannot be solved by the transportation method.
    c. The problem will require a dummy supply with a capacity of 10 units.
    d. Destinations C and D must each receive 5 units less than they require.
    e. None of the above is true.
    c (Special issues in modeling, easy)

44. An improvement index indicates
    a. whether a method other than the stepping stone should be used
    b. whether a method other than the northwest corner rule should be used
    c. how much total cost would increase or decrease if a single unit was reallocated to that cell
    d. whether the transportation cost in the upper left-hand corner of a cell is optimal
    e. how much total cost would increase or decrease if the largest possible quantity were reallocated to that cell
    c (The stepping-stone method, moderate)

45. When the number of shipments in a feasible solution is less than the number of rows plus the number of columns minus one
    a. the solution is optimal
    b. a dummy source must be created
    c. a dummy destination must be created
    d. there is degeneracy, and an artificial allocation must be created
    e. the closed path has a triangular shape
    d (Special issues in modeling, moderate)

46. In a transportation problem, degeneracy means that
    a. the problem was improperly constructed, and must be reformulated
    b. the assumptions of the transportation model have not been met
    c. the number of filled cells is too small to allow the calculation of improvement indexes
    d. the total supply and the total demand are unbalanced
    e. the number of origins is not equal to the number of destinations
    c (Special issues in modeling, easy)

47. A transportation problem has 8 origins and 6 destinations. The optimal solution of this problem will fill no more than _____ cells with quantities to be shipped.
    a. 2
    b. 13
    c. 14
    d. 48
    e. cannot be calculated without knowing the supply and demand totals
    b (Special issues in modeling, easy) {AACSB: Analytic Skills}

48. A transportation problem has 4 origins and 2 destinations. The optimal solution of this problem will fill no more than _____ cells with quantities to be shipped.
    a. 5
    b. 6
    c. 8
    d. 20
    e. All cells will be occupied.
    a (Special issues in modeling, easy) {AACSB: Analytic Skills}

49. A large transportation problem has 220 origins and 1360 destinations. The optimal solution of this problem will fill no more than about _____ of cells with quantities to be shipped.
    a. one-half of one percent
    b. five percent
    c. ten percent
    d. twenty-five
    e. All cells will be occupied.
    a (Special issues in modeling, moderate) {AACSB: Analytic Skills}

FILL-IN-THE-BLANK

50. The elements of a transportation problem that supply goods are referred to as _____.
    origins, origin points, or sources (Transportation modeling, easy)

51. The _____ finds the least-cost means of shipping supplies from several origins to several destinations.
    transportation model (Transportation modeling, easy)

52. The three information needs of a transportation problem are the origin points and the capacity at each, the destination points and the demand at each, and _____.
    the cost of shipping one unit from each origin to each destination (Transportation modeling, moderate)

53. The _____ develops an initial feasible solution for a transportation model by starting at the upper left-hand cell of a table and systematically allocating units to shipping points.
    northwest corner rule (Developing an initial solution, moderate)

54. The _____ is an iterative technique for moving from an initial feasible solution to an optimal solution in the transportation method.
    stepping-stone method (The stepping-stone method, moderate)

55. A transportation problem that has more units supplied than demanded will require a(n) _____ to balance the problem.
    dummy destination (Special issues in modeling, moderate)

56. _____ is an occurrence in transportation problems when too few shipping routes are being used.
    Degeneracy (Special issues in modeling, moderate)

57. The number of routes filled by a solution to a transportation problem is no larger than _____.
the sum of columns plus rows minus one (Special issues in modeling, moderate)

SHORT ANSWERS

58. What is transportation modeling?
Transportation modeling finds the least-cost means of shipping supplies from several origins to several destinations. (Transportation modeling, easy)

59. The transportation model is said to be a special case of linear programming. If so, then there must be a way to show a transportation problem as a system of decision variables, constraints, and an objective function. Demonstrate this relationship, using the following simple problem.
This is a critical thinking exercise. Students should recognize that each source-destination combination is a variable, and that there are S + D of them (6 in this example). The six variables are the quantities shipped by each possible route, and might be labeled S1D1, S1D2, S1D3, S2D1, S2D2, and S2D3. The objective function would be 5*S1D1 + 9*S1D2 + 4S1D3 + 2*S2D1 + 1*S2D2 + 8*S2D3. Students should also recognize that each source and each destination represent a constraint; there are five in this example. One supply constraint might read S1D1 + S1D2 + S1D3 ≤ 20. One demand constraint might read S1D1 + S2D1 ≥ 15. (Transportation modeling, difficult) {AACSB: Reflective Thinking}

	Destination 1	Destination 2	Destination 3	SUPPLY
Source 1	5	9	4	20
Source 2	2	1	8	30
DEMAND	15	10	25	

60. State, in order, the three steps in making an initial allocation with the northwest corner rule.
The three steps in making an initial allocation using the northwest corner rule are: exhaust the supply of each row before moving down to the next row; exhaust the demand requirements of each column before moving to the next column on the right; and check that all supply and demand constraints are met. (Developing an initial solution, moderate)

61. What purpose does the northwest corner rule serve?
The northwest corner is a procedure used with the transportation model that starts in the upper left-hand cell and systematically allocates units to shipping routes. Its purpose is to generate an initial feasible solution. (Developing an initial solution, easy)

62. What does the stepping-stone method do?
The stepping-stone method is an interactive technique for moving from an initial feasible solution to an optimal solution in the transportation model. (The stepping-stone method, moderate)

63. What is the difference between a feasible solution and an optimal solution?
A feasible solution, like in linear programming, is a possible problem solution that does not violate any constraints. It may or may not be optimal. The optimal solution is the answer that provides the lowest total cost or highest total profit. (The stepping-stone method, moderate)

64. When does degeneracy occur in a transportation model?
Degeneracy occurs when the number of occupied cells is less than the number of rows plus the number of columns minus one. (Special issues in modeling, moderate)

65. When is it necessary to add dummy sources or destinations to a transportation problem?
It is necessary to add dummy sources when the total demand is greater than the total supply. A dummy destination would be required when total supply exceeds total demand. (Special issues in modeling, moderate)

66. The larger a transportation problem (that is, as the problem has more rows and more columns), the smaller the fraction of all possible routes that will be filled in a solved problem. Explain.
The number of filled cells in a solved transportation problem is rows plus columns minus one. For a problem with three origins and four destinations, the number of filled cells will be no more than 3 + 4 -1 = 6, which is 6/12 or one-half of all possible routes. If a problem has six origins and eight destinations, the number of filled cells will be no more than 6 + 8 – 1 = 13, which is 13/48 of all possible routes. There are four times as many routes, but the number of filled cells barely doubles. In general, (R + C - 1) / R*C falls as R and/or C rise. (Special issues in modeling, moderate) {AACSB: Analytic Skills}

67. In formulating a transportation problem, you discover that one of the route combinations is forbidden by contract, or prohibited by law, or ruled out by company policy. How would you indicate the cost of that cell in preparing the problem to be solved?
The easiest way to "prohibit" a route is to assign it a cost sufficiently high that it simply won't be used in the optimal solution. It is not possible to give that cell a non-numeric cost in most software applications, and it is wrong to give it a zero cost (which would make it free, not prohibited). (Special issues in modeling, moderate)

68. How might the transportation method be used to help a firm add a facility to an existing distribution network? You may wish to describe a simple example.
Assume that the existing network has two sources S1 and S2 and two destinations D1 and D2, and that the firm needs more supply and is going to build a third supply point. Also assume that the firm has found two competing sites for the third facility New1 and New2. The firm must determine the shipping costs from New1 and New2 to D1 and to D2. Then the firm must solve two transportation problems. One will have three suppliers, S1, S2, and New1. The other will have three suppliers S1, S2, and New2. The cheaper total cost result indicates the preferred new facility location. It is not appropriate to solve one problem with New1 and New2 as the third and fourth supply points. (Special issues in modeling, moderate) {AACSB: Reflective Thinking}

PROBLEMS

69. A transportation problem has 6 origins and 12 destinations. How many possible routes are there for this problem? How many routes will be used in the optimal solution?
The number of possible routes is origins times destinations, or 6 * 12 = 72. The number of filled cells (routes used) in the solution is no more than origins plus destinations minus one, or 6 + 12 – 1 = 17. (Special issues in modeling, easy) {AACSB: Analytic Skills}

70. A transportation problem has 10 origins and 32 destinations. How many possible routes are there for this problem? How many routes will be used in the optimal solution?
The number of possible routes is origins times destinations, or 10 * 32 = 320. The number of filled cells (routes used) in the solution is no more than origins plus destinations minus one, or 10 + 32 – 1 = 41. (Special issues in modeling, easy) {AACSB: Analytic Skills}

71. For the data below, construct an initial feasible solution using the northwest corner rule.

COSTS	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1	12	18	9	11	105
Source 2	19	7	30	15	145
Source 3	8	10	14	16	50
Demand	80	60	70	90	300 \ 300

Step 1: The smaller value at the intersection of S1 and D1 is 80. Assign 80 to S1D1, and rule out other cells in D1. The smaller value at the intersection of S1 and D2 is 25 (105-80); assign 25 to S1D2 and rule out other cells in S1. The smaller value at the intersection of S2 and D2 is 35 (60-25); assign 35 to S2D2 and rule out other cells in S2. The smaller value at the intersection of S2 and D3 is 70; assign 70 to S2D3 and rule out other cells in D3. The remaining assignments are 40 at S2D4 and 50 at S3D4. These actions are summarized in the table below.

NWC	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1	**80**	**25**			**105**
Source 2		**35**	**70**	**40**	**145**
Source 3				**50**	**50**
Demand	**80**	**60**	**70**	**90**	**300 \ 300**

(Developing an initial solution, moderate) {AACSB: Analytic Skills}

72. For the transportation problem below, construct an initial feasible solution using the intuitive method.

COSTS	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1	12	18	9	11	45
Source 2	19	7	30	15	145
Source 3	8	10	14	16	50
Demand	80	30	70	60	240 \240

The lowest cost in the matrix is 7; assign 30 units to S2D2 and rule out all other cells in D2. Now the lowest cost in the table is 8; assign 50 units to S3D1 and rule out all other cells in S3. The smallest cost is now 9; assign 45 units to S1D3 and rule out all other S1. The remaining assignments are 60 units to S2D4, 30 units to S2D1, and 25 units to S2D3. These assignments are summarized in the table below.

Intuitive	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1			**45**		**45**
Source 2	**30**	**30**	**25**	**60**	**145**
Source 3	**50**				**50**
Demand	**80**	**30**	**70**	**60**	**240 \ 240**

(Developing an initial solution, moderate) {AACSB: Analytic Skills}

73. Consider the transportation problem in the data set and optimal solution below. Verify by hand or by calculator (show your work) the value of the objective function.

COSTS	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1	12	18	9	11	100
Source 2	21	7	30	15	150
Source 3	8	10	14	16	50
Demand	80	60	70	90	300 \ 300

Shipments	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Row Total
Source 1	30	0	70	0	100
Source 2	0	60	0	90	150
Source 3	50	0	0	0	50
Col. Total	80	60	70	90	300 \ 300

The objective is $12 *30 + $9*70 + $ 7*60 + $15*90 +$8*50 = $3,160 (The stepping-stone method, easy) {AACSB: Analytic Skills}

74. Consider the transportation problem in the data set and optimal solution below. Calculate improvement indexes on each empty cell. Is this solution optimal?

COSTS	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Source 1	12	18	9	11	100
Source 2	21	7	30	15	150
Source 3	8	10	14	16	50
Demand	80	60	70	90	300 \ 300

Shipments	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Row Total
Source 1	30	0	70	0	100
Source 2	0	60	0	90	150
Source 3	50	0	0	0	50
Col. Total	80	60	70	90	300 \ 300

The solution is optimal. (The stepping-stone method, moderate) {AACSB: Analytic Skills}

75. Find the minimum cost shipping solution for the transportation problem data set in the table below. Provide a table of shipping quantities and the minimum value for the objective function.

COSTS	Dest. 1	Dest. 2	Supply
Source 1	6	10	20
Source 2	8	3	30
Source 3	4	6	15
Source 4	12	11	20
Source 5	7	9	25
Demand	70	40	110 \ 110

(a) The optimal solution is shown in the solution below. (b) The minimum cost is $675.

Shipments	Dest. 1	Dest. 2	Row Total
Source 1	20	0	20
Source 2	0	30	30
Source 3	15	0	15
Source 4	10	10	20
Source 5	25	0	25
Col. Total	70	40	110 \ 110
Total Cost	675		

(The stepping-stone method, moderate) {AACSB: Analytic Skills}

76. Consider the transportation data set for a minimization problem below.

COSTS	Dest. 1	Dest. 2	Dest. 3	Supply
Origin 1	5	4	3	30
Origin 2	4	2	6	40
Origin 3	3	7	9	20
Demand	15	50	25	90 \ 90

a. Calculate the initial solution using the northwest corner rule.
b. Calculate improvement indexes, iterate, and solve for the optimal shipping pattern.

The initial solution and improvement indexes appear in the first table below. The optimal solution appears in the second table. (The stepping-stone method, moderate) {AACSB: Analytic Skills}

NWC	Dest. 1	Dest. 2	Dest. 3	Row Total
Origin 1	Ship 15	Ship 15	Save 5	30
Origin 2	Add 1	Ship 35	Ship 5	40
Origin 3	Save 3	Add 2	Ship 20	20
Col. Total	15	50	25	90 \ 90

Shipments	Dest. 1	Dest. 2	Dest. 3	Row Total
Origin 1	0	5	25	30
Origin 2	0	40	0	40
Origin 3	15	5	0	20
Col. Total	15	50	25	90 \ 90
Total Cost	$255			

77. Find the minimum cost solution for the transportation problem detailed in the table below. Explain carefully the meaning of any quantity in a "dummy" row or column.

COSTS	Dest 1	Dest 2	Dest 3	Supply
Source 1	30	12	5	20
Source 2	10	14	12	30
Source 3	20	11	25	75
Dummy	0	0	0	30
Demand	40	60	55	155 \ 155

The optimum solution, which costs $1370, appears in the solution below. A dummy row was added since total supply was less than total demand. Thirty units are shipped from Dummy to Destination 3. This means that Destination 3 does not receive 30 units that it demanded. The dummy row can be interpreted as unfilled demand, or shortfall. (The stepping-stone method, moderate) {AACSB: Analytic Skills}

Shipments	Dest 1	Dest 2	Dest 3	Row Total
Source 1	0	0	20	20
Source 2	25	0	5	30
Source 3	15	60	0	75
Dummy	0	0	30	30
Col. Total	40	60	55	155 \ 155
Total Cost	$1370			

78. The Shamrock Transportation Company has four terminals: A, B, C, and D. At the start of a particular day, there are 8, 8, 6, and 3 tractors available at those terminals, respectively. During the previous night, trailers were loaded at plants R, S, T, and U. The number of trailers at each plant is 2, 12, 5, and 6, respectively. The company dispatcher has determined the distances between each terminal and each plant, as follows. How many tractors should be dispatched from each terminal to each plant in order to minimize the total number of miles traveled?

COSTS	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Supply
Origin 1	21	44	25	40	8
Origin 2	42	24	45	22	8
Origin 3	78	32	42	55	6
Origin 4	44	42	32	30	3
Demand	2	12	5	6	25 \ 25

The optimal solution from Excel OM is in the table below.

Shipments	Dest 1	Dest 2	Dest 3	Dest 4	Row Total
Origin 1	2	0	5	1	8
Origin 2	0	6	0	2	8
Origin 3	0	6	0	0	6
Origin 4	0	0	0	3	3
Col. Total	2	12	5	6	25 \ 25
Total Cost	677				

(The stepping-stone method, difficult) {AACSB: Analytic Skills}

79. Find the minimum cost solution for the transportation problem detailed in the table below.

COSTS	Dest 1	Dest 2	Dest 3	Supply
Source 1	18	12	5	20
Source 2	10	14	12	30
Source 3	9	11	15	75
Demand	40	30	55	125 \ 125

Before your solution can be implemented, you discover that the combination Source 3 – Destination 1 is unavailable, due to political turmoil in the country where Source 3 is located. Solve the revised problem. How much is cost increased by this complication?

