Test Bank

Essential
University Physics
Second Edition

Richard Wolfson
Middlebury College

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Executive Editor: Nancy Whilton

Editorial Manager: Laura Kenney

Project Editor: Tema Goodwin

Senior Marketing Manager: Kerry Chapman

Associate Director of Production: Erin Gregg

Managing Editor: Corinne Benson

Production Project Manager: Mary O'Connell

ISBN 10-digit 0-321-71172-6; 13-digit 978-0-321-71172-4

PEARSON

Contents

Chapter 1 Doing Physics

1.1 Conceptual Questions

1) The current definition of the standard meter of length is based on
   A) the distance between the earth's equator and north pole.
   B) the distance between the earth and the sun.
   C) the distance traveled by light in a vacuum.
   D) the length of a particular object kept in France.

   Answer: C

2) The current definition of the standard second of time is based on
   A) the frequency of radiation emitted by cesium atoms.
   B) the earth's rotation rate.
   C) the duration of one year.
   D) the oscillation of a particular pendulum kept in France.

   Answer: A

3) The current definition of the standard kilogram of mass is based on
   A) the mass of the earth.
   B) the mass of the sun.
   C) the mass a particular object kept in France.
   D) the mass of a cesium-133 atom.

   Answer: C

4) If a woman weighs 125 lb, her mass expressed in kilograms is x kg, where x is
   A) less than 125.
   B) greater than 125.

   Answer: A

5) If a tree is 15 m tall, its height expressed in feet is x ft, where x is
   A) less than 15.
   B) greater than 15.

   Answer: B

6) If a flower is 6.5 cm wide, its width expressed in millimeters is x mm, where x is
   A) less than 6.5.
   B) greater than 6.5.

   Answer: B

7) If an operatic aria lasts for 5.75 min, its length expressed in seconds is x s, where x is
   A) less than 5.75.
   B) greater than 5.75.

   Answer: B

8) Scientists use the metric system chiefly because it is more accurate than the English system.
   A) True
   B) False

   Answer: B

9) When adding two numbers, the number of significant figures in the sum is equal to the number of significant figures in the least accurate of the numbers being added.
A) True
B) False

Answer: B

10) When determining the number of significant figures in a number, zeroes to the left of the decimal point are never counted.
A) True
B) False

Answer: B

1.2 Problems

1) Convert 1.2×10^{-3} to decimal notation.
A) 1.200
B) 0.1200
C) 0.0120
D) 0.0012
E) 0.00012

Answer: D

2) Write out the number 7.35×10^{-5} in full with a decimal point and correct number of zeros.
A) 0.00000735
B) 0.0000735
C) 0.000735
D) 0.00735
E) 0.0735

Answer: B

3) 0.0001776 can also be expressed as
A) 1.776×10^{-3}.
B) 1.776×10^{-4}.
C) 17.72×10^{4}.
D) 1772×10^{5}.
E) 177.2×10^{7}.

Answer: B

4) 0.00325×10^{-8} cm can also be expressed in mm as
A) 3.25×10^{-12} mm.
B) 3.25×10^{-11} mm.
C) 3.25×10^{-10} mm.
D) 3.25×10^{-9} mm.
E) 3.25×10^{-8} mm.

Answer: C

5) If, in a parallel universe, π has the value 3.14149, express π in that universe to four significant figures.
A) 3.141
B) 3.142
C) 3.1415
D) 3.1414
Answer: A

6) The number 0.003010 has
A) 7 significant figures.
B) 6 significant figures.
C) 4 significant figures.
D) 2 significant figures.
Answer: C

7) What is $\frac{0.674}{0.74}$ to the proper number of significant figures?
A) 0.91
B) 0.911
C) 0.9108
D) 0.9
Answer: A

8) What is the value of $\pi(8.104)^2$, written with the correct number of significant figures?
A) 206.324
B) 206.323
C) 206.3
D) 206
E) 200
Answer: C

9) What is the sum of 1123 and 10.3 written with the correct number of significant figures?
A) 1.13×10^3
B) 1133.3000
C) 1.1×10^3
D) 1133.3
E) 1133
Answer: E

10) What is the sum of 1.53 + 2.786 + 3.3 written with the correct number of significant figures?
A) 8
B) 7.6
C) 7.62
D) 7.616
E) 7.6160
Answer: B

11) What is the difference between 103.5 and 102.24 written with the correct number of significant figures?
A) 1
B) 1.3
C) 1.26
D) 1.260
E) 1.2600

Answer: B

12) What is the product of 11.24 and 1.95 written with the correct number of significant figures?
A) 22
B) 21.9
C) 21.92
D) 21.918
E) 21.9180

Answer: B

13) What is the result of 1.58 ÷ 3.793 written with the correct number of significant figures?
A) 4.1656×10^{-1}
B) 4.166×10^{-1}
C) 4.17×10^{-1}
D) 4.2×10^{-1}
E) 4×10^{-1}

Answer: C

14) What is 34 + (3) × (1.2465) written with the correct number of significant figures?
A) 37.7
B) 37.74
C) 4×10^{1}
D) 38
E) 37.7395

Answer: D

15) What is 56 + (32.00)/(1.2465 + 3.45) written with the correct number of significant figures?
A) 62.8
B) 62.812
C) 62.81
D) 63
E) 62.8123846

Answer: D

16) Add 3685 g and 66.8 kg and express your answer in milligrams (mg).
A) 7.05×10^{7} mg
B) 7.05×10^{4} mg
C) 7.05×10^{5} mg
D) 7.05×10^{6} mg

Answer: A

17) Express $(4.3 \times 10^{6})^{-1/2}$ in scientific notation.
   A) 4.8×10^{-4}
   B) 2.1×10^{3}
   C) 2.1×10^{-5}
   D) 2.1×10^{4}

   Answer: A

18) What is $0.205^{2/3}$, expressed to the proper number of significant figures?
   A) 0.348
   B) 0.35
   C) 0.3
   D) 0.3477

   Answer: A

19) The length and width of a rectangle are 1.125 m and 0.606 m, respectively. Multiplying, your calculator gives the product as 0.68175. Rounding properly to the correct number of significant figures, the area should be written as
   A) 0.7 m^2.
   B) 0.68 m^2.
   C) 0.682 m^2.
   D) 0.6818 m^2.
   E) 0.68175 m^2.

   Answer: C

20) The following exact conversion equivalents are given: 1 m = 100 cm , 1 in = 2.54 cm, and 1 ft = 12 in. If a computer screen has an area of 1.27 ft^2, this area is closest to
   A) 0.00284 m^2.
   B) 0.0465 m^2.
   C) 0.118 m^2.
   D) 0.284 m^2.
   E) 4.65 m^2.

   Answer: C

21) In addition to 1 m = 39.37 in., the following exact conversion equivalents are given: 1 mile = 5280 ft , 1 ft = 12 in , 1 hour = 60 min, and 1 min = 60 s. If a particle has a velocity of 8.4 miles per hour,its velocity, in m/s, is closest to
   A) 3.8 m/s.
   B) 3.0 m/s.
   C) 3.4 m/s.
   D) 4.1 m/s.
   E) 4.5 m/s.

   Answer: A

22) A weight lifter can bench press 171 kg. How many milligrams (mg) is this?
A) 1.71×10^8 mg
B) 1.71×10^9 mg
C) 1.71×10^7 mg
D) 1.71×10^6 mg
Answer: A

23) How many nanoseconds does it take for a computer to perform one calculation if it performs 6.7×10^7 calculations per second?
A) 15 ns
B) 67 ns
C) 11 ns
D) 65 ns
Answer: A

24) The shortest wavelength of visible light is approximately 400 nm. Express this wavelength in centimeters.
A) 4×10^{-5} cm
B) 4×10^{-7} cm
C) 4×10^{-9} cm
D) 4×10^{-11} cm
E) 400×10^{-11} cm
Answer: A

25) The wavelength of a certain laser is 0.35 micrometers, where 1 micrometer = 1×10^{-6} m. Express this wavelength in nanometers.
A) 3.5×10^2 nm
B) 3.5×10^3 nm
C) 3.5×10^1 nm
D) 3.5×10^4 nm
Answer: A

26) A certain CD–ROM disk can store approximately 6.0×10^2 megabytes of information, where 10^6 bytes = 1 megabyte. If an average word requires 9.0 bytes of storage, how many words can be stored on one disk?
A) 6.7×10^7 words
B) 5.4×10^9 words
C) 2.1×10^7 words
D) 2.0×10^9 words
Answer: A

27) A plot of land contains 5.8 acres. How many square meters does it contain? [1 acre = 43,560 ft^2]
A) 2.3×10^4 m^2
B) 7.1×10^3 m^2
C) 7.0×10^4 m^2
D) 5.0×10^4 m^2
Answer: A

28) A person on a diet loses 1.6 kg in a week. How many micrograms/second (μg/s) are lost?
A) 2.6×10^3 μg/s
B) 1.6×10^5 μg/s
C) 44 μg/s
D) 6.4×10^4 μg/s
Answer: A

29) Albert uses as his unit of length (for walking to visit his neighbors or plowing his fields) the albert (A), the distance Albert can throw a small rock. One albert is 92 meters. How many square alberts is equal to one acre? (1 acre = 43,560 ft^2 = 4050 m^2)
Answer: 1.29 A^2

30) Convert a speed of 4.50 km/h to units of ft/min. (1.00 m = 3.28 ft)
A) 0.246 ft/min
B) 82.3 ft/min
C) 165 ft/min
D) 246 ft/min
E) 886 ft/min
Answer: D

31) The exhaust fan on a typical kitchen stove pulls 600 CFM (cubic feet per minute) through the filter. Given that 1.00 in. = 2.54 cm, how many cubic meters per second does this fan pull?
A) 0.283 m^3/sec
B) 0.328 m^3/sec
C) 3.05 m^3/sec
D) 32.8 m^3/sec
Answer: A

32) The mass of a typical adult woman is closest to
A) 20 kg.
B) 35 kg.
C) 75 kg.
D) 150 kg.
Answer: C

33) The height of the ceiling in a typical home, apartment, or dorm room is closest to
A) 100 cm.
B) 200 cm.
C) 400 cm.
D) 500 cm.
Answer: B

34) Approximately how many times does an average human heart beat in a year?
A) 4×10^5
B) 4×10^6
C) 4×10^7
D) 4×10^8
E) 4×10^9
Answer: C

35) Approximately how many times does an average human heart beat in a lifetime?
A) 3×10^{11}
B) 3×10^{10}
C) 3×10^9
D) 3×10^8
E) 3×10^7
Answer: C

36) Approximately how many pennies would you have to stack to reach an average 8-foot ceiling?
A) 2×10^2
B) 2×10^3
C) 2×10^4
D) 2×10^5
E) $2 x 10^6$
Answer: B

37) Estimate the number of times the earth will rotate on its axis during a human's lifetime.
A) 3×10^4
B) 3×10^5
C) 3×10^6
D) 3×10^7
E) $3 x 10^8$
Answer: A

38) Estimate the number of pennies that would fit in a box one foot long by one foot wide by one foot tall.
A) 5×10^2
B) 5×10^3
C) 5×10^4
D) 5×10^5
E) $5 x 10^6$
Answer: C

39) A marathon is 26 mi and 385 yd long. Estimate how many strides would be required to run a marathon. Assume a reasonable value for the average number of feet/stride.
  A) 4.5×10^4 strides
  B) 4.5×10^3 strides
  C) 4.5×10^5 strides
  D) 4.5×10^6 strides
Answer: A

40) The period of a pendulum is the time it takes the pendulum to swing back and forth once. If the only dimensional quantities that the period depends on are the acceleration of gravity, g, and the length of the pendulum, ℓ, what combination of g and ℓ must the period be proportional to? (Acceleration has SI units of $\mathrm{m \cdot s^{-2}}$.).
  A) g/ℓ
  B) $g\ell^2$
  C) $g\ell$
  D) $\sqrt{g\ell}$
  E) $\sqrt{\ell/g}$
Answer: E

41) The speed of a wave pulse on a string depends on the tension, F, in the string and the mass per unit length, μ, of the string. Tension has SI units of $\mathrm{kg \cdot m \cdot s^{-2}}$ and the mass per unit length has SI units of $\mathrm{kg \cdot m^{-1}}$. What combination of F and μ must the speed of the wave be proportional to?
  A) F / μ
  B) μ / F
  C) $\sqrt{\mu / F}$
  D) $\sqrt{\mu F}$
  E) $\sqrt{F / \mu}$
Answer: A

42) The position x, in meters, of an object is given by the equation $x = A + Bt + Ct^2$, where t represents time in seconds. What are the SI units of A, B, and C?
  A) m, m, m
  B) m, s, s
  C) m, s, $\mathrm{s^2}$
  D) m, m/s, $\mathrm{m/s^2}$
  E) m/s, $\mathrm{m/s^2}$, $\mathrm{m/s^3}$
Answer: A

Chapter 2 Motion in a Straight Line

2.1 Conceptual Questions

1) If the acceleration of an object is negative, the object must be slowing down.
   A) True
   B) False

Answer: B

2) If the graph of the position as a function of time for an object is a horizontal line, that object cannot be accelerating.
   A) True
   B) False

Answer: A

3) If an object is accelerating toward a point, then it must be getting closer and closer to that point.
   A) True
   B) False

Answer: B

4) When can we be certain that the average velocity of an object is always equal to its instantaneous velocity?
   A) always
   B) never
   C) only when the velocity is constant
   D) only when the acceleration is constant
   E) only when the acceleration is changing at a constant rate

Answer: C

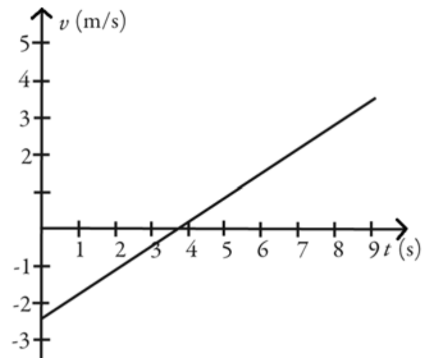
5) Suppose that an object is moving with constant nonzero acceleration. Which of the following is an accurate statement concerning its motion?
   A) In equal times its speed changes by equal amounts.
   B) In equal times its velocity changes by equal amounts.
   C) In equal times it moves equal distances.
   D) A graph of its position as a function of time has a constant slope.
   E) A graph of its velocity as a function of time is a horizontal line.

Answer: B

6) Suppose that a car traveling to the west (the $-x$ direction) begins to slow down as it approaches a traffic light. Which statement concerning its acceleration in the x direction is correct?
   A) Both its acceleration and its velocity are positive.
   B) Both its acceleration and its velocity are negative.
   C) Its acceleration is positive but its velocity is negative.
   D) Its acceleration is negative but its velocity is positive.

Answer: C

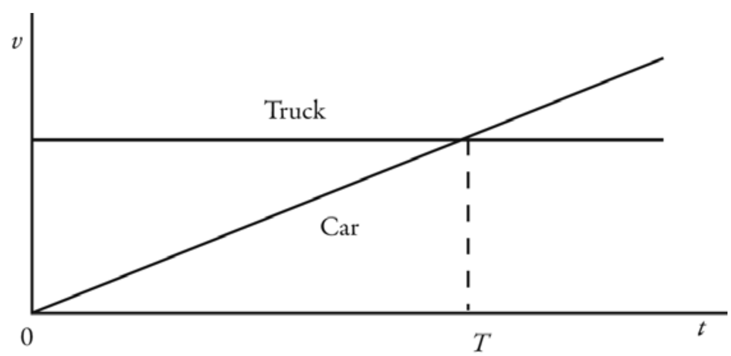
7) The motion of a particle is described in the velocity versus time graph shown in the figure. We can say that its speed



A) increases.
B) decreases.
C) increases and then decreases.
D) decreases and then increases.

Answer: D

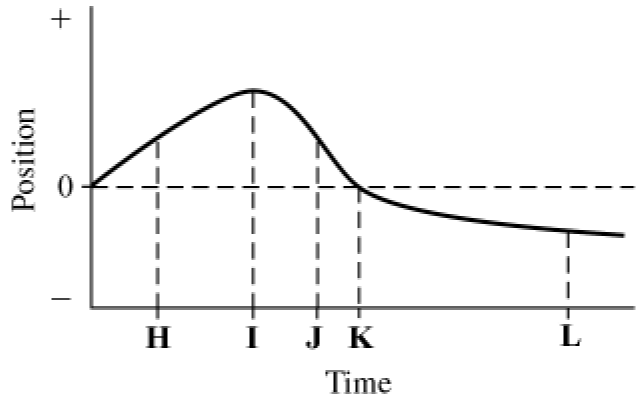
8) The motions of a car and a truck along a straight road are represented by the velocity-time graphs in the figure. The two vehicles are initially alongside each other at time $t = 0$. At time T, what is true about these two vehicles since time $t = 0$?



A) The truck will have traveled further than the car.
B) The car will have traveled further than the truck.
C) The truck and the car will have traveled the same distance.
D) The car will be traveling faster than the truck.

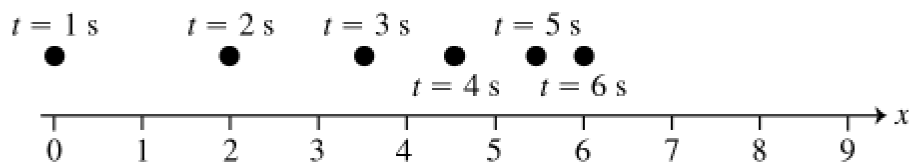
Answer: A

9) The graph in the figure shows the position of an object as a function of time. The letters H-L represent particular moments of time. At which moments shown (H, I, etc.) is the speed of the object
(a) the greatest?
(b) the smallest?



Answer: (a) J (b) I

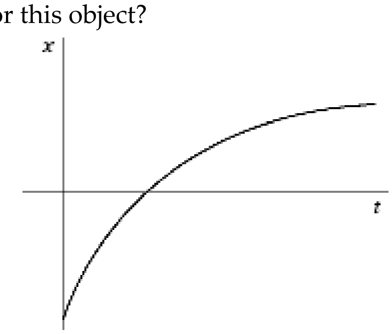
10) The figure shows the position of an object (moving along a straight line) as a function of time. Assume two significant figures in each number. Which of the following statements about this object is true over the interval shown?



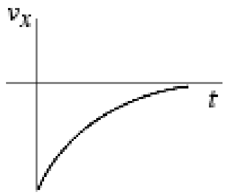
A) The object is accelerating to the left.
B) The object is accelerating to the right.
C) The acceleration of the object is in the same direction as its velocity.
D) The average speed of the object is 1.0 m/s.

Answer: A

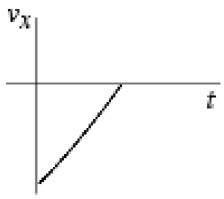
11) The figure shows the graph of the position x as a function of time for an object moving in the straight line (the x–axis). Which of the following graphs best describes the velocity along the x–axis as a function of time for this object?



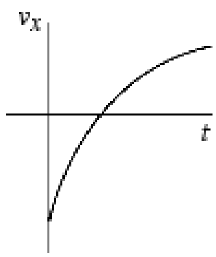
A)



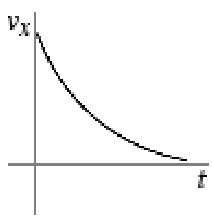
B)



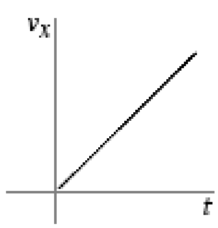
C)



D)



E)

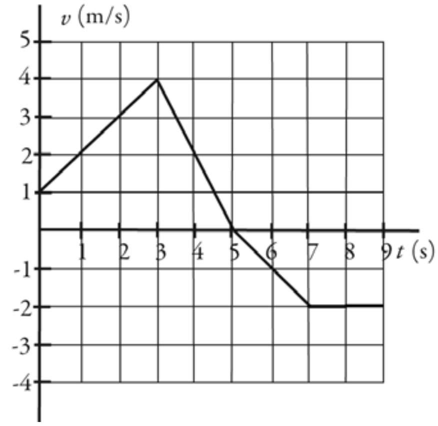


Answer: D

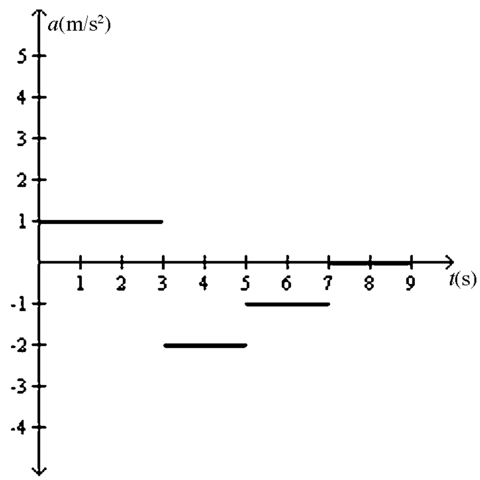
12) An object is moving with constant non-zero acceleration along the $+x$-axis. A graph of the velocity in the x direction as a function of time for this object is
   A) a horizontal straight line.
   B) a vertical straight line.
   C) a straight line making an angle with the time axis.
   D) a parabolic curve.

Answer: D

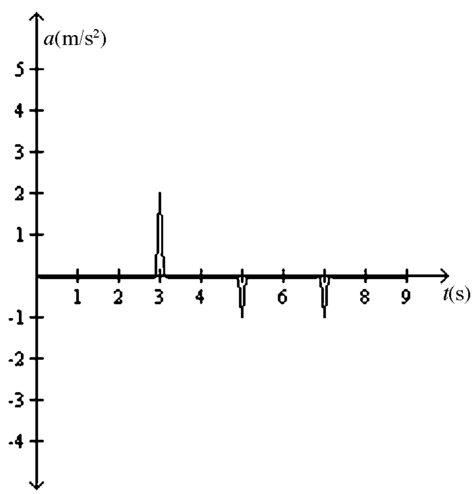
13) An object is moving in a straight line along the x–axis. A plot of its velocity in the x direction as a function of time is shown in the figure. Which graph represents its acceleration in the x direction as a function of time?



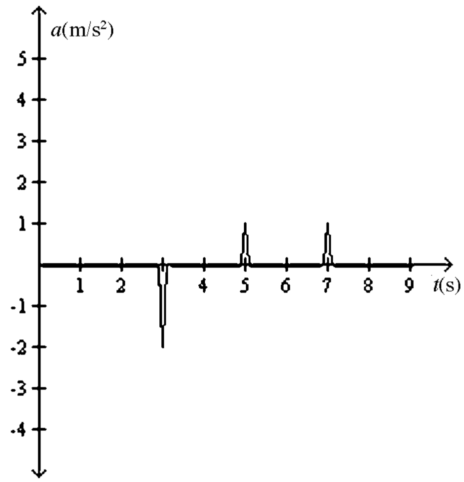
A)



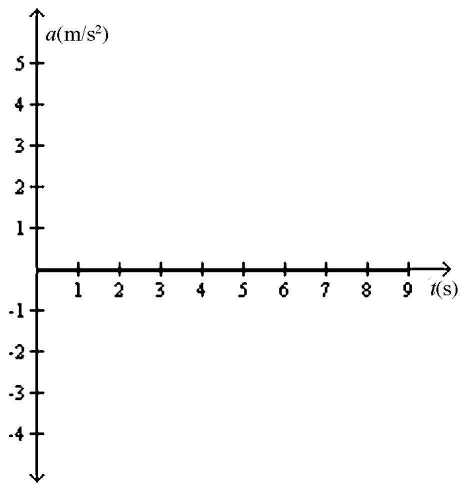
B)



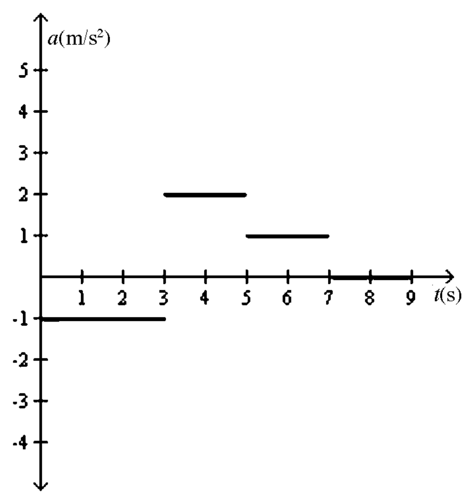
C)


a(m/s²)
5
4
3
2
1
-1
-2
-3
-4
1 2 4 5 6 7 8 9 t(s)

D)


a(m/s²)
5
4
3
2
1
-1
-2
-3
-4
1 2 3 4 5 6 7 8 9 t(s)

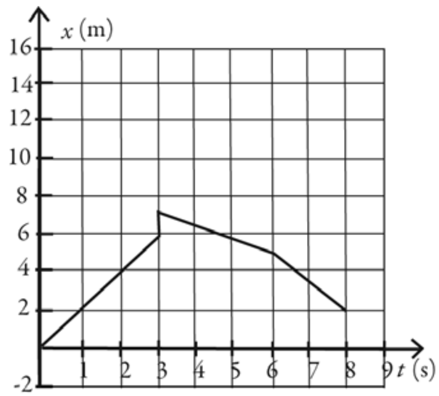
E)


a(m/s²)
5
4
3
2
1
-1
-2
-3
-4
1 2 3 4 5 6 7 8 9 t(s)

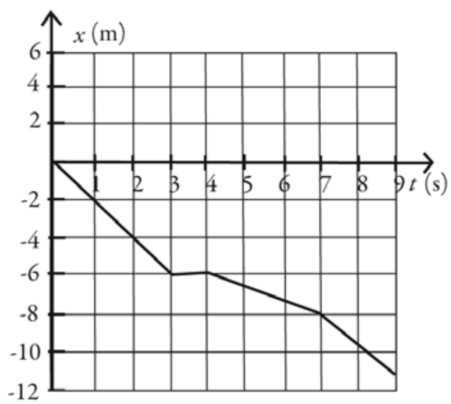
Answer: C

14) An object starts its motion with a constant velocity of 2.0 m/s toward the east. After 3.0 s, the object stops for 1.0 s. The object then moves toward the west a distance of 2.0 m in 3.0 s. The object continues traveling in the same direction, but increases its speed by 1.0 m/s for the next 2.0 s. Which graph below could represent the motion of this object?

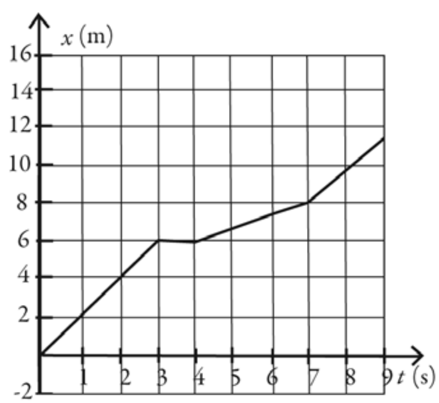
A)



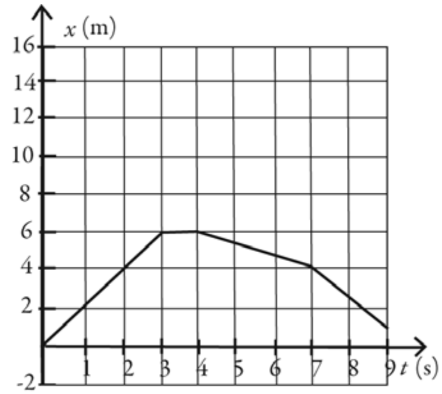
B)



C)

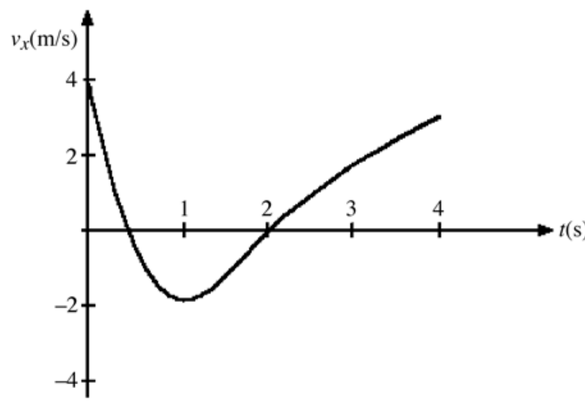


D)



Answer: D

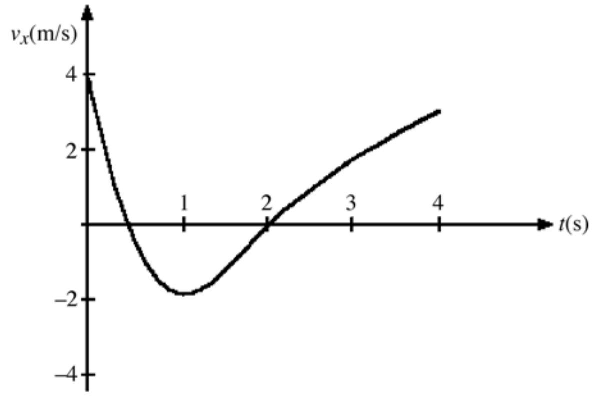
15) The figure shows the velocity of a particle as it travels along the x-axis. What is the direction of the acceleration at $t = 0.5$ s?



A) in the $+x$ direction
B) in the $-x$ direction
C) The acceleration is zero.

Answer: B

16) The figure represents the velocity of a particle as it travels along the x-axis. At what value (or values) of t is the instantaneous acceleration equal to zero?



A) $t = 0$
B) $t = 0.5$ s and $t = 2$ s
C) $t = 1$ s

Answer: C

17) A ball is thrown directly upward and experiences no air resistance. Which one of the following statements about its motion is correct?
A) The acceleration of the ball is upward while it is traveling up and downward while it is traveling down.
B) The acceleration of the ball is downward while it is traveling up and upward while it is traveling down.
C) The acceleration is downward during the entire time the ball is in the air.
D) The acceleration of the ball is downward while it is traveling up and downward while it is traveling down but is zero at the highest point when the ball stops.

Answer: C

18) Two objects are thrown from the top of a tall building and experience no appreciable air resistance. One is thrown up, and the other is thrown down, both with the same initial speed. What are their speeds when they hit the street?
A) The one thrown up is traveling faster.
B) The one thrown down is traveling faster.
C) They are traveling at the same speed.

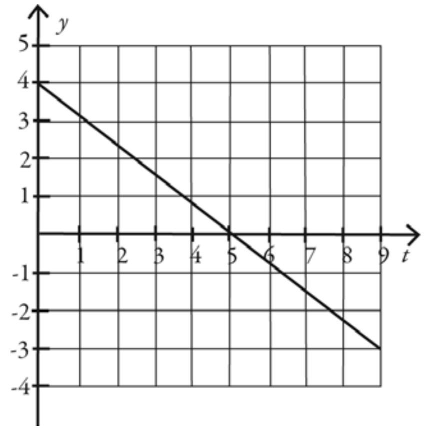
Answer: C

19) Two objects are dropped from a bridge, an interval of 1.0 s apart, and experience no appreciable air resistance. As time progresses, the DIFFERENCE in their speeds
A) increases.
B) remains constant.
C) decreases.
D) increases at first, but then stays constant.
E) decreases at first, but then stays constant.

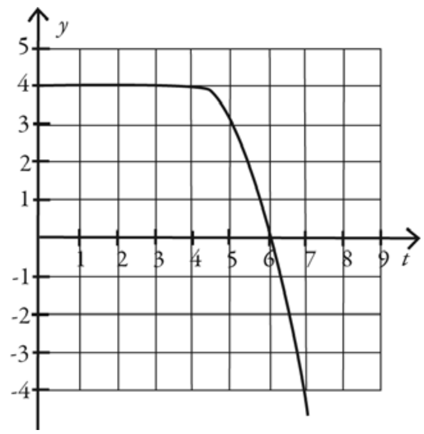
Answer: B

20) Which one of the following graphs could possibly represent the vertical position as a function of time for an object in free fall?