The first solution is in the first table; cost of this solution is $1,225.

COSTS	**Dest. 1**	**Dest. 2**	**Dest. 3**	**Supply**
Source 1			**20**	**20**
Source 2			**30**	**30**
Source 3	**40**	**30**	**5**	**75**
Demand	**40**	**30**	**55**	**125 \ 125**

The revision is accomplished by assigning the prohibited cell a very high cost, such as $1,000. This solution appears in the second table; its cost is $1,535. The increase in cost is $310.

COSTS	**Dest. 1**	**Dest. 2**	**Dest. 3**	**Supply**
Source 1	**10**		**10**	**20**
Source 2	**30**			**30**
Source 3		**30**	**45**	**75**
Demand	**40**	**30**	**55**	**125 \ 125**

(The stepping-stone method, difficult) {AACSB: Analytic Skills}

80. A firm has established a distribution network for the supply of a raw material critical to its manufacturing. Currently there are two origins for this raw material, which must be shipped to three manufacturing plants. The current network has the following characteristics:

COSTS	Plant 1	Plant 2	Plant 3	Supply
Raw material source 1	$6	$8	$9	400
Raw material source 2	$4	$7	$3	600
Demand	500	500	500	1500 \ 1000

The firm has identified two potential sites for a third raw material source; these are identified as Candidate A and Candidate B. From A, the costs to ship would be $9 to Plant 1, $10 to Plant 2, and $12 to Plant 3. From B, these costs would be $11, $14, and $8. The new source, wherever it is located, will have a capacity of 500 units. Set up—but DO NOT SOLVE— this problem as though you were going to solve it with transportation problem software.

The setup requires two transportation problems, each with three sources.

COSTS	**Plant 1**	**Plant 2**	**Plant 3**	**Supply**
Raw material source 1	**$6**	**$8**	**$9**	**400**
Raw material source 2	**$4**	**$7**	**$3**	**600**
Candidate A	**$9**	**$10**	**$12**	**500**
Demand	**500**	**500**	**500**	**1500 \ 1500**

COSTS	**Plant 1**	**Plant 2**	**Plant 3**	**Supply**
Raw material source 1	**$6**	**$8**	**$9**	**400**
Raw material source 2	**$4**	**$7**	**$3**	**600**
Candidate B	**$11**	**$14**	**$8**	**500**
Demand	**500**	**500**	**500**	**1500 \ 1500**

(Transportation modeling, moderate) {AACSB: Analytic Skills}

81. A firm has established a distribution network for the supply of a raw material critical to its manufacturing. Currently there are two origins for this raw material, which must be shipped to three manufacturing plants. The current network has the following characteristics:

COSTS	Plant 1	Plant 2	Plant 3	Supply
Raw material source 1	$6	$8	$9	400
Raw material source 2	$4	$7	$3	600
Demand	500	500	500	1500 \ 1000

The firm has identified two potential sites for a third raw material source; these are identified as Candidate A and Candidate B. From A, the costs to ship would be $9 to Plant 1, $10 to Plant 2, and $12 to Plant 3. From B, these costs would be $11, $14, and $8. The new source, wherever it is located, will have a capacity of 500 units. Solve with the transportation method. Which site should be selected?

This problem requires two transportation problems, each with three sources.

COSTS	**Plant 1**	**Plant 2**	**Plant 3**	**Supply**
Raw material source 1	**$6**	**$8**	**$9**	**400**
Raw material source 2	**$4**	**$7**	**$3**	**600**
Candidate A	**$9**	**$10**	**$12**	**500**
Demand	**500**	**500**	**500**	**1500 \ 1500**

COSTS	**Plant 1**	**Plant 2**	**Plant 3**	**Supply**
Raw material source 1	**$6**	**$8**	**$9**	**400**
Raw material source 2	**$4**	**$7**	**$3**	**600**
Candidate B	**$11**	**$14**	**$8**	**500**
Demand	**500**	**500**	**500**	**1500 \ 1500**

The solutions to these problems appear in the tables below.

COSTS	**Plant 1**	**Plant 2**	**Plant 3**	**Supply**
Raw material source 1	**400**	**0**		**400**
Raw material source 2	**100**		**500**	**600**
Candidate A		**500**		**500**
Demand	**500**	**500**	**500**	**1500 \ 1500**
Total cost				**$9,300**

COSTS	**Plant 1**	**Plant 2**	**Plant 3**	**Supply**
Raw material source 1		**400**		**400**
Raw material source 2	**500**	**100**	**0**	**600**
Candidate B			**500**	**500**
Demand	**500**	**500**	**500**	**1500 \ 1500**
Total cost				**$9,900**

Candidate A should be selected. (The stepping-stone method, difficult) {AACSB: Analytic Skills}

82. A manufacturer of semiconductor "wafers" has been attempting to convert its operations to practices more in keeping with JIT principles. The firm is now paying much more attention to the transit time between one processing stage and the next. The plant has a somewhat haphazard pattern of machine locations, partly because the machines were purchased and installed at different times, partly from a shortage of floor space, and partly from previous experiments with work cells. The bottom line is this: there are four machines that perform a certain processing phase, and three machines that perform the next phase. All units of a large class of wafers go through these two phases. The table below displays the transit time, in minutes, from each machine of the first phase to each machine of the second. Machine 3 is not really 100 minutes away from machine B; the company has prohibited that combination because of quality problems associated with that specific pairing. Supply and demand quantities are in wafers processed per week. Develop a transit time minimizing solution for this firm. What is the total transit time of this solution? Which machines are fully utilized? Which machines have some capacity unused or requirements unfilled? Was the prohibition on the 3-B combination honored?

COSTS	Phase 2, machine A	Phase 2, machine B	Phase 2, machine C	Supply
Phase 1, machine 1	7.5	2.5	4.0	700
Phase 1, machine 2	3.0	6.0	6.5	600
Phase 1, machine 3	2.5	100.0	8.0	1000
Phase 1, machine 4	5.0	8.5	7.0	700
Demand	1200	800	1500	3500 \ 3000

The solution appears in the software-generated table below. A dummy Phase 1 machine has been added because there is not perfect balance in the capacities of these two phases. The "cost" of this solution is a total transit time of 12,300 minutes per week. The destination phase Machine C required 1500 wafers, but got only 1000. All other machines in both phases are fully utilized. Yes, the quantity transferred from machine 3 to machine B is zero.

COSTS	**Phase 2, machine A**	**Phase 2, machine B**	**Phase 2, machine C**	**Supply**
Phase 1, machine 1		**700**		**700**
Phase 1, machine 2	**200**	**100**	**300**	**600**
Phase 1, machine 3	**1000**			**1000**
Phase 1, machine 4			**700**	**700**
Phase 1, dummy			**500**	**500**
Demand	**1200**	**800**	**1500**	**3500 \ 3500**
Total cost				**12,300**

(The stepping-stone method, difficult) {AACSB: Analytic Skills}

MODULE D: WAITING-LINE MODELS

TRUE/FALSE

1. Waiting-line models are useful to operations in such diverse settings as service systems, maintenance activities, and shop-floor control.
True (Introduction, easy)

2. The two characteristics of the waiting line itself are whether its length is limited or unlimited and the discipline of the people or items in it.
True (Characteristics of a waiting-line system, easy)

3. A waiting-line system has three parts: the size of the arrival population, the behavior of arrivals, and the statistical distribution of arrivals.
False (Characteristics of a waiting-line system, easy)

4. A copy center has five machines that serve many customers throughout the day; the waiting-line system for copy service has an infinite population while the waiting-line system for copier maintenance has a finite population
True (Characteristics of a waiting-line system, easy)

5. In queuing problems, arrival rates are generally described by the normal probability distribution.
False (Characteristics of a waiting-line system, moderate)

6. Balk and renege are elements of queue discipline.
False (Characteristics of a waiting-line problem, easy)

7. A hospital emergency room always follows a first-in, first-served queue discipline in the interest of fairness.
False (Characteristics of a waiting-line system, moderate)

8. In queuing problems, the term “renege” refers to the fact that some customers leave the queue before service is completed.
True (Characteristics of a waiting-line system, moderate)

9. A waiting-line system with one waiting line and three sequential processing stages is a multi-channel single-phase system.
False (Characteristics of a waiting-line problem, easy)

10. If the service time within a queuing system is constant, the service rate can be easily described by a negative exponential distribution.
False (Characteristics of a waiting-line system, moderate)

11. The cost of waiting decreases as the service level increases.
True (Queuing costs, moderate)

12. LIFS (last-in, first-served) is a common queue discipline, most often seen where people, not objects, form the waiting line.
False (Characteristics of a waiting-line problem, moderate)

13. A bank office with five tellers, each with a separate line of customers, exhibits the characteristics of a multi-phase queuing system.
False (Characteristics of a waiting-line system, moderate)

14. In the analysis of queuing models, the Poisson distribution often describes arrival rates and service times are often described by the negative exponential distribution.
True (Characteristics of a waiting-line system, moderate)

15. The study of waiting lines calculates the cost of providing good service but does not value the cost of customers' waiting time.
False (Queuing costs, moderate)

16. As the average service rate μ grows larger, the slope of the distribution of service time probabilities grows larger and larger, eventually becoming positive.
False (The variety of queuing models, easy)

17. Four of the most widely used waiting line models—M/M/1 or A, M/M/S or B, M/D/1 or C, and Limited population or D—all share three characteristics: Poisson arrivals, FIFO discipline, and exponential service times.
False (The variety of queuing models, moderate)

18. In the M/M/1 waiting line model with an arrival rate of 2 per hour and a service rate of 6 per hour, the utilization factor for the system is approximately 0.333.
True (The variety of queuing models, easy) {AACSB: Analytic Skills}

19. The greater the margin by which the arrival rate exceeds the service rate, the better the performance of the waiting line.
False (The variety of queuing models, easy)

20. An M/M/1 model and an M/D/1 model each have an arrival rate of 1 per minute and a service rate of 3 per minute; the average queue length of the M/M/1 will be twice that of the M/D/1.
True (The variety of queuing models, moderate)

21. A finite population waiting line model has an average service time T of 100 minutes and an average time between service requirements U of 400 minutes; the service factor X is 0.25.
False (The variety of queuing models, moderate) {AACSB: Analytic Skills}

MULTIPLE CHOICE

22. Study of waiting-line models helps operations managers better understand
    a. service systems such as bank teller stations
    b. maintenance activities that might repair broken machinery
    c. shop-floor control activities
    d. service systems such as amusement park rides
    e. all of the above
    e (Introduction, easy)

23. Which of the following is **not** a common queuing situation?
    a. grocery shoppers being served by checkout clerks
    b. commuters slowing or stopping at toll plazas to pay highway tolls
    c. machinery waiting to be repaired or maintained
    d. parcel delivery truck following its computer-generated route
    e. patients in a health clinic waiting to see one of several doctors
    d (Introduction, easy)

24. In queuing problems, which of the following probability distributions is typically used to describe the number of arrivals per unit of time?
    a. binomial
    b. normal
    c. Poisson
    d. exponential
    e. lognormal
    c (Characteristics of a waiting-line system, easy)

25. In queuing problems, which of the following probability distributions is typically used to describe the time to perform the service?
    a. binomial
    b. normal
    c. Poisson
    d. negative exponential
    e. lognormal
    d (Characteristics of a waiting-line system, easy)

26. The common measures of a queuing system's performance include
    a. probability that the service facility will be idle, average queue length, probability that the waiting time will exceed a specified duration
    b. average time each customer spends in the system, probability that the service system will be idle, average time each customer spends in the queue
    c. average queue length, maximum time a customer may spend in the queue, the utilization factor for the system
    d. average time each customer spends in the system, maximum queue length, probability of a specific number of customers in the system
    e. none of the above
    b (Characteristics of a waiting-line system, moderate)

27. The shopper who says to himself, “I’ve waited too long in this line. I don’t really need to buy this product today,” and leaves the store is an illustration of which element of arrival behavior?
    a. random arrival
    b. renege
    c. random departure
    d. balk
    e. none of the above
    b (Characteristics of a waiting-line system, moderate)

28. A waiting line, or queuing, system has three parts, which are
    a. distribution of arrival times, discipline while waiting, and distribution of service times
    b. arrival rate, service rate, and utilization rate
    c. arrival discipline, queue discipline, and service sequencing
    d. arrival or inputs, queue discipline or the waiting line itself, and the service facility
    e. sequencing policy, penalty for reneging, and expediting of arrivals
    d (Characteristics of a waiting-line system, moderate)

29. The source population is considered to be either _____ in its size.
    a. finite or infinite
    b. fixed or variable
    c. known or unknown
    d. random or scheduled
    e. small or large
    a (Characteristics of a waiting-line system, moderate)

30. The potential restaurant customer who says to her husband, “The line looks too long; let's eat somewhere else,” is an illustration of which element of queue discipline?
    a. first-in, first-out
    b. balk
    c. renege
    d. random departure
    e. none of the above
    b (Characteristics of a waiting-line system, moderate)

31. An airline ticket counter, with several agents for one line of customers, is an example of a
    a. single channel, single phase system
    b. single channel, multi-phase system
    c. multi-channel, single phase system
    d. multi-channel, multi-phase system
    e. none of the above
    c (Characteristics of a waiting-line system, moderate)

32. A concert hall, employing both ticket takers and ushers to seat patrons, behaves typically as a
    a. multi-channel, single phase system
    b. multi-channel, multi-phase system
    c. single channel, single phase system
    d. single channel, multi-phase system
    e. none of the above
    b (Characteristics of a waiting-line system, moderate)

33. If the food service for the university operates a cafeteria with a single serving line, that system behaves most like a
    a. single channel, single phase system
    b. single channel, multi-phase system
    c. multi-channel, single phase system
    d. multi-channel, multi-phase system
    e. none of the above
    b (Characteristics of a waiting-line system, moderate)

34. The sign at the bank that reads “Wait here for the first available teller” suggests the use of a _____ waiting line system.
    a. single phase
    b. multi-phase
    c. single channel
    d. multi-channel
    e. multiple line
    d (Characteristics of a waiting-line system, moderate)

35. A small hair styling salon has several operators. While customers do not have appointments, each is waiting to be served by a specific operator. This scenario provides an example of a
    a. multiple-channel, multi-phase, limited queue length
    b. single-channel, multi-phase, limited queue length
    c. multi-channel, limited queue length
    d. multiple single-channel systems, limited queue length
    e. none of the above
    d (Characteristics of a waiting-line system, moderate)

36. A large discount store and supermarket has a hair styling salon on its premises. The salon has several operators. Salon customers can shop in other parts of the store until their name is called for salon service, at which time the customer will be served by the next available stylist. This scenario provides an example of a
    a. multiple-channel, multi-phase, unlimited queue length
    b. single-channel, multi-phase, limited queue length
    c. multi-channel, unlimited queue length
    d. multiple single-channel systems, limited queue length
    e. none of the above
    c (Characteristics of a waiting-line system, moderate)

37. A university has only one technician in the repair station to care for the computers in the student labs. This system is most likely
    a. a single channel, limited queue system
    b. a single channel, limited population system
    c. a multi-channel, limited queue system
    d. a multi-channel, limited population system
    e. none of the above
    b (Characteristics of a waiting-line system, moderate)

38. “Women and children first!” declares the captain of a sinking ship. His directive employs which of the following queue disciplines in disembarking passengers?
    a. priority
    b. random
    c. FIFO or FIFS
    d. LIFO or LIFS
    e. none of the above
    a (Characteristics of a waiting-line system, moderate)

39. A university has several technicians in the repair station to care for the computers in the student labs. This system is most likely
    a. single channel, limited queue system
    b. single channel, limited population system
    c. multi-channel, limited queue system
    d. multi-channel, limited population system
    e. none of the above
    d (Characteristics of a waiting-line system, moderate)

40. A system in which the customer receives service from only one station and then exits the system is
    a. a single-phase system
    b. a single channel system
    c. a multiple-channel system
    d. a multiple-phase system
    e. none of the above
    a (Characteristics of a waiting-line system, easy)

41. In a repetitive focus factory, the number of phases found in the system might refer to
    a. the number of successive operations that have to be performed on a part
    b. the number of machines doing the same necessary operations
    c. the number of parts waiting to be processed
    d. all of the above depending on the layout
    e. none of the above
    a (Characteristics of a waiting-line system, moderate)

42. Which of the following is a measure of queue performance?
    a. utilization factor
    b. average queue length
    c. probability of a specific number of customers in the system
    d. average waiting time in the line
    e. all of the above
    e (Characteristics of a waiting-line system, moderate)

43. Which of the following is most likely to be served in a last-in, first-served (LIFS) queue discipline?
    a. customers checking out at a grocery store
    b. the in-basket on a manager's desk
    c. patients entering a hospital emergency room
    d. patrons waiting to be seated in a casual-dining restaurant
    e. all of the above
    b (Characteristics of a waiting-line system, easy)

44. In a repetitive focus factory, the number of channels available for the processing of a certain part would likely refer to
    a. the number of successive operations that have to be performed on that part
    b. the number of machines doing the same necessary operations
    c. the number of parts waiting to be processed
    d. all of the above depending on the layout
    e. none of the above
    b (Characteristics of a waiting-line system, moderate)

45. A waiting line meeting the assumptions of M/M/1 has average time between arrivals of 20 minutes and services items in an average of 10 minutes each; the utilization factor is approximately
    a. 0.25
    b. 0.33
    c. 0.50
    d. 0.67
    e. 3.00
    c (The variety of queuing models, moderate) {AACSB: Analytic Skills}

46. A waiting line model meeting the assumptions of M/M/1 has an arrival rate of 2 per hour and a service rate of 6 per hour; the utilization factor for the system is approximately
    a. 0.25
    b. 0.33
    c. 0.50
    d. 0.67
    e. 3.00
    b (The variety of queuing models, easy) {AACSB: Analytic Skills}

47. As the average service rate μ increases, the shape of the negative exponential distribution of service times
    a. grows steadily steeper without limit
    b. has an ever steeper slope that eventually turns positive
    c. becomes less gently curved as it moves ever closer to the graph origin
    d. takes on a more uniform slope over a wide range of service times
    e. changes in appearance from convex to concave
    c (The variety of queuing models, easy)

48. Which one of the following is **not** a characteristic of a Model A or M/M/1 system?
    a. exponential service time pattern
    b. single number of channels
    c. single number of phases
    d. Poisson arrival rate pattern
    e. limited population size
    e (The variety of queuing models, moderate)

49. Which one of the following is **not** a characteristic of a Model B or M/M/S system?
    a. unlimited population size
    b. single channel
    c. single queue
    d. single phase
    e. Poisson arrival rate pattern
    b (The variety of queuing models, moderate)

50. Which one of the following is **not** a characteristic of a Model C or M/D/1 system?
    a. single channel
    b. single phase
    c. Poisson arrival rate pattern
    d. exponential service time pattern
    e. unlimited population size
    d (The variety of queuing models, moderate)

51. In the basic queuing model (M/M/1), service times are described by
    a. continuous probability distributions
    b. negative exponential probability distributions
    c. Poisson probability distributions
    d. normal probability distributions
    e. lognormal distributions
    b (Characteristics of a waiting-line system, moderate)

52. In the basic queuing model (M/M/1), arrival rates are distributed by
    a. continuous probability distributions
    b. normal probability distributions
    c. negative exponential probability distributions
    d. Poisson distributions
    e. lognormal distributions
    d (The variety of queuing models, moderate)

53. A single-phase waiting-line system meets the assumptions of constant service time or M/D/1. Units arrive at this system every 10 minutes on average. Service takes a constant 4 minutes. The average length of the queue L_q is
    a. 0.4
    b. 0.133
    c. 4.167
    d. 4.583
    e. 6
    b (Characteristics of a waiting-line system, moderate) {AACSB: Analytic Skills}

54. Which of the following is **not** an assumption of the M/M/1 model?
    a. The first customers to arrive are the first customers served.
    b. Each arrival comes independently of the arrival immediately before and after that arrival.
    c. The population from which the arrivals come is very large or infinite in size.
    d. Customers do not renege.
    e. Service times occur according to a normal curve.
    e (The variety of queuing models, moderate)

55. A single-phase waiting-line system meets the assumptions of constant service time or M/D/1. Units arrive at this system every 12 minutes on average. Service takes a constant 8 minutes. The average length of the queue L_q is approximately
    a. 0.67
    b. 2.5
    c. 4.5
    d. 5.0
    e. 7.5
    a (Characteristics of a waiting-line system, moderate) {AACSB: Analytic Skills}

56. A single-phase waiting-line system meets the assumptions of constant service time or M/D/1. Units arrive at this system every 12 minutes on average. Service takes a constant 8 minutes. The average number in the system L_s is approximately
    a. 2.25
    b. 2.5
    c. 3.0
    d. 1.33
    e. 5.0
    d (Characteristics of a waiting-line system, moderate) {AACSB: Analytic Skills}

57. A queuing model which follows the M/M/1 assumptions has $\lambda = 2$ and $\mu = 3$. The average number in the system is
    a. 2/3
    b. 1
    c. 1.5
    d. 2
    e. 6
    d (The variety of queuing models, moderate) {AACSB: Analytic Skills}

58. A queuing model which follows the M/M/1 assumptions has $\lambda = 3$ and $\mu = 2$. The average number in the system is
    a. -3
    b. 3
    c. 0.667
    d. 150 percent
    e. growing without limit, since λ is larger than μ.
    e (The variety of queuing models, moderate) {AACSB: Analytic Skills}

59. Students arrive randomly at the help desk of the computer lab. There is only one service agent, and the time required for inquiry varies from student to student. Arrival rates have been found to follow the Poisson distribution, and the service times follow the negative exponential distribution. The average arrival rate is 12 students per hour, and the average service rate is 20 students per hour. What is the average service time for this problem?
    a. 1 minute
    b. 2 minutes
    c. 3 minutes
    d. 5 minutes
    e. 20 minutes
    c (The variety of queuing models, moderate) {AACSB: Analytic Skills}

60. A queuing model which follows the M/M/1 assumptions has $\lambda = 10$ and $\mu = 12$. The average number in the system is
    a. 0.83
    b. 2
    c. 2.5
    d. 5
    e. 6
    d (The variety of queuing models, moderate) {AACSB: Analytic Skills}

61. A queuing model which follows the M/M/1 assumptions has $\lambda = 2$ and $\mu = 8$. The average number in the system L_s is _____ and the utilization of the system is _____.
    a. 3; 100 percent
    b. 0.33; 25 percent
    c. 4; 33 percent
    d. 6; 25 percent
    e. 4; 25 percent
    b (The variety of queuing models, moderate) {AACSB: Analytic Skills}

62. Four of the most widely used waiting line models—M/M/1 or A, M/M/S or B, M/D/1 or C, and Limited population or D—all share three characteristics, which are
    a. normal arrivals, FIFO discipline, and normal service times
    b. Poisson arrivals, FIFO discipline, and a single-service phase
    c. Poisson arrivals, FIFO discipline, and exponential service times
    d. Poisson arrivals, no queue discipline, and exponential service times
    e. none of these
    b (The variety of queuing models, moderate)

63. A queuing model which follows the M/M/1 assumptions has $\lambda = 2$ and $\mu = 3$. The average waiting time in the system is
    a. 2/3
    b. 1
    c. 1.5
    d. 2
    e. 6
    b (The variety of queuing models, moderate) {AACSB: Analytic Skills}

64. Students arrive randomly at the help desk of the computer lab. There is only one service agent, and the time required for inquiry varies from student to student. Arrival rates have been found to follow the Poisson distribution, and the service times follow the negative exponential distribution. The average arrival rate is 12 students per hour, and the average service rate is 20 students per hour. What is the utilization factor?
    a. 20%
    b. 30%
    c. 40%
    d. 50%
    e. 60%
    e (The variety of queuing models, moderate) {AACSB: Analytic Skills}

65. A finite population waiting line model has an average service time T of 100 minutes and an average time between service requirements U of 400 minutes; the service factor X is
    a. 0.20
    b. 0.25
    c. 4
    d. 5
    e. 300 minutes
    a (The variety of queuing models, easy) {AACSB: Analytic Skills}

66. A finite population waiting line model has an average service time T of 200 minutes and an average time between service requirements U of 300 minutes; the service factor X is
    a. 0.20
    b. 0.40
    c. 0.60
    d. 0.67
    e. 2.5
    b (The variety of queuing models, easy) {AACSB: Analytic Skills}

67. Students arrive randomly at the help desk of the computer lab. There is only one service agent, and the time required for inquiry varies from student to student. Arrival rates have been found to follow the Poisson distribution, and the service times follow the negative exponential distribution. The average arrival rate is 12 students per hour, and the average service rate is 20 students per hour. A student has just entered the system. How long is she expected to stay in the system?
    a. 0.125 minute
    b. 0.9 minute
    c. 1.5 minutes
    d. 7.5 minutes
    e. 0.075 hour
    d (The variety of queuing models, moderate) {AACSB: Analytic Skills}

68. Students arrive randomly at the help desk of the computer lab. There is only one service agent, and the time required for inquiry varies from student to student. Arrival rates have been found to follow the Poisson distribution, and the service times follow the negative exponential distribution. The average arrival rate is 12 students per hour, and the average service rate is 20 students per hour. How many students, on the average, will be waiting in line at any one time?
    a. 0.9 students
    b. 1.5 students
    c. 3 students
    d. 4 students
    e. 36 students
    a (The variety of queuing models, moderate) {AACSB: Analytic Skills}

69. A waiting-line system that meets the assumptions of M/M/S has $\lambda = 5$, $\mu = 4$, and M = 2. For these values, P_o is approximately 0.23077 and L_s is approximately 2.05128. The average time a unit spends waiting in this system
    a. is approximately 0.1603
    b. is approximately 0.2083
    c. is approximately 0.4103
    d. is approximately 0.8013
    e. cannot be calculated because λ is larger than μ
    a (The variety of queuing models, moderate) {AACSB: Analytic Skills}

70. A waiting-line system that meets the assumptions of M/M/1 has $\lambda = 1$, $\mu = 4$. For this system, P_o is _____ and utilization is _____.
    a. 0.75; 0.25
    b. 0.80; .20
    c. -3; -4
    d. 3; 4
    e. none of these
    a (The variety of queuing models, moderate) {AACSB: Analytic Skills}

71. A waiting-line system that meets the assumptions of M/M/S has $\lambda = 5$, $\mu = 4$, and M = 2. For these values, P_o is approximately 0.23077 and L_s is approximately 2.05128. The average number of units waiting in the queue
    a. is approximately 0.1603
    b. is approximately 0.4103
    c. is approximately 0.8013
    d. is approximately 1.0417
    e. cannot be calculated because λ is larger than μ
    c (The variety of queuing models, moderate) {AACSB: Analytic Skills}

72. A waiting-line system that meets the assumptions of M/M/1 has $\lambda = 1$, $\mu = 4$. For this system, the probability of more than two units in the system is approximately
    a. zero
    b. 0.015625
    c. 0.0625
    d. 0.25
    e. 0.9375
    b (The variety of queuing models, moderate) {AACSB: Analytic Skills}

73. A waiting-line system that meets the assumptions of M/M/1 has $\lambda = 1$, $\mu = 4$. For this system, the probability of **fewer** than two units in the system is approximately
    a. 0.0625
    b. 0.25
    c. 0.75
    d. 0.9375
    e. certain
    d (The variety of queuing models, difficult) {AACSB: Analytic Skills}

FILL-IN-THE-BLANK

74. A waiting line or _____ is where items or people are in a line awaiting service; _____ is a body of knowledge about waiting lines.
queue, queuing theory (Introduction, easy)

75. A(n) _____ is a discrete probability distribution that often describes the arrival rate in queuing theory.
Poisson distribution (Characteristics of a waiting-line system, moderate)

76. The _____ of a waiting line and the probability that the queue is empty add to one.
utilization (Characteristics of a waiting-line system, moderate)

77. A(n) _____occurs when an arrival refuses to enter a waiting line; a(n) _____occurs when an arrival joins a waiting line, then leaves it.
balk, renege (Characteristics of a waiting-line system, moderate)

78. A waiting line has a(n) _____ population if, as arrivals take place, the likelihood of additional arrivals is decreased.
finite or limited (Characteristics of a waiting-line system, moderate)

79. Of the three types of queue discipline, only _____ is assumed by the four primary waiting line models.
FIFO or FIFS or first-in, first served (Characteristics of a waiting-line system, moderate)

80. A(n) _____ queuing system has one line and one server.
single-channel (Characteristics of a waiting-line system, moderate)

81. A(n) _____ queuing system has one waiting line, but several servers; a(n) _____ queuing system is one in which the customer receives services from several stations before exiting the system
multiple-channel, multiple-phase (Characteristics of a waiting-line system, moderate)

82. A(n) _____ queuing system is one in which the customer receives service from only one station and then exits the system.
single-phase (Characteristics of a waiting-line system, moderate)

83. The _____ probability distribution is a continuous probability distribution often used to describe the service time in a queuing system.
negative exponential (Characteristics of a waiting-line system, moderate)

84. In a finite or limited population waiting line, the _____ is calculated from the average service time and average time between service requirements before the problem can be completed.
service factor (Characteristics of a waiting-line system, moderate)

SHORT ANSWERS

85. Provide an example of a limited or finite population for a queue.
Answers will vary, but the textbook provides copiers at a copying shop in terms of breakdowns and repair. (Characteristics of a waiting-line system, moderate)

86. What does it mean to have a patient customer in a waiting line?
A patient customer is one who waits in the queue until he or she has been served, and exits the system normally. A patient customer does not balk or renege. (Characteristics of a waiting-line system, moderate)

87. What is queue discipline? State three rules for queue discipline. Which of these rules appears most frequently in the four main models?
Queue discipline is the rule that determines the sequence in which arrivals will receive service. Choices include (1) FIFO, FIFS, or first-in, first-served, (2) LIFO, LIFS, or last-in, first-served, and (3) priority, such as the triage area of a hospital emergency room. FIFO is the only one assumed by the four models. (Characteristics of a waiting-line system, moderate)

88. Describe the difference between FIFO and LIFO queue disciplines.
FIFO (first-in, first-out) serves first the customer who entered earliest and who has been in line longest; LIFO serves first the customer who entered most recently. FIFO exhibits a fairness to people waiting; LIFO is something like an in-basket on a desk, where the top piece of paper was the last entered, but the first to be serviced. (Characteristics of a waiting-line system, moderate)

89. Customers take a number as they join the waiting line of the customer service counter at a discount store. There are two customer service agents. Provide the most likely characteristics of this system.
a. name of model
b. number of channels
c. number of phases
d. arrival rate distribution
e. service time distribution
f. population size
g. queue discipline
Multi-channel system (M/M/S); two; single; Poisson; exponential; unlimited; and FIFO. (Characteristics of a waiting-line system, moderate)

90. Students arrive randomly at the help desk of a computer lab. There is only one service agent, and the service time varies from one student to the other. Provide the most likely characteristics for this system.
a. name of model
b. number of channels
c. number of phases
d. arrival rate distribution
e. service time distribution
f. population size
g. queue discipline
Single channel system (M/M/1); single; single; Poisson; exponential; unlimited; and FIFO. (Characteristics of a waiting-line system, moderate)

91. Why does it matter whether a population of arrivals is limited or unlimited? Compose your answer in a well-organized, convincing paragraph.
If an arrival population is unlimited, then one arrival has no effect on the likelihood of the next. All arrivals will be determined by the underlying probability distribution. If, however, the population is limited, then one arrival, by leaving the outside population and entering the waiting line, means that there are fewer potential arrivals. In turn, that decreases the probability of the next arrival, and requires techniques beyond the typical probability distributions. In an extreme case, if all members of the population are in the waiting line, then there can no further arrivals at all!(Characteristics of a waiting-line system, moderate)

92. What are L_s and L_q, as used in waiting line terminology? Which is larger, L_s or L_q? Explain.
L_s is the average number of units in the system. L_q is the average number of units in the waiting line. L_s includes the average number of units in line as well as the average number of units being served. Consequently, L_s is larger than L_q by the average number of units actually being serviced. (Characteristics of a waiting-line system, moderate)