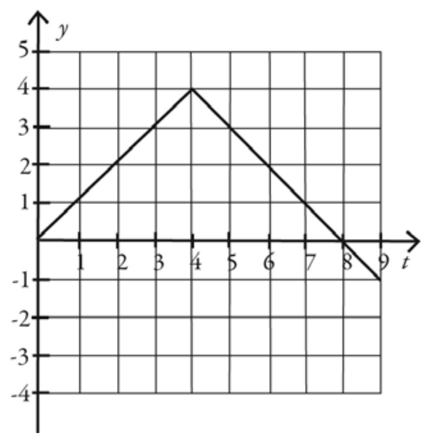
A)



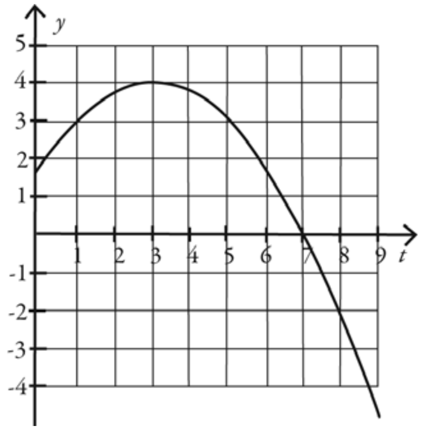
B)



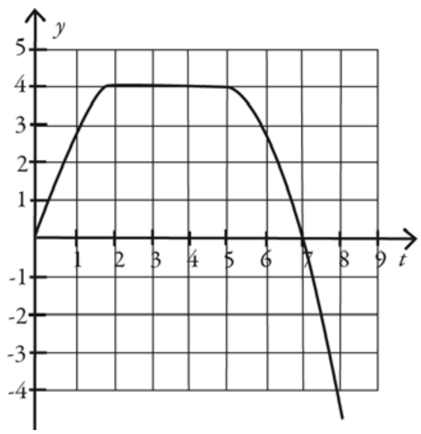
C)



D)



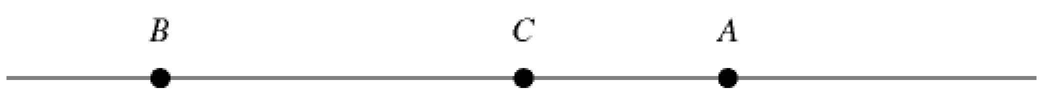
E)



Answer: D

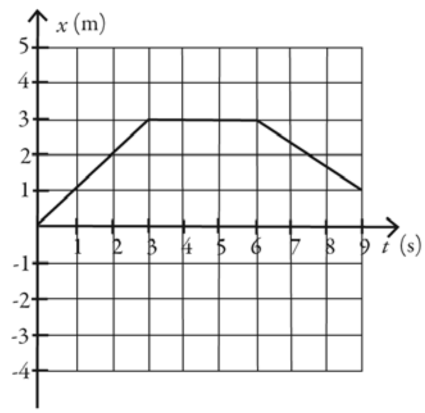
2.2 Problems

1) A cat runs along a straight line (the x–axis) from point A to point B to point C, as shown in the figure. The distance between points A and C is 5.00 m, the distance between points B and C is 10.0 m, and the positive direction of the x–axis points to the right. The time to run from A to B is 20.0 s, and the time from B to C is 8.00 s. As the cat runs along the x–axis between points A and C
(a) what is the magnitude of its average velocity?
(b) what is its average speed?



Answer: (a) 0.179 m/s (b) 0.893 m/s

2) The figure shows the position of an object as a function of time. During the time interval from time $t = 0.0$ s and time $t = 9.0$ s
(a) what is the length of the path the object followed?
(b) what is the displacement of the object?

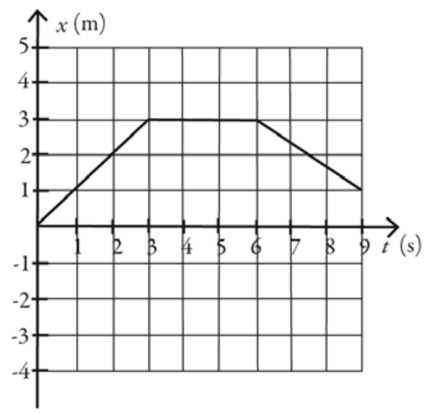


Answer: (a) 5.0 m (b) 1.0 m

3) As part of an exercise program, a woman walks south at a speed of 2.00 m/s for 60.0 minutes. She then turns around and walks north a distance 3000 m in 25.0 minutes
(a) What is the woman's average velocity during her entire motion?
A) 0.824 m/s south
B) 1.93 m/s south
C) 2.00 m/s south
D) 1.79 m/s south
E) 800 m/s south
(b) What is the woman's average speed during her entire motion?
A) 0.824 m/s
B) 1.93 m/s
C) 2.00 m/s
D) 1.79 m/s
E) 800 m/s

Answer: (a) A (b) C

4) The figure shows the position of an object as a function of time, with all numbers accurate to two significant figures. Between time $t = 0.0$ s and time $t = 9.0$ s
(a) what is the average speed of the object?
(b) what is the average velocity of the object?



Answer: (a) 0.56 m/s (b) 0.11 m/s

5) If the fastest you can safely drive is 65 mi/h, what is the longest time you can stop for dinner if you must travel 541 mi in 9.6 h total?
A) 1.0 h
B) 1.3 h
C) 1.4 h
D) You can't stop at all.

Answer: B

6) Arthur and Betty start walking toward each other when they are 100 m apart. Arthur has a speed of 3.0 m/s and Betty has a speed of 2.0 m/s. Their dog, Spot, starts by Arthur's side at the same time and runs back and forth between them at 5.0 m/s. By the time Arthur and Betty meet, what distance has Spot run?

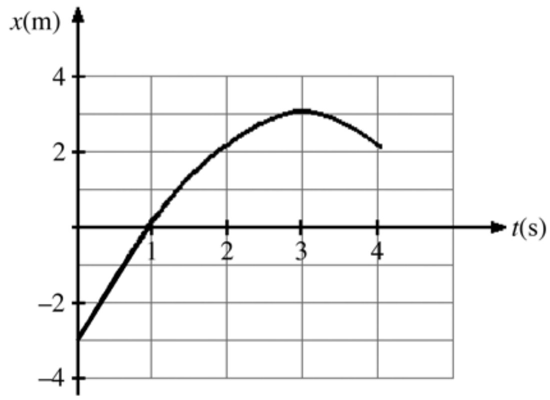
Answer: 100 m

7) A racing car accelerates uniformly from rest along a straight track. This track has markers spaced at equal distances along it from the start, as shown in the figure. The car reaches a speed of 140 km/h as it passes marker 2. Where on the track was the car when it was traveling at 70 km/h?

A) Before marker 1
B) At marker 1
C) Between marker 1 and marker 2

Answer: A

8) The figure represents the position of a particle as it travels along the x–axis. Between $t = 2$ s and $t = 4$ s, what is (a) the average speed of the particle and (b) the average velocity of the particle?



Answer: (a) 1.0 m/s (b) 0.00 m/s

9) The position of an object as a function of time is given by $x = bt^2 - ct$, where $b = 2.0$ m/s^2 and $c = 6.7$ m/s, and x and t are in SI units. What is the instantaneous velocity of the object when $t = 2.2$?

A) 1.7 m/s
B) 2.1 m/s
C) 2.3 m/s
D) 2.7 m/s

Answer: B

10) The position of an object is given by $x = at3 - bt2 + ct$, where $a = 4.1$ m/s^3, $b = 2.2$ m/s^2, $c = 1.7$ m/s, and x and t are in SI units. What is the instantaneous acceleration of the object when $t = 0.7$ s?

A) –13 m/s^2
B) 2.9 m/s^2
C) 4.6 m/s^2
D) 13 m/s^2

Answer: D

11) The velocity of an object as a function of time is given by $v(t) = 2.00$ m/s + (3.00 m/s) t – (1.0 m/s^2) t^2. Determine the instantaneous acceleration of the object at time $t = 5.00$ s.

A) –8.00 m/s^2
B) –7.00 m/s^2
C) 2.00 m/s^2
D) 0.00 m/s^2
E) –2.00 m/s^2

Answer: B

12) The position of an object as a function of time is given by $x(t) = at^3 - bt^2 + ct - d$, where $a = 3.6\ \text{m/s}^3$, $b = 4.0\ \text{m/s}^2$, $c = 60$ m/s and $d = 7.0$ m.
(a) Find the instantaneous acceleration at $t = 2.4$ s.
(b) Find the average acceleration over the first 2.4 seconds.

Answer: (a) 44 m/s^2
(b) 18 m/s^2

13) The velocity of an object is given by the expression $v(t) = 3.00\ \text{m/s} + (4.00\ \text{m/s}^3)t^2$, where t is in seconds. Determine the position of the object as a function of time if it is located at $x = 1.00$ m at time $t = 0.000$ s.
A) $(4.00\ \text{m/s})t + 1.00$ m
B) $(3.00\ \text{m/s})t + (1.33\ \text{m/s3})t^3$
C) $(4.00\ \text{m/s})t$
D) 1.33 m
E) $1.00\ \text{m} + (3.00\ \text{m/s})t + (1.33\ \text{m/s}^3)t^3$

Answer: E

14) The acceleration of an object as a function of time is given by $a(t) = (3.00\ \text{m/s}^3)t$, where t is in seconds. If the object is at rest at time $t = 0.00$ s, what is the velocity of the object at time $t = 6.00$ s?
A) 18.0 m/s
B) 54.0 m/s
C) 0.00 m/s
D) 15.0 m/s
E) 108 m/s

Answer: B

15) The acceleration of an object as a function of time is given by $a(t) = (3.00\ \text{m/s}^3)t$, where t is in seconds. If the object has a velocity 1.00 m/s at time $t = 1.00$ s, what is the displacement of the object between time $t = 2.00$ s and time $t = 4.00$ s?
A) 33.0 m
B) 30.0 m
C) 36.0 m
D) 27.0 m

Answer: D

16) A car accelerates from 10.0 m/s to 30.0 m/s at a rate of 3.00 m/s^2. How far does the car travel while accelerating?
A) 80.0 m
B) 133 m
C) 226 m
D) 399 m

Answer: B

17) A dragster starts from rest and travels 1/4 mi in 6.70 s with constant acceleration. What is its velocity when it crosses the finish line?
A) 296 mi/h
B) 269 mi/h
C) 188 mi/h
D) 135 mi/h
Answer: B

18) A airplane that is flying level needs to accelerate from a speed of 2.00×10^2 m/s to a speed of 2.40×10^2 m/s while it flies a distance of 1.20 km. What must be the acceleration of the plane?
A) 4.44 m/s^2
B) 2.45 m/s^2
C) 7.33 m/s^2
D) 5.78 m/s^2
E) 1.34 m/s^2
Answer: C

19) A runner maintains constant acceleration after starting from rest as she runs a distance of 60.0 m. The runner's speed at the end of the 60.0 m is 9.00 m/s. How much time did it take the runner to complete the 60.0 m distance?
A) 6.67 s
B) 15.0 s
C) 9.80 s
D) 10.2 s
E) 13.3 s
Answer: A

20) An object starts from rest at time $t = 0.00$ s and moves in the $+x$ direction with constant acceleration. The object travels 12.0 m from time $t = 1.00$ s to time $t = 2.00$ s. What is the acceleration of the object?
A) -12.0 m/s^2
B) 24.0 m/s^2
C) -4.00 m/s^2
D) 4.00 m/s^2
E) 8.00 m/s^2
Answer: E

21) A car starts from rest and accelerates with a constant acceleration of 1.00 m/s^2 for 3.00 s. The car continues for 5.00 s at constant velocity. How far has the car traveled from its starting point?
A) 24.0 m
B) 9.00 m
C) 19.5 m
D) 4.50 m
E) 15.0 m
Answer: C

22) A ball rolls across a floor with an acceleration of 0.100 m/s^2 in a direction opposite to its velocity. The ball has a velocity of 4.00 m/s after rolling a distance 6.00 m across the floor. What was the initial speed of the ball?
A) 4.15 m/s
B) 5.85 m/s
C) 4.60 m/s
D) 5.21 m/s
E) 3.85 m/s
Answer: A

23) A car is 200 m from a stop sign and traveling toward the sign at 40.0 m/s. At this time, the driver suddenly realizes that she must stop the car. If it takes 0.200 s for the driver to apply the brakes, what must be the magnitude of the constant acceleration of the car after the brakes are applied so that the car will come to rest at the stop sign?
A) 2.89 m/s^2
B) 3.89 m/s^2
C) 4.17 m/s^2
D) 3.42 m/s^2
E) 2.08 m/s^2
Answer: C

24) A speeding car is traveling at a constant 30.0 m/s when it passes a stationary police car. If the police car delays for 1.00 s before starting, what must be the magnitude of the constant acceleration of the police car to catch the speeding car after the police car travels a distance of 300 m?
A) 6.00 m/s^2
B) 3.00 m/s^2
C) 7.41 m/s^2
D) 1.45 m/s^2
E) 3.70 m/s^2
Answer: C

25) A soccer ball is released from rest at the top of a grassy incline. After 8.6 seconds, the ball travels 87 meters and 1.0 s after this, the ball reaches the bottom of the incline.
(a) What was the magnitude of the ball's acceleration, assume it to be constant?
(b) How long was the incline?
Answer: a) 2.4 m/s^2 b) 110 m

26) A package is dropped from a helicopter moving upward at 15 m/s. If it takes 16.0 s before the package strikes the ground, how high above the ground was the package when it was released if air resistance is negligible?
A) 810 m
B) 1000 m
C) 1200 m
D) 1500 m
Answer: B

27) A ball is projected upward at time $t = 0.0$ s, from a point on a roof 90 m above the ground. The ball rises, then falls and strikes the ground. The initial velocity of the ball is 36.2 m/s if air resistance is negligible. The time when the ball strikes the ground is closest to
A) 9.4 s
B) 9.0 s
C) 8.7 s
D) 9.7 s
E) 10 s

Answer: A

28) At the same moment from the top of a building 3.0×10^2 m tall, one rock is dropped and one is thrown downward with an initial velocity of 10 m/s. Both of them experience negligible air resistance. How much EARLIER does the thrown rock strike the ground?
A) 0.95 s
B) 0.86 s
C) 0.67 s
D) They land at exactly the same time.

Answer: A

29) Two identical objects A and B fall from rest from different heights to the ground and feel no appreciable air resistance. If object B takes TWICE as long as object A to reach the ground, what is the ratio of the heights from which A and B fell?
A) $h_A/h_B = 1/\sqrt{2}$
B) $h_A/h_B = 1/2$
C) $h_A/h_B = 1/4$
D) $h_A/h_B = 1/8$

Answer: C

30) A foul ball is hit straight up into the air with a speed of 30.0 m/s.
(a) Calculate the time required for the ball to rise to its maximum height.
(b) Calculate the maximum height reached by the ball.
(c) Determine the time at which the ball pass a point 25.0 m above the point of contact between the bat and ball.
(d) Explain why there are two answers to part (c).

Answer: (a) 3.06 s (b) 45.9 m (c) 0.995 s and 5.13
(d) One value is for the ball traveling upward; one value is for the ball traveling downward.

31) A rock is dropped from the top of a vertical cliff and takes 3.00 s to reach the ground below the cliff. A second rock is thrown vertically from the cliff, and it takes this rock 2.00 s to reach the ground below the cliff from the time it is released. With what velocity was the second rock thrown, assuming no air resistance?
A) 4.76 m/s upward
B) 5.51 m/s downward
C) 12.3 m/s upward
D) 4.76 m/s downward
E) 12.3 m/s downward

Answer: E

32) To determine the height of a flagpole, Abby throws a ball straight up and times it. She sees that the ball goes by the top of the pole after 0.50 s and then reaches the top of the pole again after a total elapsed time of 4.1 s. How high is the pole above the point where the ball was launched? (You can ignore air resistance.)

A) 10 m
B) 13 m
C) 16 m
D) 18 m
E) 26 m

Answer: A

33) A test rocket is fired straight up from rest with a net acceleration of 20.0 m/s^2. After 4.00 seconds the motor turns off, but the rocket continues to coast upward with no appreciable air resistance. What maximum elevation does the rocket reach?

A) 487 m
B) 327 m
C) 320 m
D) 408 m
E) 160 m

Answer: A

34) A toy rocket is launched vertically from ground level (y = 0.00 m), at time t = 0.00 s. The rocket engine provides constant upward acceleration during the burn phase. At the instant of engine burnout, the rocket has risen to 72 m and acquired a velocity of 30 m/s. The rocket continues to rise in unpowered flight, reaches maximum height, and falls back to the ground with negligible air resistance. The speed of the rocket upon impact on the ground is closest to

A) 48 m/s
B) 44 m/s
C) 39 m/s
D) 54 m/s
E) 59 m/s

Answer: A

35) A ball is projected upward at time t = 0.00 s, from a point on a roof 70 m above the ground and experiences negligible air resistance. The ball rises, then falls and strikes the ground. The initial velocity of the ball is 28.5 m/s. Consider all quantities as positive in the upward direction. The velocity of the ball when it is 39 m above the ground is closest to

A) −38 m/s.
B) −30 m/s.
C) −23 m/s.
D) −15 m/s.
E) −45 m/s.

Answer: A

36) On the earth, when an astronaut throws a 0.250–kg stone vertically upward, it returns to his hand a time T later. On planet X he finds that, under the same circumstances, the stone returns to his hand in $2T$. In both cases, he throws the stone with the same initial velocity and it feels negligible air resistance. The acceleration due to gravity on planet X (in terms of g) is

A) $g/4$.
B) $g/2$.
C) $g/\sqrt{2}$.
D) $g\sqrt{2}$.
E) $2g$.

Answer: B

37) Two identical stones are dropped from rest and feel no air resistance as they fall. Stone A is dropped from height h, and stone B is dropped from height $2h$. If stone A takes time t to reach the ground, stone B will take time

A) $4t$.
B) $2t$.
C) $t\sqrt{2}$.
D) $t/\sqrt{2}$.
E) $t/2$.

Answer: C

38) A rock is thrown directly upward from the edge of the roof of a building that is 66.2 meters tall. The rock misses the building on its way down, and is observed to strike the ground 4.00 seconds after being thrown. Neglect any effects of air resistance. With what speed was the rock thrown?

Answer: 3.05 m/s

39) A rocket takes off vertically from the launchpad with no initial velocity but a constant upward acceleration of 2.25 m/s^2. At 15.4 s after blastoff, the engines fail completely so the only force on the rocket from then on is the pull of gravity.
(a) What is the maximum height the rocket will reach above the launchpad?
(b) How fast is the rocket moving at the instant before it crashes onto the launchpad?
(c) How long after engine failure does it take for the rocket to crash onto the launchpad?

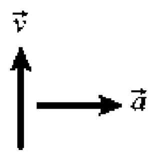
Answer: (a) 328 m (b) 80.2 m/s (c) 11.7 s

Chapter 3 Motion in Two and Three Dimensions

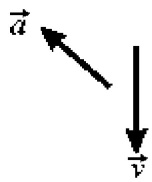
3.1 Conceptual Questions

1) Shown below are the velocity and acceleration vectors for a person in several different types of motion. In which case is the person slowing down and turning to his right?

A)

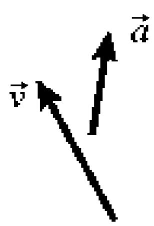


B)

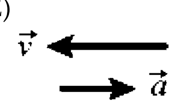


C)

D)



E)



Answer: B

2) While an object is in projectile motion (with upward being positive) with no air resistance

A) the horizontal component of its velocity remains constant and the horizontal component of its acceleration is equal to $-g$.
B) the horizontal component of its velocity remains constant and the vertical component of its acceleration is equal to $-g$.
C) the horizontal component of its velocity remains constant and the vertical component of its acceleration is equal to zero.
D) the vertical component of both its velocity and its acceleration remain constant.
E) the vertical component of its velocity remains constant and the vertical component of its acceleration is equal to $-g$.

Answer: B

3) For general projectile motion, when the projectile is at the highest point of its trajectory
   A) its acceleration is zero.
   B) its velocity is perpendicular to the acceleration.
   C) its velocity and acceleration are both zero.
   D) the horizontal component of its velocity is zero.
   E) the horizontal and vertical components of its velocity are zero.

   Answer: B

4) Alice and Tom dive from an overhang into the lake below. Tom simply drops straight down from the edge, but Alice takes a running start and jumps with an initial horizontal velocity of 25 m/s. Neither person experiences any significant air resistance. Just as they reach the lake below
   A) the speed of Alice is larger than that of Tom.
   B) the splashdown speed of Alice is larger than that of Tom.
   C) they will both have the same speed.
   D) the speed of Tom will always be 9.8 m/s larger than that of Alice.
   E) the speed of Alice will always be 25 m/s larger than that of Tom.

   Answer: A

5) Alice and Tom dive from an overhang into the lake below. Tom simply drops straight down from the edge, but Alice takes a running start and jumps with an initial horizontal velocity of 25 m/s. Neither person experiences any significant air resistance. Compare the time it takes each of them to reach the lake below.
   A) Alice reaches the surface of the lake first.
   B) Tom reaches the surface of the lake first.
   C) Alice and Tom will reach the surface of the lake at the same time.

   Answer: C

6) Jan and Len throw identical rocks off a tall building at the same time. The ground near the building is flat. Jan throws her rock straight downward. Len throws his rock downward and outward such that the angle between the initial velocity of the rock and the horizon is 30°. Len throws the rock with a speed twice that of Jan's rock. If air resistance is negligible, which rock hits the ground first?
   A) They hit at the same time.
   B) Jan's rock hits first.
   C) Len's rock hits first.
   D) It is impossible to know from the information given.

   Answer: A

7) A monkey is sitting at the top of a tree 20 m above ground level. A person standing on the ground wants to feed the monkey. He uses a bow and arrow to launch the food to the monkey. If the person knows that the monkey is going to drop from the tree at the same instant that the person launches the food, how should the person aim the arrow containing the food? Air resistance is small enough to be ignored.
   A) He should aim it at the monkey.
   B) He should aim it below the monkey.
   C) He should aim it above the monkey.

   Answer: A

8) A pilot drops a package from a plane flying horizontally at a constant speed. Neglecting air resistance, when the package hits the ground the horizontal location of the plane will
   A) be behind the package.
   B) be over the package.
   C) be in front of the package.
   D) depend of the speed of the plane when the package was released.

   Answer: B

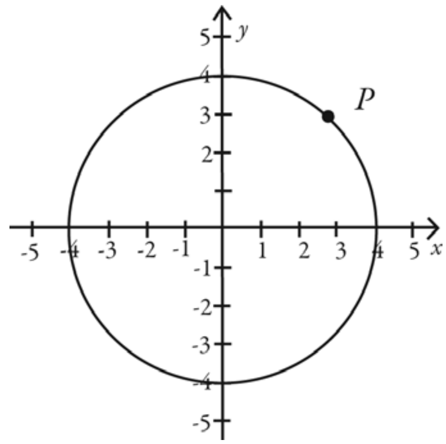
9) For an object in uniform circular motion, its velocity and acceleration vectors are always perpendicular to each other at every point in the path.
   A) True
   B) False

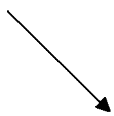
   Answer: A

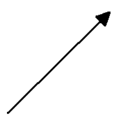
10) If an object travels at a constant speed in a circular path, the acceleration of the object is
   A) larger in magnitude the smaller the radius of the circle.
   B) in the same direction as the velocity of the object.
   C) smaller in magnitude the smaller the radius of the circle.
   D) in the opposite direction of the velocity of the object.
   E) zero.

   Answer: A

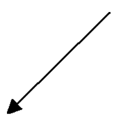
11) Point P in the figure indicates the position of an object traveling at constant speed clockwise around the circle. Which arrow best represents the direction of the acceleration of the object at point P?

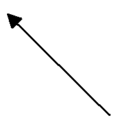


A) 

B) 

C) 

D) 

E) 

Answer: D

12) If you set the cruise control of your car to a certain speed and take a turn, the speed of the car will remain the same. Is the car accelerating?

A) Yes
B) No

Answer: A

13) Which of the following is an accurate statement?
A) The magnitude of a vector can be zero even though one of its components is not zero.
B) It is possible to add a scalar quantity to a vector.
C) Even though two vectors have unequal magnitudes, it is possible that their vector sum is zero.
D) Rotating a vector about an axis passing through the tip of the vector does not change the vector.
E) The magnitude of a vector is independent of the coordinate system used.

Answer: E

14) If $\vec{A} - \vec{B} = 0$, then the vectors $\vec{A}$ and $\vec{B}$ have equal magnitudes and are directed in the opposite directions from each other.
A) True
B) False

Answer: B

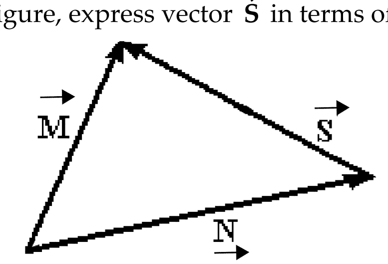
15) Under what condition is $|\vec{A} - \vec{B}| = A + B$?
A) The magnitude of vector $\vec{B}$ is zero.
B) Vectors $\vec{A}$ and $\vec{B}$ are in opposite directions.
C) Vectors $\vec{A}$ and $\vec{B}$ are in the same direction.
D) Vectors $\vec{A}$ and $\vec{B}$ are in perpendicular directions.
E) The statement is never true.

Answer: B

16) If $A > B$, under what condition is $|\vec{A} - \vec{B}| = \boldsymbol{A} - \boldsymbol{B}$?
A) The statement is never true.
B) Vectors $\vec{A}$ and $\vec{B}$ are in opposite directions.
C) Vectors $\vec{A}$ and $\vec{B}$ are in the same direction.
D) Vectors $\vec{A}$ and $\vec{B}$ re in perpendicular directions.
E) The statement is always true.

Answer: C

17) For the vectors shown in the figure, express vector $\vec{S}$ in terms of vectors $\vec{M}$ and $\vec{N}$.



Answer: $\vec{S} = \vec{M} - \vec{N}$

18) The magnitude of a vector can never be less than the magnitude of one of its components.
A) True
B) False
Answer: A

19) If the magnitude of vector $\vec{A}$ is less than the magnitude of vector $\vec{B}$, then the x component of $\vec{A}$ is less than the x component of $\vec{B}$.
A) True
B) False
Answer: B

20) If the eastward component of vector $\vec{A}$ is equal to the westward component of vector $\vec{B}$ and their northward components are equal. Which one of the following statements about these two vectors is correct?
A) Vector $\vec{A}$ is parallel to vector $\vec{B}$.
B) Vectors $\vec{A}$ and $\vec{B}$ point in opposite directions.
C) Vector $\vec{A}$ is perpendicular to vector $\vec{B}$.
D) The magnitude of vector $\vec{A}$ is equal to the magnitude of vector $\vec{B}$.
E) The magnitude of vector $\vec{A}$ is twice the magnitude of vector $\vec{B}$.
Answer: D

21) If all the components of a vector are equal to 1, then that vector is a unit vector.
A) True
B) False
Answer: B

3.2 Problems

1) Object A has a position as a function of time given by $\vec{r}_A(t) = (3.00 \text{ m/s})t\,\hat{i} + (1.00 \text{ m/s}^2)t^2\hat{j}$.

Object B has a position as a function of time given by $\vec{r}_B(t) = (4.00 \text{ m/s})t\hat{i} + (-1.00 \text{ m/s}^2)t^2\hat{j}$. All quantities are SI units. What is the distance between object A and object B at time $t = 3.00$ s?
A) 34.6 m
B) 15.0 m
C) 18.3 m
D) 3.46 m
E) 29.8 m
Answer: C

2) An object has a position given by $\vec{r} = [2.0\text{ m} + (5.00\text{ m/s})t]\hat{i} + [3.0\text{ m} - (2.00\text{ m/s}^2)t^2]\hat{j}$, where quantities are in SI units. What is the speed of the object at time $t = 2.00$ s?
A) 6.40 m/s
B) 9.43 m/s
C) 7.00 m/s
D) 7.65 m/s
E) 13.0 m/s

Answer: B

3) An object has a position given by $\vec{r} = [2.0\text{ m} + (3.00\text{ m/s})t]\hat{i} + [3.0\text{ m} - (2.00\text{ m/s}^2)t^2]\hat{j}$, where all quantities are in SI units. What is the magnitude of the acceleration of the object at time $t = 2.00$ s?
A) 1.00 m/s^2
B) 0.00 m/s^2
C) 0.522 m/s^2
D) 4.00 m/s^2
E) 2.00 m/s^2

Answer: D

4) The horizontal coordinates of a Frisbee™ in a strong wind are given by
$x = -12t + 4t^2$ and $y = 10t - 3t^2$, where x and y are in meters, and t is in seconds.
(a) What is the acceleration of the Frisbee? Give a magnitude and a direction, measuring angles from the positive x direction.
(b) What is the magnitude of the velocity at $t = 2.0$ s, accurate to the nearest m/s?

Answer: (a) 10 m/s^2, 323°
(b) 4 m/s

5) An electron moves with a constant horizontal velocity of 3.0×10^6 m/s and no initial vertical velocity as it enters a deflector inside a TV tube. The electron strikes the screen after traveling 17.0 cm horizontally and 40.0 cm vertically upward with no horizontal acceleration. What is the constant vertical acceleration provided by the deflector? (The effects of gravity can be ignored.)
A) 2.5×10^{14} m/s^2
B) 8.3×10^2 m/s^2
C) 1.4×10^4 m/s^2
D) 1.2×10^{14} m/s^2

Answer: A

6) A hockey puck slides off the edge of a table at point A with an initial velocity of 20.0 m/s and experiences no air resistance. The height of the tabletop above the ground is 2.00 m.
(a) What is the speed (not the velocity) of the puck just before it touches the ground?
(b) What is the distance between point A and the point where the puck hits the ground?

Answer: (a) 21.0 m/s (b) 12.9 m

7) A hockey puck slides off the edge of a table with an initial velocity of 28.0 m/s. and experiences no air resistance. The height of the tabletop above the ground is 2.00 m. What is the angle below the horizontal of the velocity of the puck just before it hits the ground?
   A) 77.2°
   B) 72.6°
   C) 12.8°
   D) 12.6°
   E) 31.8°

   Answer: D

8) A boy throws a rock with an initial velocity of 2.15 m/s at 30.0° above the horizontal. If air resistance is negligible, how long does it take for the rock to reach the maximum height of its trajectory?
   A) 0.110 s
   B) 0.194 s
   C) 0.215 s
   D) 0.303 s

   Answer: A

9) What is the maximum distance we can shoot a dart, from ground level, provided our toy dart gun gives a maximum initial velocity of 2.78 m/s and air resistance is negligible?
   A) 0.789 m
   B) 1.58 m
   C) 1.39 m
   D) 0.394 m

   Answer: A

10) A catapult is tested by Roman legionnaires. They tabulate the results in a papyrus and 2000 years later the archaeological team reads (distances translated into modern units):
    Range = 0.20 km; angle of launch = $\pi/4$; landing height = launch height. What is the initial velocity of launch of the boulders if air resistance is negligible?
    A) 44 m/s
    B) 1.4 m/s
    C) 22 m/s
    D) 0.69 m/s

    Answer: A

11) A hobby rocket reaches a height of 72.3 m and lands 111 m from the launch point with no air resistance. What was the angle of launch?
    A) 69.0°
    B) 67.4°
    C) 22.6°
    D) 44.8°

    Answer: A

12) A ball is thrown at a 60.0° angle above the horizontal across level ground. It is thrown from a height of 2.00 m above the ground with a speed of 20.0 m/s and experiences no appreciable air resistance. The time the ball remains in the air before striking the ground is closest to
    A) 16.2 s.
    B) 3.07 s.
    C) 3.32 s.
    D) 3.53 s.
    E) 3.64 s.