93. There is only one bay and one type of service at an automatic car wash. Provide the most likely characteristics of this system.
a. name of model
b. number of channels
c. number of phases
d. arrival rate distribution
e. service time distribution
f. population size
g. queue discipline
Constant service (M/D/1); single; single; Poisson; constant; unlimited; and FIFO. (Characteristics of a waiting-line system, moderate)

94. What is the waiting-line problem? Why is it important to operations?
A waiting-line problem concerns the question of finding the appropriate level of service where customers waiting for service form a line (or queue). Analysis of queues helps operations managers understand service systems, maintenance activities, and shop-floor control activities. (Characteristics of a waiting-line system, easy)

95. What are the components in a waiting-line system?
The components of a waiting-line system are the arrivals, or inputs, the waiting line itself, and the service facility. (Characteristics of a waiting-line system, easy)

96. Describe the important operating characteristics of a queuing system.
The operating characteristics usually considered of theoretical importance are:
- **The average time each customer or object spends in the queue**
- **The average length of the queue**
- **The average time each customer spends in the system (waiting time plus service time)**
- **The average number of customers in the system**
- **The probability that the service facility will be idle**
- **The utilization factor**
- **The probability of a specific number of customers in the system**

(Characteristics of a waiting-line system, moderate)

97. In an earlier chapter, you were introduced to a "traditional" view of costs and a "full cost" view of costs, with respect to a certain type of analysis. How might that lesson apply here? In particular, might operations managers pay more attention to some kinds of costs than others?
This is a critical-thinking exercise for students. Service costs are probably easy for operations managers to identify and to calculate, and may well be direct company expenses. On the other hand, waiting costs may be more subjective, hard to quantify, or perhaps are borne by customers, not the firm. In this case, operations managers might pay more attention to what costs they bear and experience, and less attention to those that are borne by others. The result of this bias leads to a reduction in the level of service, because the "savings" in reduced wait costs are not fully recognized. (Queuing costs, easy) {AACSB: Reflective Thinking}

98. What costs are present in waiting line analysis? How do these costs vary with the level of service?
The costs are the cost of providing service, and the cost of waiting time. The cost of providing service rises in a linear fashion with increases in the service level. The cost of waiting time decreases in a nonlinear fashion as the service level increases. (Queuing costs, easy)

99. What are the assumptions underlying the M/M/1 waiting line model? Which of these also hold for the M/D/1 model?
The assumptions underlying the standard waiting line or queuing model are:
1. **Arrivals are served on a "first come, first served" (FCFS, or FIFO) basis; and every arrival waits to be served regardless of the length of the line or queue.**
2. **All arrivals are independent of preceding arrivals, and the average number of arrivals per unit time (arrival rate) does not change over time.**
3. **Arrival rates are described by a Poisson probability distribution, and arrivals come from an infinite or very large source.**
4. **Service times vary from one customer to another and are independent of one another, but their average rate is known.**
5. **Service times are described by a negative exponential probability distribution.**
6. **The effective service rate is faster than the arrival rate.**

Assumptions 4 and 5 do not apply to M/D/1.
(The variety of queuing models, moderate)

100. You have seen that, in an M/D/1 problem, the average queue length is exactly one-half the average queue length of an otherwise identical M/M/1 problem. Are all other performance statistics one-half as large also? Explain.
Only the average queue length and average waiting time are halved. Utilization is exactly the same. L_s and W_s are smaller in M/D/1 than in M/M/1, but not by exactly one-half. (The variety of queuing models, moderate)

101. Why must the service rate be greater than the arrival rate in a single-channel system?
If the service rate is not greater than the arrival rate, the line will increase in length indefinitely. (The variety of queuing models, moderate)

102. Most banks have changed from having a line in front of each teller to a system where one line feeds all tellers. Which system is better? Why?
It is inherently more efficient to have a queuing system whereby one line feeds all tellers. (The variety of queuing models, moderate)

PROBLEMS

103. A waiting line meeting the M/M/1 assumptions has an arrival rate of 4 per hour and a service rate of 12 per hour. What is the probability that the waiting line is empty?
$P_o = 1 - \lambda/\mu = 1 - 4/12 = 8/12$ or 0.667. (The variety of queuing models, easy) {AACSB: Analytic Skills}

104. A waiting line meeting the M/M/1 assumptions has an arrival rate of 4 per hour and a service rate of 12 per hour. What is the average time a unit spends in the system and the average time a unit spends waiting?
$W_s = 1 / (\mu - \lambda) = 1 / (12 - 4) = 1/8$ or 0.125; $W_q = \lambda / (\mu*(\mu-\lambda)) = 4 / (12*8) = 1/24$ or 0.0417. (The variety of queuing models, easy) {AACSB: Analytic Skills}

105. A waiting line meeting the M/M/1 assumptions has an arrival rate of 10 per hour and a service rate of 12 per hour. What is the average time a unit spends in the system and the average time a unit spends waiting?
$W_s = 1 / (\mu - \lambda) = 1 / (12 - 10) = 1/2$ or 0.5; $W_q = \lambda / (\mu*(\mu-\lambda)) = 10 / (12*2) = 10 / 24$ or 0.4167. (The variety of queuing models, easy) {AACSB: Analytic Skills}

106. A waiting line meeting the M/M/1 assumptions has an arrival rate of 10 per hour and a service rate of 12 per hour. What is the probability that the waiting line is empty?
$P_o = 1 - \lambda/\mu = 1 - 10/12 = 2/12$ or 0.1667. (The variety of queuing models, easy) {AACSB: Analytic Skills}

107. A crew of mechanics at the Highway Department garage repair vehicles that break down at an average of $\lambda = 7.5$ vehicles per day (approximately Poisson in nature). The mechanic crew can service an average of $\mu = 10$ vehicles per day with a repair time distribution that approximates an exponential distribution.
a. What is the utilization rate for this service system?
b. What is the average time before the facility can return a breakdown to service?
c. How much of that time is spent waiting for service?
d. How many vehicles are likely to be in the system at any one time?
(a) Utilization is $\rho = 7.5 / 10 = .75$ or 75 percent; (b) $W_s = 1 / (10 - 7.5) = 1 / 2.5 = 0.4$ days; (c) $W_q = 7.5 / 10*(10-7.5) = 0.3$ days; (d) $L_s = 7.5 / (10-7.5) = 7.5 / 2.5 = 3$ units. (The variety of queuing models, easy) {AACSB: Analytic Skills}

108. A crew of mechanics at the Highway Department garage repair vehicles that break down at an average of $\lambda = 7$ vehicles per day (approximately Poisson in nature). The mechanic crew can service an average of $\mu = 11$ vehicles per day with a repair time distribution that approximates an exponential distribution.
a. What is the utilization rate for this service system?
b. What is the average time before the facility can return a breakdown to service?
c. How much of that time is spent waiting for service?
d. How many vehicles are likely to be waiting for service at any one time?
(a) Utilization is $\rho = 7 / 11 = .636$ or 64 percent; (b) $W_s = 1 / (11-7) = 1/4 = 0.25$ days; (c) $W_q = 7 / 11*(11-7) = 7 / 44 = 0.16$ days; (d) $L_q = 7*7 / 11*(11-7) = 49 / 44 = 1.114$ units (The variety of queuing models, easy) {AACSB: Analytic Skills}

109. A crew of mechanics at the Highway Department garage repair vehicles which break down at an average of $\lambda = 5$ vehicles per day (approximately Poisson in nature). The mechanic crew can service an average of $\mu = 10$ vehicles per day with a repair time distribution that approximates an exponential distribution.
a. What is the probability that the system is empty?
b. What is the probability that there is precisely one vehicle in the system?
c. What is the probability that there is more than one vehicle in the system?
d. What is the probability of 5 or more vehicles in the system?
(a)$P_0 = 1 - 5/10 = 0.50$; (b) $P_{n>1} = (5/10)^2 = 0.25$; the probability of exactly one is .50 -.25 = .25; (c) 0.25 as previously calculated; (d) the probability of five or more is $P_{n>4} = (5/10)^5 = 0.0313$. (The variety of queuing models, moderate) {AACSB: Analytic Skills}

110. A crew of mechanics at the Highway Department garage repair vehicles that break down at an average of $\lambda = 8$ vehicles per day (approximately Poisson in nature). The mechanic crew can service an average of $\mu = 11$ vehicles per day with a repair time distribution that approximates an exponential distribution. The crew cost is approximately $300 per day. The cost associated with lost productivity from the breakdown is estimated at $150 per vehicle per day (or any fraction thereof). What is the expected cost of this system?
The number of vehicles out of service is $L_s = 8 / (11-8) = 8/3 = 2.667$. The cost of waiting is $150 x L_s = $150 x 2.667 = $400. Server cost is $300 per day for a total of $700. (The variety of queuing models, moderate) {AACSB: Analytic Skills}

111. A crew of mechanics at the Highway Department garage repair vehicles that break down at an average of $\lambda = 8$ vehicles per day (approximately Poisson in nature). The mechanic crew can service an average of $\mu = 10$ vehicles per day with a repair time distribution that approximates an exponential distribution.
a. What is the probability that the system is empty?
b. What is the probability that there is precisely one vehicle in the system?
c. What is the probability that there is more than one vehicle in the system?
d. What is the probability of 5 or more vehicles in the system?
(a) $P_0 = 1 - 8/10 = 0.20$; (b) $P_{n>1} = (8/10)^2 = 0.64$; the probability of exactly one is .36 -.20 = .16; (c) 0.64 as previously calculated; (d) $P_{n>4} = (8/10)^5 = 0.32768$. (The variety of queuing models, moderate) {ACSB: Analytic Skills}

112. A crew of mechanics at the Highway Department garage repair vehicles that break down at an average of $\lambda = 8$ vehicles per day (approximately Poisson in nature). The mechanic crew can service an average of $\mu = 11$ vehicles per day with a repair time distribution that approximates an exponential distribution. The crew cost is approximately $300 per day. The cost associated with lost productivity from the breakdown is estimated at $150 per vehicle per day (or any fraction thereof). Which is cheaper, the existing system with one service crew, or a revised system with two service crews?
L_s for the single server is $8 / (11-8) = 8/3 = 2.667$. The single-server system server cost is $300 per day; wait cost is $150 x 2.667 = $400, for a total of $700. For the two-server system, L_s = 0.8381. The two-server system will double the server cost to $600, but reduce the wait cost to $150 x .8381 = $125.72, for a total of $725.72. The single-server system is cheaper. (The variety of queuing models, difficult) {AACSB: Analytic Skills}

113. A dental clinic at which only one dentist works is open only two days a week. During those two days, the traffic is uniformly busy with patients arriving at the rate of three per hour. The doctor serves patients at the rate of one every 15 minutes.
a. What is the probability that the clinic is empty (except for the dentist)?
b. What percentage of the time is the dentist busy?
c. What is the average number of patients in the waiting room?
d. What is the average time a patient spends in the office (wait plus service)?
e. What is the average time a patient waits for service?
(a) $P_o = 1 – 3/4 = 0.25$; (b) The dentist is busy when the clinic is not empty, or 1 - .25 = 0.75 or 75 percent of the time; (c) $L_q = 3*3 / 4*(4-3) = 2.25$; (d) $W_s = 1 / (4-3) = 1$ hour; (e) $W_q = 3 / 4*(4-3) = 0.75$ hours. (The variety of queuing models, easy) {AACSB: Analytic Skills}

114. A dental clinic at which only one dentist works is open only two days a week. During those two days, the traffic arrivals follow a Poisson distribution with patients arriving at the rate of three per hour. The doctor serves patients at the rate of one every 15 minutes.
a. What is the probability that the clinic is empty (except for the dentist)?
b. What is the probability that there are one or more patients in the system?
c. What is the probability that there are four patients in the system?
d. What is the probability that there are four or more patients in the system?
(a) $P_o = 1 – 3/4 = 0.25$; (b) The probability that there are one or more patients is $P_{n>0} = 3/4$ or .75; (c) The probability of exactly four patients is $P_{n>3} - P_{n>4}$=.3164 – .2373 = .0791; (d) .3164 as previously calculated. (The variety of queuing models, moderate) {AACSB: Analytic Skills}

115. At the order fulfillment center of a major mail-order firm, customer orders, already packaged for shipment, arrive at the sorting machines to be sorted for loading onto the appropriate truck for the parcel's address. The arrival rate at the sorting machines is at the rate of 100 per hour following a Poisson distribution. The machine sorts at the constant rate of 150 per hour.
a. What is the utilization rate of the system?
b. What is the average number of packages waiting to be sorted?
c. What is the average number of packages in the sorting system?
d. How long must the average package wait until it gets sorted?
e. What would L_q and W_q be if the service rate were exponential, not constant?
(a) The utilization rate is $\rho = 100/150 = 0.67$ or 67 percent; (b) $L_q = 100*100 / (2*150*50) = .67$; (c) $L_s = .67 + 100/150 = 1.33$; (d) $W_q = 100 / (2*150*50) = 0.0067$ hours, or 0.4 minutes. (e) Both values would be exactly doubled from the constant service rate results: $L_q = 1.33$ and $W_q = .0133$. (The variety of queuing models, moderate) {AACSB: Analytic Skills}

116. At the order fulfillment center of a major mail-order firm, customer orders, already packaged for shipment, arrive at the sorting machines to be sorted for loading onto the appropriate truck for the parcel's address. The arrival rate at the sorting machines is at the rate of 140 per hour following a Poisson distribution. The machine sorts at the constant rate of 150 per hour.
a. What is the utilization rate of the system?
b. What is the average number of packages waiting to be sorted?
c. What is the average number of packages in the sorting system?
d. How long must the average package wait until it gets sorted?
(a) The utilization rate is $\rho = 140/150 = 0.9333$ or 93.33 percent; (b) $L_q = 6.53$; (c) $L_s = 7.47$; (d) $W_q = 0.0467$ hours, or less than 3 minutes. Parts (b)-(d) are supported by the excerpt from ExcelOM results below.

Results

Average server utilization(r)	**0.933333**
Average number of customers in the queue(L_q)	**6.533333**
Average number of customers in the system(L)	**7.466667**
Average waiting time in the queue(W_q)	**0.046667**
Average time in the system(W)	**0.053333**
Probability (% of time) system is empty (P_0)	**0.066667**

(The variety of queuing models, moderate) {AACSB: Analytic Skills}

117. A waiting-line system that meets the assumptions of M/M/1 has $\lambda = 1$, $\mu = 4$. Calculate P_o. Build a table showing the probability of more than 0, 1, 2, 3, 4, 5, 6,and 7 units in the system. Round to six decimal places in your work

Number in system	Probability of n or more	
0	**.25**	**$P_o = .75$**
1	**.0625**	
2	**.015625**	
3	**.003906**	
4	**.000977**	
5	**.000244**	
6	**.000061**	
7	**.000015**	

(The variety of queuing models, moderate) {AACSB: Analytic Skills}

118. Genco, Inc., a small manufacturer of diesel-generator sets has four shearing machines. Because of the age of these machines, they need minor repairs after 30 hours of use. Analysis of previous breakdowns indicates that breakdowns follow a Poisson distribution. The facility employs one repairman specifically to repair these machines. Average repair time is two hours following an exponential distribution.
    a. What is the service factor for this system?
    b. What is the average number of these machines in service?
    c. What is the impact of adding a second repairman?

(a) X = 2/(2+30) = .0625; (b) 4 - .2987 = 3.7123 machines; (c) 4 - .2514 = 3.7486, there is a slight improvement in availability of these machines. The table below summarizes the software results from ExcelOM.

One server		Two servers	
Average server utilization (r)	0.246753	Average server utilization (r)	0.124954
Average number of customers in the queue (L_q)	0.051957	Average number of customers in the queue (L_q)	0.001464
Average number of customers in the system (L)	0.29871	Average number of customers in the system (L)	0.251373
Average waiting time in the queue (W_q)	0.421129	Average waiting time in the queue (W_q)	0.011717
Average time in the system (W)	2.421129	Average time in the system (W)	2.011717
Probability (% of time) system is empty (P_0)	0.753247	Probability (% of time) system is empty (P_0)	0.772099
Effective arrival rate	0.123376	Effective arrival rate	0.124954

(The variety of queuing models, difficult) {AACSB: Analytic Skills}

119. A finite population waiting line model with a single server has an average service time T of 200 minutes and an average time between service requirements U of 300 minutes. Calculate the service factor X. If the population consists of 5 elements, what are the average number waiting, the average number being serviced, and the average number running? Refer to Table D.7.