    Answer: E

13) A rock is thrown at a window that is located 18.0 m above the ground. The rock is thrown at an angle of 40.0° above horizontal. The rock is thrown from a height of 2.00 m above the ground with a speed of 30.0 m/s and experiences no appreciable air resistance. If the rock strikes the window on its upward trajectory, from what horizontal distance from the window was it released?
    A) 53.2 m
    B) 48.7 m
    C) 71.6 m
    D) 29.8 m
    E) 27.3 m

    Answer: E

14) An airplane is flying at a speed of $2.00\ 10^{2}$ m/s in level flight at an altitude of $8.00\ 10^{2}$ m. A package is to be dropped from the airplane to land on a target on the ground. Ignore air resistance.
    (a) At what horizontal distance away from the target should the package be released so that it lands on the target?
    (b) In what direction relative to the horizontal will the package be traveling when it hits the ground?

    Answer: (a) 2.56 km (b) 32.1° below the horizontal

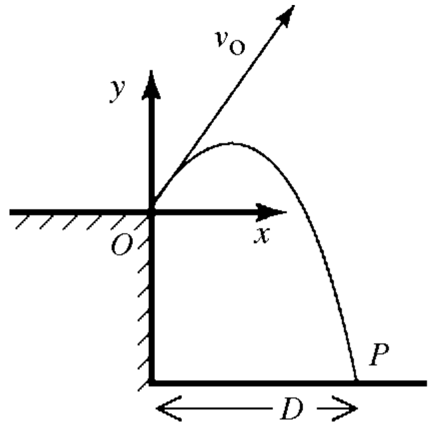
15) A child throws a ball with an initial speed of 8.00 m/s at an angle of 40.0° above the horizontal. The ball leaves her hand 1.00 m above the ground and experience negligible air resistance.
    (a) How far from where the child is standing does the ball hit the ground?
    (b) How long is the ball in flight before it hits the ground?

    Answer: (a) 7.46 m (b) 1.22 s

16) A child throws a ball with an initial speed of 8.00 m/s at an angle of 40.0° above the horizontal. The ball leaves her hand 1.00 m above the ground and experience negligible air resistance.
    (a) What is the magnitude of the ball's velocity just before it hits the ground?
    (b) At what angle below the horizontal does the ball approach the ground?

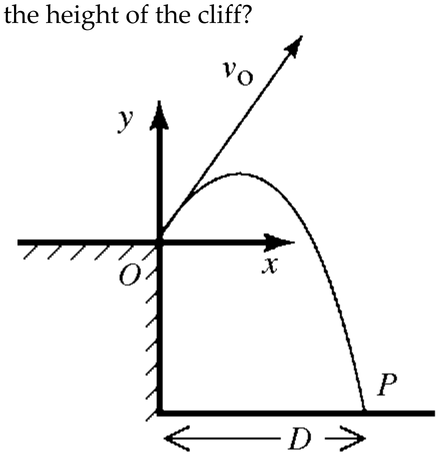
    Answer: (a) 9.14 m/s (b) 47.9°

17) A projectile is fired from point *0* at the edge of a cliff, with initial velocity components of v_{0x} = 60 m/s and v_{0y} =175 m/s, as shown in the figure.The projectile rises and then falls into the sea at point *P*. The time of flight of the projectile is 40.0 s, and it experiences no appreciable air resistance in flight. What is the magnitude of the velocity of the projectile 21.0 s after it is fired?



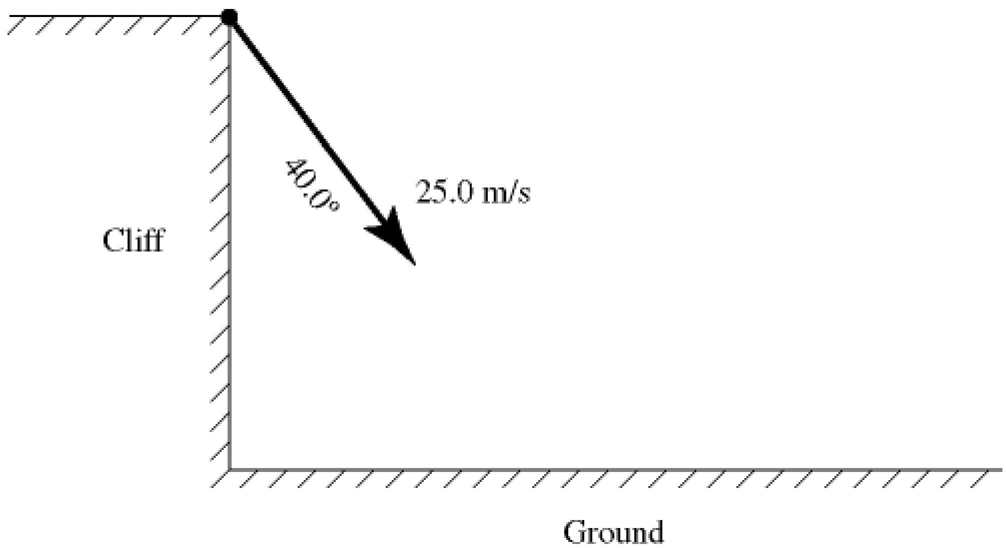
Answer: 67.4 m/s

18) A projectile is fired from point *0* at the edge of a cliff, with initial velocity components of v_{0x} = 60.0 m/s and v_{0y} = 175 m/s, as shown in the figure. The projectile rises and then falls into the sea at point *P*. The time of flight of the projectile is 40.0 s, and it experiences no appreciable air resistance in flight. What is the height of the cliff?



Answer: 840 m

19) A hiker throws a stone from the upper edge of a vertical cliff. The stone's initial velocity is 25.0 m/s directed at 40.0° with the face of the cliff, as shown in the figure. The stone hits the ground 3.75 s after being thrown and feels no appreciable air resistance as it falls.
(a) What is the height of the cliff?
(b) How far from the foot of the cliff does the stone land?
(c) How fast is the stone moving just before it hits the ground?



Answer: (a) 141 m (b) 60.3 m (c) 58.2 m/s

20) A projectile returns to its original height 4.08 s after being launched, during which time it travels 76.2 m horizontally. If air resistance can be neglected, what was the projectile's initial speed?

Answer: 27.4 m/s

21) A plane flying at 70.0 m/s suddenly stalls. If the acceleration during the stall is 9.8 m/s^2 directly downward, the stall lasts 5.0 s, and the plane was originally climbing at 25° to the horizontal, what is the velocity after the stall?
A) 66 m/s at 17° below the horizontal
B) 66 m/s at 17° above the horizontal
C) 80 m/s at 37° below the horizontal
D) 80 m/s at 37° above the horizontal

Answer: A

22) A rescue plane flying horizontally at 72.6 m/s spots a survivor in the ocean 182 m directly below and releases an emergency kit with a parachute. . Because of the shape of the parachute, it experiences insignificant horizontal air resistance. If the kit descends with a constant vertical acceleration of 5.82 m/s^2, how far away from the survivor will it hit the waves?
A) 574 m
B) 4.54 km
C) 406 m
D) 602 m

Answer: A

23) An airplane flies between two points on the ground that are 500 km apart. The destination is directly north of the origination of the flight. The plane flies with an air speed of 120 m/s. If a constant wind blows at 10.0 m/s due west during the flight, what direction must the plane fly relative to north to arrive at the destination?
A) 4.78° east of north
B) 4.76° east of north
C) 85.2° west of north
D) 4.78° west of north
E) 4.76° west of north

Answer: A

24) A plane has an eastward heading at a speed of 156 m/s (relative to the air). A 20.0 m/s wind is blowing southward while the plane is flying. The velocity of the plane relative to the ground is
A) 157 m/s at an angle 7.31° south of east.
B) 157 m/s at an angle 7.31° east of south.
C) 155 m/s at an angle 7.36° south of east.
D) 155 m/s at an angle 7.36° east of south.
E) 157 m/s at an angle 7.36° south of east.

Answer: A

25) A swimmer heading directly across a river 200 m wide reaches the opposite bank in 6 min 40 s, during which time she is swept downstream 480 m.
(a) How fast can she swim in still water?
(b) What is the speed of the current?

Answer: (a) 0.50 m/s (b) 1.2 m/s

26) A small boat is moving at a velocity of 3.35 m/s when it is accelerated by a river current perpendicular to the initial direction of motion. If the acceleration of the current is 0.750 m/s^2, what will be the new velocity of the boat after 33.5 s?
A) 25.3 m/s at 82.4° from initial direction of motion
B) 25.3 m/s at 7.59° from initial direction of motion
C) 640.1 m/s at 82.4° from initial direction of motion
D) 640.1 m/s at 7.59° from initial direction of motion

Answer: A

27) You want to swim straight across a river that is 76 m wide. You find that you can do this if you swim at an angle of $\theta = 28°$ from the upstream direction at a constant rate of 1.5 m/s relative to the water. At what rate does the river flow? The angle θ is measured from the river bank (directly upstream is $\theta = 0°$ while directly across the river is $\theta = 90°$).
A) 1.3 m/s
B) 0.70 m/s
C) 1.6 m/s
D) 1.8 m/s

Answer: A

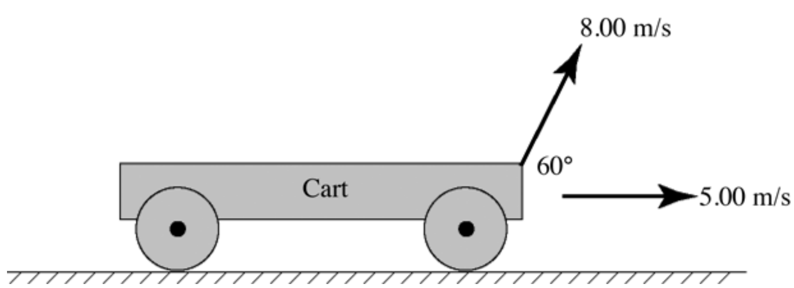
28) A long–distance swimmer is able to swim through still water at 4.0 km/h. She wishes to try to swim from Port Angeles, Washington, directly north to Victoria, British Columbia, a distance of 50 km. An ocean current flows through the Strait of Juan de Fuca from west to east at 3.0 km/h. In what direction (relative to north) should she swim to make the crossing along a straight line between the two cities?
A) 37° west of north
B) 37° east of north
C) 41° west of north
D) 41° east of north
E) 49° west of north

Answer: E

29) A plane flies directly between two cities, *A* and *B*, which are separated by 2300 mi. From *A* to *B*, the plane flies into a 65 mi/h headwind. On the return trip from *B* to *A*, the wind velocity is unchanged. The trip from *B* to *A* takes 65 min less than the trip from *A* to *B*. What is the airspeed of the plane, assuming it is the same in both directions?
A) 530 mi/h
B) 400 mi/h
C) 480 mi/h
D) 610 mi/h

Answer: A

30) A cart is moving with a constant horizontal velocity of 5.00 m/s. A small pebble is launched from the front of the cart with a velocity of 8.00 m/s at 60.0° above the horizontal as measured relative to the cart (see figure) and experiences no significant air resistance. Just as the pebble returns to the level from which it was launched, its distance from the front of the cart is closest to



A) 2.83 m.
B) 4.60 m.
C) 5.66 m.
D) 9.19 m.
E) 11.3 m.

Answer: C

31) A ball is tied to the end of a cable of negligible mass. The ball is spun in a circle with a radius 2.00 m making 7.00 revolutions every 10.0 seconds. What is the magnitude of the acceleration of the ball?

A) 67.9 m/s^2
B) 38.7 m/s^2
C) 29.3 m/s^2
D) 14.8 m/s^2
E) 74.2 m/s^2

Answer: B

32) An electrical motor spins at a constant 2857.0 rev/min. If the armature radius is 2.685 cm, what is the acceleration of the outer edge of the armature?

A) 2403 m/s^2
B) 844.4 m/s^2
C) 241,100 m/s^2
D) 84.40 m/s^2

Answer: A

33) A satellite orbits the earth a distance of 1.50×10^7 m above the planet's surface and takes 8.65 hours for each revolution about the earth. The earth's radius is 6.38×10^6 m. The acceleration of this satellite is closest to

A) 0.0690 m/s^2.
B) 0.870 m/s^2.
C) 1.91 m/s^2.
D) 2.72 m/s^2.
E) 9.80 m/s^2.

Answer: B

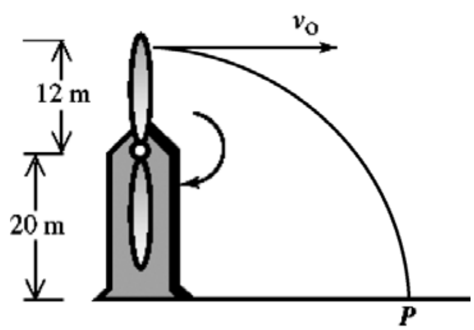
34) An aircraft performs a maneuver called an "aileron roll." During this maneuver, the plane turns like a screw as it maintains a straight flight path, which sets the wings in circular motion. If it takes it 35 s to complete the circle and the wingspan of the plane is 11 m, what is the acceleration of the wing tip?

A) 0.18 m/s^2
B) 0.99 m/s^2
C) 5.6 m/s^2
D) 1.0 m/s^2

Answer: A

35) An object moves in a circle of radius R at constant speed with a period T. If you want to change only the period in order to cut the object's acceleration in half, the new period should be
A) $T/4$.
B) $T/2$.
C) $T/\sqrt{2}$.
D) $T\sqrt{2}$.
E) $4T$.
Answer: D

36) A wind farm generator uses a two-bladed propeller (see figure) mounted on a pylon at a height of 20 m. The length of each propeller blade is 12 m. A small piece from the tip of the propeller breaks off when the propeller is vertical. At that instant, the period of the motion of the propeller is 1.2 s. The fragment flies off horizontally, falls with negligible air resistance, and strikes the ground at P.
(a) How far is point P from the base of the pylon?
(b) At what angle with respect to the vertical is the fragment moving just as it strikes the ground at P?



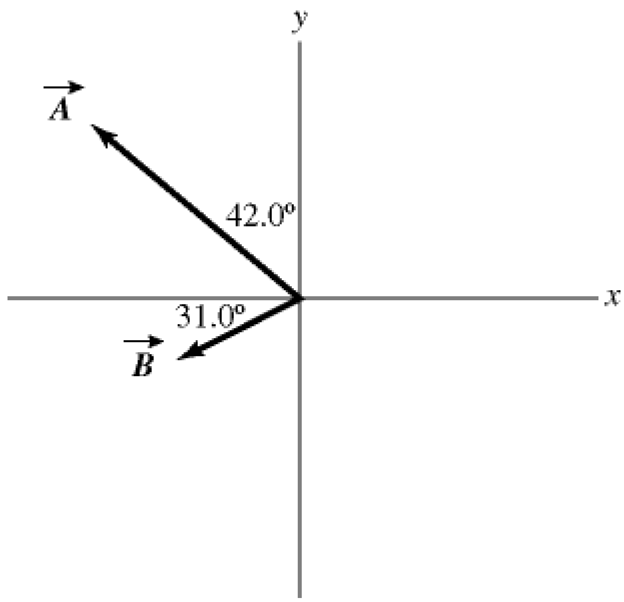
Answer: (a) 160 m (b) 68°

37) A disk-shaped space station 175 m in diameter spins uniformly about an axis perpendicular to the plane of the disk through its center. How many rpm (rev/min) must this disk make so that the acceleration of all points on its rim is g/2?
Answer: 2.26 rev/min

38) Two particles, A and B, are in uniform circular motion about a common center. The acceleration of particle A is 8.5 times that of particle B. The period of particle B is 2.0 times the period of particle A. The ratio of the radius of the motion of particle A to that of particle B is closest to
A) $r_A/r_B = 2.1$.
B) $r_A/r_B = 4.3$.
C) $r_A/r_B = 18$.
D) $r_A/r_B = 0.24$.
E) $r_A/r_B = 17$.
Answer: A

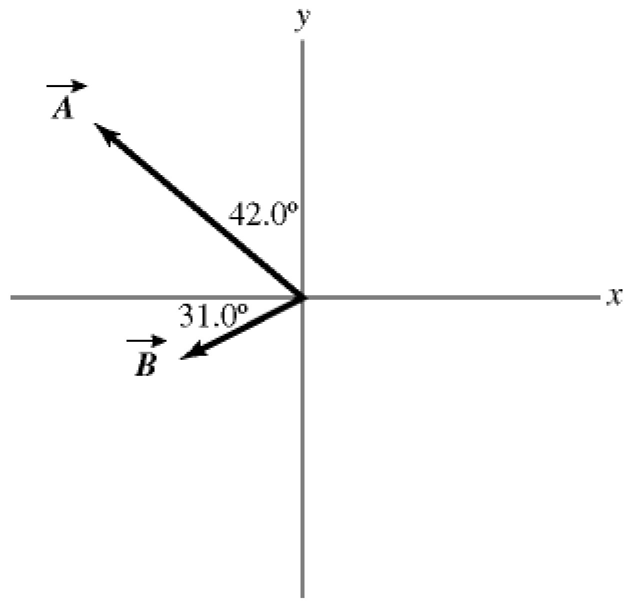
39) You walk 55 m to the north, then turn 60° to your right and walk another 45 m. How far are you from where you originally started?
A) 87 m
B) 50 m
C) 94 m
D) 46 m
Answer: A

40) Vectors $\vec{A}$ and $\vec{B}$ are shown in the figure. Vector $\vec{C}$ is given by $\vec{C} = \vec{B} - \vec{A}$. The magnitude of vector $\vec{A}$ is 16.0 units, and the magnitude of vector $\vec{B}$ is 7.00 units. What is the magnitude of vector $\vec{C}$?



A) 9.00
B) 9.53
C) 15.5
D) 16.2
E) 17.5
Answer: D

41) Vectors $\vec{A}$ and $\vec{B}$ are shown in the figure. Vector $\vec{C}$ is given by $\vec{C} = \vec{B} - \vec{A}$. The magnitude of vector $\vec{A}$ is 16.0 units, and the magnitude of vector $\vec{B}$ is 7.00 units. What is the angle of vector $\vec{C}$, measured counterclockwise from the $+x$–axis?



A) 16.9°
B) 22.4°
C) 73.1°
D) 287°
E) 292°

Answer: D

42) A rabbit trying to escape a fox runs north for 8.0 m, darts northwest for 1.0 m, then drops 1.0 m down a hole into its burrow. What is the magnitude of the net displacement of the rabbit?

A) 8.8 m
B) 8.1 m
C) 66 m
D) 10 m

Answer: A

43) You walk 53 m to the north, then turn 60° to your right and walk another 45 m. Determine the direction of your displacement vector. Express your answer as an angle relative to east.

A) 63° N of E
B) 50° N of E
C) 57° N of E
D) 69° N of E

Answer: A

44) Vector $\vec{A}$ has a magnitude 5.00 and points in a direction 40.0° clockwise from the negative y axis. What are the x and y components of vector $\vec{A}$.

A) $A_x = 3.83$ and $A_y = 3.21$
B) $A_x = 3.83$ and $A_y = -3.21$
C) $A_x = -3.21$ and $A_y = -3.83$
D) $A_x = -3.21$ and $A_y = 3.83$
E) $A_x = 4.29$ and $A_y = 2.16$

Answer: C

45) The components of vector $\vec{A}$ are $A_x = +3.90$ and $A_y = -4.00$. What is the angle measured counterclockwise from the +x–axis to vector $\vec{A}$?

A) 314°
B) 134°
C) 224°
D) 136°
E) 46.0°

Answer: A

46) Vector $\vec{\mathbf{A}}$ has a magnitude of 5.5 cm and points along the x–axis. Vector $\vec{\mathbf{B}}$ has a magnitude of 7.5 cm and points at +30° above the negative x–axis.

(a) Determine the x and y components of Vector $\vec{\mathbf{A}}$.
(b) Determine the x and y components of Vector $\vec{\mathbf{B}}$.
(c) Determine x and y components of the sum of these two vectors.
(d) Determine the magnitude and direction of the sum of these two vectors.

Answer: (a) $A_x = 5.5$ cm, $A_y = 0$
(b) $B_x = -6.5$ cm, $B_y = 3.8$ cm
(c) $R_x = -1.0$ cm, $R_y = 3.8$ cm
(d) 3.9 cm at 75° above $-x$–axis

47) Vector $\vec{\mathbf{A}}$ has a magnitude of 75.0 cm and points at 30° above the positive x–axis. Vector $\vec{\mathbf{B}}$ has a magnitude of 25.0 cm and points along the negative x–axis. Vector $\vec{\mathbf{C}}$ has a magnitude of 40.0 cm and points at 45° below the negative x–axis.

(a) Determine the x and y components of Vector $\vec{\mathbf{A}}$.
(b) Determine the x and y components of Vector $\vec{\mathbf{B}}$.
(c) Determine the x and y components of Vector $\vec{\mathbf{C}}$.
(d) Determine x and y components of the sum of these three vectors.
(e) Determine the magnitude and direction of the sum of these three vectors.

Answer: (a) $A_x = 65$ cm, $A_y = 38$ cm
(b) $B_x = -25$ cm, $B_y = 0$
(c) $C_x = -28$ cm, $C_y = -28$ cm
(d) $R_x = 12$ cm, $R_y = 9.2$ cm
(e) 15 cm at 38° above $+x$–axis

48) A helicopter is flying horizontally with a speed of 444 m/s over a hill that slopes upward with a 2% grade (that is, the "rise" is 2% of the "run"). What is the component of the helicopter's velocity perpendicular to the sloping surface of the hill?
A) 8.9 m/s
B) 220 m/s
C) 435 m/s
D) 444 m/s
Answer: A

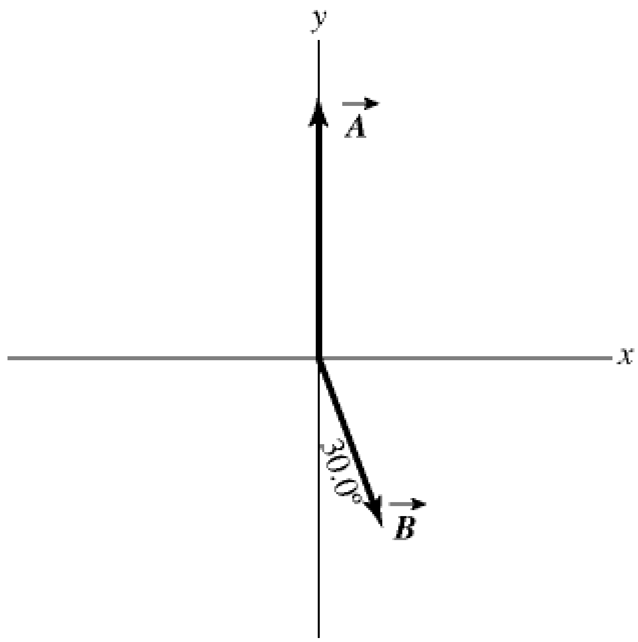
49) An apple falls from an apple tree growing on a 20° slope. The apple hits the ground with an impact velocity of 16.2 m/s straight downward. What is the component of the apple's impact velocity parallel to the surface of the slope?
A) 5.5 m/s
B) 8.7 m/s
C) 12 m/s
D) 15 m/s
Answer: A

50) The components of vector $\vec{A}$ are $A_x = +2.2$ and $A_y = -6.9$, and the components of vector $\vec{B}$ are given are $B_x = -6.1$ and $B_y = -2.2$. What is the magnitude of the vector $\vec{B} - \vec{A}$?
A) 9.5
B) 6.1
C) 9.9
D) 91
E) 0.76
Answer: A

51) The components of vector $\vec{B}$ are $B_x = -3.5$ and $B_y = -9.7$, and the components of vector $\vec{C}$ are $C_x = -6$ and $C_y = +8.1$. What is the angle (less than 180 degrees) between vectors $\vec{B}$ and $\vec{C}$?
A) 124°
B) 56°
C) 17°
D) 163°
E) 106°
Answer: A

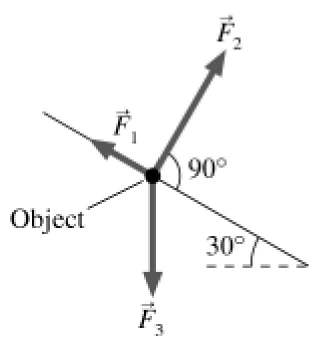
52) An airplane undergoes the following displacements: First, it flies 66 km in a direction 30° east of north. Next, it flies 49 km due south. Finally, it flies 100 km 30° north of west. Using vector components, determine how far the airplane ends up from its starting point.
A) 79 km
B) 81 km
C) 82 km
D) 78 km
E) 76 km
Answer: A

53) In the figure, the magnitude of vector $\vec{A}$ is 18.0 units, and the magnitude of vector $\vec{B}$ is 12.0 units. What vector $\vec{C}$ must be added to the vectors $\vec{A}$ and $\vec{B}$ so that the resultant of these three vectors points in the $-x$ direction and has a magnitude of 7.50 units? Use vector components to find your answer, and express vector $\vec{C}$ by giving its magnitude and the angle it makes with the $+x$-axis taking counterclockwise to be positive.



Answer: 15.5, 209°

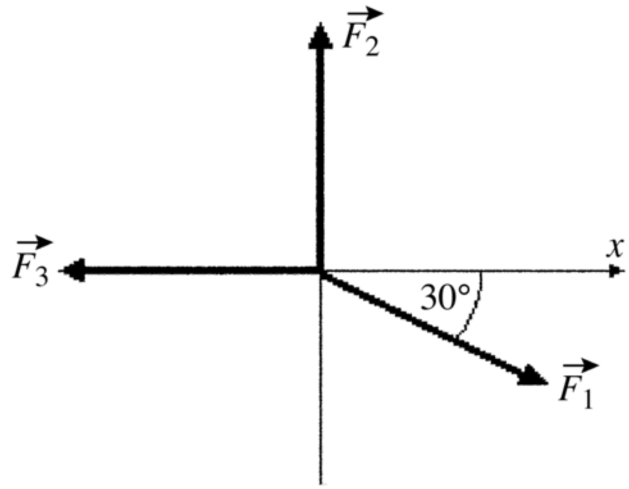
54) Three forces are exerted on an object placed on a tilted floor. Forces are vectors. The three forces are directed as shown in the figure. If the forces have magnitudes $F_1 = 1.0$ N, $F_2 = 8.0$ N and $F_3 = 7.0$ N, where N is the standard unit of force, what is the component of the *net force* $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3$ parallel to the floor?



A) 2.5 N
B) 5.1 N
C) 6.0 N
D) 7.8 N

Answer: A

55) As shown in the figure, three force vectors act on an object. The magnitudes of the forces as shown in the figure are $F_1 = 80.0$ N, $F_2 = 60.0$ N, and $F_3 = 40.0$ N, where N is the standard SI unit of force. The resultant force acting on the object is given by



A) 180 N at an angle 60.0° with respect to $+x$-axis.
B) 60.0 N at an angle 90.0° with respect to $+x$-axis.
C) 20.0 N at an angle 34.3° with respect to $+x$-axis.
D) 35.5 N at an angle 34.3° with respect to $+x$-axis.
E) 40.0 N at an angle 60.0° with respect to $+x$-axis.

Answer: D

56) A teacher sends her students on a treasure hunt. She gives the following instructions:
1. Walk 300 m north
2. Walk 400 m northwest
3. Walk 700 m east-southeast and the treasure is buried there.

As all the other students walk off following the instructions, Jane physics student quickly adds the displacements and walks in a straight line to find the treasure. How far and in what direction does Jane need to walk?

A) 187 m in a direction 67.3° north of east
B) 481 m in a direction 40.9° north of east
C) 399 m in a direction 52.5° north of east
D) 284 m in a direction 28.2° west of north
E) The treasure position cannot be reached in one straight walk.

Answer: B

57) Vector $\vec{A} = -3.00\,\hat{i} + 3.00\,\hat{j}$ and vector $\vec{B} = 3.00\,\hat{i} + 4.00\,\hat{j}$. What is vector $\vec{C} = \vec{A} + \vec{B}$?

A) $0.00\,\hat{i} + 3.00\,\hat{j}$
B) $7.00\,\hat{i} + 7.00\,\hat{j}$
C) $-3.00\,\hat{i} + 7.00\,\hat{j}$
D) $0.00\,\hat{i} + 7.00\,\hat{j}$
E) $-3.00\,\hat{i} - 3.00\,\hat{j}$

Answer: D

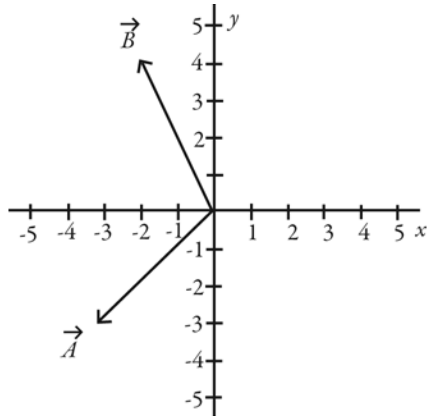
58) Vector $\vec{A} = 1.00\,\hat{i} + -2.00\,\hat{j}$ and vector $\vec{B} = 3.00\,\hat{i} + 4.00\,\hat{j}$. What are the magnitude and direction of vector $\vec{C} = \vec{A} + \vec{B}$?
A) 7.21 in a direction 33.7° counterclockwise from the positive x axis
B) 6.00 in a direction 63.4° counterclockwise from the positive x axis
C) 4.47 in a direction 6.34° counterclockwise from the positive x axis
D) 4.47 in a direction 26.6° counterclockwise from the positive x axis
E) 7.21 in a direction 56.3° counterclockwise from the positive x axis
Answer: D

59) What is the magnitude of $\vec{A} + \vec{B} + \vec{C}$, where $\vec{A} = 1.00\,\hat{i} + 4.00\,\hat{j} - 1.00\,\hat{k}$, $\vec{B} = 3.00\,\hat{i} - 1.00\,\hat{j} - 4.00\,\hat{k}$ and $\vec{C} = -1.00\,\hat{i} + 1.00\,\hat{j}$?
A) 7.07
B) 2.00
C) 10.76
D) 6.78
E) 8.12
Answer: A

60) If $\vec{A} = +4\,\hat{i} - 2\,\hat{j} - 3\,\hat{k}$ and $\vec{C} = -4\,\hat{i} - 2\,\hat{j} - 3\,\hat{k}$, which of the following numbers is closest to the magnitude of $\vec{A} - \vec{C}$?
A) 8
B) 7
C) 9
D) 10
E) 11
Answer: A

61) Vector $\vec{A} = -1.00\hat{i} + -2.00\hat{j}$ and vector $\vec{B} = 3.00\,\hat{i} + 4.00\,\hat{j}$. What are the magnitude and direction of vector $\vec{C} = 3.00\vec{A} + 2.00\vec{B}$?
A) 3.61 in a direction −56.3° counterclockwise from the positive x–axis
B) 3.61 in a direction 56.3° counterclockwise from the positive x–axis
C) 3.61 in a direction 33.7° counterclockwise from the positive x–axis
D) 5.00 in a direction 56.3° counterclockwise from the positive x axis
E) 6.72 in a direction 34.4° counterclockwise from the positive x–axis
Answer: C

62) Vectors $\vec{A}$ and $\vec{B}$ are shown in the figure. What is $\left|-5.00\vec{A} + 4.00\vec{B}\right|$?



A) 31.8
B) $-32.0\hat{i} - 2.00\hat{j}$
C) 1028
D) 34.0
E) $-2.00\hat{i} - 32.0\hat{j}$

Answer: A

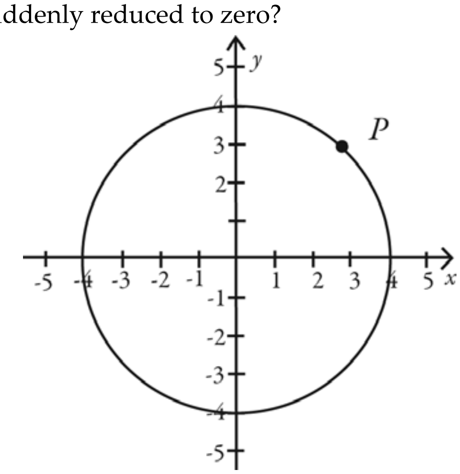
Chapter 4 Force and Motion

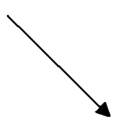
4.1 Conceptual Questions

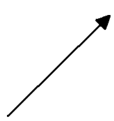
1) You swing a bat and hit a heavy box with a force of 1500 N. The force the box exerts on the bat is
   A) exactly 1500 N only if the box does not move.
   B) exactly 1500 N whether or not the box moves.
   C) greater than 1500 N if the box moves.
   D) less than 1500 N if the box moves.
   E) greater than 1500 N if the bat bounces back.

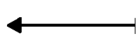
   Answer: B

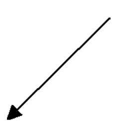
2) Point *P* in the figure indicates the position of an object traveling at constant speed clockwise around the circle. Which arrow best represent the direction the object would travel if the net external force on it were suddenly reduced to zero?

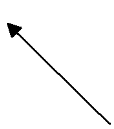


   A)


   B)


   C) 

   D)


   E)


   Answer: D

3) An object is moving to the right, and experiencing a net force that is directed to the right. The magnitude of the force is decreasing with time. The speed of the object is
   A) increasing.
   B) decreasing.
   C) constant in time.

   Answer: A

4) In order to get an object moving, you must push harder on it than it pushes back on you.
   A) True
   B) False

   Answer: B

5) In order to lift a bucket of concrete, you must pull up harder on the bucket than it pulls down on you.
   A) True
   B) False

   Answer: B

6) A 615 N student standing on a scale in an elevator notices that the scale reads 645 N. From this information, the student knows that the elevator must be moving
   A) downward.
   B) upward.
   C) You cannot tell if it is moving upward or downward.

   Answer: C

7) A car is being towed at constant velocity on a horizontal road using a horizontal chain. The tension in the chain must be equal to the weight of the car in order to maintain constant velocity.
   A) True
   B) False

   Answer: B

8) You are standing in a moving bus, facing forward, and you suddenly fall forward as the bus comes to an immediate stop. The force acting on you that causes you to fall forward is
   A) the force of gravity.
   B) the normal force due to your contact with the floor of the bus.
   C) the force due to static friction between you and the floor of the bus.
   D) the force due to kinetic friction between you and the floor of the bus.
   E) No forces were acting on you to cause you to fall.

   Answer: E

9) Consider what happens when you jump up in the air. Which of the following is the most accurate statement?
   A) It is the upward force exerted by the ground that pushes you up, but this force cannot exceed your weight.
   B) You are able to spring up because the earth exerts a force upward on you that is greater than the downward force you exert on the earth.
   C) Since the ground is stationary, it cannot exert the upward force necessary to propel you into the air. Instead, it is the internal forces of your muscles acting on your body itself that propels your body into the air.
   D) When you push down on the earth with a force greater than your weight, the earth will push back with the same magnitude force and thus propel you into the air.
   E) When you jump up the earth exerts a force F_1 on you and you exert a force F_2 on the earth. You go up because $F_1 > F_2$.

   Answer: D

10) A 20-ton truck collides with a 1500-lb car and causes a lot of damage to the car. During the collision
   A) the force on the truck due to the collision is slightly greater than the force on the car.
   B) the force of on the truck due to the collision is exactly equal to the force on the car.
   C) the force on the car due to the collision is much greater than the force on the truck.
   D) the car and the truck have the same magnitude acceleration.

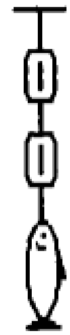
   Answer: B

11) Two objects, each of weight W, hang vertically by spring scales as shown in the figure. The pulleys and the strings attached to the objects have negligible weight, and there is no appreciable friction in the pulleys. The reading in each scale is

   A) W.
   B) more than W, but not quite twice as much.
   C) less than W.
   D) $2W$.
   E) more than $2W$.

   Answer: A

12) A fish weighing 16 N is weighed using two spring scales, each of negligible weight, as shown in the figure. What will be the readings of the scales?

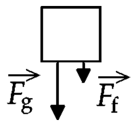


A) The bottom scale will read 16 N, and the top scale will read zero.
B) Each scale will read 16 N.
C) The top scale will read 16 N, and the bottom scale will read zero.
D) The scales will have different readings, but the sum of the two readings will be 16 N.
E) Each scale will read 8 N.

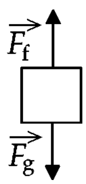
Answer: B

13) Which one of the following free–body diagrams best represents the free–body diagram, with correct relative force magnitudes, of a person in an elevator that is traveling upward with an unchanging velocity? $\vec{F}_f$ is the force of the floor on the person and $\vec{F}_g$ is the force of gravity on the person.

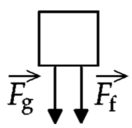
A)



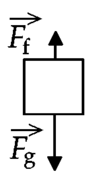
B)



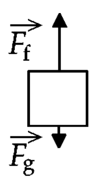
C)



D)



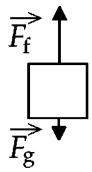
E)



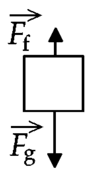
Answer: B

14) Which one of the following free-body diagrams best represents the free-body diagram, with correct relative force magnitudes, of a person in an elevator that is traveling upward but is gradually slowing down at a rate of 9 m/s^2? $\vec{F}_f$ is the force of the floor on the person and $\vec{F}_g$ is the force of gravity on the person.

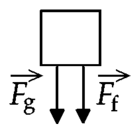
A)



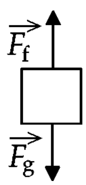
B)



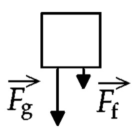
C)



D)



E)



Answer: B

15) A box slides down a frictionless plane inclined at an angle θ above the horizontal. The gravitational force on the box is directed

A) parallel to the plane in the same direction as the movement of the box.
B) parallel to the plane in the opposite direction as the movement of the box.
C) perpendicular to the plane.
D) vertically.
E) at an angle θ below the inclined plane.

Answer: D

16) An object is moving forward with a constant velocity. Which statement about this object MUST be true?

A) The net force on the object is zero.
B) The net force on the object is in the forward direction.
C) No forces are acting on the object.
D) The acceleration of the object is in the forward direction.

Answer: A

17) Suppose you are playing hockey on a new-age ice surface for which there is no friction between the ice and the hockey puck. You wind up and hit the puck as hard as you can. After the puck loses contact with your stick, the puck will
   A) start to slow down.
   B) not slow down or speed up.
   C) speed up a little, and then slow down.
   D) speed up a little, and then move at a constant speed.

   Answer: B

18) A ball is tossed vertically upward. When it reaches its highest point (before falling back downward)
   A) the velocity is zero, the acceleration is directed downward, and the force of gravity acting on the ball is directed downward.
   B) the velocity is zero, the acceleration is zero, and the force of gravity acting on the ball is zero.
   C) the velocity is zero, the acceleration is zero, and the force of gravity acting on the ball is directed downward.
   D) the velocity and acceleration reverse direction, but the force of gravity on the ball remains downward.
   E) the velocity, acceleration, and the force of gravity on the ball all reverse direction.

   Answer: A

19) A dog is standing in the bed of a pickup truck. The bed is coated with ice, causing the force of friction between the dog and the truck to be zero. The truck is initially at rest, and then accelerates to the right, moving along a flat road. As seen from a stationary observer (watching the truck move to the right), the dog
   A) does not move left or right, but the back of the truck moves towards the dog.
   B) moves to the right, but not as quickly as the truck is moving to the right, causing it to slide towards the back of the truck.
   C) moves to the right at the same rate as the truck, so it doesn't slide.
   D) moves to the left, as the truck moves to the right, causing the dog to slide towards the back of the truck.

   Answer: A

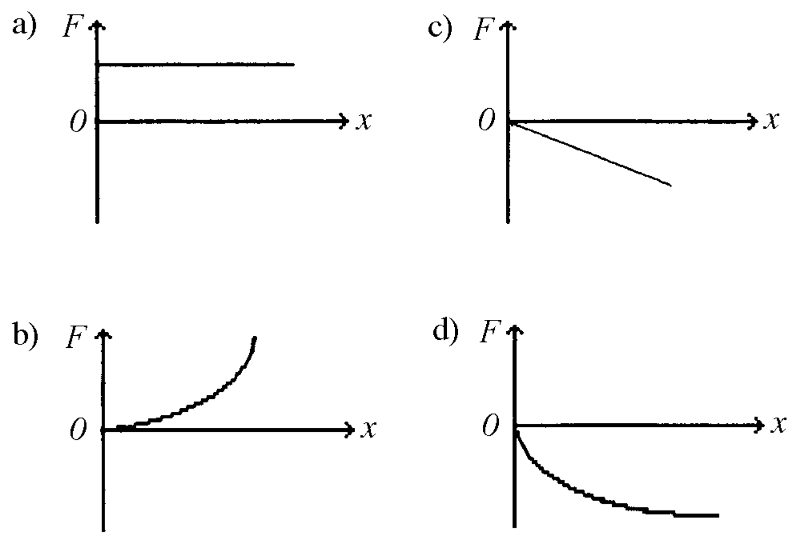
20) You are seated in a bus and notice that a hand strap that is hanging from the ceiling hangs away from the vertical in the backward direction. From this observation, you can conclude that
   A) the velocity of the bus is forward.
   B) the velocity of the bus is backward.
   C) You cannot conclude anything about the direction of the velocity of the bus.

   Answer: C

21) Consider a plot of the displacement (x) as a function of the applied force (F) for an ideal elastic spring. The slope of the curve would be
   A) the spring constant.
   B) the reciprocal of the spring constant.
   C) the acceleration due to gravity.
   D) the reciprocal of the acceleration of gravity.
   E) the mass of the object attached to the spring.

   Answer: B

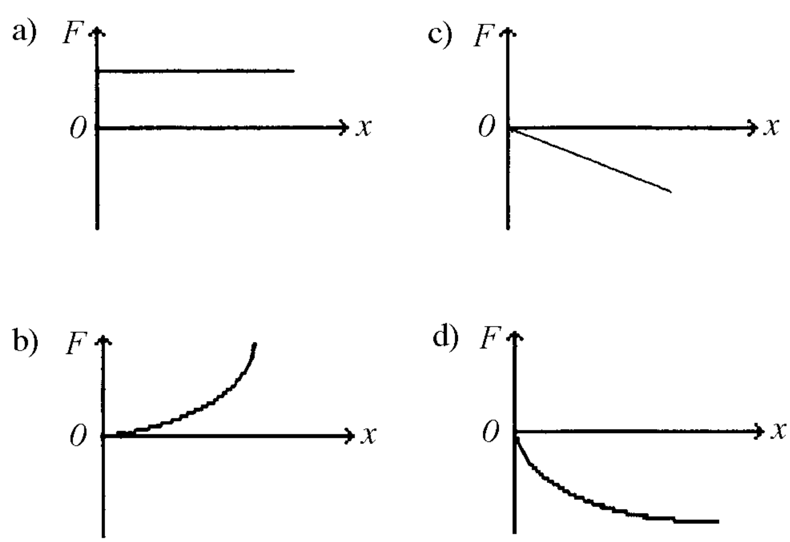
22) Which of the graphs in the figure illustrates Hooke's Law?



A) Graph a
B) Graph b
C) Graph c
D) graph d

Answer: B

23) Which of the graphs in the figure represents a spring that gets less stiff the more it is stretched?



A) Graph a
B) Graph b
C) Graph c
D) Graph d

Answer: D

4.2 Problems

1) A block lies on a horizontal frictionless surface. A horizontal force of 100 N is applied to the block giving rise to an acceleration of 3.0 m/s^2.
(a) Determine the mass of the block.
(b) Calculate the distance the block will travel if the force is applied for 10 s.
(c) Calculate the speed of the block after the force has been applied for 10 s.

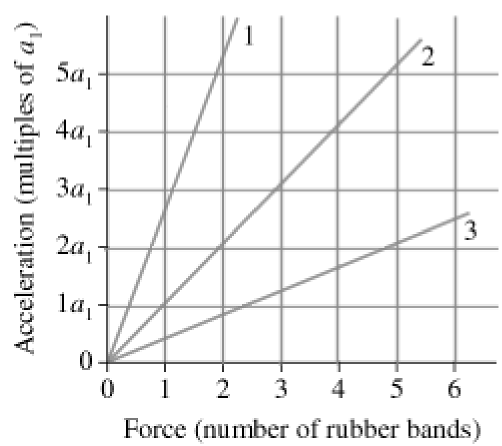
Answer: (a) 33 kg (b) 150 m (c) 30 m/s

2) If a 5.0 kg box is pulled simultaneously by a 10.0 N force and a 5.0 N force, then its acceleration must be

A) 3.0 m/s^2.
B) 2.2 m/s^2.
C) 1.0 m/s^2.
D) We cannot tell from the information given.

Answer: D

3) The figure shows an acceleration–versus–force graph for three objects pulled by rubber bands. The mass of object 2 is 36 kg. What are the masses of objects 1 and 3?



A) 14 kg and 90 kg
B) 72 kg and 18 kg
C) 90 kg and 18 kg
D) 14 kg and 72 kg

Answer: A

4) A 7.0–kg object is acted on by two forces. One of the forces is 10.0 N acting toward the east. Which of the following forces is the other force if the acceleration of the object is 1.0 m/s^2 toward the east?

A) 6.0 N east
B) 3.0 N west
C) 12 N east
D) 9.0 N west
E) 7.0 N west

Answer: B

5) The International Space Station has a mass of 1.8×10^5 kg. A 70.0-kg astronaut inside the station pushes off one wall of the station so she accelerates at 1.50 m/s^2. What is the magnitude of the acceleration of the space station as the astronaut is pushing off the wall? Give your answer relative to an observer who is space walking and therefore does not accelerate with the space station due to the push.
   A) 5.8×10^{-4} m/s^2
   B) 1.50 m/s^2
   C) 4.7×10^{-4} m/s^2
   D) zero
   E) 3.9×10^{-3} m/s^2

   Answer: A

6) On a horizontal frictionless floor, a worker of weight 0.900 kN pushes horizontally with a force of 0.200 kN on a box weighing 1.80 kN. As a result of this push, which statement could be true?
   A) The box will not move because the push is less than its weight.
   B) The worker and box will both have an acceleration of 1.08 m/s^2, but in opposite directions.
   C) The worker and box will both have an acceleration of 2.17 m/s^2, but in opposite directions.
   D) The worker will accelerate at 1.08 m/s^2 and the box will accelerate at 2.17 m/s^2, but in opposite directions.
   E) The worker will accelerate at 2.17 m/s^2 and the box will accelerate at 1.08 m/s^2, but in opposite directions.

   Answer: E

7) A 50.0-N box is sliding on a rough horizontal floor, and the only horizontal force acting on it is friction. You observe that at one instant the box is sliding to the right at 1.75 m/s and that it stops in 2.25 s with uniform acceleration. What magnitude force does friction exert on this box?
   A) 3.97 N
   B) 8.93 N
   C) 38.9 N
   D) 50.0 N
   E) 490 N

   Answer: A

8) A block is on a frictionless horizontal table, on earth. This block accelerates at 1.9 m/s^2 when a 90 N horizontal force is applied to it. The block and table are then set up on the moon where the acceleration due to gravity is 1.62 m/s^2. What is the weight of the block on the moon?
   A) 77 N
   B) 67 N
   C) 58 N
   D) 48 N
   E) 39 N

   Answer: A

9) A block is on a frictionless horizontal table, on earth. This block accelerates at 3.6 m/s^2 when a 90 N horizontal force is applied to it. The block and table are then set up on the moon where the acceleration due to gravity is 1.62 m/s^2. A horizontal force of 45 N is applied to the block when it is on the moon. What acceleration does this force impart to the block?
A) 1.8 m/s^2
B) 1.6 m/s^2
C) 2.0 m/s^2
D) 2.2 m/s^2
E) 2.3 m/s^2
Answer: A

10) An 1100-kg car traveling at 27.0 m/s starts to slow down and comes to a complete stop in 578 m. What is the magnitude of the average braking force acting on the car?
A) 690 N
B) 550 N
C) 410 N
D) 340 N
Answer: A

11) On its own, a certain tow-truck has a maximum acceleration of 3.0 m/s^2. What would be the maximum acceleration when this truck was towing a bus of twice its own mass?
A) 2.5 m/s^2
B) 2.0 m/s^2
C) 1.5 m/s^2
D) 1.0 m/s^2
Answer: D

12) In a ballistics test, a 1.50-g bullet is fired through a 28.0-kg block traveling horizontally toward the bullet. In this test, the bullet takes 11.4 ms to pass through the block as it reverses the block's velocity from 1.75 m/s to the right to 1.20 m/s to the left with constant acceleration. Find the magnitude of the force that the bullet exerts on the block during this ballistics test.
Answer: 7.25×10^3 N

13) A 10,000-kg rocket blasts off from earth with a uniform upward acceleration of 2.00 m/s^2 and feels no air resistance. The upward thrust force its engines must provide during this acceleration is closest to
A) 20,000 N.
B) 980,000 N.
C) 118,000 N.
D) 78,000 N.
Answer: C

14) 15) Bumpers on cars are not of much use in a collision. To see why, calculate the average force a bumper would have to exert if it brought a 1200–kg car (a so–called compact model) to a rest in 15 cm when the car had an initial speed of 2.0 m/s (about 4.5 mph). (Bumpers are built with springs that compress to provide a stopping force without, hopefully, denting the metal.)

A) 1.8×10^4 N
B) 1.6×10^4 N
C) 5.4×10^4 N
D) 6.5×10^5 N
E) 3.2×10^4 N

Answer: B

15) A box of mass 50 kg is at rest on a horizontal frictionless surface. A constant horizontal force F then acts on the box and accelerates it to the right. It is observed that it takes the box 6.9 seconds to travel 28 meters. What is the magnitude of the force?

Answer: 59 N

16) A locomotive is pulling 19 freight cars, each of which is loaded with the same amount of weight. The mass of each freight car (with its load) is 37,000 kg. If the train is accelerating at 0.22 m/s^2 on a level track, what is the tension in the coupling between the second and third cars? (The car nearest the locomotive is counted as the first car, and friction is negligible.)

Answer: 140,000 N

17) A 1000–kg car is driving toward the north along a straight horizontal road at a speed of 20.0 m/s. The driver applies the brakes and the car comes to a rest uniformly in a distance of 200 m. What are the magnitude and direction of the net force applied to the car to bring it to rest?

A) 1.00 N north
B) 10.0×10^3 N south
C) 1.00×10^3 N south
D) 1.00 N south
E) 100 N south

Answer: C

18) A construction worker pulls a box of tools on a smooth horizontal floor with a force of 100 N in a direction of 37.0° above the horizontal. The mass of the box and the tools is 40.0 kg.
(a) Draw a free–body diagram for the box.
(b) Calculate the acceleration of the box.
(c) How hard does the floor push up on the box?

Answer: (a) The box is acted on by the force of gravity which points downward toward the center of the earth. The normal force is directed toward the box perpendicular to the surface of the floor. The pulling force is directed away from the box at an angle 37.0 degrees above the horizontal.
(b) 2.00 m/s^2
(c) 332 N

19) A 60.0-kg person rides in an elevator while standing on a scale. The scale reads 400 N. The acceleration of the elevator is closest to

A) 3.13 m/s^2 downward.
B) 6.67 m/s^2 downward.
C) zero.
D) 9.80 m/s^2 downward.
E) 6.67 m/s^2 upward.

Answer: A

20) A 60.0-kg person rides in elevator while standing on a scale. The elevator is traveling downward but slowing down at a rate of 2.00 m/s^2. The reading on the scale is closest to

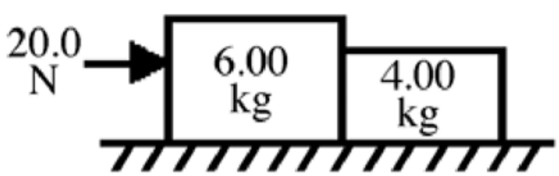
A) 589 N.
B) 708 N.
C) 469 N.
D) 120 N.
E) 349 N.

Answer: B

21) Three boxes in contact rest side-by-side on a smooth, horizontal floor. Their masses are 5.0-kg, 3.0-kg, and 2.0-kg, with the 3.0-kg box in the center. A force of 50 N pushes on the 5.0-kg box, which pushes against the other two boxes.
(a) Draw the free-body diagrams for each of the boxes.
(b) What magnitude force does the 3.0-kg box exert on the 5.0-kg box?
(c) What magnitude force does the 3.0-kg box exert on the 2.0-kg box?

Answer: (a) The following forces act on the 5.0-kg box: the force due to gravity, normal force, contact force between 5.0-kg mass and 3.0-kg mass, the force of 50 N pushing on the box. The following forces act on the 3.0-kg box: the force due to gravity, normal force, contact force between the 5.0-kg box and the 3.0-kg box, the contact force between the 3.0-kg box and the 2.0-kg box. The following forces act on the 2.0-kg box: the force due to gravity, normal force, contact force between the 3.0-kg box and the 2.0-kg box.
(b) 25 N
(c) 10 N

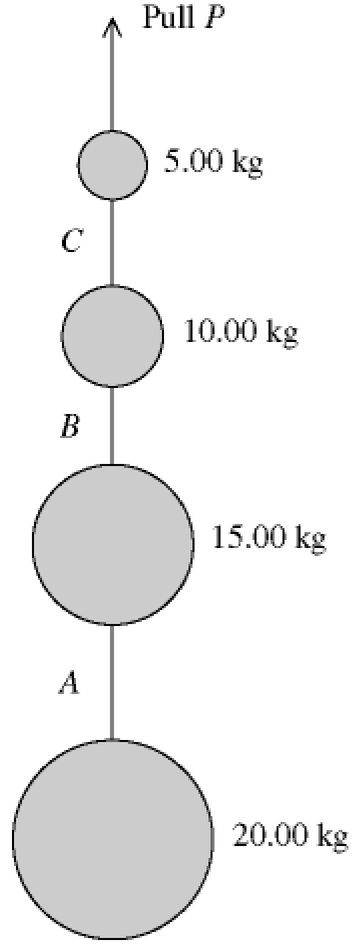
22) A 6.00-kg block is in contact with a 4.00-kg block on a horizontal frictionless surface as shown in the figure. The 6.00-kg block is being pushed by a horizontal 20.0-N force as shown. What is the magnitude of the force that the 6.00-kg block exerts on the 4.00-kg block?



A) 6.00 N
B) 20.0 N
C) 8.00 N
D) 4.00 N
E) 10.0 N

Answer: C

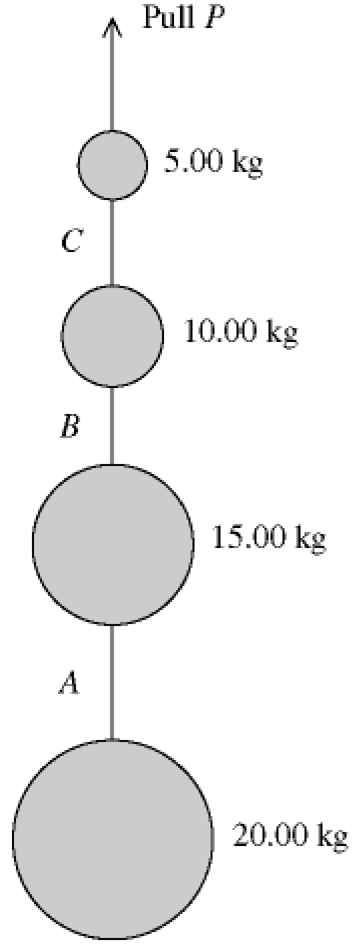
23) A series of weights connected by very light cords are given an upward acceleration of 4.00 m/s^2 by a pull P, as shown in the figure. A, B, and C are the tensions in the connecting cords. The pull P is closest to



A) 690 N.
B) 490 N.
C) 290 N.
D) 200 N.
E) 50 N.

Answer: A

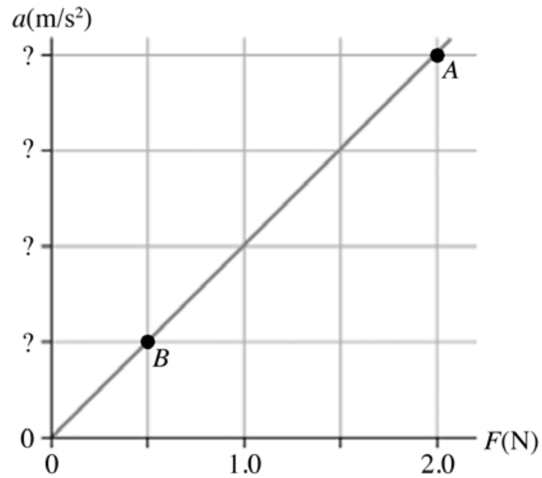
24) A series of weights connected by very light cords are given an upward acceleration of 4.00 m/s^2 by a pull *P*, as shown in the figure. *A*, *B*, and *C* are the tensions in the connecting cords. The SMALLEST of the three tensions, *A*, *B*, and *C*, is closest to



A) 80.0 N.
B) 196 N.
C) 276 N.
D) 483 N.
E) 621 N.

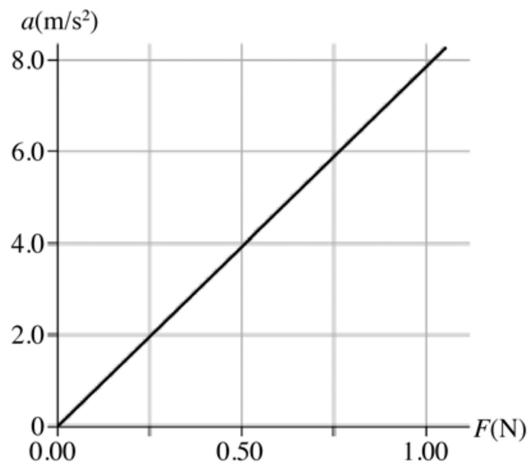
Answer: C

25) The figure shows a graph of the acceleration of a 125-g object as a function of the net force acting on it. What is the acceleration at points A and B?



Answer: A: 16 m/s^2, B: 4.0 m/s^2

26) The figure shows a graph of the acceleration of an object as a function of the net force acting on it. The mass of this object, in grams, is closest to



A) 130.
B) 11.
C) 89.
D) 8000.

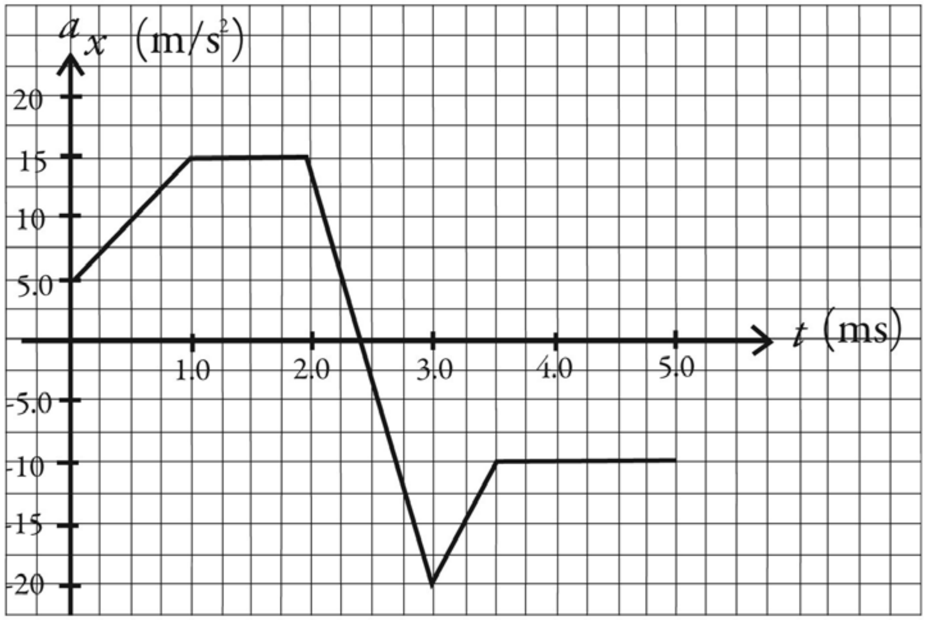
Answer: A

27) Two forces act on a 55-kg object. One force has magnitude 65 N directed 59° clockwise from the positive x-axis, and the other has a magnitude 35 N at 32° clockwise from the positive y-axis. What is the magnitude of this object's acceleration?

A) 1.1 m/s^2
B) 1.3 m/s^2
C) 1.5 m/s^2
D) 1.7 m/s^2

Answer: A

28) The graph in the figure shows the x component of the acceleration of a 2.4–kg object as a function of time (in ms).

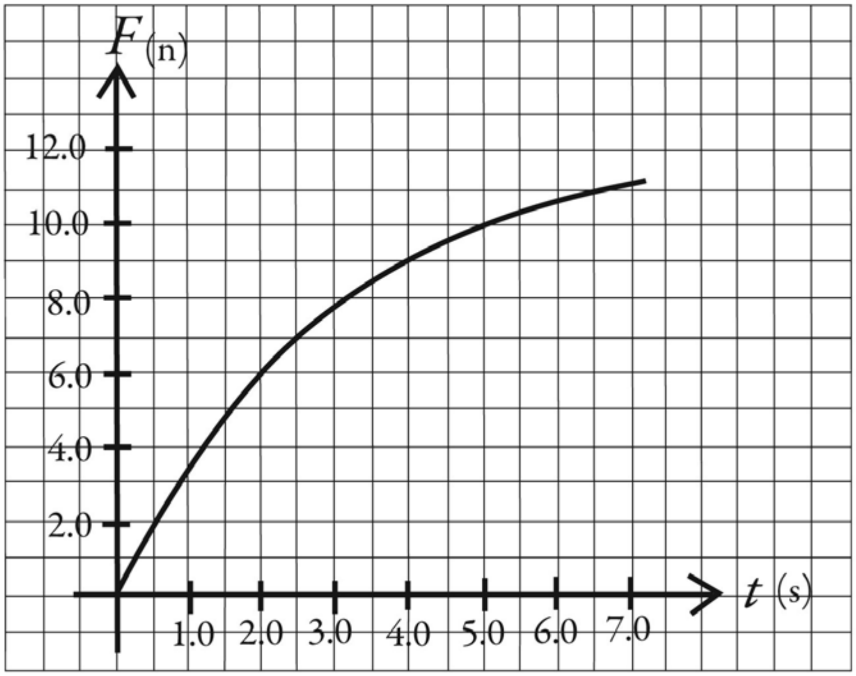


(a) At what time(s) does the x component of the net force on the object reach its maximum magnitude, and what is that maximum magnitude?

(b) What is the x component of the net force on the object at time $t = 0.0$ ms and at $t = 4.0$ ms?

Answer: (a) At 3.0 ms, 48 N (b) 12 N, −24 N

29) The graph in the figure shows the net force acting on a 3.0-kg object as a function of time.



(a) What is the acceleration of this object at time $t = 2.0$ s?
(b) Draw, to scale, a graph of the acceleration of this object as a function of time over the range $t = 0.00$ s to $t = 7.0$ s.

Answer: (a) 2.0 m/s^2
(b) The acceleration-time graph looks the same as the force-time graph except on the vertical axis the numbers (starting at 2.0) are replaced by 0.67, 1.3, 2.0, 2.7, 3.3, and 4.0.