The service factor is X = T / (T + U) = 200 / (200 + 300) = 0.40. For a population of five, the table factors are D = .952 and F = 0.493. The number waiting is L = N*(1-F) = 5*(1-0.493) = 5*.507 = 2.535. The number being serviced is H = F*N*X = .493*5*.4 = 0.986. The number running is J = N*F*(1-X) = 5*.493*.60 = 1.479. (The variety of queuing models, moderate) {AACSB: Analytic Skills}

120. A finite population waiting line model with a single server has an average service time T of 50 minutes and an average time between service requirements U of 350 minutes. Calculate the service factor X. If the population consists of 5 elements, what are the average number waiting, the average number being serviced, and the average number running? Refer to Table D.7.

The service factor is X = T / (T + U) = 50 / (50 + 350) = 0.125. For a population of five, the table factors are D = .473 and F = 0.920. The number waiting is L = N*(1-F) = 5*(1-0.920) = 5*.080 =0.400. The number being serviced is H = F*N*X = .920*5*.125 = 0.575. The number running is J = N*F*(1-X) = 5*.920*.875 = 4.025. (The variety of queuing models, moderate) {AACSB: Analytic Skills}

MODULE E: LEARNING CURVES

TRUE/FALSE

1. Experience curves may be valid for industrial applications, but have no role in services such as health care procedures.
False (Introduction, easy)

2. Experience curves are the opposite of learning curves—as one rises, the other falls.
False (Introduction, easy)

3. Learning curves are based on the premise that people and organizations become better at their tasks as the tasks are repeated.
True (Introduction, moderate)

4. The earliest application of learning curves appears in the work of architect Frank Lloyd Wright.
False (Introduction, easy)

5. Learning curves can only be applied to labor.
False (Introduction, moderate)

6. If the learning rate for a process is 100 percent, then each unit in a series of units will have the same labor requirements.
True (Introduction, moderate)

7. If the first unit in a series of units takes 200 days to complete, and the learning rate is 80%, then the second unit will take 160 days.
True (Introduction, easy) {AACSB: Analytic Skills}

8. An 80% learning curve means that with each unit increase in production, labor requirements fall by 20%.
False (Introduction, moderate)

9. A 90% learning curve implies that each time the production volume is doubled the direct time per unit is reduced to 90% of its previous value.
True (Introduction, easy)

10. The learning rate in the steel industry and the learning rate in heart surgery have both been estimated at 79 percent.
True (Introduction, and Learning curves in services and manufacturing, moderate)

11. A project manager bases his time and labor estimates on a learning rate of 86%. The actual learning rate turns out to be 89%. The manager, because of the decreased learning, will complete his project in more time and with more labor use.
True (Learning curves in manufacturing and services, moderate)

12. The learning curve may not be permanent; it can be disrupted by changes in process, personnel, or product.
True (Learning curves in services and manufacturing, moderate)

13. Learning curves can be used to establish budgets.
True (Learning curves in services and manufacturing, moderate)

14. The arithmetic approach (or successive doubling approach) to learning curve calculations allows us to determine the hours required for any unit.
False (Applying the learning curve, moderate)

15. The logarithmic approach to learning curve calculations allows us to determine the hours required for any unit.
True (Applying the learning curve, moderate)

16. The learning curve coefficient approach may be simpler to use than the logarithmic approach, but it requires the presence of a table of learning coefficients.
True (Applying the learning curve, moderate)

17. In the formula $T_N=T_1N^b$ for the learning curve, the exponent b is the learning rate, expressed as a decimal.
False (Applying the learning curve, moderate)

18. A firm that successfully pursues a steeper-than-industry-average learning curve and manages costs down may still fail if, by underestimating a strong competitor, it fails to gain the added volume necessary for the learning curve to exist.
True (Strategic implications of learning curves, moderate)

19. On an ordinary graph, unit times decrease at a decreasing rate, but on a log-log graph, the learning "curve" appears as a straight line.
True (Strategic implications of learning curves, moderate)

20. Reevaluation of learning curves is inappropriate.
False (Limitations of learning curves, moderate)

MULTIPLE CHOICE

21. The fundamental premise underlying learning curve analysis is that
    a. tasks can be easily learned in organizations
    b. organizations and people become better at their tasks as the tasks are repeated
    c. learning takes place when people in organizations change
    d. total labor costs decrease as the number of production units increases
    e. doubling output cuts labor requirements per unit in half
    b (Introduction, moderate)

22. Which of the following best conveys the essence of learning curves?
    a. As the number of repetitions increases, time per unit increases.
    b. As the number of repetitions decreases, time per unit increases.
    c. As the number of repetitions increases, time per unit decreases.
    d. As the number of repetitions increases, time per unit remains constant.
    e. As the number of repetitions increases, time per unit doubles.
    c (Introduction, moderate)

23. A learning curve
    a. plots man-hours per dollar versus time
    b. is mathematically described by a parabola
    c. should be plotted on polar coordinate graph paper
    d. is based on the premise that organizations learn from experience
    e. follows a normal distribution
    d (Introduction, easy)

24. Learning curves have a variety of purposes, which can be placed into these broad categories:
    a. services, industry, and military
    b. internal, external, and strategic
    c. wholesale, distribution, and retail
    d. arithmetic, logarithmic, and learning coefficients
    e. positive learning, neutral learning, and negative learning
    b (Introduction, easy)

25. Learning curves (or experience curves) were first applied to industry by _____ who was studying _____.
    a. Frank Lloyd Wright; architecture
    b. Frank Gilbreth; worker efficiency
    c. T. P. Wright; air frame manufacture
    d. Lilian Gilbreth; factory efficiency
    e. Frederick W. Taylor; scientific management
    c (Introduction, easy)

26. A job with a 90% learning curve required 20 hours for the initial unit. The fourth unit should require approximately how many hours?
    a. 16
    b. 16.2
    c. 18
    d. 20
    e. 54.2
    b (Introduction, easy) {AACSB: Analytic Skills}

27. Learning curves can be applied to a variety of purposes internal to a firm, including
    a. labor forecasting
    b. scheduling
    c. establishing costs
    d. establishing budgets
    e. all of these
    e (Introduction, easy)

28. Which of the following statements regarding the usefulness of learning curves is **false**?
    a. An external use of learning curves is in supply chain negotiations.
    b. A strategic use of learning curves is in evaluating company and industry performance.
    c. An internal use of learning curves is in establishing costs.
    d. An internal use of learning curves is in labor forecasting.
    e. A strategic use of learning curves is in establishing budgets.
    e (Introduction, easy)

29. The fact that human activities typically improve when they are done on a repetitive basis is described by a
    a. normal distribution curve
    b. binomial distribution curve
    c. learning curve
    d. Poisson distribution curve
    e. exponential curve
    c (Introduction, easy)

30. A 100% learning curve implies that
    a. learning is taking place for all products and workers
    b. learning is taking place at the best possible level
    c. a 100% reduction in the direct labor time takes place each time the production is doubled
    d. no learning is taking place
    e. None of the above is true.
    d (Introduction, moderate)

31. Which of the following statements is most appropriate with respect to a 70% learning curve?
    a. There will be a 70% decrease in direct labor per unit each time the production volume doubles.
    b. Each successive unit of production will take 70% of the direct labor of the previous unit.
    c. There will be a 30% decrease in direct labor per unit each time production volume doubles.
    d. Thirty percent of the production will be defective until full learning takes place.
    e. None of the above is true.
    c (Introduction, moderate)

32. The learning curve rate is
    a. the percentage of time it will take to make each unit when the production rate doubles
    b. the log-log of the annual rate change divided by the average unit cost
    c. always based on constant value dollars
    d. only considered valid after one year of data is accumulated
    e. always based on a constant work force
    a (Introduction, easy)

33. Which of the following statements comparing learning rates to improvement rates is **true**?
    a. The learning rate is the same as the improvement rate.
    b. The learning rate is a decimal value while the improvement rate is a percentage.
    c. A 90 percent learning curve corresponds to a 10 percent rate of improvement.
    d. Learning rates apply to labor only, while improvement rates apply to all resources.
    e. "Learning rates" is American usage, while "improvement rates" is British.
    c (Learning curves in services and manufacturing, easy)

34. Learning curves are
    a. the same for all products but different for different organizations
    b. the same for all organizations but different for different products
    c. the same for all organizations and all products
    d. different for different organizations and different products
    e. appropriate in services but not in manufacturing
    d (Learning curves in services and manufacturing, moderate

35. The learning rate depends on the characteristics of a company. Which one of the following companies usually has the lowest learning rate and, therefore, the most learning?
    a. a product-focused company which produces high-volume products to stock
    b. a process-focused company which accepts orders from different customers with different specifications
    c. a company with a newly-installed flexible manufacturing system (FMS)
    d. a continuous process company
    e. a labor intensive company

    e (Learning curves in services and manufacturing, difficult)

36. Which one of the following statements about learning curves is **true**?
    a. A learning curve assumes that the direct labor requirements per unit will DECREASE at an INCREASING rate as cumulative production increases.
    b. Learning at a capital intensive operation will usually be LESS than it is for a labor intensive operation.
    c. Learning for simple products will usually be MORE than it is for complex products.
    d. Learning curves can be used only for individuals, not for the whole organization
    e. None of the above is true.

    b (Learning curves in services and manufacturing, moderate)

37. The learning rate for a product is 80 percent. The first unit took 100 hours to complete. The manufacturer wants to determine how many hours the fifth unit will take by using the logarithmic method. The coefficient **b** for that calculation is approximately
    a. -.0969
    b. -.2231
    c. -.3219
    d. .80
    e. 1.903

    c (Learning curves in services and manufacturing, moderate) {AACSB: Analytic Skills}

38. The learning rate for a product is 90 percent. The first unit took 10 hours to complete. The manufacturer wants to determine how many hours the fourth unit will take by using the logarithmic method. The coefficient **b** for that calculation is approximately
    a. -.1053
    b. -.1520
    c. -.3219
    d. .6931
    e. 8.1

    b (Learning curves in services and manufacturing, moderate) {AACSB: Analytic Skills}

39. The first unit of a product took 832 hours to build, and the learning rate is 75%. How long will it take to make the 10th unit? (Use at least three decimals in the exponent if you use the logarithmic approach.)
    a. less than 250 hours
    b. from 251 to 275 hours
    c. from 276 to 300 hours
    d. from 301 to 325 hours
    e. 325 or more hours

    d (Applying the learning curve, moderate) {AACSB: Analytic Skills}

40. The first unit of a product took 832 hours to build, and the learning rate is 75%. How long will it take to make the 30th unit? (Use at least three decimals in the exponent if you use the logarithmic approach.)
    a. less than 200 hours
    b. from 200 to 225 hours
    c. from 225 to 250 hours
    d. from 2501 to 275 hours
    e. 275 or more hours
    b (Applying the learning curve, moderate) {AACSB: Analytic Skills}

41. The first unit of a product took 832 hours to build, and the learning rate is 90%. How long will it take to make the 25th unit? (Use at least three decimals in the exponent if you use the logarithmic approach.)
    a. time $\leq$ 500 hours
    b. 500 < time $\leq$ 525
    c. 525 < time $\leq$ 530
    d. 530 < time $\leq$ 550
    e. time > 550
    b (Applying the learning curve, moderate) {AACSB: Analytic Skills}

42. The first unit of a product took 50 hours to build, and the learning rate is 80%. How long will it take to make the third unit? (Use at least three decimals in the exponent if you use the logarithmic approach.)
    a. under 30 hours
    b. about 32 hours
    c. about 35 hours
    d. about 50 hours
    e. about 75 hours
    c (Applying the learning curve, moderate) {AACSB: Analytic Skills}

43. The first unit of a product took 50 hours to build, and the learning rate is 85%. How long will it take to make the 10th unit? (Use at least three decimals in the exponent if you use the logarithmic approach.)
    a. less than 24 hours
    b. from 25 to 30 hours
    c. from 30 to 35 hours
    d. from 35 to 40 hours
    e. more than 40 hours
    b (Applying the learning curve, moderate) {AACSB: Analytic Skills}

44. The first unit of a product took 1,000 hours to build and the learning curve is 85%. How long will it take to make the first 5 units? (Use Table E.3)
    a. less than 4,005 hours
    b. from 4,005 to 4,015 hours
    c. from 4,015 to 4,025 hours
    d. from 4,025 to 4,035 hours
    e. from 4,035 to 4,045 hours
    d (Applying the learning curve, moderate) {AACSB: Analytic Skills}

45. The first unit of a product took 900 hours to build and the learning curve is 90%. How long will it take to make the first 3 units? (Use Table E.3)
    a. less than or equal to 2,470 hours
    b. from 2,470 to 2,472 hours
    c. from 2,472 to 2,475 hours
    d. from 2,475 to 2,478 hours
    e. from 2,478 to 2,481 hours
    b (Applying the learning curve, moderate) {AACSB: Analytic Skills}

46. The first unit of a product took 80 work days. The learning rate is estimated to be 90%. The time for the fourth unit will be about ____ work days and the time for the first four units will be about ____ work days. (Use Table E.3)
    a. 51; 250
    b. 250; 51
    c. 65; 285
    d. 51; cannot be determined
    e. 65; cannot be determined
    c (Applying the learning curve, moderate) {AACSB: Analytic Skills}

47. A defense contractor has just started producing turbines for a new government contract. The first turbine took 7000 hours to produce. If the learning curve is 90%, how long will it take to produce the 10th turbine? (Use at least three decimals in the exponent if you use the logarithmic approach.)
    a. less than 4800 hours
    b. from 4800 to 4900 hours
    c. from 4900 to 5000 hours
    d. from 5000 to 5100 hours
    e. over 5100 hours
    c (Applying the learning curve, moderate) {AACSB: Analytic Skills}

48. A defense contractor has just started producing engines for a new government contract. The first engine took 800 hours to produce. If the learning rate is 80%, how long will it take to produce the first 20 engines? (Use at least three decimals in the exponent if you use the logarithmic approach.)
    a. less than or equal to 1000 hours
    b. from 1000 to 8000 hours
    c. from 8000 to 8500 hours
    d. from 8500 to 10000 hours
    e. 10,000 or more hours
    c (Applying the learning curve, moderate) {AACSB: Analytic Skills}

49. It took 60 hours to make the first unit of a product. After the second and third units were made, the learning rate was estimated to be 80%. At $10 per hour, estimate the labor bill for the fourth unit. (Use at least three decimals in the exponent if you use the logarithmic approach.)
    a. $400 or less
    b. from $400 to $420
    c. from $420 to $440
    d. from $1800 to $2000
    e. over $2000
    a (Applying the learning curve, moderate) {AACSB: Analytic Skills}

50. A manager is trying to estimate the appropriate learning curve for a certain job. The manager notes that the first four units had a total time of 30 minutes. Which learning curve would yield approximately this result if the first unit took 9 minutes?
    a. 0.70
    b. 0.75
    c. 0.80
    d. 0.85
    e. 0.90
    d (Applying the learning curve, difficult) {AACSB: Analytic Skills}

51. Which one of the following courses of actions would **not** be taken by a firm wanting to pursue a learning curve steeper than the industry average?
    a. following an aggressive pricing policy
    b. focusing on continuing cost reduction
    c. keeping capacity equal to demand to control costs
    d. focusing on productivity improvement
    e. building on shared experience
    c (Strategic implications of learning curves, moderate)

52. Which of the following is **false** regarding learning curves?
    a. Learning curves differ from company to company.
    b. Learning curves can always be used for indirect labor.
    c. Changes in personnel can change the learning curve.
    d. The learning curve may spike for a short time even if it is going to drop in the long run.
    e. All of the above are true.
    b (Limitations of learning curves, moderate)

53. Which of the following is a limitation of the use of learning curves?
    a. Change in personnel, design, or procedure leave the learning curve unchanged.
    b. Learning curves are applicable to services as well as to manufacturing.
    c. The culture of the workplace may alter the learning curve.
    d. Direct labor and indirect labor follow the same learning curves.
    e. Applications of learning curves are of tactical, not strategic, importance.
    c (Limitations of learning curves, easy)