30) A spring stretches by 21.0 cm when a 135 N object is attached. What is the weight of a fish that would stretch the spring by 31 cm?
A) 199 N
B) 91.0 N
C) 145 N
D) 279 N

Answer: A

31) An object attached to an ideal massless spring is pulled across a frictionless surface. If the spring constant is 45 N/m and the spring is stretched by 0.88 m when the object is accelerating at 2.0 m/s^2, what is the mass of the object?
A) 20 kg
B) 17 kg
C) 22 kg
D) 26 kg

Answer: A

32) In the figure, two identical ideal massless springs have unstretched lengths of 0.25 m and spring constants of 700 N/m. The springs are attached to a small cube and stretched to a length L of 0.30 m as in Figure A. An external force P pulls the cube a distance D = 0.020 m to the right and holds it there. (See Figure B.) The external force P, that holds the cube in place in Figure B, is closest to

Figure A

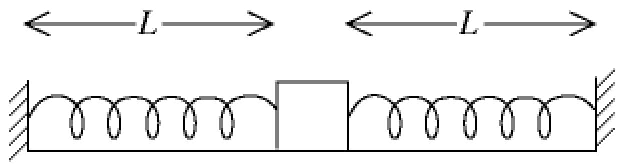
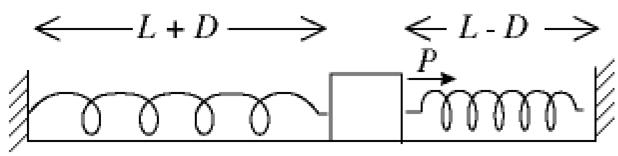


Figure B



A) 28 N.
B) 25 N.
C) 21 N.
D) 18 N.
E) 14 N.

Answer: A

Chapter 5 Using Newton's Laws

5.1 Conceptual Questions

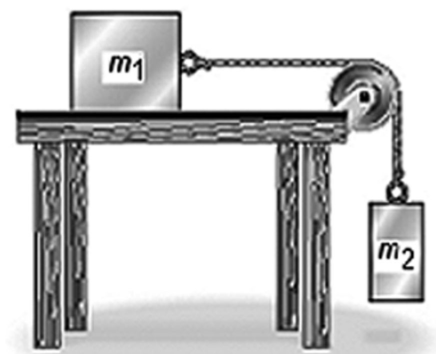
1) A stalled car is being pushed up a hill at constant velocity by three people. The net force on the car is
A) zero.
B) up the hill and equal to the weight of the car.
C) down the hill and equal to the weight of the car.
D) up the hill and greater than the weight of the car.
E) down the hill and greater than the weight of the car.

Answer: A

2) A box of mass m is pulled with a constant acceleration a along a horizontal frictionless floor by a wire that makes an angle of 15° above the horizontal. If T is the tension in this wire, then
A) $T = ma$.
B) $T > ma$.
C) $T < ma$.

Answer: B

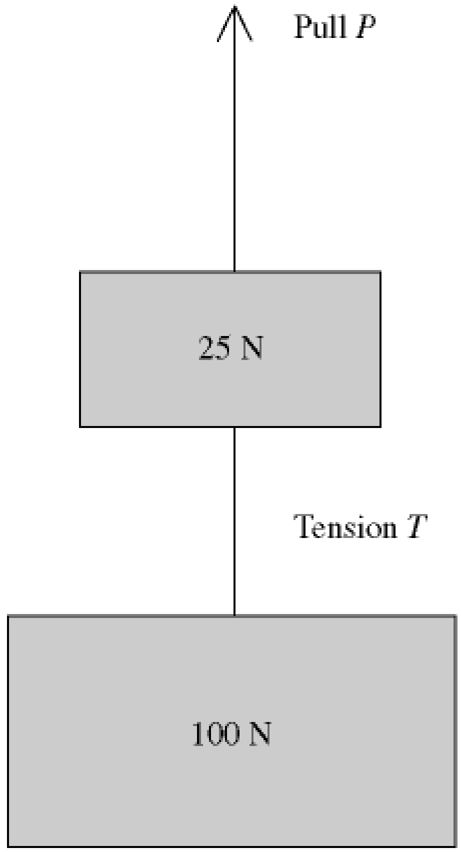
3) Two objects having masses m_1 and m_2 are connected to each other as shown in the figure and are released from rest. There is no friction on the table surface or in the pulley. The masses of the pulley and the string connecting the objects are completely negligible. What must be true about the tension T in the string just after the objects are released?



A) $T = m_2g$
B) $T > m_2g$
C) $T < m_2g$
D) $T = m_1g$
E) $T > m_1g$

Answer: C

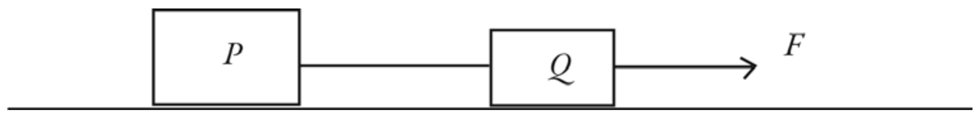
4) Two weights are connected by a massless wire and pulled upward with a constant speed of 1.50 m/s by a vertical pull P. The tension in the wire is T (see figure). Which one of the following relationships between T and P must be true?



A) $T > P$
B) $T = P$
C) $P + T = 125$ N
D) $P = T + 25$ N
E) $P = T + 100$ N

Answer: D

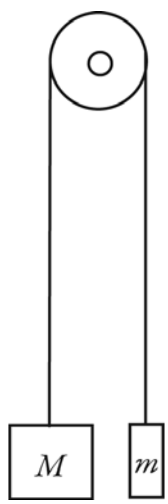
5) Two bodies P and Q on a smooth horizontal surface are connected by a light cord. The mass of P is greater than that of Q. A horizontal force $\vec{F}$ (of magnitude F) is applied to Q as shown in the figure, accelerating the bodies to the right. The magnitude of the force exerted by the connecting cord on body P will be



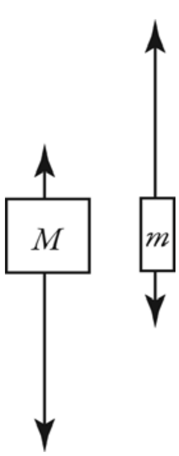
A) zero.
B) less than F but not zero.
C) equal to F.
D) greater than F.

Answer: B

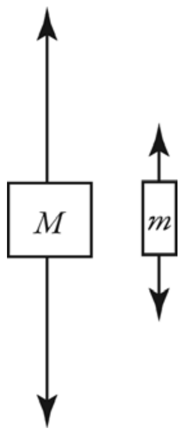
6) Two unequal masses M and m ($M > m$) are connected by a light cord passing over a pulley of negligible mass, as shown in the figure. When released, the system accelerates. Friction is negligible. Which figure below gives the correct free-body force diagrams for the two masses in the moving system?



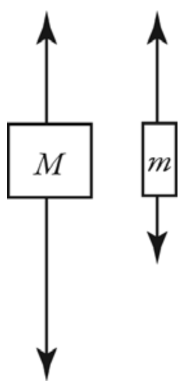
A)



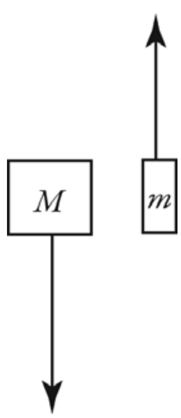
B)



C)



D)



Answer: C

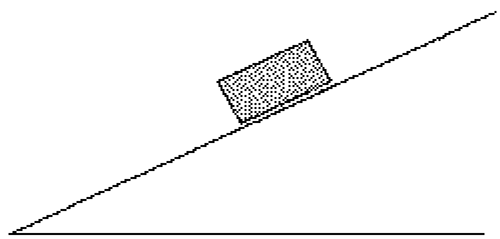
7) Two objects have masses *m* and 5*m*, respectively. They both are placed side by side on a frictionless inclined plane and allowed to slide down from rest.
   A) It takes the lighter object 5 times longer to reach the bottom of the incline than the heavier object.
   B) It takes the lighter object 10 times longer to reach the bottom of the incline than the heavier object.
   C) It takes the heavier object 5 times longer to reach the bottom of the incline than the lighter object.
   D) It takes the heavier object 10 times longer to reach the bottom of the incline than the lighter object.
   E) The two objects reach the bottom of the incline at the same time.

   Answer: E

8) A crate is sliding down an inclined ramp at a constant speed of 0.55 m/s. The vector sum of all the forces acting on this crate must point down the ramp.
   A) True
   B) False

   Answer: B

9) A brick is resting on a rough incline as shown in the figure. The friction force acting on the brick, along the incline, is



   A) zero.
   B) equal to the weight of the brick.
   C) greater than the weight of the brick.
   D) less than the weight of the brick.

   Answer: D

10) A woman is straining to lift a large crate, without success because it is too heavy. We denote the forces on the crate as follows: P is the upward force the woman exerts on the crate, C is the vertical contact force exerted on the crate by the floor, and W is the weight of the crate. How are the magnitudes of these forces related while the woman is trying unsuccessfully to lift the crate?
   A) $P + C = W$
   B) $P + C < W$
   C) $P + C > W$
   D) $P = C$

   Answer: A

11) If you swing a bucket of water fast enough in a vertical circle, at the highest point the water does not spill out because an outward force balances the pull of gravity on the water.
A) True
B) False
Answer: B

12) A string is attached to the rear-view mirror of a car. A ball is hanging at the other end of the string. The car is driving around in a circle, at a constant speed. Which of the following lists gives all of the forces directly acting on the ball?
A) tension and gravity
B) tension
C) tension, gravity, and the centripetal force
D) tension, gravity, the centripetal force, and friction
Answer: A

13) Suppose a highway curve is properly banked to eliminate friction for a speed of 45 mph. If your tires were bald and you wanted to avoid sliding on the road, you would have to drive
A) somewhat below 45 mph.
B) somewhat above 45 mph.
C) at exactly 45 mph.
Answer: C

14) When a parachutist jumps from an airplane, he eventually reaches a constant speed, called the terminal speed. Once he has reached terminal speed
A) his acceleration is equal to g.
B) the force of air drag on him is equal to zero.
C) the force of air drag on him is equal to g.
D) his speed is equal to g.
E) the force of air drag on him is equal to his weight.
Answer: E

15) Suppose the force of the air drag on an object is proportional to the speed of the object and in the direction opposite the object's velocity. If you throw an object upward, the magnitude of its acceleration is greatest
A) right after the object is released.
B) at the top of its trajectory.
C) The acceleration of the object is the same throughout the entire trajectory.
Answer: A

5.2 Problems

1) The following four forces act on a 4.00 kg object:

$\vec{F}_1$ = 300 N east

$\vec{F}_2$ = 700 N north

$\vec{F}_3$ = 500 N west

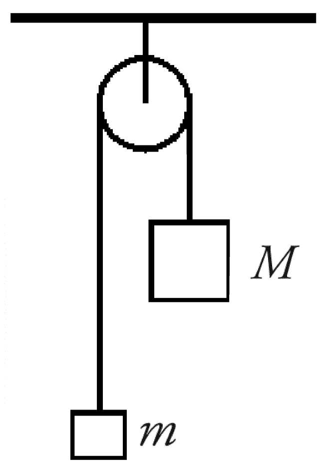
$\vec{F}_4$ = 600 N south

What is the acceleration of the object?

A) 224 N in a direction 63.4° north of west
B) 300 N in a direction 63.4° north of west
C) 300 N in a direction 26.6° north of west
D) 224 N in a direction 26.6° north of west
E) 2100 N in a direction 26.6° north of west

Answer: D

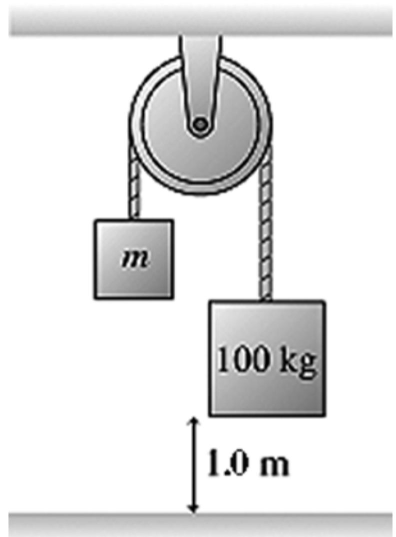
2) Two objects are connected by a very light flexible string as shown in the figure, where M = 0.60 kg and m = 0.40 kg. You can ignore friction and the mass of the pulley.



(a) Draw free-body diagrams for each object.
(b) Calculate the magnitude of the acceleration of each object.
(c) Calculate the tension in the string.

Answer: (a) The force of gravity acts downward and tension acts upward on each object.
(b) 2.0 m/s2
(c) 4.7 N

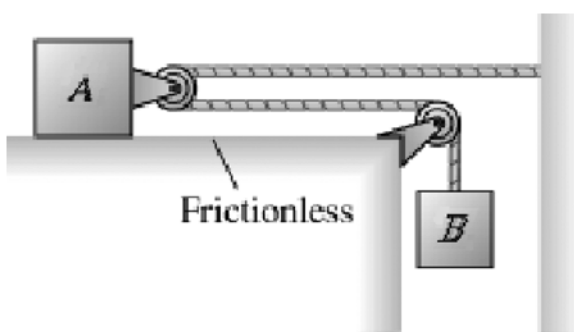
3) The figure shows a 100–kg block being released from rest from a height of 1.0 m. It then takes it 0.90 s to reach the floor. What is the mass *m* of the other block? The pulley has no appreciable mass or friction.



A) 60 kg
B) 54 kg
C) 48 kg
D) 42 kg

Answer: A

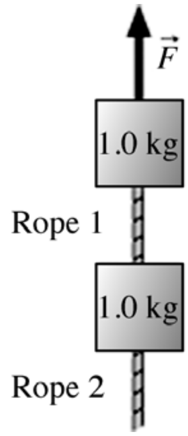
4) A wooden block *A* of mass 4.0 kg slides on a frictionless table when pulled using a massless string and pulley array by a hanging box *B* of mass 5.0 kg, as shown in the figure. What is the acceleration of block *A* as it slides on the frictionless table? **Hint:** Think carefully about the acceleration constraint.



A) 4.1 m/s^2
B) 3.5 m/s^2
C) 3.1 m/s^2
D) 2.7 m/s^2

Answer: A

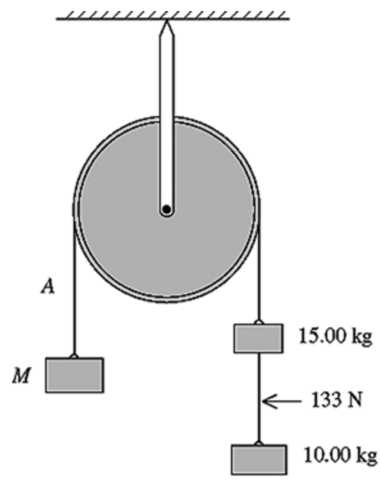
5) The figure shows two 1.0 kg–blocks connected by a rope. A second rope hangs beneath the lower block. Both ropes have a mass of 250 g. The entire assembly is accelerated upward at 2.3 m/s^2 by force $\vec{F}$. What is the tension at the top end of rope 1?



A) 18 N
B) 15 N
C) 2.9 N
D) 3.5 N

Answer: A

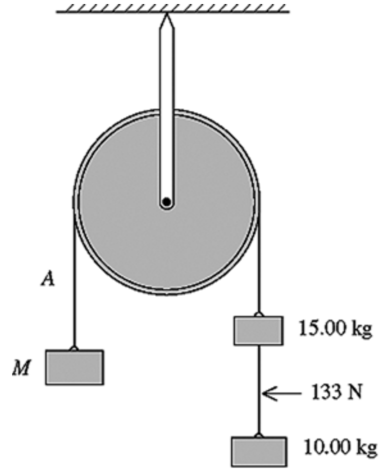
6) Three objects are connected by massless wires over a massless frictionless pulley as shown in the figure. The tension in the wire connecting the 10.0–kg and 15.0–kg objects is measured to be 133 N. What is the mass *M*?



A) 8.33 kg
B) 33.9 kg
C) 35.0 kg
D) 52.8 kg
E) 95.0 kg

Answer: D

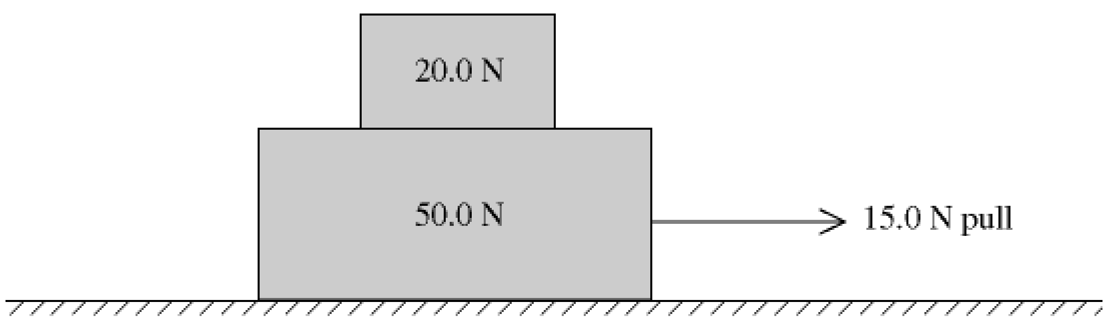
7) Three objects are connected by massless wires over a massless frictionless pulley as shown in the figure. The tension in the wire connecting the 10.0–kg and 15.0–kg objects is measured to be 133 N. What is the tension in wire *A*?



A) 87.5 N
B) 245 N
C) 280 N
D) 333 N
E) 517 N

Answer: D

8) A 20.0–N box rests on a 50.0–N box on a perfectly smooth horizontal floor. When a horizontal 15.0–N pull to the right is exerted on the lower box (see figure), both boxes move together. Find the magnitude and direction of the net external force on the upper box.



Answer: 4.29 N to the right

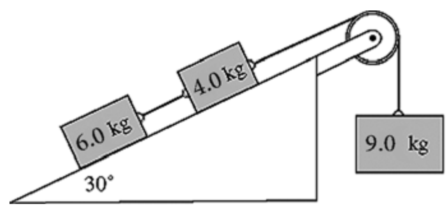
9) A block is given a very brief push up a 20.0° frictionless incline to give it an initial speed of 12.0 m/s.
(a) How far along the surface of the plane does the block slide before coming to rest?
(b) How much time does it take to return to its starting position?

Answer: (a) 21.5 m (b) 7.16 s

10) A child on a sled starts from rest at the top of a 15° slope. If the trip to the bottom takes 15.2 s how long is the slope? Assume that frictional forces may be neglected.
A) 293 m
B) 586 m
C) 1130 m
D) 147 m

Answer: A

11) A system comprising blocks, a light frictionless pulley, a frictionless incline, and connecting ropes is shown in the figure. The 9.0–kg block accelerates downward when the system is released from rest. The tension in the rope connecting the 6.0–kg block and the 4.0–kg block is closest to



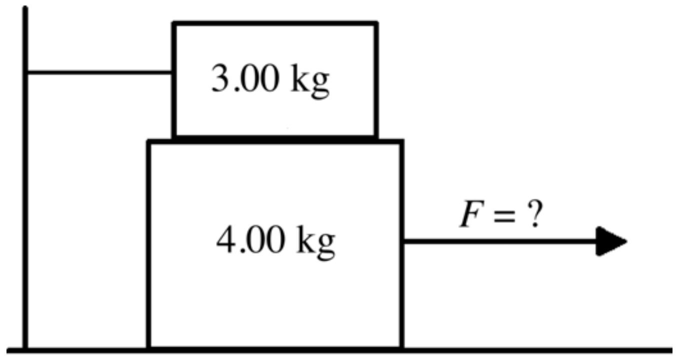
A) 30 N.
B) 33 N.
C) 36 N.
D) 39 N.
E) 42 N.

Answer: E

12) A 50.0–kg box rests on a horizontal surface. The coefficient of static friction between the box and the surface is 0.300 and the coefficient of kinetic friction is 0.200. What is the friction force on the box if
(a) a horizontal 140–N push is applied to it?
(b) a horizontal 175–N push is applied to it?

Answer: (a) 140 N (b) 98.0 N

13) A 4.00-kg block rests between the floor and a 3.00-kg block as shown in the figure. The 3.00-kg block is tied to a wall by a horizontal rope. If the coefficient of static friction is 0.800 between each pair of surfaces in contact, what horizontal force F must be applied to the 4.00-kg block to make it move?



A) 16.2 N
B) 54.9 N
C) 21.1 N
D) 23.5 N
E) 78.4 N

Answer: E

14) A 150-N box is being pulled horizontally in a wagon accelerating uniformly at 3.00 m/s^2. The box does not move relative to the wagon, the coefficient of static friction between the box and the wagon's surface is 0.600, and the coefficient of kinetic friction is 0.400. The friction force on this box is closest to

A) 450 N.
B) 90.0 N.
C) 60.0 N.
D) 45.9 N.

Answer: D

15) In a shuffleboard game, the puck slides a total of 12 m before coming to rest. If the coefficient of kinetic friction between the puck and the horizontal board is 0.28, what was the initial speed of the puck?

A) 8.1 m/s
B) 29.0 m/s
C) 6.5 m/s
D) 7.3 m/s

Answer: A

16) A driver in a 1000 kg car traveling at 20 m/s slams on the brakes and skids to a stop. If the coefficient of friction between the tires and the horizontal road is 0.80, how long will the skid marks be?
A) 26 m
B) 21 m
C) 33 m
D) 24 m

Answer: A

17) Jason takes off from rest across level water on his jet-powered skis. The combined mass of Jason and his skis is 75 kg (the mass of the fuel is negligible). The skis have a thrust of 200 N and a coefficient of kinetic friction on water of 0.10. Unfortunately, the skis run out of fuel after only 48 s. What is Jason's top speed?
A) 81 m/s
B) 130 m/s
C) 13 m/s
D) 48 m/s

Answer: A

18) Jason takes off from rest across level water on his jet-powered skis. The combined mass of Jason and his skis is 75 kg (the mass of the fuel is negligible). The skis have a thrust of 200 N and a coefficient of kinetic friction on water of 0.10. Unfortunately, the skis run out of fuel after only 67 s. How far has Jason traveled when he finally coasts to a stop?
A) 10,000 m
B) 7600 m
C) 5400 m
D) 3800 m

Answer: A

19) Kieran takes off from rest down a 50 m high, 10° slope on his jet-powered skis. The skis have a thrust of 280 N parallel to the surface of the slope. The combined mass of skis and Kieran is 50 kg (the fuel mass is negligible). Kieran's speed at the bottom is 40 m/s. What is the coefficient of kinetic friction of his skis on snow?
A) 0.47
B) 0.58
C) 0.23
D) 0.29

Answer: A

20) A factory robot drops a 10 kg computer onto a conveyor belt running at 3.1 m/s. The materials are such that $\mu_s = 0.50$ and $\mu_k = 0.30$ between the belt and the computer. How far is the computer dragged before it is riding smoothly on the belt?
A) 1.6 m
B) 0.98 m
C) 2.3 m
D) 3.0 m

Answer: A

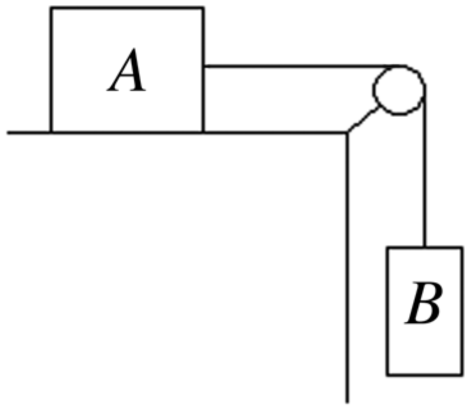
21) You push downward on a box at an angle 25° below the horizontal with a force of 750 N. If the box is on a flat horizontal surface for which the coefficient of static friction with the box is 0.76, what is the mass of the heaviest box you will be able to move?
A) 59 kg
B) 68 kg
C) 54 kg
D) 82 kg
Answer: A

22) A person is dragging a packing crate of mass 100 kg across a rough horizontal floor where the coefficient of kinetic friction is 0.400. He exerts a force F sufficient to accelerate the crate forward. At what angle above horizontal should his pulling force be directed in order to achieve the maximum acceleration?
A) 21.8°
B) 27.7°
C) 30°
D) 34.5°
E) 45°
Answer: A

23) A packing crate rests on a horizontal surface. It is acted on by three horizontal forces: 600 N to the left, 200 N to the right, and friction. The weight of the crate is 400 N. If the 600-N force is removed, the resultant force acting on the crate is
A) zero.
B) 200 N to the right.
C) 200 N to the left.
D) 400 N to the left.
E) impossible to determine from the information given.
Answer: A

24) A pickup truck is moving at 25 m/s with a toolbox of mass m resting on the bed of the truck 2.5 m behind the cab. Suddenly the brakes are applied, causing the toolbox to slide, and the truck comes to a stop in 4.7 s. The coefficient of kinetic friction between the toolbox and the bed of the truck is 0.28. After the brakes are applied, how much time elapses before the toolbox strikes the cab?
Answer: 1.4 s

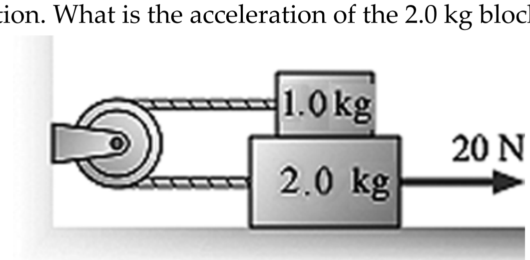
25) Two boxes are connected by a weightless cord running over a very light frictionless pulley as shown in the figure. Box *A*, of mass 8.0 kg, is initially at rest on the top of the table. The coefficient of kinetic friction between box *A* and the table is 0.10. Box *B* has a mass of 15.0 kg, and the system begins to move just after it is released.



(a) Draw the free–body diagrams for each of the boxes, identifying all of the forces acting on each one.
(b) Calculate the acceleration of each box.
(c) What is the tension in the cord?

Answer: (a) Box *A* is acted on by the downward force of gravity, the upward normal force due to the table top, the tension in the string toward the right, and the force of friction due to the table top toward the left. Box *B* is acted on by the downward force of gravity and the upward tension of the string.
(b) 6.1 m/s^2
(c) 56 N

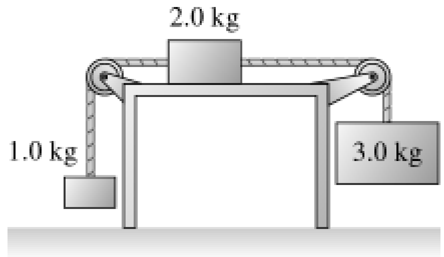
26) A rope pulls on the lower block in the figure with a tension force of 20 N. The coefficient of kinetic friction between the lower block and the surface is 0.16. The coefficient of kinetic friction between the lower block and the upper block is also 0.16. The pulley has no appreciable mass or friction. What is the acceleration of the 2.0 kg block?



A) 4.1 m/s^2
B) 5.1 m/s^2
C) 8.4 m/s^2
D) 9.2 m/s^2

Answer: A

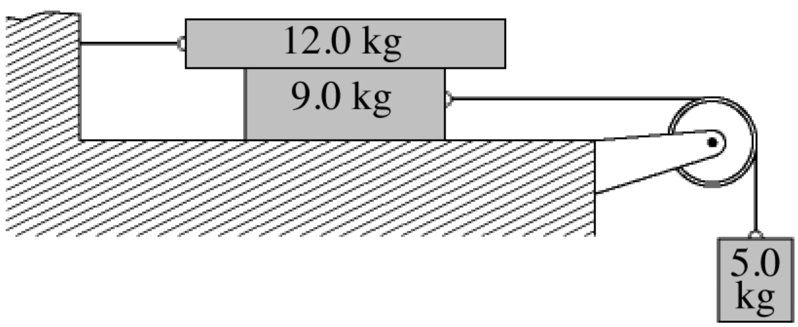
27) Three objects are connected as shown in the figure. The strings and frictionless pulleys have negligible masses, and the coefficient of kinetic friction between the 2.0-kg block and the table is 0.25. What is the acceleration of the 2.0-kg block?



A) 2.5 m/s^2
B) 1.7 m/s^2
C) 3.2 m/s^2
D) 4.0 m/s^2

Answer: A

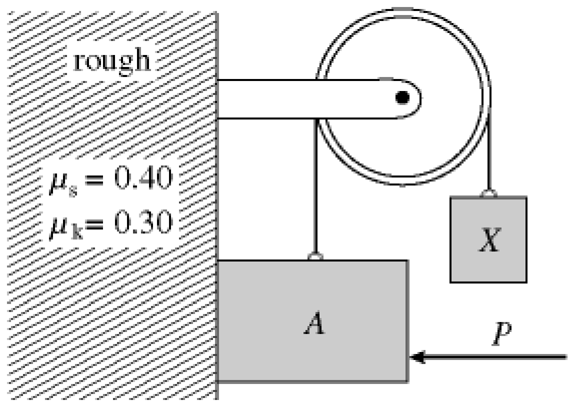
28) A system comprised blocks, a light frictionless pulley, and connecting ropes is shown in the figure. The 9.0-kg block is on a perfectly smooth horizontal table. The surfaces of the 12-kg block are rough, with μ_k = 0.30 between the block and the table. If the 5.0-kg block accelerates downward when it is released, find its acceleration.



A) 1.0 m/s^2
B) 1.2 m/s^2
C) 1.4 m/s^2
D) 1.6 m/s^2
E) 1.8 m/s^2

Answer: A

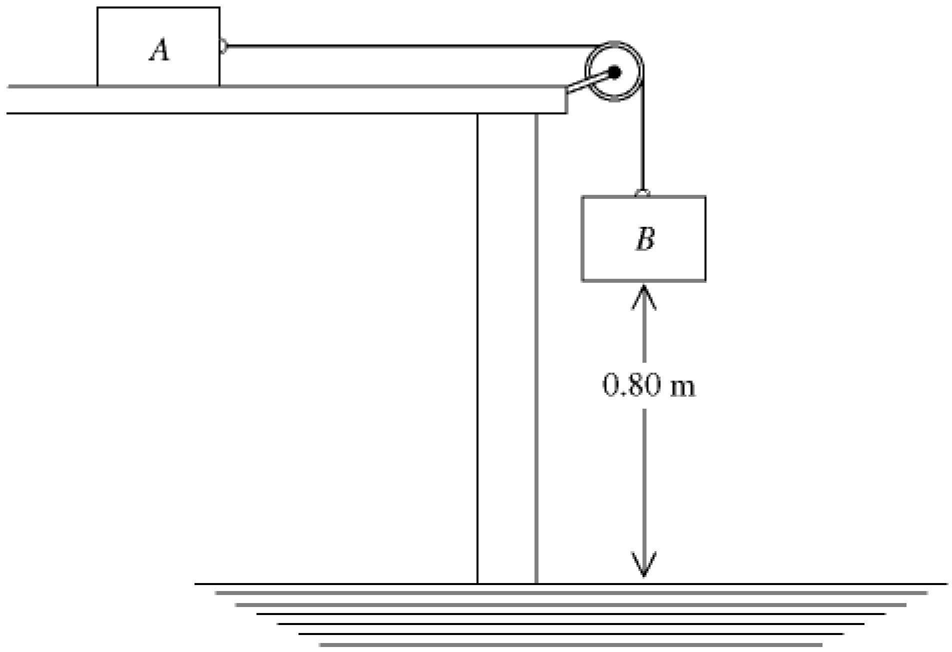
29) Block *A* of mass 5.0 kg and block *X* are attached to a rope which passes over a pulley, as shown in the figure. An 80-N force *P* is applied horizontally to block *A*, keeping it in contact with a rough vertical face. The coefficients of static and kinetic friction between the wall and block *A* are $\mu_s = 0.40$ and $\mu_k = 0.30$. The pulley is light and frictionless. The mass of block *X* is adjusted until block *A* moves upward with an acceleration of 1.6 m/s^2. What is the mass of block *X*?



A) 9.9 kg
B) 9.3 kg
C) 8.7 kg
D) 8.1 kg
E) 7.5 kg

Answer: A

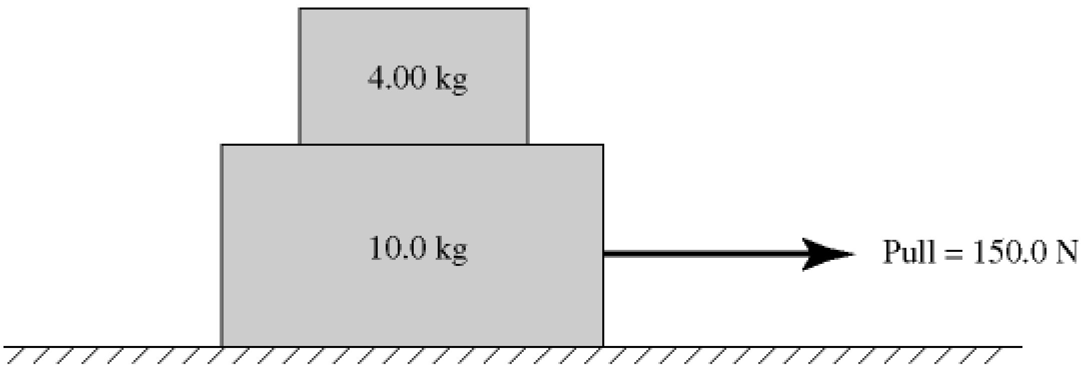
30) In the figure, two wooden blocks each of 0.30 kg mass are connected by a string that passes over a very light frictionless pulley. One block slides on a horizontal table, while the other hangs suspended by the string, as shown in the figure. At time $t = 0$, the suspended block is 0.80 m over the floor, and the blocks are released from rest. After 2.5 s, the suspended block reaches the floor. What is the coefficient of kinetic friction between the table and the sliding block?



A) 0.35
B) 0.52
C) 0.84
D) 0.65
E) 0.95

Answer: E

31) A 4.00–kg box sits atop a 10.0–kg box on a horizontal table. The coefficient of kinetic friction between the two boxes *and* between the lower box and the table is 0.600, while the coefficient of static friction between these same surfaces is 0.800. A horizontal pull to the right is exerted on the lower box, as shown in the figure, and the boxes move together. What is the friction force on the UPPER box?



A) 19.3 N to the right
B) 19.3 N to the left
C) 23.5 N to the right
D) 31.4 N to the right
E) 31.4 N to the left

Answer: A

32) A 6.0 kg box slides down an inclined plane that makes an angle of 39° with the horizontal. If the coefficient of kinetic friction is 0.19, at what rate does the box accelerate down the slope?

A) 4.7 m/s^2
B) 5.2 m/s^2
C) 5.5 m/s^2
D) 6.2 m/s^2

Answer: A

33) A 200 g hockey puck is launched up a metal ramp that is inclined at a 30° angle. The coefficients of static and kinetic friction between the hockey puck and the metal ramp are μ_s = 0.40 and μ_k = 0.30, respectively. The puck's initial speed is 63 m/s. What vertical height does the puck reach above its starting point?

A) 130 m
B) 270 m
C) 200 m
D) 66 m

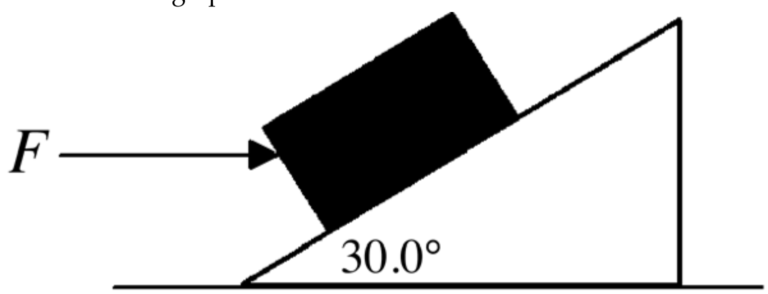
Answer: A

34) A 200 g hockey puck is launched up a metal ramp that is inclined at a 30° angle. The coefficients of static and kinetic friction between the hockey puck and the metal ramp are μ_s = 0.40 and μ_k = 0.30, respectively. The puck's initial speed is 4.9 m/s. What speed does it have when it slides back down to its starting point?

A) 2.8 m/s
B) 3.5 m/s
C) 4.2 m/s
D) 4.9 m/s

Answer: A

35) A 4.00–kg block rests on a 30.0° incline as shown in the figure. If the coefficient of static friction between the block and the incline is 0.700, what magnitude horizontal force *F* must act on the block to start it moving up the incline?



A) 34.0 N
B) 51.1 N
C) 54.7 N
D) 84.0 N
E) 76.4 N

Answer: D

36) A box is sliding down an incline tilted at a 12.0° angle above horizontal. The box is initially sliding down the incline at a speed of 1.50 m/s. The coefficient of kinetic friction between the box and the incline is 0.340. How far does the box slide down the incline before coming to rest?

A) 0.920 m
B) 2.33 m
C) 1.78 m
D) 0.720 m
E) The box does not stop. It accelerates down the plane.

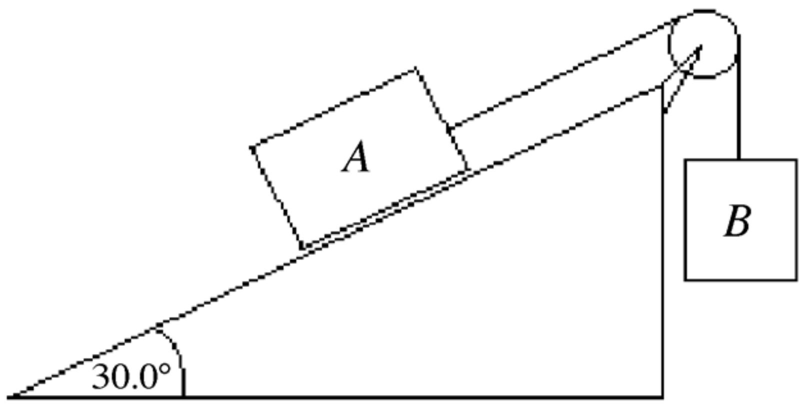
Answer: A

37) A 50.0–kg block is being pulled up a 16.0° slope by a force of 250 N which is parallel to the slope. The coefficient of kinetic friction between the block and the slope is 0.200. What is the magnitude of the acceleration of the block?

A) 0.528 m/s^2
B) 0.158 m/s^2
C) 0.412 m/s^2
D) 0.983 m/s^2
E) 0.260 m/s^2

Answer: C

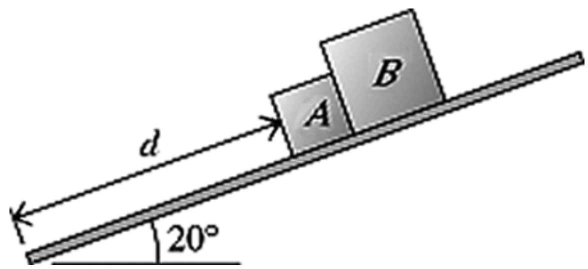
38) Two blocks are connected by a string that goes over an ideal pulley as shown in the figure. Block *A* has a mass of 3.00 kg and can slide over a rough plane inclined 30.0° to the horizontal. The coefficient of kinetic friction between block *A* and the plane is 0.400. Block *B* has a mass of 2.77 kg. What is the acceleration of the blocks?



A) 0.392 m/s^2
B) 1.96 m/s^2
C) 3.12 m/s^2
D) 5.35 m/s^2
E) 0.00 m/s^2

Answer: A

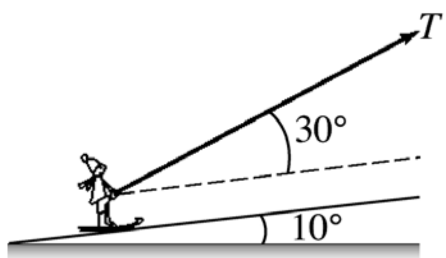
39) The figure shows two packages that start sliding down a 20° ramp from rest a distance $d = 6.6$ m along the ramp from the bottom. Package A has a mass of 5.0 kg and a coefficient of kinetic friction 0.20 between it and the ramp. Package B has a mass of 10 kg and a coefficient of kinetic friction 0.15 between it and the ramp. How long does it take package A to reach the bottom?



A) 2.7 s
B) 3.0 s
C) 3.2 s
D) 3.5 s

Answer: A

40) In the figure, a T–bar ski tow pulls a skier up a hill inclined at 10° above horizontal. The skier starts from rest and is pulled by a cable that exerts a tension T at an angle of 30° above the surface of the hill. The mass of the skier is 60 kg and the effective coefficient of kinetic friction between the skis and the snow is 0.100. What is the maximum tension in the cable if the starting acceleration is not to exceed 0.400 g?



A) 246 N
B) 366 N
C) 431 N
D) 187 N
E) 535 N

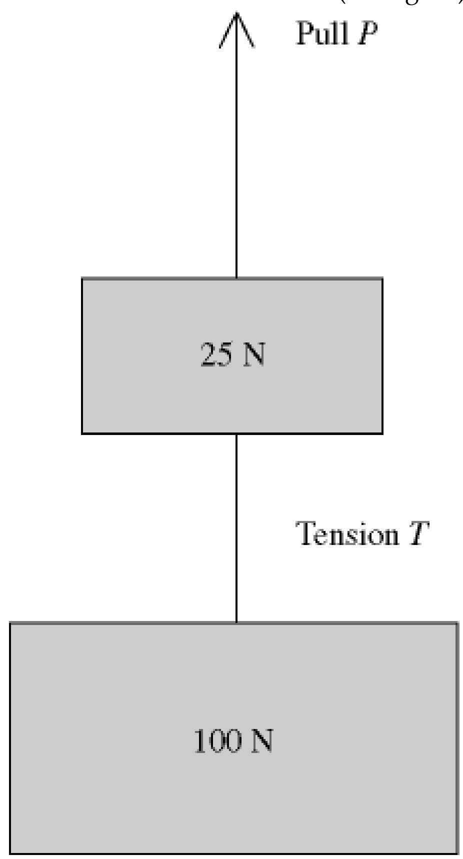
Answer: C

41) A 250–kg crate is on a rough ramp, inclined at 30° above the horizontal. The coefficient of kinetic friction between the crate and ramp is 0.22. A horizontal force of 5000 N is applied to the crate, pushing it up the ramp. What is the acceleration of the crate?

A) 8.4 m/s^2
B) 10 m/s^2
C) 12 m/s^2
D) 13 m/s^2
E) 3.4 m/s^2

Answer: A

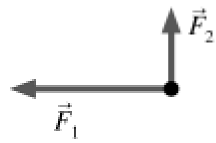
42) Two weights are connected by a massless wire and pulled upward with a constant speed of 1.50 m/s by a vertical pull P. The tension in the wire is *T* (see figure). *P* is closest to



A) 25 N.
B) 125 N.
C) 187.5 N.
D) 245 N.
E) 1225 N.

Answer: B

43) The figure shows two forces acting at right angles on an object. They have magnitudes $F_1 = 6.3$ N and $F_2 = 2.1$ N. What third force will cause the object to be in equilibrium (acceleration equals zero)?



A) 6.6 N at 162° counterclockwise from $\vec{F}_1$

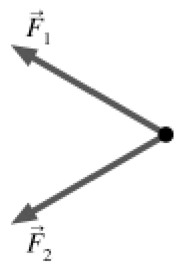
B) 6.6 N at 108° counterclockwise from $\vec{F}_1$

C) 4.2 N at 162° counterclockwise from $\vec{F}_1$

D) 4.2 N at 108° counterclockwise from $\vec{F}_1$

Answer: A

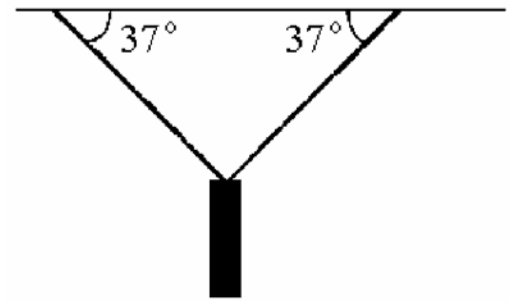
44) The figure shows two forces, each of magnitude 4.6 N, acting on an object. The angle between these forces is 40°, and they make equal angles above and below the horizontal. What third force will cause the object to be in equilibrium (acceleration equals zero)?



A) 8.6 N pointing to the right
B) 7.0 N pointing to the right
C) 4.3 N pointing to the right
D) 3.5 N pointing to the right

Answer: A

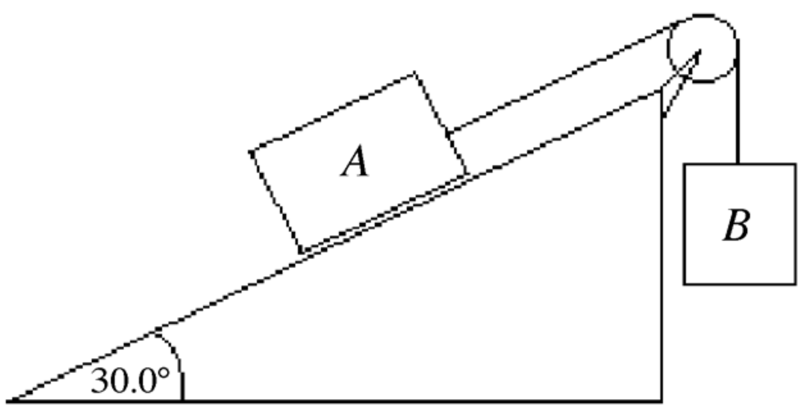
45) A traffic light weighing 100 N is supported by two ropes as shown in the figure. The tensions in the ropes are closest to



A) 50 N.
B) 56 N.
C) 63 N.
D) 66 N.
E) 83 N.

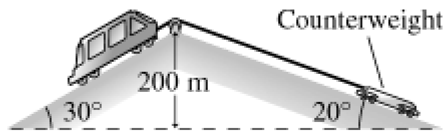
Answer: E

46) Two blocks are connected by a string that goes over an ideal pulley as shown in the figure and pulls on block *A* parallel to the surface of the plane. Block *A* has a mass of 3.00 kg and can slide along a rough plane inclined 30.0° to the horizontal. The coefficient of static friction between block *A* and the plane is 0.400. What mass should block *B* have in order to start block *A* sliding up the plane?



Answer: 2.54 kg

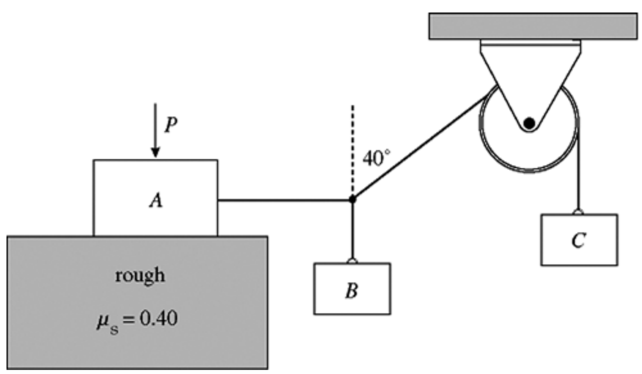
47) The figure shows a 2000 kg cable car descending a high hill. A counterweight of mass 1800 kg on the other side of the hill aids the brakes in controlling the cable car's speed. The rolling friction of both the cable car and the counterweight are negligible. How much braking force does the cable car need to descend at constant speed?



A) 3800 N
B) 2900 N
C) 2000 N
D) 980 N

Answer: A

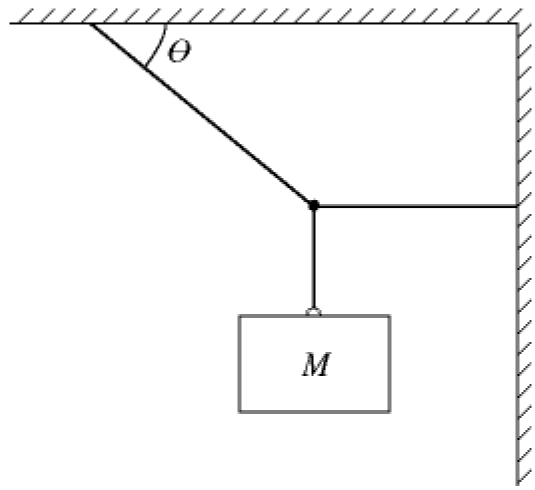
48) A system of blocks and a frictionless pulley is shown in the figure. Block *A* has a mass of 2.0 kg and is on a rough horizontal surface for which $\mu_s = 0.40$ between the surface and block *A*. The rope pulls horizontally on block *A*. Block *C* has a mass of 1.0 kg. An external force $P = 23.0$ N, applied vertically to block *A*, maintains the system at rest as shown in the figure. What is the friction force on block *A*?



A) 6.3 N
B) 6.9 N
C) 7.5 N
D) 5.7 N
E) 5.1 N

Answer: A

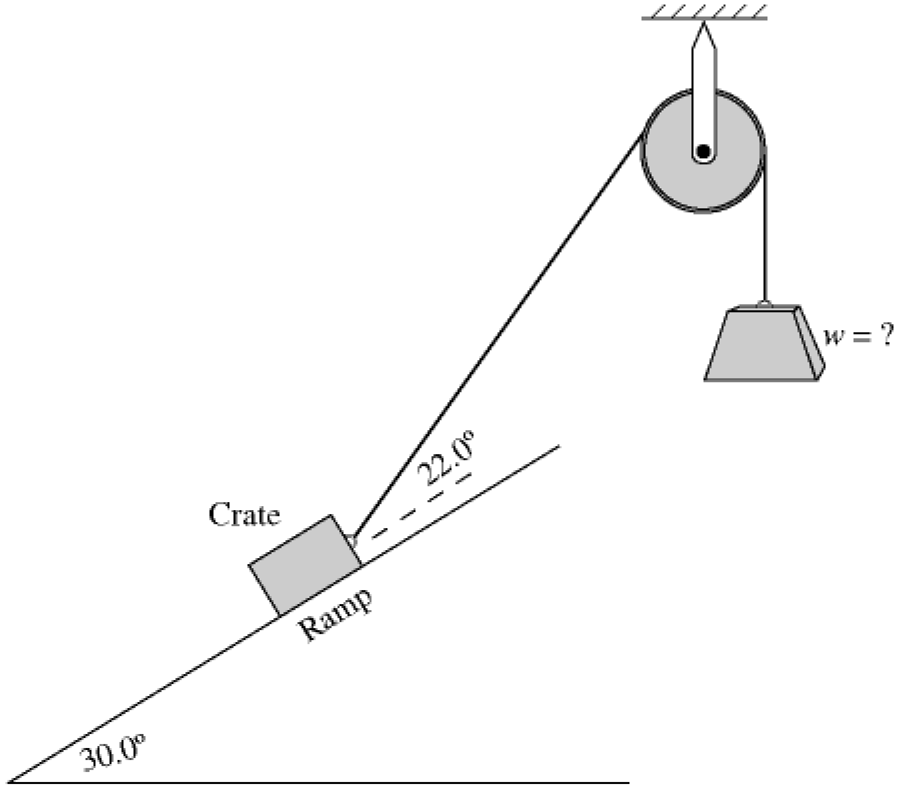
49) In the figure, a block of mass M hangs at rest. The rope that is fastened to the wall is horizontal and has a tension off 52 N. The rope that is fastened to the ceiling has a tension of 91 N,and makes an angle θ with the ceiling. What is the angle θ?



A) 55°
B) 35°
C) 30°
D) 63°
E) 45°

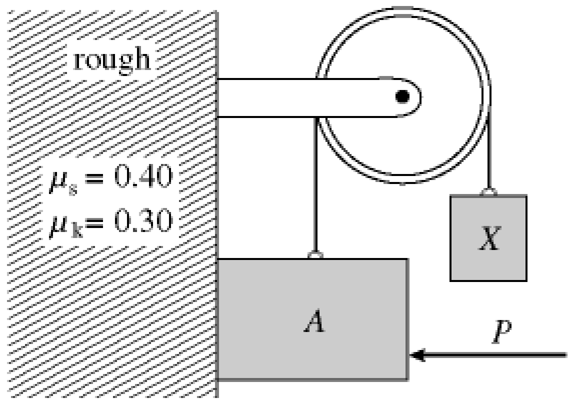
Answer: A

50) A 1520–N crate is to be held in place on a ramp that rises at 30.0° above the horizontal (see figure). The massless rope attached to the crate makes a 22.0° angle above the surface of the ramp. The coefficients of friction between the crate and the surface of the ramp are $\mu_k = 0.450$ and $\mu_s = 0.650$. The pulley has no appreciable mass or friction. What is the MAXIMUM weight w that can be used to hold this crate stationary on the ramp?



Answer: 1380 N

51) Block A of mass 8.0 kg and block X are attached to a rope that passes over a pulley. A 50-N force P is applied horizontally to block A, keeping it in contact with a rough vertical face. The coefficients of static and kinetic friction between the wall and block A are $\mu_s = 0.40$ and $\mu_k = 0.30$. The pulley is light and frictionless. In the figure, the mass of block X is adjusted until block A descends at constant velocity of 4.75 cm/s when it is set into motion. What is the mass of block X?



A) 6.5 kg
B) 7.2 kg
C) 8.0 kg
D) 8.8 kg
E) 9.5 kg

Answer: A

52) A 23 kg mass is connected to a nail on a frictionless table by a massless string 1.3 m long. There is no appreciable friction between the nail and the string. If the tension in the string is 51 N while the mass moves in a uniform circle on the table, how long does it take for the mass to make one complete revolution?
A) 4.8 s
B) 3.8 s
C) 4.5 s
D) 5.2 s

Answer: A

53) A car travels at a steady 40.0 m/s around a horizontal curve of radius 200 m. What is the minimum coefficient of static friction between the road and the car's tires that will allow the car to travel at this speed without sliding?
A) 1.23
B) 0.816
C) 0.736
D) 0.952
E) 0.662

Answer: B

54) A car enters a 300-m radius horizontal curve on a rainy day when the coefficient of static friction between its tires and the road is 0.600. What is the maximum speed at which the car can travel around this curve without sliding?
A) 29.6 m/s
B) 33.1 m/s
C) 24.8 m/s
D) 42.0 m/s
E) 37.9 m/s

Answer: D

55) A car drives over a hilltop that has a radius of curvature 0.120 km at the top of the hill. At what speed would the car be traveling when it tires just barely lose contact with the road when the car is at the top of the hill?
A) 45.5 m/s
B) 41.8 m/s
C) 34.3 m/s
D) 22.2 m/s
E) 27.6 m/s

Answer: C

56) A 1000-kg car is slowly picking up speed as it goes around a horizontal curve whose radius is 100 m. The coefficient of static friction between the tires and the road is 0.350. At what speed will the car begin to skid sideways?
A) 9.25 m/s
B) 23.6 m/s
C) 34.3 m/s
D) 35.0 m/s
E) 18.5 m/s

Answer: E

57) A 600-kg car is going around a banked curve with a radius of 110 m at a speed of 24.5 m/s. What is the appropriate banking angle so that the car stays on its path without the assistance of friction?
A) 29.1°
B) 13.5°
C) 33.8°
D) 56.2°
E) 60.9°

Answer: A

58) A 600-kg car traveling at 24.5 m/s is going around a curve having a radius of 120 m that is banked at an angle of 20°.
(a) Is the curve properly banked for the car's speed?
(b) What is the minimum coefficient of static friction required between the road and the car's tires so the car does not skid?

Answer: (a) No (b) 0.12

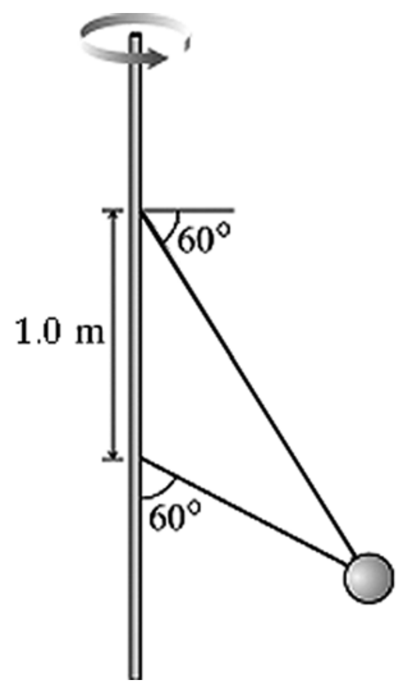
59) A 600–kg car traveling at 30.0 m/s is going around a curve having a radius of 120 m that is banked at an angle of 25.0°. The coefficient of static friction between the car's tires and the road is 0.300. What is the magnitude of the force exerted by friction on the car?
A) 1590 N
B) 3430 N
C) 7240 N
D) 7820 N
E) 795 N

Answer: A

60) Engineers are designing a curved section of a highway. If the radius of curvature of the curve is 194 m, at what angle should the curve be banked so that a car traveling at 29.0 m/s will stay on the road without the aid of frictional forces?
A) 23.9°
B) 16.7°
C) 21.0°
D) 26.1°

Answer: A

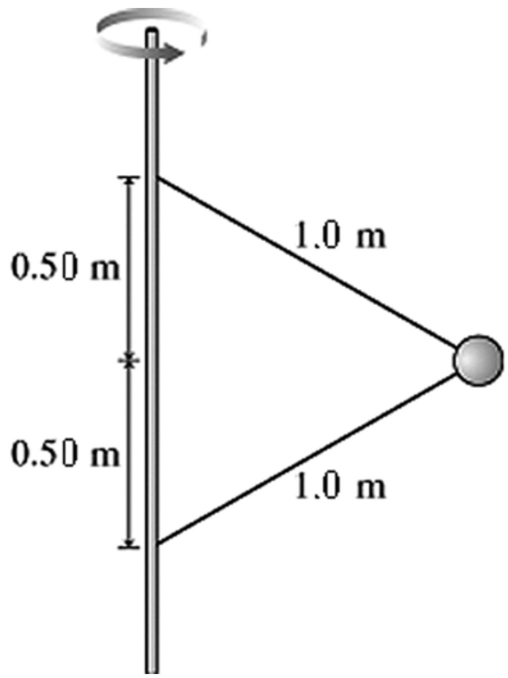
61) The figure shows two wires tied to a 3.3 kg sphere that revolves in a horizontal circle at constant speed. At this particular speed the tension is the SAME in both wires. What is the tension?



A) 24 N
B) 32 N
C) 44 N
D) 22 N

Answer: A

62) The figure shows two wires that are tied to a 710 g mass that revolves in a horizontal circle at a constant speed of 7.5 m/s. What is the tension in the upper wire?



A) 34 N
B) 20 N
C) 27 N
D) 41 N

Answer: A

63) Future space stations will create an artificial gravity by rotating. Consider a cylindrical space station 390 m diameter rotating about its central axis. Astronauts walk on the inside surface of the space station. What rotation period will provide "normal" gravity?

A) 28 s
B) 40 s
C) 6.3 s
D) 4.4 s

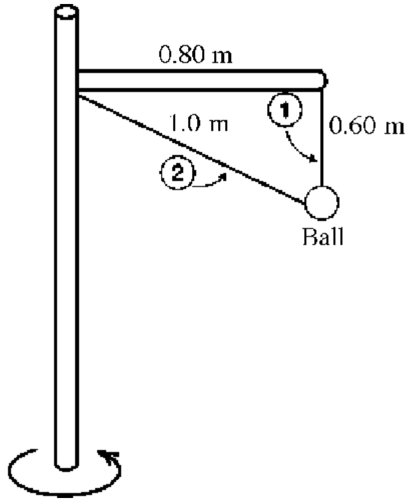
Answer: A

64) A new roller coaster contains a loop–the–loop in which the car and rider are completely upside down. If the radius of the loop is 13.2 m, with what minimum speed must the car traverse the loop so that the rider does not fall out while upside down at the top? Assume the rider is not strapped to the car.

A) 11.4 m/s
B) 12.5 m/s
C) 10.1 m/s
D) 14.9 m/s

Answer: A

65) A ball of mass 5.0 kg is suspended by two wires from a horizontal arm that is attached to a vertical shaft, as shown in the figure. The shaft is in uniform rotation about its axis. The rate of rotation is adjusted until the tensions in the two wires are EQUAL. At that speed, the radial acceleration of the ball is closest to



A) 4.9 m/s^2.
B) 5.9 m/s^2.
C) 6.9 m/s^2.
D) 7.9 m/s^2.
E) 9.9 m/s^2.

Answer: A

66) A roadway for stunt drivers is designed for racecars moving at a speed of 40 m/s. A curved section of the roadway is a circular arc of 230 m radius. The roadway is banked so that a vehicle can go around the curve with the friction force from the road equal to zero. At what angle is the roadway banked?

A) 35°
B) 37°
C) 33°
D) 31°
E) 29°

Answer: A

67) A person on a sled coasts down a hill and then goes over a slight rise with speed 2.7 m/s. The top of this rise can be modeled as a circle of radius 4.1 m. The sled and occupant have a combined mass of 110 kg. If the coefficient of kinetic friction between the snow and the sled is 0.10, what friction force is exerted on the sled by the snow as the sled goes over the top of the rise?

Answer: 88 N

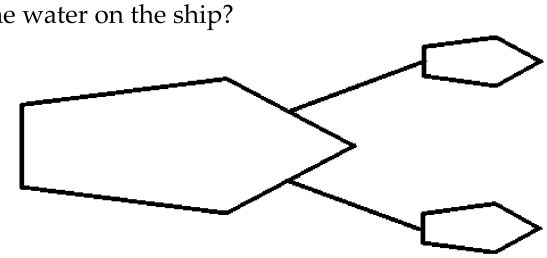
68) A Ferris wheel has diameter of 10 m and makes one revolution in 8.0 seconds. A person weighing 670 N is sitting on one of the benches attached at the rim of the wheel. What is the apparent weight (that is, the normal force exerted on her by the bench) of the person as she passes through the highest point of her motion?

Answer: 460 N

69) The magnitude of the drag force of air resistance on a certain 20.0-kg object is proportional to its speed. If the object has a terminal speed 80.0 m/s, what is the magnitude of the drag force on the object when it is falling with a speed 30.0 m/s?
A) 196 N
B) 7.50 N
C) 15.0 N
D) 73.5 N
E) 42.7 N
Answer: D

70) A 30.0-kg object experiences a drag force due to air resistance with a magnitude proportional to the square of its speed. The object falls with an acceleration of 4.00 m/s^2 downward when it is falling downward at 70.0 m/s. What is its terminal speed?
A) 110 m/s
B) 157 m/s
C) 91.0 m/s
D) 172 m/s
E) 108 m/s
Answer: C

71) A ship is being pulled through a harbor at constant velocity by two tugboats as shown in the figure. The lines attached to the two tugboats have the same tension of 200,000 N. Each line makes an angle of 28.0° with the direction the ship is being towed. What is the magnitude of the drag force due to the water on the ship?



A) 177×10^5 N
B) 1.88×10^5 N
C) 93.9×10^4 N
D) zero
E) 3.53×10^5 N
Answer: E

72) A 1.20-kg ball is hanging from the end of a rope. The rope hangs at an angle 25.0° from the vertical when a 15.0 m/s horizontal wind is blowing. If the wind's force on the rope is negligible, what drag force does the wind exert on the ball?
A) 32.3 N
B) 24.1 N
C) 3.68 N
D) 5.48 N
E) 11.8 N
Answer: D

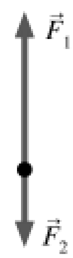
73) An 80.0–kg object is falling and experiences a drag force due to air resistance. The magnitude of this drag force depends on its speed, v, and obeys the equation $F_{drag} = (12.0\ \text{N} \cdot \text{s/m})v + (4.00\ \text{N} \cdot \text{s}^2/\text{m}^2)v^2$. What is the terminal speed of this object?
A) 6.45 m/s
B) 72.2 m/s
C) 34.2 m/s
D) 12.6 m/s
E) 47.3 m/s

Answer: D

74) An object weighing 4.00 N falls from rest subject to a frictional drag force given by $F_{drag} = bv^2$, where v is the speed of the object and $b = 3.00\ \text{N} \cdot \text{s}^2/\text{m}^2$. What terminal speed will this object approach?
A) 1.78 m/s
B) 3.42 m/s
C) 1.15 m/s
D) 2.25 m/s
E) 0.75 m/s

Answer: C

75) The figure shows two forces acting on an object, with magnitudes $F_1 = 78$ N and $F_2 = 26$ N.What third force will cause the object to be in equilibrium (acceleration equals zero)?