54. Which of the following is **not** a limitation of the use of learning curves?
    a. Any change in personnel, design, or procedure can alter the learning curve.
    b. Time measurements on early units completed must be accurate.
    c. The culture of the workplace may alter the learning curve.
    d. Direct labor and indirect labor may not follow the same learning curves.
    e. All of these are limitations of learning curves.
    e (Limitations of learning curves, easy)

FILL-IN-THE-BLANK

55. The earliest industrial application of learning curves came from a report by _____.
    T. P. Wright (Introduction, easy)

56. _____ are based on the premise that people and organizations get better at their tasks as the tasks are repeated.
Learning curves (Introduction, easy)

57. If the learning rate for a process is 80 percent, that same process has a 20 percent _____.
improvement rate (Learning curves in services and manufacturing, moderate)

58. Failure to consider the effects of learning can lead to _____ of labor needs.
overestimates (Learning curves in services and manufacturing, moderate)

59. The _____ is the simplest approach to learning curve problems.
arithmetic approach (Applying the learning curve, moderate)

60. To use the table of learning curve coefficients, you must specify _____ and _____.
the learning rate, the unit of interest (Applying the learning curve, moderate)

61. When learning curves are plotted on _____scales, the "curves" become straight lines.
logarithmic or log-log (Strategic implications of learning curves, easy)

SHORT ANSWERS

62. Describe the earliest application of learning curve concepts to industry.
T. P. Wright, working for Curtis-Wright Corp. in the 1930s, described how labor costs of building aircraft decreased with learning. (Introduction, easy)

63. In addition to labor, to which other variables have learning curves been applied?
The text cites materials and purchased components. The text also names surgical survival rates as a variable that improves with learning. (Introduction, easy)

64. What is the basic premise underlying the learning curve?
The basic premise underlying the learning curve is that organizations, like people, become better at their tasks as the tasks are repeated. (Introduction, easy)

65. Why do different organizations have different learning curves?
The rate of learning varies depending upon the quality of management and the potential of the process and product. (Learning curves in services and manufacturing, moderate)

66. When comparing a 70% learning curve versus a 90% learning curve, which one results in a more rapid reduction in labor requirements? Why?
Learning curves are defined in terms of the complements of their improvement rates. A 70% learning curve implies a 30% decrease in time each time the number of replications is doubled. A 90% learning curve implies a 10% decrease in time each time the number of replications is doubled. Therefore, the reduction in labor requirements is more rapid at 70% than at 90%. (Learning curves in services and manufacturing, moderate)

67. What problems in scheduling can arise if adjustments for learning curve effects in operations are not made?
Labor and productive facilities being idle a portion of the time; and firms may refuse additional work because improvements that result from learning are not considered. (Learning curves in services and manufacturing, moderate)

68. "By tradition, learning rates are defined in terms of the complements of their improvement rates." Explain.
The improvement in labor usage might be expressed as a 10% reduction. The complement of 10% is 90%. We refer to learning not by the 10% improvement, but by improvement to 90% of the old value. The latter number, not the former, expresses learning rates. (Learning curves in services and manufacturing, moderate)

69. Two manufacturers have very different learning rates; one is under 70% while the other is over 80%. What factors might lead to such a gap?
The two firms might not have the same labor content in their output: learning is generally associated with high labor content output. The two firms might not have equally standardized outputs; if the product keeps changing, there is limited basis for learning to occur. One firm might be engaged in high-volume, standardized production where little learning remains. (Learning curves in services and manufacturing, moderate)

70. Explain how learning curves might be applied in a scheduling application.
Learning curves can determine the total labor required to produce a specified number of units. Knowing the unit and total labor requirements, managers can better calculate how long before each unit will be finished, and can schedule shipment of finished goods accordingly. Also, managers can determine how many workers to schedule during the manufacturing process; that number might fall as learning takes place. (Introduction, easy) {AACSB: Reflective Thinking}

71. Explain how learning curves might be applied in a bid preparation application.
Learning curves can determine the reduction in labor and/or materials required to produce a specified number of units. Knowing these cost components, managers are better prepared to determine what to bid and when to promise finished goods. (Introduction, easy) {AACSB: Reflective Thinking}

72. Identify one advantage and one disadvantage of the arithmetic approach over the logarithmic approach to learning curve calculations.
Advantage: simplest approach to learning curve problems. Disadvantage: can't find values for every value of n, only for exact doublings. (Applying learning curves, moderate)

73. What cautions are in order when using learning curves?
The cautions when using learning curves include:
1. Estimates for each organization should be developed rather than applying someone else's.
2. When current information becomes available, reevaluation is appropriate.
3. Any change in personnel, design, or procedure can be expected to alter the learning curve.
4. Learning curves do not always apply to indirect labor and materials.
5. The culture of the work place, as well as resource availability and changes in the process, may alter the learning curve. (Limitations of learning curves, moderate)

74. What can cause a learning curve to vary from a smooth downward slope?
Several factors can affect the smooth downward slope of a learning curve, including new technology, phasing out of a product line, moving experienced employees to a new line. (Limitations of learning curves, moderate)

PROBLEMS

75. In the logarithmic approach to learning curve calculations, you have used the formula $T_N = T_1 \cdot (N^b)$. For a problem with a 92 percent learning rate, what is **b**?
$b = \frac{\log r}{\log 2} = \frac{\log .92}{\log 2} = \frac{-.03621}{.30103} = -.12029$. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

76. In the logarithmic approach to learning curve calculations, you have used the formula $T_N = T_1 \cdot (N^b)$. Your manager shows you a problem for which **b** is specified as -.18442. What learning rate does that value represent?
The easiest way to answer is to assume T_1 =1, and multiply that by 2 raised to the power b. That will give the result 0.88, which is the learning rate. To verify, b for 88 percent learning is: $b = \frac{\log r}{\log 2} = \frac{\log .2}{\log 2} = \frac{-.05552}{.30103} = -.18442$. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

77. In the Learning-Curve Coefficients table for 70 percent learning, the sixth unit has a unit time value of 0.398. Verify that table entry by use of the logarithmic formula. Use five decimals in your work.
The factor b for 70 percent learning is log .7 / log 2 = -.15490 / .30103 = -.51457. For the sixth unit, the logarithmic approach results in $6^{-.51457}$ = .39773. This differs from the table entry only by rounding. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

78. The Learning-Curve Coefficients table reports that for 70 percent learning, the eighth unit has a unit time value of 0.343. Verify that table entry by use of the arithmetic method.
Successive doubling at 70 percent learning results in a factor of .700 for unit two, .490 for unit four, and 0.343 for unit eight. (Applying the learning curve, easy) {AACSB: Analytic Skills}

79. Your firm has a contract to make 20 specialty lenses for night vision equipment. The first one took 40 hours. Learning is expected at the 85% rate. How long will it take to finish all 20 units?
The best solution method uses Table E.3. For 85 percent learning, total time for 20 units, the table factor is 12.402. Total time for all 20 units is 12.402 * 40 = 496.1 hours. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

80. Your firm has expertise with a special type of hand-finished furniture. The learning rate is known to be 82%. If the first piece of furniture took 6 hours, use the logarithmic approach to determine how long it will take to do the third unit.
For 82% learning, the factor b = log(.82)/log(2) = -0.2863. $T_3 = T_1N^b = 6(3)^{-0.2863} = 6 * 0.7301 = 4.38$ hours. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

81. Your firm has expertise with a special type of hand-finished furniture. The learning rate is known to be 82%. If the first piece of furniture took 6 hours, *estimate* how long it will take to complete the third unit.
Using the arithmetic approach, the second unit will take 0.82 * 6 = 4.92 hours and the fourth unit will take 0.82 * 0.82 * 6 = 4.03 hours. The third unit must take an amount of labor between these two values, but not exactly halfway. There is more absolute improvement from unit 2 to unit 3 than from unit 3 to unit 4. A reasonable estimate would be about 4.4 or 4.5 hours (the answer from Excel OM is 4.38 hours). (Applying the learning curve, moderate) {AACSB: Analytic Skills}

82. The first unit took 79 hours; the tenth took 46 hours. What learning rate is implied by the data?
The improvement is 46/79 = 0.582 at 10 units; this closely matches the learning rate of 85%. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

83. Your firm has expertise with a special type of hand-finished furniture. The learning rate is known to be 82%. If the first piece of furniture took 6 hours, how long will it take to do the second? How long will it take to do the fourth?
Use the successive doubling (arithmetic) approach. The second will take 0.82 * 6 = 4.92 hours; the fourth will take 0.82 * 0.82 * 6 = 4.03 hours. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

84. You are about to undertake manufacture of a labor-intensive electronics component. The first unit took 300 hours. You are not sure whether the learning rate is 70% or 80%. The initial phase of the contract calls for 6 of these components.
a. How much time will it take to complete all six at 70% learning?
b. How much time will it take to complete all six at 80% learning?
From Table E.3, 70 percent learning, the factor for total time for six units is 3.593; for 80 percent learning, the factor is 4.299. (a) 3.593 * 300 = 1077.8 hours; (b) 4.299 * 300 = 1289.8 hours. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

85. A certain product under development took 200 hours for the production of its 2nd unit and 180 hours for its 4th unit.
a. What is the learning rate?
b. How much time did the first unit take?
c. How much time would the production of the 10th unit take? (Use both the logarithmic and the Table E.3 approach. Do the two versions agree?)
(a) 90%; (b) 222.2 hours; (c) $T_{10} = T_1N^b = 222.2(10)^{-.152}$ = 156.6 hours; from Table E.3, 222.2 * 0.705 = 156.7 hours. They generate the same result. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

86. A contractor builds large ships for the Department of Defense. A recent contract called for 12 amphibious landing platforms. It was originally estimated that the first of these would cost $1 billion and that 80 percent learning would be appropriate. In fact, the first ship cost $1.6 billion and the second $1.12 billion. What is the revised learning rate? What will be the total cost of the twelve ships? Is it higher or lower than the original estimates? If the defense department cuts the contract from 12 ships to 9, what happens to the average cost per ship?
The original estimates called for $1 billion * 7.227 = $7.227 billion for 12 ships. The revised learning rate is 70 percent. At the revised costs and learning rates, 12 ships will cost $1.6 billion * 5.501 = $8.802 billion. If the contract is reduced to 9 ships, the cost would be $1.6 billion * 4.626 = $7.402 billion. The average cost of 12 ships is $773.5 million each; the average cost of nine is $822.4 million each. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

87. A small manufacturer that offers "hand crafted" furniture has developed a new style of desk that they believe will be very successful in the marketplace. It is expected that the first desk will take about 60 hours of craftsmen's time to complete. They expect a 90% learning curve for this desk. How long will it take to make the 20th desk? The firm is considering accepting an order for 25 desks. How many hours of labor will this require for all 25?
The 20th desk will require 38.1 hours. All 25 will require 1063 hours.
(Applying the learning curve, moderate) {AACSB: Analytic Skills}

88. Your company is making experimental turbochargers for a new design of high-powered farm tractors. The production schedule for these new components is contained in the table below.

Month	Turbochargers
1	4
2	6
3	7
4	8
5	5

The first turbocharger, a trial unit, took 900 hours to produce. Based on your experience with similar products, the learning factor is 85%. You have 20 employees, and each employee works 160 hours per month. How many hours will be required in each month? In which month(s) will overtime be required to meet the production schedule?

Use the Total time column of the 85% section of Table E.3. The first four turbochargers require 900 * 3.345 = 3,010 hours. The first 10 turbochargers require 900 * 7.116 = 6,404 hours. From this answer, deduce that units 5 through 10 take 6,404 – 3,010 = 3,394 hours. The 20 employees contribute 3200 hours per month. Therefore, overtime is not needed in the first month but is needed in the second. Overtime is also needed in months 3 and 4, but not in month 5. The table below contains calculation details. (Applying the learning curve, difficult) {AACSB: Analytic Skills}

Month	Number of Turbochargers	Cumulative Turbochargers	Total Time Factor From Table E.3	Cumulative hours	Hours this month
1	**4**	**4**	**3.345**	**3,010**	**3,010**
2	**6**	**10**	**7.116**	**6,404**	**3,394**
3	**7**	**17**	**10.898**	**9,808**	**3,404**
4	**8**	**25**	**14.801**	**13,321**	**3,513**
5	**5**	**30**	**17.091**	**16,111**	**2,790**

89. Sally suspects strongly that there is a learning curve associated with solving problems assigned for operations management. She notes that it took her approximately 33 minutes to solve the first problem and 20 minutes to solve the fifth problem.

a. Estimate Sally's learning percentage.

b. Using your answer from part a, estimate how much longer it will take Sally to finish the three problems that remain.

(a) Her improvement from the first to fifth unit is 20/33 = 0.606. This value is close to the entry 0.596 for the fifth unit under the 80% learning rate column of Table E.3. Thus her learning rate is 80%. (b) The total for eight problems is 33 * 5.346 = 176.4 minutes. She has already spent 33 * 3.738 = 123 minutes on the first five problems. She has 53 minutes remaining. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

90. Joe's Manufacturing is considering bidding on a small order for 5 units. Based on similar products that they have made in the past, they believe that the first unit will take 500 labor hours. They also believe that there will be an 80% learning rate. How many hours of labor should Joe include for his bid?
From Table E.3, the total time factor for 5 units and 80 percent learning is 3.738. The total number of labor hours for all five units would be 500 * 3.738 = 1,869 hours.
(Applying the learning curve, moderate) {AACSB: Analytic Skills}

91. A company is preparing a bid on a government contract for 40 units of a certain product. The operations manager estimates the assembly time required for the first two units to be 10.4 hours and 8.3 hours, respectively.
a. What is the appropriate learning curve?
b. What is the average time per unit for the 40 units?
c. Which unit, if any, will require approximately one-half the time of the first unit?
(a) The learning rate is 8.3/10.4 = 0.798 or approximately 80%. (b) The group of 40 units will take 10.4 * 17.193 = 178.8 hours total, for an average of 4.47 hours each. (c) The 9th unit has a unit time factor of 0.493, meaning that it requires approximately 50% of the labor of the first unit. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

92. A small manufacturer builds wooden pleasure boats in a craftsman manner by traditional labor-intensive methods. The first boat is estimated to take 650 hours of skilled labor, which cost $40 per hour. They currently have three workers that can work 2,000 hours a year. They assume that there is a 90% learning rate. How many boats can they make in their first year?
The number of hours available for the first year is 6,000 hours. Use the total time factor from the 90 percent column of Table E.3. The total number of hours needed to make eleven units is 650 * 8.689 = 5,648 hours; twelve would require 650 * 9.374 = 6,093 hours.
(Applying the learning curve, moderate) {AACSB: Analytic Skills}

93. You are a cost accountant for a firm that specializes in "small" (under 10 billion dollars) defense contracts for specialty electronics products, such as fully portable, miniaturized CD-ROM imaging stations and global positioning transmitters/transponders. Your company is well respected in this field. One project up for competitive bids is a Field Service, Hands-Free, Individual Multi-Protocol Secure Communicator (a battlefield version of a cellular telephone, but built into each soldier's helmet, and containing necessary encryption technology). The Department of Defense wants 8 of these experimental devices to test their practicality. You have reviewed the contract specifications, and estimated that the first FSHFIMPSC should require 2350 hours, and that the product is subject to a 75% learning rate. All costs of the project (machine purchase, machine time, direct and indirect labor, and materials) have been bundled (allocated) into an hourly labor rate of $172 per hour. Determine the total project cost using the provided data.
From Table E.3, 2350 * 4.802 = 11,284.7 hours will be needed. At $172 per hour, the total cost is $1,940,968.40. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

94. A metal works fabricator is about to release a new model of his firm's copper sculpture and fountain. The operations manager estimates that this product is subject to a 90 percent learning rate on labor only—the material bill is not affected by experience. The firm prices its work based on cost—the sum of materials plus 30 percent and labor plus 50 percent. (This allows the firm to practice a little "demand management" for its very popular works.) The first item has already been finished; the material bill was $800 and labor totaled 40 hours. The firm pays its metalworking artisans an average of $18 per hour. What should be the asking price of the first unit? The second?
Based on the pricing formula, the first unit should be priced at $800*1.30 + 40*$18*1.50 = $1,040 + $1,080 = $2,120. The second unit will be cheaper because of the learning effect: $800*1.30 + 36*$18*1.50 = $1,040 + 972 = $2,012. (Applying the learning curve, moderate) {AACSB: Analytic Skills}

MODULE F: SIMULATION

TRUE/FALSE

1. Simulation has numerous applications in modern business, but few of these are in the area of operations.
False (Introduction, easy)

2. All forms of simulation are based on probability or chance.
False (Introduction, easy)

3. The idea behind simulation is threefold: (1) to imitate a real-world situation mathematically, (2) then to study its properties and operating characteristics, and (3) finally to draw conclusions and make action decisions based on the results of the simulation.
True (What is simulation?, easy)

4. Simulation is usually capable of producing a more appropriate answer to a complex problem than can be obtained from a mathematical model.
True (What is simulation? moderate)

5. Virtually all large-scale simulations take place on computers, but small simulations can be conducted by hand.
True (What is simulation? easy) {AACSB: Use of IT}

6. One effective use of simulation is to study problems for which the mathematical models of operations management are not realistic enough.
True (Advantages and disadvantages of simulation, moderate)

7. Simulation allows managers to test the effects of major policy decisions on real-life systems without disturbing the real system.
True (Advantages and disadvantages of simulation, moderate)

8. Simulation provides optimal solutions to problems.
False (Advantages and disadvantages of simulation, moderate)

9. Like mathematical and analytical models, simulation is restricted to using the standard probability distributions.
False (Advantages and disadvantages of simulation, moderate)

10. Simulation models are inexpensive to design and use.
False (Advantages and disadvantages of simulation, moderate)

11. Simulation models, because they are based on the generation of random numbers, fail to give the same solution in repeated use to any particular problem.
True (Advantages and disadvantages of simulation, moderate)

12. By starting random number intervals at 01, not 00, the top of each range is the cumulative probability.
True (Monte Carlo simulation, moderate)

13. A simulation model is designed to arrive at a single specific numerical answer to a given problem.
False (Advantages and disadvantages of simulation, moderate)

14. A simulation is "Monte Carlo" when the elements of a system being simulated exhibit chance in their behavior.
True (Monte Carlo simulation, moderate)

15. Random number intervals are based on cumulative probability distributions.
True (Monte Carlo simulation, moderate)

16. Simulation is the attempt to duplicate the features, appearance, and characteristics of a real system, usually via a computerized model.
True (What is simulation?, easy)

17. Results of simulation experiments with large numbers of trials or long experimental runs will generally be better than those with fewer trials or shorter experimental runs.
True (Monte Carlo simulation, moderate)

18. Some reasons for the use of simulation in queuing are that the four standard queuing models do not allow for LIFO (or LIFS) discipline, for multi-phase waiting lines, or for unusual arrival and service distributions.
True (Simulation of a queuing problem, easy)

19. In most real-world inventory problems, lead time and demand vary in ways that make simulation a necessity because mathematical modeling is extremely difficult.
True (Simulation and inventory analysis, easy)

20. One reason for using simulation rather than an analytical model in an inventory problem is that the simulation is able to handle probabilistic demand and lead times.
True (Simulation and inventory analysis, moderate)

21. The Las Vegas method is a simulation technique that uses random elements when chance exists in their behavior.
False (Monte Carlo simulation, easy)

22. Simulation can use any probability distribution that the user defines.
True (Advantages and disadvantages of simulation, moderate)

MULTIPLE CHOICE

23. Which of the following statements regarding simulation is true?
    a. Simulation can be physical or mathematical.
    b. Simulation has numerous areas of application in operations.
    c. Simulation attempts to duplicate a real system.
    d. Monte Carlo simulation is a chance-based mathematical model of a real system.
    e. All of these are true.
    e (What is simulation?, moderate)

24. Which of the following is **not** an application of simulation in the area of operations?
    a. personnel scheduling
    b. truck dispatching
    c. plant (or facility) layout
    d. inventory management using EOQ principles
    e. inventory planning and control
    d (What is simulation?, moderate)

25. The seven steps in the use of simulation include all but which of the following?
    a. Define the problem.
    b. Construct a mathematical model.
    c. Introduce important variable associated with the problem.
    d. Find the optimal solution.
    e. Run the experiment.
    d (What is simulation?, moderate)

26. Which of the following is **true** regarding simulation?
    a. Small problems can be done by hand.
    b. Most simulations are computerized.
    c. Real-world complications can be included in simulation models.
    d. Simulation is most suitable where standard analytical models are too complex.
    e. All of the above are true.
    e (Advantages and disadvantages of simulation, moderate) {AACSB: Use of IT}

27. Which of the following is **true** regarding simulation?
    a. If an analytical model can't solve a problem, neither can a simulation.
    b. Simulation can only be done by computer.
    c. Monte Carlo simulation requires the use of random numbers.
    d. Simulation models are inexpensive.
    e. All of the above are true.
    c (Advantages and disadvantages of simulation, moderate)

28. Which of the following is **true** regarding the use of simulation?
    a. It is always very easy to build a simulation model.
    b. It is very inexpensive to use a simulation model.
    c. It always yields optimum solutions.
    d. It allows time-compression in testing major policy decisions.
    e. Few constraints, if any, have to be considered.
    d (Advantages and disadvantages of simulation, moderate)

29. Simulation is used for several reasons, including
    a. MODEL development is a fast process
    b. it is inexpensive
    c. the models are usually simple
    d. it can handle large and complex real-world problems
    e. it always generates optimal solutions
    d (Advantages and disadvantages of simulation, moderate)

30. One of the advantages of simulation is that
    a. it is much less expensive than a mathematical solution
    b. it always generates a more accurate solution than a mathematical solution
    c. the policy changes may be tried out without disturbing the real-life system
    d. model development is less time consuming than for mathematical models
    e. model solutions are transferable to a wide variety of problems
    c (Advantages and disadvantages of simulation, moderate)

31. One of the disadvantages of simulation is that it
    a. does not allow for very complex problem solutions
    b. is not very flexible
    c. is a trial-and-error approach that may produce different solutions in different runs
    d. is very limited in the type of probability distribution that can be used
    e. interferes with the production systems while the program is being run
    c (Advantages and disadvantages of simulation, moderate)

32. "Time compression" and the ability to pose "what-if" questions are elements of
    a. Monte Carlo analysis
    b. the disadvantages of simulation
    c. physical simulations but not mathematical simulations
    d. the advantages of simulation
    e. the broad threefold idea of simulation
    d (Advantages and disadvantages of simulation, moderate)

33. Setting up a probability distribution, building a cumulative probability distribution, and generating random numbers are
    a. necessary when the underlying probability distribution is normal
    b. three of the five steps in Monte Carlo analysis
    c. elements of physical simulation but not mathematical simulation
    d. the three steps involved in simulating a queuing problem
    e. advantages of simulation
    c (Monte Carlo simulation, moderate)

34. From a portion of a probability distribution, you read that P(demand = 0) is 0.05 and P(demand = 1) is 0.10. The **cumulative** probability for demand ≤ 1 would be
    a. 0.05
    b. 0.075
    c. 0.10
    d. 0.15
    e. cannot be determined
    d (Monte Carlo simulation, moderate) {AACSB: Analytic Skills}

35. From a portion of a probability distribution, you read that P(demand = 1) is 0.05, P(demand = 2) is 0.15, and P(demand = 3) is .20. The **cumulative** probability for demand ≤ 3 would be
    a. 0.133
    b. 0.200
    c. 0.400
    d. 0.600
    e. cannot be determined from the information given
    e (Monte Carlo simulation, moderate) {AACSB: Analytic Skills}

36. From a portion of a probability distribution, you read that P(demand = 0) is 0.05, P(demand = 1) is 0.10, and P(demand = 2) is 0.20. The two-digit random number intervals for this distribution beginning with 01 are
    a. 01 through 05, 01 through 10, and 01 through 20
    b. 00 through 04, 05 through 14, and 15 through 34
    c. 01 through 05, 06 through 15, and 16 through 35
    d. 00 through 04, 00 through 09, and 00 through 19
    e. 01 through 06, 07 through 16, and 17 through 36
    c (Monte Carlo simulation, moderate) {AACSB: Analytic Skills}

37. From a portion of a probability distribution, you read that P(demand = 0) is 0.25, and P(demand = 1) is 0.30. The random number intervals for this distribution beginning with 01 are
    a. 01 through 25, and 26 through 30
    b. 01 through 25, and 01 through 30
    c. 01 through 25, and 26 through 55
    d. 00 through 25, and 26 through 55
    e. 00 through 25, and 26 through 30
    c (Monte Carlo simulation, moderate) {AACSB: Analytic Skills}

38. A distribution of service times at a waiting line indicates that service takes 6 minutes 30 percent of the time, 7 minutes 40 percent of the time, 8 minutes 20 percent of the time, and 9 minutes 10 percent of the time. In preparing this distribution for Monte Carlo analysis, the service time 8 minutes would be represented by the random number range
    a. 20 through 40
    b. 21 through 40
    c. 70 through 90
    d. 71 through 90
    e. none of these
    d (Monte Carlo simulation, moderate) {AACSB: Analytic Skills}

39. A distribution of service times at a waiting line shows that service takes 6 minutes 30 percent of the time, 7 minutes 40 percent of the time, 8 minutes 20 percent of the time, and 9 minutes 10 percent of the time. This distribution has been prepared for Monte Carlo analysis. The first two random numbers drawn are 53 and 74. The simulated service times are ____ minutes, then ____ minutes.
    a. 6; 7
    b. 7; 7
    c. 7; 8
    d. 8; 9
    e. cannot determine, because no service time probability is that large
    c (Monte Carlo simulation, moderate) {AACSB: Analytic Skills}

40. A distribution of service times at a waiting line indicates that service takes 12 minutes 30 percent of the time and 14 minutes 70 percent of the time. In preparing this distribution for Monte Carlo analysis, the service time 13 minutes would be represented by the random number range
    a. 00 through 29
    b. 01 through 30
    c. 30 through 99
    d. 31 through 00
    e. none of these; 13 minutes is not a possible outcome
    e (Monte Carlo simulation, moderate) {AACSB: Analytic Skills}

41. A distribution of service times at a waiting line indicates that service takes 12 minutes 30 percent of the time and 14 minutes 70 percent of the time. This distribution has been prepared for Monte Carlo analysis. The first four random numbers drawn are 07, 60, 77, and 49. The average service time of this simulation is
    a. 12 minutes
    b. 13 minutes
    c. 13.5 minutes
    d. 14 minutes
    e. none of these
    c (Monte Carlo simulation, moderate) {AACSB: Analytic Skills}

42. A distribution of lead times in an inventory problem indicates that lead time was 1 day 20 percent of the time, 2 days 30 percent of the time, 3 days 30 percent of the time, and. 4 days 20 percent of the time. This distribution has been prepared for Monte Carlo analysis. The first four random numbers drawn are 06, 63, 57, and 02. The average lead time of this simulation is
    a. 1.75 days
    b. 2 days
    c. 3 days
    d. 3.5 days
    e. none of these
    b (Monte Carlo simulation, moderate) {AACSB: Analytic Skills}

43. The effects of OM policies over many months or years can be obtained by computer simulation in a short time. This phenomenon is referred to as
    a. time suppression
    b. time suspension
    c. time compression
    d. time inversion
    e. time conversion
    c (Advantages and disadvantages of simulation, moderate) {AACSB: Use of IT}

44. One of the disadvantages of simulation is that it
    a. does not allow for very complex problem solutions
    b. is not very flexible
    c. may be very expensive and time-consuming to develop
    d. is very limited in the type of probability distribution that can be used
    e. interferes with the production systems while the program is being run
    c (Advantages and disadvantages of simulation, moderate)

45. One of the disadvantages of simulation is that it
    a. does not allow for very complex problem solutions
    b. produces solutions and inferences that are not usually transferable to other problems
    c. cannot study the interactive effects of individual components or variables
    d. is very limited in the type of probability distribution that can be used
    e. interferes with the production systems while the program is being run
    b (Advantages and disadvantages of simulation, moderate)

46. One of the advantages of simulation is that
    a. it is much less expensive than a mathematical solution
    b. it always generates a more accurate solution than a mathematical solution
    c. it can study the interactive effects of individual components or variables
    d. model development is less time consuming than for mathematical models
    e. model solutions are transferable to a wide variety of problems
    c (Advantages and disadvantages of simulation, moderate)

47. One of the advantages of simulation is that
    a. real-world complications can be included that most OM models cannot permit
    b. it always generates a more accurate solution than a mathematical solution
    c. it is a trial-and-error approach that may produce different solutions in repeated runs
    d. model development is less time consuming than for mathematical models
    e. model solutions are transferable to a wide variety of problems
    a (Advantages and disadvantages of simulation, moderate)

FILL-IN-THE-BLANK

48. _____ is the attempt to duplicate the features, appearance, and characteristics of a real system, usually via a computerized model.
    Simulation (What is simulation? easy) {AACSB: Use of IT}

49. The _____ method is a simulation technique that uses random elements when chance exists in their behavior.
    Monte Carlo (What is simulation? moderate)

50. A(n) _____ is the accumulation of individual probabilities of a distribution.
    cumulative probability distribution (Monte Carlo simulation, moderate)

51. A(n) _____ is a series of digits that have been selected by a totally random process.
    random number (Monte Carlo simulation, moderate)

52. The effects of OM policies over many months or years can be obtained by computer simulation in a short time. This phenomenon is referred to as _____ .
    time compression (Advantages and disadvantages of simulation, moderate) {AACSB: Use of IT}

53. The numbers used to represent each possible value or outcome in a computer simulation are referred to as _____ .
    random-number intervals (Monte Carlo simulation, moderate) {AACSB: Use of IT}

SHORT ANSWERS

54. Would you simulate a problem for which there is an exact mathematical model already?
In terms of getting the problem solved, the mathematical model would be preferred. The problem would have an exact or optimal answer calculated by the mathematical model. Simulating this problem would introduce variability in the form of simulation results that differ with each run. However, there might be some gain in understanding from simulating a problem that is already well modeled. Such simulation might be of benefit in debugging a simulation program. (Advantages and disadvantages of simulation, moderate) {AACSB: Reflective Thinking}

55. Define simulation.
Simulation is the attempt to duplicate the features, appearance, and characteristics of a real system, usually via a computerized model. (Introduction, easy) {AACSB: Use of IT}

56. Identify five applications of simulation.
The five applications of simulation can be picked from a list in Table F.1. Some highlights are traffic-light timing, bus scheduling, plant layout, production scheduling, inventory planning, and waiting line analysis. (Introduction, easy)

57. State the three-fold idea behind simulation.
The three-fold idea behind simulation is to imitate a real-world situation mathematically; then to study its properties and operating characteristics; and finally to draw conclusions and make action decisions based on the results of the simulation. (What is simulation? moderate)

58. Identify the seven steps involved in using simulation.
1. Define the problem.
2. Introduce the important variables.
3. Construct the numerical model.
4. Set up possible courses of action.
5. Run the experiment.
6. Consider the results (perhaps modifying the model).
7. Decide what course of action to take.
(What is simulation?, easy)

59. What is the Monte Carlo method?
The Monte Carlo method is a simulation technique that uses random elements when chance exists in their behavior. (Monte Carlo simulation, easy)

60. Identify, in order, the five steps required to implement the Monte Carlo simulation technique.
The steps of the Monte Carlo simulation technique are: set up a probability distribution for important variables; build a cumulative probability distribution for each of these variables; establish an interval of random numbers for each variable; generate sets of random numbers; and actually simulate a set of trials. (Monte Carlo simulation, moderate)

61. Explain how Monte Carlo simulation uses random numbers.
First, a cumulative probability distribution is set up for the element being modeled. From this, a set of random number intervals is established. A random number is generated and matched against the set of intervals. The random number will fall into only one interval, and that determines the value for the element being modeled. (Monte Carlo simulation, moderate)

62. What are the advantages and disadvantages of simulation models?
Advantages:
- **Simulation is relatively straightforward and flexible.**
- **It can be used to analyze large and complex real-world situations that cannot be solved by closed-form operations management models.**
- **Simulation allows for inclusion of real-world complications that most OM models cannot permit.**
- **"Time compression" is possible with simulation.**
- **Simulation allows "What if __?" type questions.**
- **Simulations do not interfere with the real-world system under study.**
- **Simulation allows us to study the interactive effect of individual components or variables in order to determine which ones are important.**

Disadvantages:
- **Good simulation models are very expensive.**
- **Simulation does not generate optimal solutions.**
- **Managers must generate all the conditions and constraints for the solutions that they want to examine.**
- **Each simulation model is unique. Its solutions and inferences are not usually transferable to other problems.**

(Advantages and disadvantages of simulation, moderate)

63. Provide a small example illustrating how random numbers are used in Monte Carlo simulation.
For example, demand can be 0, 40% of the time, or 1, 60% of the time. The cumulative distribution is demand = 0, 0.40, and demand = 1, 1.00. The random number intervals are 01 through 40 for demand = 0 and 41 through 00 for demand = 1. A random number of 36 indicates demand = 0. Examples will vary. (Monte Carlo simulation, moderate) {Reflective Thinking}

64. A waiting-line problem that cannot be modeled by standard distributions has been simulated. The table below shows the result of a Monte Carlo simulation. (Assume that the simulation began at 8:00 a.m. and there is only one server.) Why do you think this problem does not fit the standard distribution for waiting lines? Explain briefly how a Monte Carlo simulation might work where analytical models cannot.