A) 52 N pointing down
B) 52 N pointing up
C) 82 N pointing down
D) 82 N pointing up

Answer: A

Chapter 6 Work, Energy, and Power

6.1 Conceptual Questions

1) If the dot product of two nonzero vectors is zero, the vectors must be perpendicular to each other.
   A) True
   B) False

   Answer: A

2) If two nonzero vectors point in the same direction, their dot product must be zero.
   A) True
   B) False

   Answer: B

3) The value of the dot product of two vectors depends on the particular coordinate system being used.
   A) True
   B) False

   Answer: B

4) Two men, Joel and Jerry, push against a wall. Jerry stops after 10 min, while Joel is able to push for 5.0 min longer. Compare the work they do.
   A) Both men do positive work, but Joel does 75% more work than Jerry.
   B) Both men do positive work, but Joel does 50% more work than Jerry.
   C) Both men do positive work, but Jerry does 50% more work than Joel.
   D) Both men do positive work, but Joel does 25% more work than Jerry.
   E) Neither of them does any work.

   Answer: E

5) A stock person at the local grocery store has a job consisting of the following five segments:
   (1) picking up boxes of tomatoes from the stockroom floor
   (2) accelerating to a comfortable speed
   (3) carrying the boxes to the tomato display at constant speed
   (4) decelerating to a stop
   (5) lowering the boxes slowly to the floor.
   During which of the five segments of the job does the stock person do positive work on the boxes?
   A) (1) and (5)
   B) (1) only
   C) (1), (2), (4), and (5)
   D) (1) and (2)
   E) (2) and (3)

   Answer: D

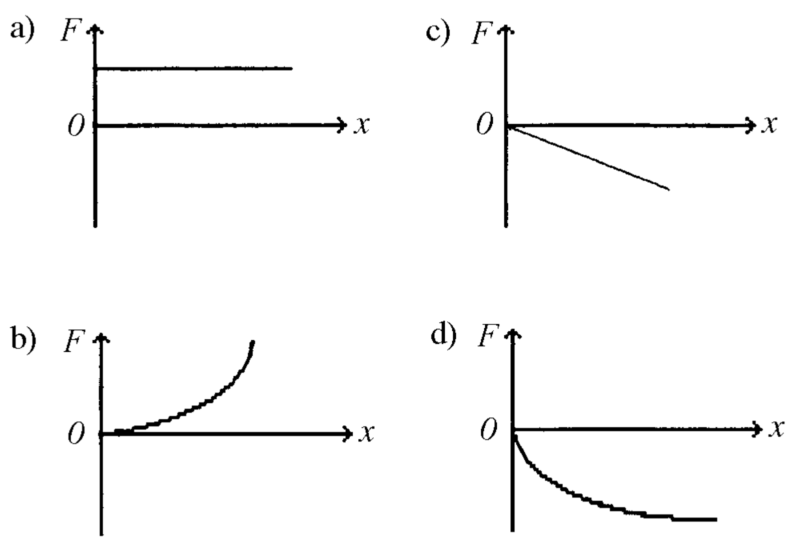
6) A 3.00-kg ball swings rapidly in a complete vertical circle of radius 2.00 m by a light string that is fixed at one end. The ball moves so fast that the string is always taut and perpendicular to the velocity of the ball. As the ball swings from its lowest point to its highest point
   A) the work done on it by gravity and the work done on it by the tension in the string are both equal to –118 J.
   B) the work done on it by gravity is –118 J and the work done on it by the tension in the string is +118 J.
   C) the work done on it by gravity is +118 J and the work done on it by the tension in the string is –118 J.
   D) the work done on it by gravity is –118 J and the work done on it by the tension in the string is zero.
   E) the work done on it by gravity and the work done on it by the tension in the string are both equal to zero.

   Answer: D

7) Consider a plot of the displacement (x) as a function of the applied force (F) for an ideal elastic spring. The slope of the curve would be
   A) the spring constant.
   B) the reciprocal of the spring constant.
   C) the acceleration due to gravity.
   D) the reciprocal of the acceleration of gravity.
   E) the mass of the object attached to the spring.

   Answer: B

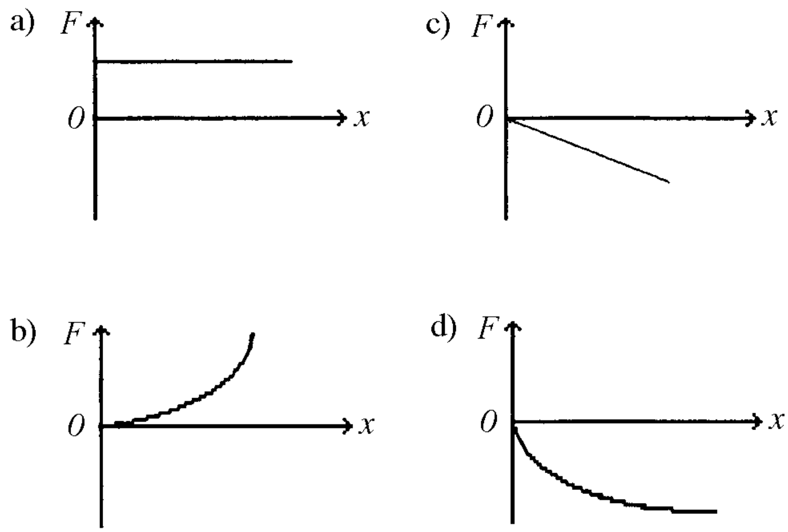
8) Which of the graphs in the figure illustrates Hooke's Law?



   A) Graph a
   B) Graph b
   C) Graph c
   D) graph d

   Answer: B

9) Which of the graphs in the figure represents a spring that gets less stiff the more it is stretched?



A) Graph a
B) Graph b
C) Graph c
D) Graph d

Answer: D

10) A 4.0-kg object is moving with speed 2.0 m/s. A 1.0-kg object is moving with speed 4.0 m/s. Both objects encounter the same constant braking force, and are brought to rest. Which object travels the greater distance before stopping?
A) the 4.0-kg object
B) the 1.0-kg object
C) Both objects travel the same distance.
D) It is impossible to know without knowing how long each force acts.

Answer: C

11) If a force always acts perpendicular to an object's direction of motion, that force cannot change the object's kinetic energy.
A) True
B) False

Answer: A

12) Three cars (car *F*, car *G*, and car *H*) are moving with the same velocity when the driver suddenly slams on the brakes, locking the wheels. The most massive car is car *F*, the least massive is car *H*, and all three cars have identical tires.

(a) Which car travels the longest distance to skid to a stop?

A) Car *F*
B) Car *G*
C) Car *H*
D) They all travel the same distance in stopping.

(b) For which car does friction do the largest amount of work in stopping the car?

A) Car *F*
B) Car *G*
C) Car *H*
D) The amount of work done by friction is the same for all cars.

Answer: (a) D (b) A

13) Two objects, one of mass *m* and the other of mass 2*m*, are dropped from the top of a building. When they hit the ground

A) both of them will have the same kinetic energy.
B) the heavier one will have twice the kinetic energy of the lighter one.
C) the heavier one will have four times the kinetic energy of the lighter one.
D) the heavier one will have $\sqrt{2}$ times the kinetic energy of the lighter one.

Answer: B

6.2 Problems

1) Determine the scalar product of $\vec{A} = 6.0\hat{\boldsymbol{i}} + 4.0\hat{\boldsymbol{j}} - 2.0\hat{k}$ and $\vec{B} = 5.0\hat{\boldsymbol{i}} - 6.0\hat{\boldsymbol{j}} - 3.0\hat{\boldsymbol{k}}$.

A) $30\hat{\boldsymbol{i}} + 24\hat{\boldsymbol{j}} + 6\hat{\boldsymbol{k}}$
B) $30\hat{\boldsymbol{i}} - 24\hat{\boldsymbol{j}} + 6\hat{\boldsymbol{k}}$
C) 12
D) 60
E) undefined

Answer: C

2) Determine the angle between the directions of vector $\vec{A} = 3.00\hat{\boldsymbol{i}} + 1.00\hat{\boldsymbol{j}}$ and vector $\vec{B} = -3.00\hat{\boldsymbol{i}} + 3.00\hat{\boldsymbol{j}}$.

A) 26.6°
B) 30.0°
C) 88.1°
D) 117°
E) 45.2°

Answer: D

3) The scalar product of vector $\vec{A} = 3.00\hat{i} + 2.00\hat{j}$ and vector $\vec{B}$ is 10.0. Which of the following vectors could be vector $\vec{B}$?
A) $2.00\hat{i} + 4.00\hat{j}$
B) $4.00\hat{i} + 6.00\hat{j}$
C) $5.00\hat{i} + 4.00\hat{j}$
D) $12.0\hat{i}$
E) $2.00\hat{i} + 2.00\hat{j}$
Answer: E

4) The angle between vector $\vec{A} = 2.00\hat{i} + 3.00\hat{j}$ and vector $\vec{B}$ is 45.0°. The scalar product of vectors $\vec{A}$ and $\vec{B}$ is 3.00. If the x component of vector $\vec{B}$ is positive, what is vector $\vec{B}$.
A) $4.76\hat{i} + 0.952\hat{j}$
B) $1.15\hat{i} + 0.231\hat{j}$
C) $2.96\hat{i} + -0.973\hat{j}$
D) $0.871\hat{i} + 0.419\hat{j}$
E) $3.42\hat{i} + 0.684\hat{j}$
Answer: B

5) What is the angle between the vector $\vec{A} = +3\hat{i} - 2\hat{j} - 3\hat{k}$ and the $+y$–axis?
A) 115°
B) 65°
C) 25°
D) 155°
E) 90°
Answer: A

6) If $\vec{A} = 3\hat{i} - \hat{j} + 4\hat{k}$ and $\vec{B} = x\hat{i} + \hat{j} - 5\hat{k}$, find x so $\vec{B}$ will be perpendicular to $\vec{A}$.
Answer: 7

7) Two boys searching for buried treasure are standing underneath the same tree. One boy walks 18 m east and then 18 m north. The other boy walks 16 m west and then 11 m north. Find the scalar product of their net displacements from the tree.
Answer: $-90\ m^2$

8) A rectangular box is positioned with its vertices at the following points:

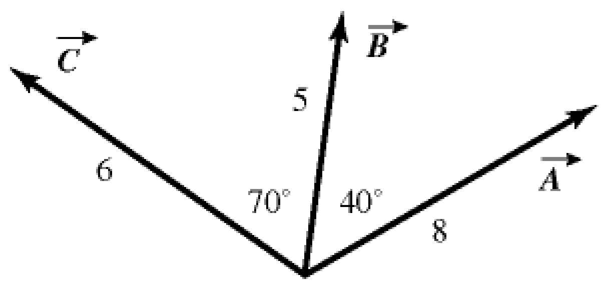
$A = (0,0,0)$	$C = (2,4,0)$	$E = (0,0,3)$	$G = (2,4,3)$
$B = (2,0,0)$	$D = (0,4,0)$	$F = (2,0,3)$	$H = (0,4,3)$

If the coordinates all have three significant figures, the angle between the line segments *AG* and *AH* is closest to:

A) 21.8°.
B) 22.5°.
C) 26.6°.
D) 36.9°.
E) 45.0°.

Answer: A

9) For the vectors shown in the figure, assume numbers are accurate to two significant figures. The scalar product $\vec{A} \times \vec{C}$ is closest to



A) zero.
B) 16.
C) 45.
D) −16.
E) −45.

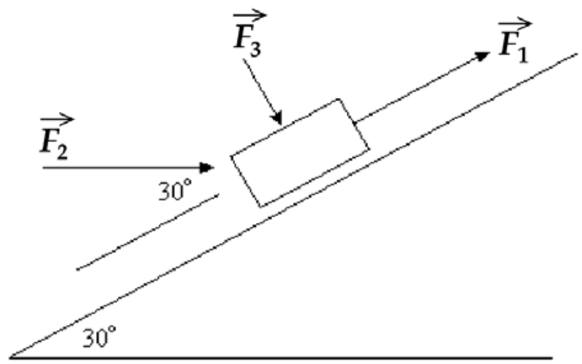
Answer: D

10) Three forces, $F_1 = 20.0$ N, $F_2 = 40.0$ N, and $F_3 = 10.0$ N act on an object with a mass of 2.00 kg which can move along a frictionless inclined plane as shown in the figure. The questions refer to the instant when the object has moved through a distance of 0.600 m along the surface of the inclined plane in the upward direction. Calculate the amount of work done by

(a) F_1

(b) F_2

(c) F_3.



Answer: (a) 12.0 J (b) 20.8 J (c) 0.00 J

11) You carry a 7.0 kg bag of groceries 1.2 m above the level floor at a constant velocity of 75 cm/s across a room that is 2.3 m room. How much work do you do on the bag in the process?

A) 0.0 J
B) 82 J
C) 158 J
D) 134 J

Answer: A

12) A student slides her 80.0–kg desk across the level floor of her dormitory room a distance 4.00 m at constant speed. If the coefficient of kinetic friction between the desk and the floor is 0.400, how much work did she do?

A) 128 J
B) 3.14 kJ
C) 26.7 J
D) 1.26 kJ
E) 24.0 J

Answer: D

13) Find the net work done by friction on the body of a snake slithering in a complete circle of 3.93 m radius. The coefficient of friction between the ground and the snake is 0.25, and the snake's weight is 54.0 N.

A) –330 J
B) 0 J
C) –3300 J
D) –670 J

Answer: A

14) A crane lifts a 425 kg steel beam vertically a distance of 117 m. How much work does the crane do on the beam if the beam accelerates upward at 1.8 m/s^2? Neglect frictional forces.

A) 5.8×10^5 J
B) 3.4×10^5 J
C) 4.0×10^5 J
D) 4.9×10^5 J

Answer: A

15) An airplane flies 120 km at a constant altitude in a direction 30.0° north of east. A wind is blowing that results in a net horizontal force on the plane due to the air of 2.40 kN in a direction 10.0° south of west. How much work is done on the plane by the air?

A) -2.71×10^8 J
B) -0.985×10^8 J
C) -221×10^8 J
D) 221×10^8 J
E) 0.821×10^8 J

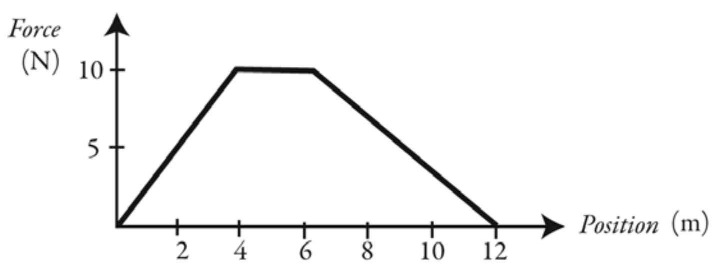
Answer: A

16) A traveler pulls on a suitcase strap at an angle 36° above the horizontal. If 908 J of work are done by the strap while moving the suitcase a horizontal distance of 15 m, what is the tension in the strap?

A) 75 N
B) 61 N
C) 85 N
D) 92 N

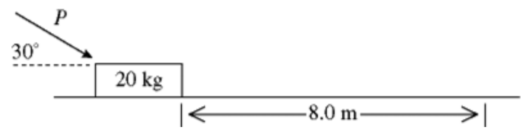
Answer: A

17) An object is acted upon by a force that represented by the force vs. position graph in the figure. What is the work done as the object moves
(a) from 4 m to 6 m?
(b) from 6 m to 12 m?



Answer: (a) 20 J (b) 30 J

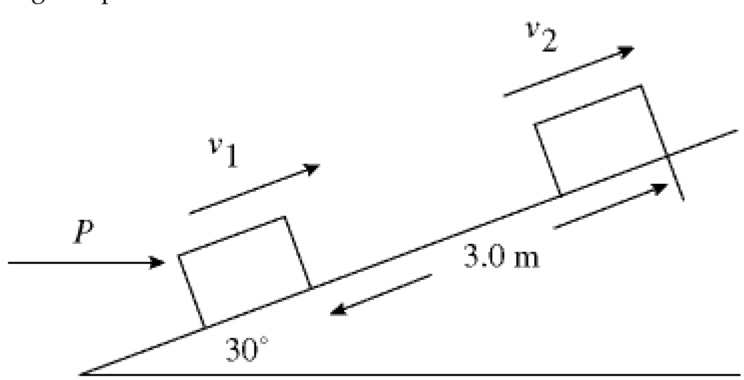
18) In the figure, a constant external force $P = 160$ N is applied to a 20.0–kg box, which is on a rough horizontal surface. While the force pushes the box a distance of 8.00 m, the speed changes from 0.500 m/s to 2.60 m/s. The work done by friction during this process is closest to



A) −1040 J.
B) +1110 J.
C) +1170 J.
D) +1040 J.
E) −1170 J.

Answer: A

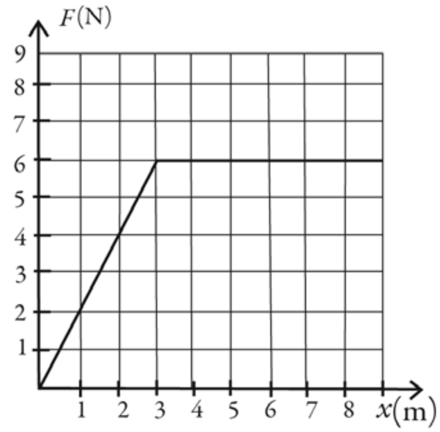
19) In the figure, a 700–kg crate is on a rough surface inclined at 30°. A constant external force P = 5600 N is applied horizontally to the crate. As the force pushes the crate a distance of 3.00 m up the incline, the speed changes from 1.40 m/s to 2.50 m/s. How much work does gravity do on the crate during this process?



A) −10,300 J
B) −3400 J
C) +10,300 J
D) +3400 J
E) zero

Answer: A

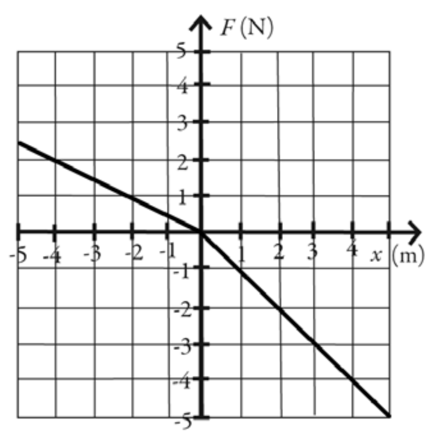
20) A graph of the force on an object as a function of its position is shown in the figure. Determine the amount of work done by this force on an object that moves from $x = 1.0$ m to $x = 6.0$ m. (Assume an accuracy of 2 significant figures for the numbers on the graph.)



A) 26 J
B) 29 J
C) 22 J
D) 35 J
E) 27 J

Answer: A

21) A graph of the force on an object as a function of its position is shown in the figure. Determine the amount of work done by this force on the object during a displacement from $x = -2.00$ m to $x = 2.00$ m. (Assume an accuracy of 3 significant figures for the numbers on the graph.)



A) −12.0 J
B) −3.00 J
C) −1.00 J
D) 12.0 J
E) 3.00 J

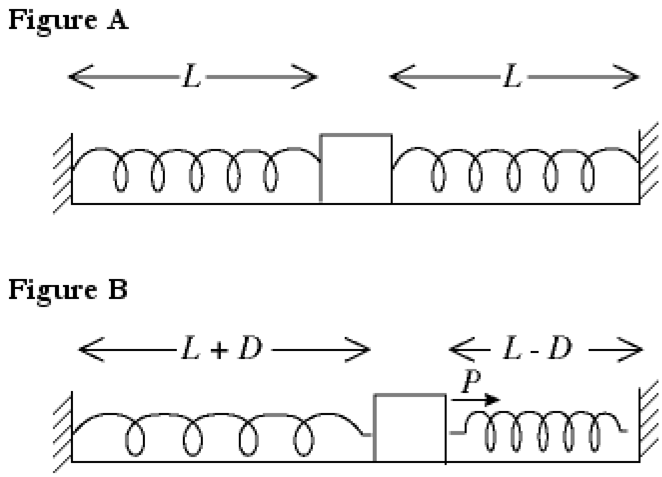
Answer: C

22) A force $\vec{F} = 12\text{ N}\,\hat{i} - 10\text{ N}\,\hat{j}$ acts on an object. How much work does this force do as the object moves from the origin to the point $\vec{r} = 13\text{ m}\,\hat{i} + 11\text{ m}\,\hat{j}$?
A) 46 J
B) 266 J
C) 37 J
D) 62 J
Answer: A

23) A spring stretches by 21.0 cm when a 135 N object is attached. What is the weight of a fish that would stretch the spring by 31 cm?
A) 199 N
B) 91.0 N
C) 145 N
D) 279 N
Answer: A

24) An object attached to an ideal massless spring is pulled across a frictionless surface. If the spring constant is 45 N/m and the spring is stretched by 0.88 m when the object is accelerating at 2.0 m/s^2, what is the mass of the object?
A) 20 kg
B) 17 kg
C) 22 kg
D) 26 kg
Answer: A

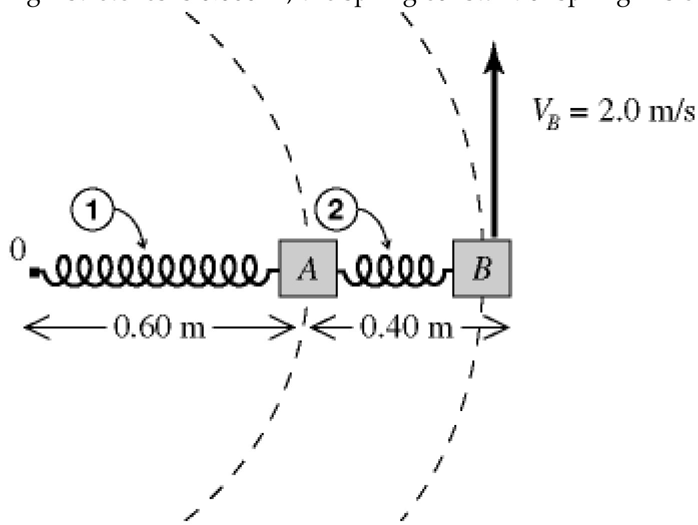
25) In the figure, two identical ideal massless springs have unstretched lengths of 0.25 m and spring constants of 700 N/m. The springs are attached to a small cube and stretched to a length L of 0.30 m as in Figure A. An external force P pulls the cube a distance $D = 0.020$ m to the right and holds it there. (See Figure B.) The external force P, that holds the cube in place in Figure B, is closest to



A) 28 N.
B) 25 N.
C) 21 N.
D) 18 N.
E) 14 N.

Answer: A

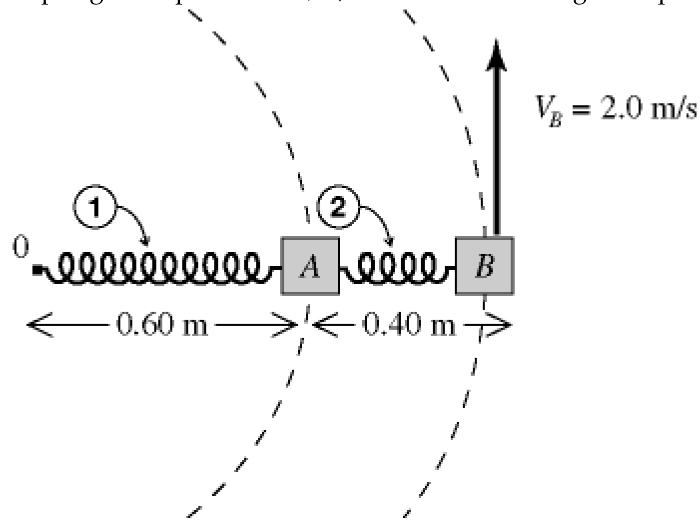
26) Block *A* (0.40 kg) and block *B* (0.30 kg) are on a frictionless table (see figure). Spring 1 connects block *A* to a frictionless peg at *0* and spring 2 connects block *A* and block *B*. When the blocks are in uniform circular motion about *0*, the springs have lengths of 0.60 m and 0.40 m, as shown. The springs are ideal and massless, and the linear speed of block *B* is 2.0 m/s. If the distance that spring 2 stretches is 0.060 m, the spring constant of spring 2 is closest to



A) 18 N/m.
B) 20 N/m.
C) 22 N/m.
D) 24 N/m.
E) 26 N/m.

Answer: B

27) Block *A* (0.40 kg) and block *B* (0.30 kg) are on a frictionless table (see figure). Spring 1 connects block *A* to a frictionless peg at *0* and spring 2 connects block *A* and block *B*. When the blocks are in uniform circular motion about *0*, the springs have lengths of 0.60 m and 0.40 m, as shown. The springs are ideal and massless, and the linear speed of block *B* is 2.0 m/s. If the spring constant of spring 1 is equal to 30 N/m, the unstretched length of spring 1 is closest to



A) 0.51 m.
B) 0.52 m.
C) 0.53 m.
D) 0.54 m.
E) 0.55 m.

Answer: C

28) A force on a particle depends on position such that $F(x) = (3.00\ \text{N/m}^2)x^2 + (6.00\ \text{N/m})x$ for a particle constrained to move along the x-axis. What work is done by this force on a particle that moves from $x = 0.00$ m to $x = 2.00$ m?
A) 10.0 J
B) 20.0 J
C) −48.0 J
D) 24.0 J
E) 48.0 J

Answer: B

29) A person pushes horizontally on a heavy box and slides it across the level floor at constant velocity. The person pushes with a 60.0 N force for the first 6.88 m, at which time he begins to tire. The force he exerts then starts to decrease linearly from 60.0 N to 0.00 N across the remaining 6.88 m. How much total work did the person do on the box?
A) 619 J
B) 826 J
C) 495 J
D) 925 J

Answer: A

30) It requires 49 J of work to stretch an ideal very light spring from a length of 1.4 m to a length of 2.9 m. What is the value of the spring constant of this spring?
   A) 15 N/m
   B) 44 N/m
   C) 29 N/m
   D) 22 N/m

Answer: A

31) A force $F = bx^3$ acts in the x direction, where the value of b is 3.7 N/m^3. How much work is done by this force in moving an object from x = 0.00 m to x = 2.6 m?
   A) 42 J
   B) 13 J
   C) 50 J
   D) 57 J

Answer: A

32) In the figure, two identical springs have unstretched lengths of 0.25 m and spring constants of 300 N/m. The springs are attached to a small cube and stretched to a length L of 0.36 m as in Figure A. An external force P pulls the cube a distance D = 0.020 m to the right and holds it there. (See Figure B.) The work done by the external force P in pulling the cube 0.020 m is closest to

Figure A

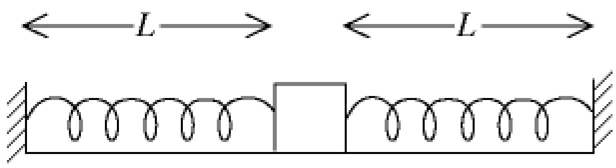
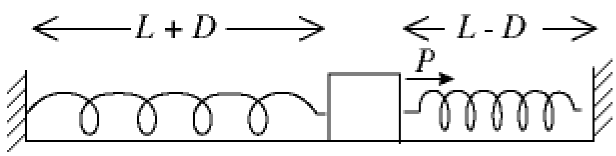


Figure B



   A) 0.12 J.
   B) 0.060 J.
   C) 6.0 J.
   D) 12 J.
   E) 0.80 J.

Answer: A

33) A 1000.0 kg car is moving at 15 km/h. If a 2000.0 kg truck has 18 times the kinetic energy of the car, how fast is the truck moving?
A) 45 km/h
B) 63 km/h
C) 54 km/h
D) 36 km/h
Answer: A

34) How much energy is needed to change the speed of a 1600 kg sport utility vehicle from 15.0 m/s to 40.0 m/s?
A) 1.10 MJ
B) 10.0 kJ
C) 20.0 kJ
D) 40.0 kJ
E) 0.960 MJ
Answer: A

35) The coefficient of the restitution of an object is defined as the ratio of its outgoing to incoming speed when the object collides with a rigid surface. For an object with a coefficient of 0.78, what fraction of the object's kinetic energy is lost during a single collision?
A) 39%
B) 16%
C) 47%
D) 61%
Answer: A

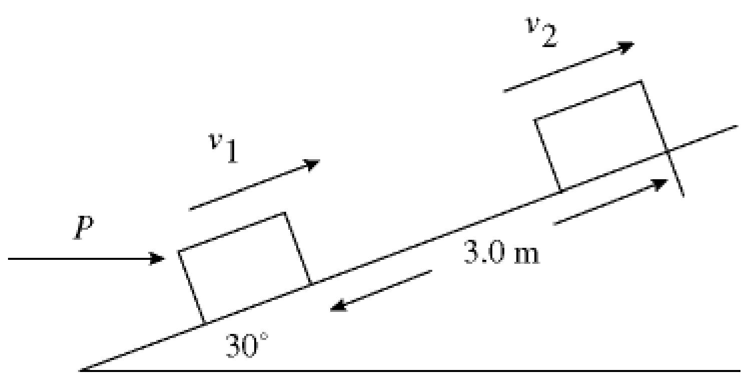
36) A worker lifts a 20.0-kg bucket of concrete from the ground up to the top of a 20.0-m tall building. The bucket is initially at rest, but is traveling at 4.0 m/s when it reaches the top of the building. What is the minimum amount of work that the worker did in lifting the bucket?
A) 3.92 kJ
B) 400 J
C) 560 J
D) 4.08 kJ
E) 160 J
Answer: D

37) A ball is thrown upward at an angle with a speed and direction such that it reaches a maximum height of 16.0 m above the point it was released, with no appreciable air resistance. At its maximum height it has a speed of 18.0 m/s. With what speed was the ball released?
A) 25.3 m/s
B) 22.2 m/s
C) 33.0 m/s
D) 29.2 m/s
E) 36.9 m/s
Answer: A

38) A 1000 kg car experiences a net force of 9500 N while decelerating from 30.0 m/s to 23.4 m/s. How far does it travel while slowing down?
A) 18.5 m
B) 17.4 m
C) 20.2 m
D) 21.9 m
Answer: A

39) A constant horizontal pull acts on a sled on a horizontal frictionless ice pond. The sled starts from rest. When the pull acts over a distance x, the sled acquires a speed v and a kinetic energy K. If the same pull instead acts over twice this distance:
A) The sled's speed will be $2v$ and its kinetic energy will be $2K$.
B) The sled's speed will be $2v$ and its kinetic energy will be $K\sqrt{2}$.
C) The sled's speed will be $v\sqrt{2}$ and its kinetic energy will be $2K$.
D) The sled's speed will be $v\sqrt{2}$ and its kinetic energy will be $K\sqrt{2}$.
E) The sled's speed will be $4v$ and its kinetic energy will be $2K$.
Answer: C

40) In the figure, a 900–kg crate is on a rough surface inclined at 30°. A constant external force $P = 7200$ N is applied horizontally to the crate. While this force pushes the crate a distance of 3.0 m up the incline, its velocity changes from 1.2 m/s to 2.3 m/s. How much work does friction do during this process?