Customer Number	Arrival Time	Service Time	Service Ends
1	8:05	2	8:07
2	8:06	10	8:17
3	8:10	15	8:32
4	8:20	12	8:44
5	8:30	4	8:48

Service times do not appear to be exponential. Rather, they seem to be extreme—very short or very long. Simulation can handle this with a cumulative probability distribution and a set of random number intervals. The Monte Carlo simulation will, with a large enough number of trials, mimic the reality of this system. (Monte Carlo simulation, difficult) {AACSB: Reflective Thinking}

65. Explain what is meant by "simulation is not limited to using the standard probability distributions."
"Standard models" include normal, binomial, beta, uniform, Poisson, exponential, and other probability distributions. Each has a specific set of assumptions and parameters. Real-world (empirical) systems can have any distribution imaginable. Simulation can mimic these real-world distributions by use of random number intervals based on real-world behavior, and can therefore generate more realistic models than would occur if a standard model were used in place of a system-specific one. (Monte Carlo simulation, moderate)

66. Explain what is meant by the concept of “time compression” in simulation modeling.
The effects of OM policies over many months or years can be obtained by computer simulation in a short time. (**Advantages and disadvantages of simulation, moderate) {AACSB: Use of IT}**

67. Explain the difference between *random numbers* and *random number intervals*.
Random numbers are a series of digits that have been selected by a totally random process. Random number intervals are numbers used to represent each possible value or outcome in a computer simulation. During simulation, a particular random number is matched against the random number intervals to determine the value for the element being modeled that particular time. (Monte Carlo simulation, moderate)

PROBLEMS

68. A waiting-line problem that cannot be modeled by standard distributions has been simulated. The table below shows the result of a Monte Carlo simulation. (Assume that the simulation began at 8:00 a.m. and there is only one server.)

Customer Number	Arrival Time	Service Time	Service Ends
1	8:06	2	8:08
2	8:07	10	8:18
3	8:12	10	8:28
4	8:24	11	8:39
5	8:30	5	8:44

a. What is the average waiting time in line?
b. What is the average time in the system?
(a) Waiting time is 0 + 1 + 6 + 4 + 9 = 20. Average waiting time is 20/5 = 4.0 min; (b) Total time in system is 2 + 11 + 16 + 15 + 14 = 58. Average time in system is 58/5 = 11.6 min. (Simulation of a queuing problem, moderate) {AACSB: Analytic Skills}

69. A distribution of service times at a waiting line shows that service takes 6 minutes 40 percent of the time, 7 minutes 30 percent of the time, 8 minutes 20 percent of the time, and 9 minutes 10 percent of the time. Prepare the probability distribution, the cumulative probability distribution, and the random number intervals for this problem.

Service time	Probability	Cumulative probability	Random number intervals
6	**.40**	**.40**	**01-40**
7	**.30**	**.70**	**41-70**
8	**.20**	**.90**	**71-90**
9	**.10**	**1.00**	**91-00**

(Simulation of a queuing problem, easy) {AACSB: Analytic Skills}

70. A warehouse manager needs to simulate the demand placed on a product that does not fit standard models. The concept being measured is "demand during lead time," where both lead time and daily demand are variable. The historical record for this product suggests the following probability distribution. Convert this distribution into random number intervals.

Demand during lead time	Probability
100	.02
120	.15
140	.25
160	.15
180	.13
200	.30

Demand during lead time	**Probability**	**Cumulative probability**	**Random number intervals**
100	**.02**	**.02**	**01-02**
120	**.15**	**.17**	**03-17**
140	**.25**	**.42**	**18-42**
160	**.15**	**.57**	**43-57**
180	**.13**	**.70**	**58-70**
200	**.30**	**1.00**	**71-00**

(Simulation and inventory analysis, moderate) {AACSB: Analytic Skills}

71. A distribution of service times at a waiting line shows that service takes 6 minutes 40 percent of the time, 7 minutes 30 percent of the time, 8 minutes 20 percent of the time, and 9 minutes 10 percent of the time. Prepare the probability distribution, the cumulative probability distribution, and the random number intervals for this problem. The first five random numbers are 37, 69, 53, 80, and 60. What is the average service time of this simulation run?

Service time	**Probability**	**Cumulative probability**	**Random number intervals**	**Simulation frequency**
6	**.40**	**.40**	**01-40**	**1 (37)**
7	**.30**	**.70**	**41-70**	**3 (69, 53, 60)**
8	**.20**	**.90**	**71-90**	**1 (80)**
9	**.10**	**1.00**	**91-00**	**0**

The average service time is 1*6 + 3*7 + 1*8 = 35 / 5 = 7 minutes. (Simulation of a queuing problem, moderate) {AACSB: Analytic Skills}

72. A distribution of service times at a waiting line indicates that service takes 12 minutes 30 percent of the time and 14 minutes 70 percent of the time. Prepare the probability distribution, the cumulative probability distribution, and the random number intervals for this problem.

Service time	**Probability**	**Cumulative probability**	**Random number intervals**
12	**.30**	**.30**	**01-30**
14	**.70**	**1.00**	**31-00**

(Simulation of a queuing problem, easy) {AACSB: Analytic Skills}

73. A distribution of service times at a waiting line indicates that service takes 12 minutes 30 percent of the time and 14 minutes 70 percent of the time. Prepare the probability distribution, the cumulative probability distribution, and the random number intervals for this problem. The first six random numbers were 99, 29, 27, 75, 89, and 78. What is the average service time for this simulation run?

Service time	Probability	Cumulative probability	Random number intervals	Simulation frequency
12	**.30**	**.30**	**01-30**	**2 (29, 27)**
14	**.70**	**1.00**	**31-00**	**4 (99, 75, 89, 78)**

The average service time is 2*12 + 4*14 = 80 / 6 = 13.33 minutes. (Simulation of a queuing problem, easy) {AACSB: Analytic Skills}

74. Historical records on a certain product indicate the following behavior for demand. The data represent the 300 days that the business was open during 2000. Convert these data into random number intervals.

Demand in cases	Number of occurrences
7	52
8	9
9	14
10	39
11	72
12	102

Demand in cases	Number of occurrences	Probability	Cumulative probability	Random number intervals
7	**52**	**.18**	**.18**	**01-18**
8	**9**	**.03**	**.21**	**19-21**
9	**14**	**.05**	**.26**	**22-26**
10	**39**	**.14**	**.40**	**27-40**
11	**72**	**.25**	**.65**	**41-65**
12	**102**	**.35**	**1.00**	**66-00**

(Simulation and inventory analysis, moderate) {AACSB: Analytic Skills}

75. A small store is trying to determine if its current checkout system is adequate. Currently, there is only one cashier, so it is a single-channel, single-phase system. The store has collected information on the interarrival time, and service time distributions. They are represented in the tables below. Use the following two-digit random numbers given below to simulate 10 customers through the checkout system. What is the average time in line, and average time in system? (Set first arrival time to the interarrival time generated by first random number.)

Interarrival time (minutes)	Probability
3	.25
4	.25
5	.30
6	.20

Service time (minutes)	Probability
1	.30
2	.40
3	.20
4	.10

Random numbers for interarrival times: 07, 60, 77, 49, 76, 95, 51, 16, 14, 85
Random numbers of service times: 57, 17, 36, 72, 85, 31, 44, 30, 26, 09

Interarrival time (minutes)	**Probability**	**RN assignment**	**Service time (minutes)**	**Probability**	**RN assignment**
3	**.25**	**01-25**	**1**	**.30**	**01-30**
4	**.25**	**26-50**	**2**	**.40**	**31-70**
5	**.30**	**51-80**	**3**	**.20**	**71-90**
6	**.20**	**81-00**	**4**	**.10**	**91-00**

Customer number	**RN**	**Interarrival time**	**Arrival time**	**Service begins**	**RN**	**Service time**	**Service ends**	**Time in line**	**Time in System**
1	**07**	**3**	**3**	**3**	**57**	**2**	**5**	**0**	**2**
2	**60**	**5**	**5**	**5**	**17**	**1**	**6**	**0**	**1**
3	**77**	**5**	**10**	**10**	**36**	**2**	**12**	**0**	**2**
4	**49**	**4**	**14**	**14**	**72**	**3**	**17**	**0**	**3**
5	**76**	**5**	**19**	**19**	**85**	**3**	**22**	**0**	**3**
6	**95**	**6**	**25**	**25**	**31**	**2**	**27**	**0**	**2**
7	**51**	**5**	**30**	**30**	**44**	**2**	**32**	**0**	**2**
8	**16**	**1**	**31**	**32**	**30**	**1**	**33**	**1**	**2**
9	**14**	**1**	**32**	**33**	**26**	**1**	**34**	**1**	**2**
10	**85**	**6**	**38**	**38**	**09**	**1**	**39**	**0**	**1**

Average time in line = 2/10 = 0.2 minutes; Average time in system = 20/10 = 2.0 minutes.
(Simulation of a queuing problem, moderate) {AACSB: Analytic Skills}

76. Sam's hardware store has an order policy of ordering 12 gallons of a specific primer whenever 7 gallons are on hand. The store would like to see how well their policy works. Assume that beginning inventory in period 1 is 10 units, that orders are placed at the end of the week to be received one week later. (In other words, if an order is placed at the end of week one, it is available at the beginning of week 3.) Assume that if inventory is not on hand, it will result in a lost sale. The weekly demand distribution obtained from past sales is found in the table below. Also, use the random numbers that are provided and simulate 10 weeks worth of sales. How many sales are lost?

Weekly sales	Probability
3	.20
4	.30
5	.20
6	.20
7	.10

Random numbers for sales: 37, 60, 79, 21, 85, 71, 48, 39, 31, 35

Weekly sales	**Probability**	**RN assignment**
3	**.20**	**01-20**
4	**.30**	**21-50**
5	**.20**	**51-70**
6	**.20**	**71-90**
7	**.10**	**91-00**

Week	**Order received**	**Beginning inventory**	**RN**	**Sales**	**Ending inventory**	**Order?**	**Lost sales**
1		**10**	**37**	**4**	**6**	**Y**	
2		**6**	**60**	**5**	**1**		
3	**12**	**13**	**79**	**6**	**7**	**Y**	
4		**7**	**21**	**4**	**3**		
5	**12**	**15**	**85**	**6**	**9**		
6		**9**	**71**	**6**	**3**	**Y**	
7		**3**	**48**	**4**	**0**		**1**
8	**12**	**12**	**39**	**4**	**8**		
9		**8**	**31**	**4**	**4**	**Y**	
10		**4**	**35**	**4**	**0**		

Over the 10 weeks only 1 gallon of sales is lost.
(Simulation and inventory analysis, moderate) {AACSB: Analytic Skills}

77. The lunch counte at a small restaurant has difficulty handling the lunch business. Currently, there is only one cashier in a single-channel, single-phase system. The restaurant has collected information on the interarrival time, and service time distributions from past lunch hours. They are represented in the tables below. Use the following two-digit random numbers given below to simulate 10 customers through the checkout system. What is the average time in line, and average time in system? (Set first arrival time to the interarrival time generated by first random number.)

Interarrival time (minutes)	Probability
1	.20
2	.20
3	.30
4	.20
5	.10

Service time (minutes)	Probability
1	.20
2	.30
3	.30
4	.20

Random numbers for interarrival times: 32, 73, 41, 38, 73, 01, 09, 64, 34, 55
Random numbers of service times: 84, 55, 25, 71, 34, 57, 50, 44, 95, 64

Interarrival time (minutes)	**Probability**	**RN assignment**	**Service time (minutes)**	**Probability**	**RN assignment**
1	**.20**	**01-20**	**1**	**.20**	**01-20**
2	**.20**	**21-40**	**2**	**.30**	**21-50**
3	**.30**	**41-70**	**3**	**.30**	**51-80**
4	**.20**	**71-90**	**4**	**.20**	**81-00**
5	**.10**	**91-00**			

Customer number	**RN**	**Interarrival time**	**Arrival time**	**Service begins**	**RN**	**Service time**	**Service ends**	**Time in line**	**Time in System**
1	**32**	**2**	**2**	**2**	**84**	**4**	**6**	**0**	**4**
2	**73**	**4**	**6**	**6**	**55**	**3**	**9**	**0**	**3**
3	**41**	**3**	**9**	**9**	**25**	**2**	**11**	**0**	**2**
4	**38**	**2**	**11**	**11**	**71**	**3**	**14**	**0**	**3**
5	**73**	**4**	**15**	**15**	**34**	**2**	**17**	**0**	**2**
6	**01**	**1**	**16**	**17**	**57**	**3**	**20**	**1**	**4**
7	**09**	**1**	**17**	**20**	**50**	**2**	**22**	**3**	**5**
8	**64**	**3**	**20**	**22**	**44**	**2**	**24**	**2**	**4**
9	**34**	**2**	**22**	**24**	**95**	**4**	**28**	**2**	**6**
10	**44**	**3**	**25**	**28**	**64**	**3**	**31**	**3**	**6**

Average time in line = 11/10 = 1.1 minutes; Average time in system = 39/10 = 3.9 minutes. (Simulation of a queuing problem, moderate) {AACSB: Analytic Skills}

78. Julie's Diamond Boutique is very concerned with its order policies related to one-carat diamond solitaires. Their current policy is to order 10 diamonds whenever their inventory reaches 6 diamonds. Currently there are 8 diamonds on hand. Orders are placed at the end of the month and take one month to arrive (e.g., if an order is placed at the end of month 1, it will be available at the beginning of month 3). The following distribution of monthly sales has been developed using historical sales. If Julie's does not have a diamond on hand, it will result in a lost sale. Use the following random numbers to determine the number of lost sales of one-carat solitaires at Julie's over 12 months.

Monthly sales	Probability
3	.20
4	.30
5	.20
6	.20
7	.10

Random numbers for sales: 10, 24, 03, 32, 23, 59, 95, 34, 34, 51, 08, 48

Monthly sales	**Probability**	**RN assignment**
3	**.20**	**01-20**
4	**.30**	**21-50**
5	**.20**	**51-70**
6	**.20**	**71-90**
7	**.10**	**91-00**

Month	**Order received**	**Beginning inventory**	**RN**	**Sales**	**Ending inventory**	**Order?**	**Lost sales**
1		**8**	**10**	**3**	**5**	**Y**	
2		**5**	**24**	**4**	**1**		
3	**10**	**11**	**03**	**3**	**8**		
4		**8**	**32**	**4**	**4**	**Y**	
5		**4**	**23**	**4**	**0**		
6	**10**	**10**	**59**	**5**	**5**	**Y**	
7		**5**	**95**	**7**	**0**		**2**
8	**10**	**10**	**34**	**4**	**6**	**Y**	
9		**6**	**34**	**4**	**2**		
10	**10**	**12**	**51**	**5**	**7**		
11		**7**	**08**	**3**	**4**	**Y**	
12		**4**	**48**	**4**	**0**		

Over the 12 months 2 sales are lost.
(Simulation and inventory analysis, moderate) {AACSB: Analytic Skills}