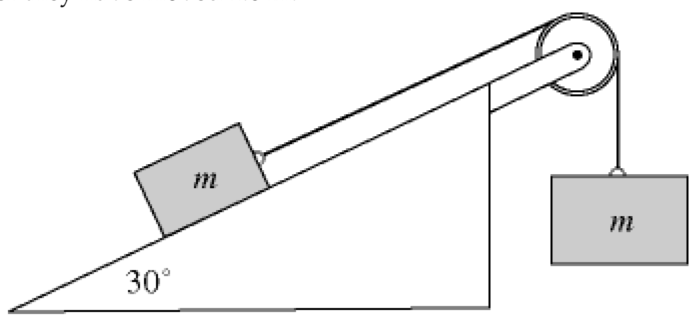
A) –3700 J
B) –7200 J
C) +3700 J
D) +7200 J
E) zero
Answer: A

41) A 5.00–kg box slides 4.00 m across the floor before coming to rest. What is the coefficient of kinetic friction between the floor and the box if the box had an initial speed of 3.00 m/s?
A) 1.13
B) 0.587
C) 0.115
D) 0.229
E) 0.267
Answer: C

42) You slam on the brakes of your car in a panic, and skid a certain distance on a straight, level road. If you had been traveling twice as fast, what distance would the car have skidded, under identical conditions?
A) It would have skidded 4 times farther.
B) It would have skidded 2 times farther.
C) It would have skidded $\sqrt{2}$ times farther.
D) It would have skidded $1/\sqrt{2}$ times farther.
E) It would have skidded 1/2 as far.

Answer: A

43) In the figure, two boxes, each of mass 24 kg, are at rest and connected as shown. The coefficient of kinetic friction between the inclined surface and the box is 0.31. Find the speed of the boxes just after they have moved 1.6 m.



Answer: 1.9 m/s

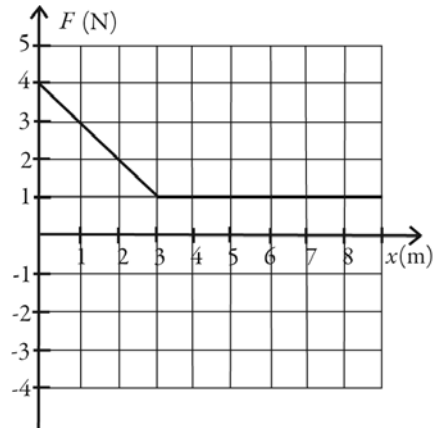
44) A 4.00–kg mass is attached to a very light ideal spring hanging vertically and hangs at rest in the equilibrium position. The spring constant of the spring is 1.00 N/cm. The mass is pulled downward 2.00 cm and released. What is the speed of the mass when it is 1.00 cm above the point from which it was released?
A) 0.0443 m/s
B) 0.0744 m/s
C) 0.0201 m/s
D) 0.0866 m/s
E) The mass will not reach the height specified.

Answer: D

45) An unusual spring has a restoring force of magnitude $F = (2.00\ \text{N/m})x + (1.00\ \text{N/m}^2)x^2$, where x is the stretch of the spring from its equilibrium length. A 3.00–kg object is attached to this spring and released from rest after stretching the spring 1.50 m. If the object slides over a frictionless horizontal surface, how fast is it moving when the spring returns to its equilibrium length?
A) 2.06 m/s
B) 4.33 m/s
C) 3.27 m/s
D) 5.48 m/s
E) 1.50 m/s

Answer: E

46) The force on a 3.00–kg object as a function of position is shown in the figure. If an object is moving at 2.50 m/s when it is located at x = 2.00 m, what will its speed be when it reaches x = 8.00 m? (Assume that the numbers on the graph are accurate to 3 significant figures.)



A) 3.25 m/s
B) 3.70 m/s
C) 4.10 m/s
D) 2.90 m/s
E) 4.50 m/s

Answer: A

47) A 7.0–kg rock is subject to a variable force given by the equation

$$F(x) = 6.0\text{ N} - (2.0\text{ N/m})x + (6.0\text{ N/m}^2)x^2$$

If the rock initially is at rest at the origin, find its speed when it has moved 9.0 m.

Answer: 20 m/s

48) A 1500–kg car accelerates from 0 to 25 m/s in 7.0 s with negligible friction and air resistance. What is the average power delivered by the engine? (1 hp = 746 W)

A) 50 hp
B) 60 hp
C) 70 hp
D) 80 hp
E) 90 hp

Answer: E

49) A child pulls on a wagon with a horizontal force of 75 N. If the wagon moves horizontally a total of 42 m in 3.0 min, what is the average power generated by the child?

A) 18 W
B) 22 W
C) 24 W
D) 27 W

Answer: A

50) A car needs to generate 75.0 hp in order to maintain a constant velocity of 27.3 m/s on a flat road. What is the magnitude of the total resistive force acting on the car (due to friction, air resistance, etc.)? (1 hp = 746 W)

A) 2.05×10^3 N
B) 2.75 N
C) 1.03×10^3 N
D) 2.87×10^3 N

Answer: A

51) How long will it take a 7.08 hp motor to lift a 250 kg beam directly upward at constant velocity from the ground to a height of 45.0 m? Assume frictional forces are negligible. (1 hp = 746 W)

A) 20.9 s
B) 1.56×10^4 s
C) 2.18×10^4 s
D) 39.7 s

Answer: A

52) Calculate the minimum average power output necessary for a 55.8 kg person to run up a 12.0 m long hillside, which is inclined at 25.0° above the horizontal, in 3.00 s. You can neglect the person's kinetic energy. Express your answer in horsepower. (1 hp = 746 W)

A) 1.24 hp
B) 2.93 hp
C) 1.86 hp
D) 0.740 hp

Answer: A

53) If electricity costs 6.00¢/kWh (kilowatt–hour), how much would it cost you to run a 120 W stereo system 4.0 hours per day for 4.0 weeks?

A) $0.81
B) $0.12
C) $1.38
D) $2.27

Answer: A

54) The work performed as a function of time for a process is given by $W = at^3$, where $a = 2.4\ \mathrm{J/s^3}$. What is the instantaneous power output at $t = 3.7$ s?

A) 99 W
B) 69 W
C) 138 W
D) 207 W

Answer: A

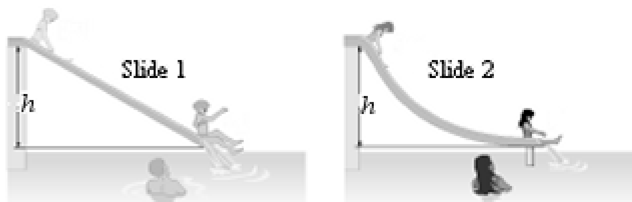
Chapter 7 Conservation of Energy

7.1 Conceptual Questions

1) Is it possible for a system to have negative potential energy?
   A) Yes, as long as the kinetic energy is positive.
   B) Yes, as long as the total energy is positive.
   C) Yes, since the choice of the zero of potential energy is arbitrary.
   D) No, because the kinetic energy of a system must equal its potential energy.
   E) No, because this would have no physical meaning.

   Answer: C

2) Swimmers at a water park have a choice of two frictionless water slides as shown in the figure. Although both slides drop over the same height, h, slide 1 is straight while slide 2 is curved, dropping quickly at first and then leveling out. How does the speed v_1 of a swimmer reaching the end of slide 1 compares with v_2, the speed of a swimmer reaching the end of slide 2?



   A) $v_1 > v_2$
   B) $v_1 < v_2$
   C) $v_1 = v_2$
   D) No simple relationship exists between v_1 and v_2 because we do not know the curvature of slide 2.

   Answer: C

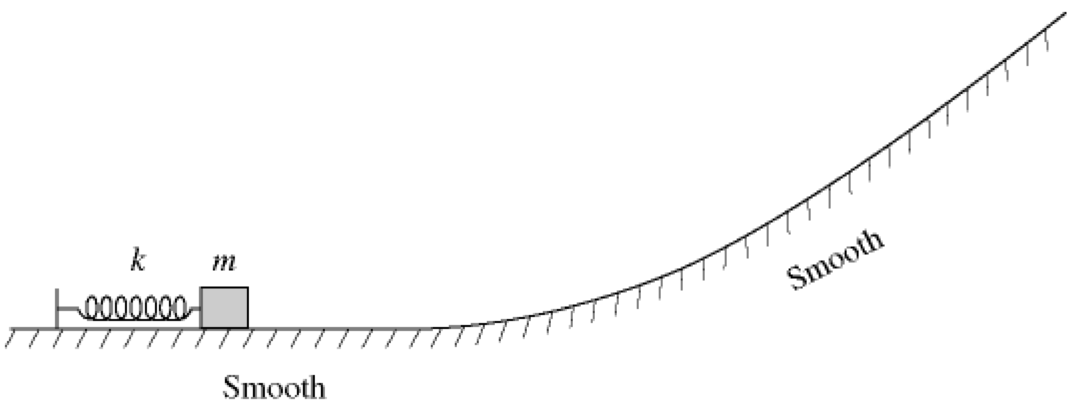
3) Two stones, one of mass m and the other of mass $2m$, are thrown directly upward with the same velocity at the same time from ground level and feel no air resistance. Which statement about these stones is true?
   A) The heavier stone will go twice as high as the lighter one because it initially had twice as much kinetic energy.
   B) Both stones will reach the same height because they initially had the same amount of kinetic energy.
   C) At their highest point, both stones will have the same gravitational potential energy because they reach the same height.
   D) At its highest point, the heavier stone will have twice as much gravitational potential energy as the lighter one because it is twice as heavy.
   E) The lighter stone will reach its maximum height sooner than the heavier one.

   Answer: D

4) Two identical balls are thrown directly upward, ball A at speed v and ball B at speed $2v$, and they feel no air resistance. Which statement about these balls is correct?
  A) Ball B will go twice as high as ball A because it had twice the initial speed.
  B) Ball B will go four times as high as ball A because it had four times the initial kinetic energy.
  C) The balls will reach the same height because they have the same mass and the same acceleration.
  D) At its highest point, ball B will have twice as much gravitational potential energy as ball A because it started out moving twice as fast.
  E) At their highest point, the acceleration of each ball is instantaneously equal to zero because they stop for an instant.

Answer: B

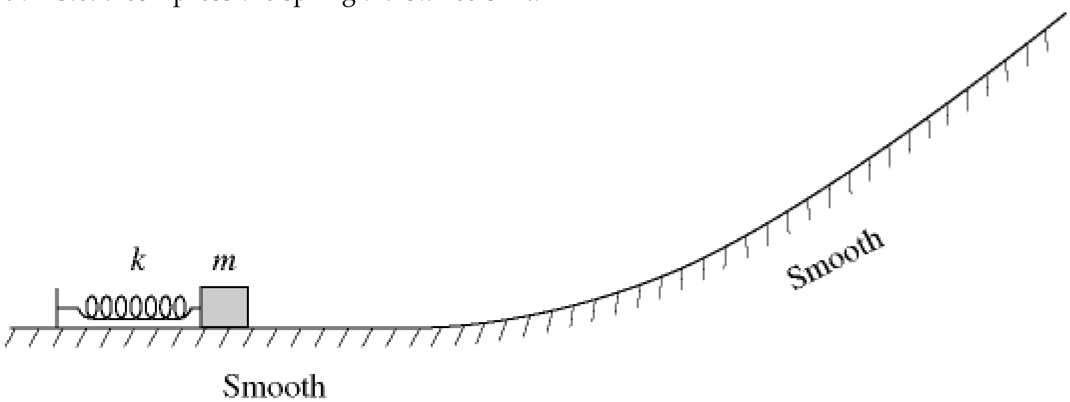
5) A box of mass m is pressed against (but is not attached to) an ideal spring of force constant k and negligible mass, compressing the spring a distance x. After it is released, the box slides up a frictionless incline as shown in the figure and eventually stops. If we repeat this experiment with a box of mass $2m$



  A) the lighter box will go twice as high up the incline as the heavier box.
  B) just as it moves free of the spring, the lighter box will be moving twice as fast as the heavier box.
  C) both boxes will have the same speed just as they move free of the spring.
  D) both boxes will reach the same maximum height on the incline.
  E) just as it moves free of the spring, the heavier box will have twice as much kinetic energy as the lighter box.

Answer: A

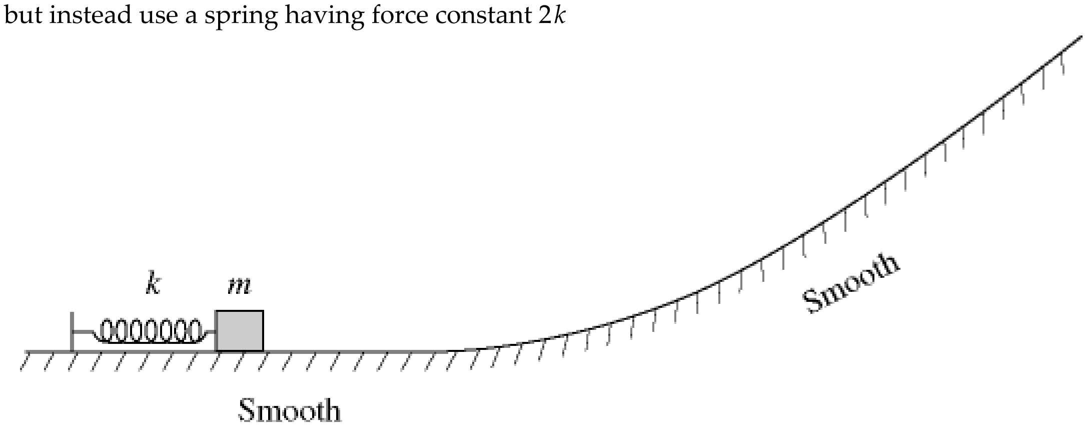
6) A box of mass m is pressed against (but is not attached to) an ideal spring of force constant k and negligible mass, compressing the spring a distance x. After it is released, the box slides up a frictionless incline as shown in the figure and eventually stops. If we repeat this experiment but instead compress the spring a distance of $2x$



A) the box will go up the incline twice as high as before.
B) just as it moves free of the spring, the box will be traveling twice as fast as before.
C) just as it moves free of the spring, the box will be traveling four times as fast as before.
D) just as it moves free of the spring, the box will have twice as much kinetic energy as before.
E) just before it is released, the box has twice as much elastic potential energy as before.

Answer: B

7) A box of mass m is pressed against (but is not attached to) an ideal spring of force constant k and negligible mass, compressing the spring a distance x. After it is released, the box slides up a frictionless incline as shown in the figure and eventually stops. If we repeat this experiment but instead use a spring having force constant $2k$



A) the box will go up the incline twice as high as before.
B) just as it moves free of the spring, the kinetic energy of the box will be twice as great as before.
C) just as it moves free of the spring, the speed of the box will be $\sqrt{2}$ times as great as before.
D) All of the above choices are correct.
E) None of the above choices is correct.

Answer: D

8) When an object is solely under the influence of conservative forces, the sum of its kinetic and potential energies does not change.
   A) True
   B) False

   Answer: A

9) A ball drops some distance and gains 30 J of kinetic energy. Do NOT ignore air resistance. How much gravitational potential energy did the ball lose?
   A) more than 30 J
   B) exactly 30 J
   C) less than 30 J

   Answer: A

10) A ball drops some distance and loses 30 J of gravitational potential energy. Do NOT ignore air resistance. How much kinetic energy did the ball gain?
   A) more than 30 J
   B) exactly 30 J
   C) less than 30 J

   Answer: C

11) Block 1 and block 2 have the same mass, m, and are released from the top of two inclined planes of the same height making 30° and 60° angles with the horizontal direction, respectively. If the coefficient of friction is the same in both cases, which of the blocks is going faster when it reaches the bottom of its respective incline?
   A) We must know the actual masses of the blocks to answer.
   B) Both blocks have the same speed at the bottom.
   C) Block 1 is faster.
   D) Block 2 is faster.
   E) There is not enough information to answer the question because we do not know the value of the coefficient of kinetic friction.

   Answer: D

12) A girl throws a stone from a bridge. Consider the following ways she might throw the stone. The speed of the stone as it leaves her hand is the same in each case, and air resistance is negligible.
   Case A: Thrown straight up.
   Case B: Thrown straight down.
   Case C: Thrown out at an angle of 45° above horizontal.
   Case D: Thrown straight out horizontally.

   In which case will the speed of the stone be greatest when it hits the water below?
   A) Case A
   B) Case B
   C) Case C
   D) Case D
   E) The speed will be the same in all cases.

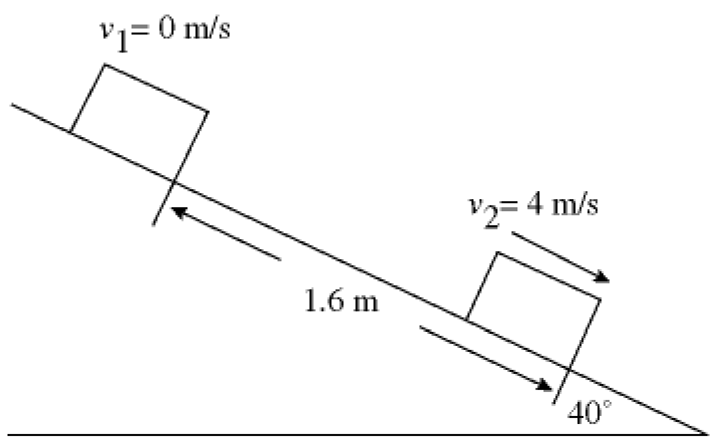
   Answer: E

13) Which, if any, of the following statements concerning the work done by a conservative force is NOT true?
A) It can always be expressed as the difference between the initial and final values of a potential energy function.
B) It is independent of the path of the body and depends only on the starting and ending points.
C) When the starting and ending points are the same, the total work is zero.
D) All of the above statements are true.
E) None of the above statements are true.

Answer: D

7.2 Problems

1) An 8.0–kg block is released from rest, with v_1 = 0.00 m/s, on a rough incline, as shown in the figure. The block moves a distance of 1.6–m down the incline, in a time interval of 0.80 s, and acquires a velocity of v_2 = 4.0 m/s. How much work does gravity do on the block during this process?



A) +81 J
B) +100 J
C) +120 J
D) −81 J
E) −100 J

Answer: A

2) You do 174 J of work while pulling your sister back on a swing, whose chain is 5.10 m long. You start with the swing hanging vertically and pull it until the chain makes an angle of 32.0° with the vertical with your sister is at rest. What is your sister's mass, assuming negligible friction?
A) 22.9 kg
B) 19.5 kg
C) 26.3 kg
D) 28.4 kg

Answer: A

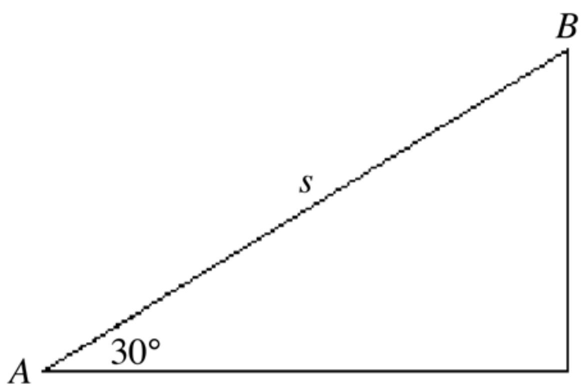
3) An athlete stretches a spring an extra 40.0 cm beyond its initial length. How much energy has he transferred to the spring, if the spring constant is 52.9 N/cm?
   A) 423 J
   B) 4230 kJ
   C) 423 kJ
   D) 4230 J

   Answer: A

4) A tennis ball bounces on the floor three times. If each time it loses 22.0% of its energy due to heating, how high does it rise after the third bounce, provided we released it 2.3 m from the floor?
   A) 110 cm
   B) 11 cm
   C) 110 mm
   D) 140 cm

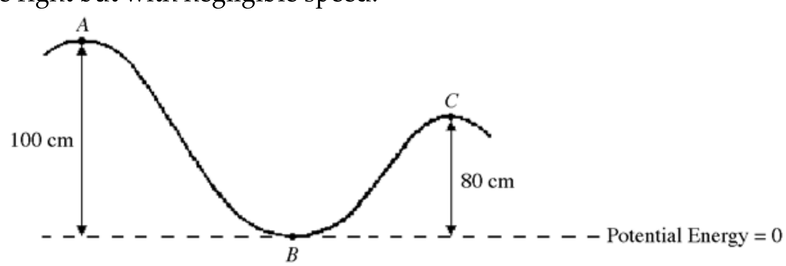
   Answer: A

5) It requires 6.0 J of work is needed to push a 2.0-kg object from point *A* to point *B* of the frictionless ramp as shown in the figure. What is the length *s* of the ramp from *A* to *B*?



   Answer: 0.61 m

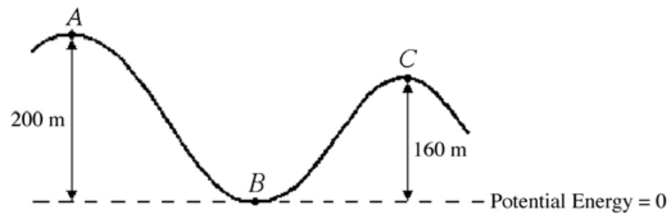
6) A 2.0 g bead slides along a frictionless wire, as shown in the figure. At point *A*, the bead is moving to the right but with negligible speed.



   (a) What is the potential energy of the bead at point *A*?
   (b) What is the kinetic energy of the bead at point *B*?
   (c) What is the speed of the bead at point *B*?
   (d) What is the speed of the bead at point *C*?

   Answer: (a) 2.0×10^{-2} J (b) 2.0×10^{-2} J (c) 4.4 m/s (d) 2.0 m/s

7) A roller coaster of mass 80.0 kg is moving with a speed of 20.0 m/s at position A as shown in the figure. The vertical height above ground level at position A is 200 m. Neglect friction.



(a) What is the total mechanical energy of the roller coaster at point A?
(b) What is the total mechanical energy of the roller coaster at point B?
(c) What is the speed of the roller coaster at point B?
(d) What is the speed of the roller coaster at point C?

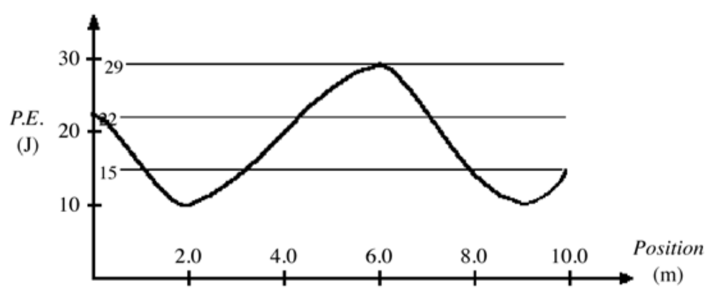
Answer: (a) 1.73×10^5 J (b) 1.73×10^5 J (c) 65.7 m/s (d) 34.4 m/s

8) A mass is pressed against (but is not attached to) an ideal horizontal spring on a frictionless horizontal surface. After being released from rest, the mass acquires a maximum speed v and a maximum kinetic energy K. If instead the mass initially compresses the spring twice as far:

A) Its maximum speed will be $2v$ and its maximum kinetic energy will be $2K$.
B) Its maximum speed will be $2v$ and its maximum kinetic energy will be $\sqrt{2}K$.
C) Its maximum speed will be $v\sqrt{2}$ and its maximum kinetic energy will be $2K$.
D) Its maximum speed will be $2v$ and its maximum kinetic energy will be $4K$.
E) Its maximum speed will be $4v$ and its maximum kinetic energy will be $2K$.

Answer: C

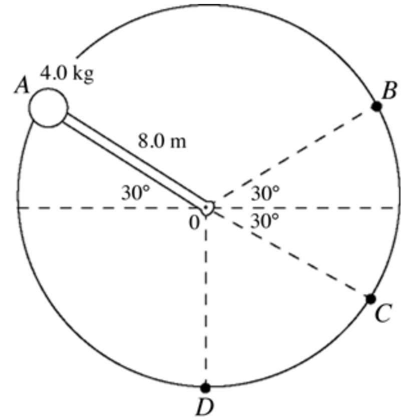
9) A 2.0 kg mass is moving along the x–axis. The potential energy curve as a function of position is shown in the figure. The kinetic energy of the object at the origin is 12 J. The system is conservative, and there is no friction.



(a) What will be the kinetic energy at 2.0 m along the $+x$–axis?
(b) What will be the speed of the object at 6.0 m along the $+x$–axis?

Answer: (a) 24 J (b) 2.2 m/s

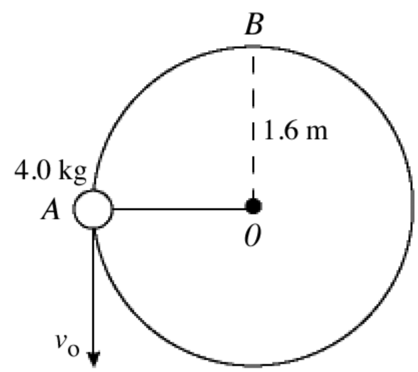
10) An 8.0–m massless rod is loosely pinned to a frictionless pivot at *0*, as shown in the figure. A very small 4.0–kg ball is attached to the other end of the rod. The ball is held at *A*, where the rod makes a 30° angle above the horizontal, and is released. The ball–rod assembly then swings freely with negligible friction in a vertical circle between *A* and *B*. The tension in the rod when the ball passes through the lowest point at *D* is closest to



A) 160 N.
B) 200 N.
C) 120 N.
D) 80 N.
E) 40 N.

Answer: A

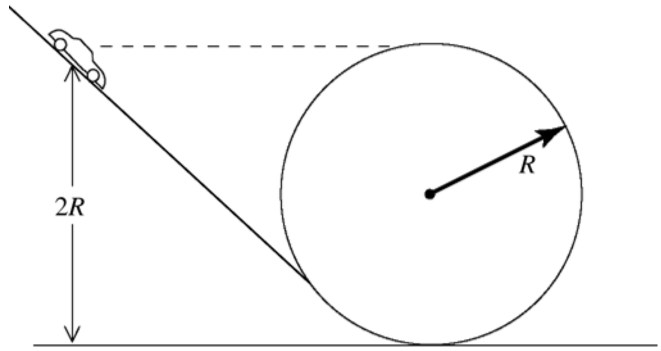
11) In the figure, a 4.0–kg ball is on the end of a 1.6–m rope that is fixed at *0*. The ball is held at point *A*, with the rope horizontal, and is given an initial downward velocity. The ball moves through three quarters of a circle with no friction and arrives at *B*, with the rope barely under tension. The initial velocity of the ball, at point *A*, is closest to



A) 4.0 m/s
B) 5.6 m/s
C) 6.3 m/s
D) 6.9 m/s
E) 7.9 m/s

Answer: D

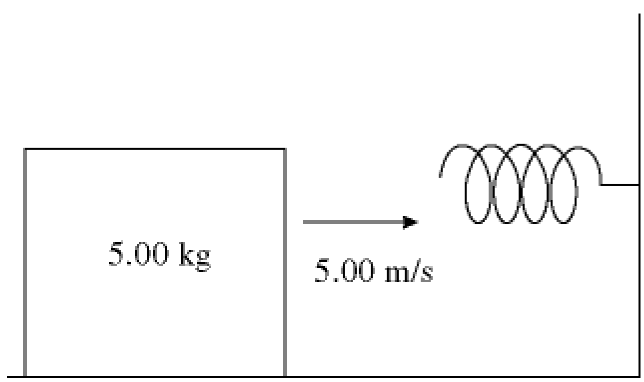
12) In the figure, a very small toy race car of mass m is released from rest on the loop–the–loop track. If it is released at a height $2R$ above the floor, how high is it above the floor when it leaves the track, neglecting friction?



A) 1.67 R
B) 2.00 R
C) 1.50 R
D) 1.33 R
E) 1.25 R

Answer: A

13) In the figure, a 5.00–kg block is moving at 5.00 m/s along a horizontal frictionless surface toward an ideal massless spring that is attached to a wall. After the block collides with the spring, the spring is compressed a maximum distance of 0.68 m. What is the speed of the block when it has moved so that the spring is compressed to only one–half of the maximum distance?



Answer: 4.3 m/s

14) A 60.0-kg person drops from rest a distance of 1.20 m to a platform of negligible mass supported by an ideal stiff spring of negligible mass. The platform drops 6.00 cm before the person comes to rest. What is the spring constant of the spring?
A) 2.56×10^5 N/m
B) 3.92×10^5 N/m
C) 5.45×10^4 N/m
D) 4.12×10^5 N/m
E) 8.83×10^4 N/m
Answer: D

15) A spring-loaded dart gun is used to shoot a dart straight up into the air, and the dart reaches a maximum height of 24 meters above its point of release. The same dart is shot up a second time from the same gun, but this time the spring is compressed only half as far (compared to the first shot). How far up does the dart go this time? (Neglect friction and assume the spring is ideal and massless.)
A) 6.0 m
B) 12 m
C) 3.0 m
D) 48 m
Answer: A

16) A block slides down a frictionless inclined ramp. If the ramp angle is 17.0° and its length is 30.0 m, find the speed of the block as it reaches the bottom of the ramp, assuming it started sliding from rest at the top.
A) 13.1 m/s
B) 172 m/s
C) 9.26 m/s
D) 24.0 m/s
Answer: A

17) Consider the motion of a 1.00-kg particle that moves with potential energy given by $U(x) = (-2.00\ \text{J}\cdot\text{m})/x + (4.00\ \text{J}\cdot\text{m}^2)/x^2$. Suppose the particle is moving with a speed of 3.00 m/s when it is located at $x = 1.00$ m. What is the speed of the object when it is located at $x = 5.00$ m?
A) 2.13 m/s
B) 3.00 m/s
C) 4.68 m/s
D) 3.67 m/s
Answer: D

18) A car on a roller coaster starts at zero speed at an elevation above the ground of 26 m. It coasts down a slope, and then climbs a hill. The top of the hill is at an elevation of 16 m. What is the speed of the car at the top of the hill? Neglect any frictional effects.
A) 14 m/s
B) 18 m/s
C) 10 m/s
D) 9.0 m/s
E) 6.0 m/s
Answer: A

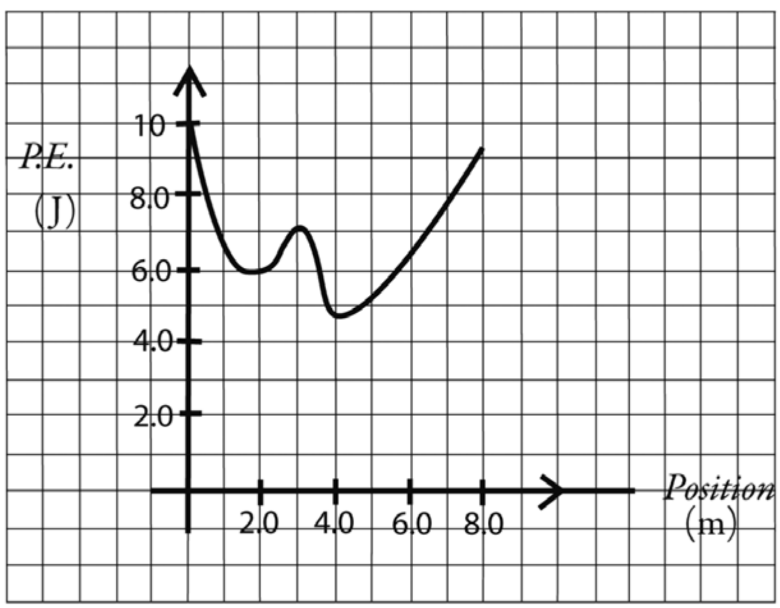
19) A projectile is fired from ground level at an angle of 40.0° above horizontal at a speed of 30.0 m/s. What is the speed of the projectile when it has reached a height equal to 50.0% of its maximum height?
   A) 26.0 m/s
   B) 27.4 m/s
   C) 28.7 m/s
   D) 26.7 m/s
   E) 28.1 m/s

Answer: D

20) A very small 100-g object is attached to one end of a massless 10-cm rod that is pivoted without friction about the opposite end. The rod is held vertical, with the object at the top, and released, allowing the rod to swing. What is the speed of the object at the instant that the rod is horizontal?
   A) 0.71 m/s
   B) 4.0 m/s
   C) 1.4 m/s
   D) 2.8 m/s
   E) 2.8 m/s

Answer: D

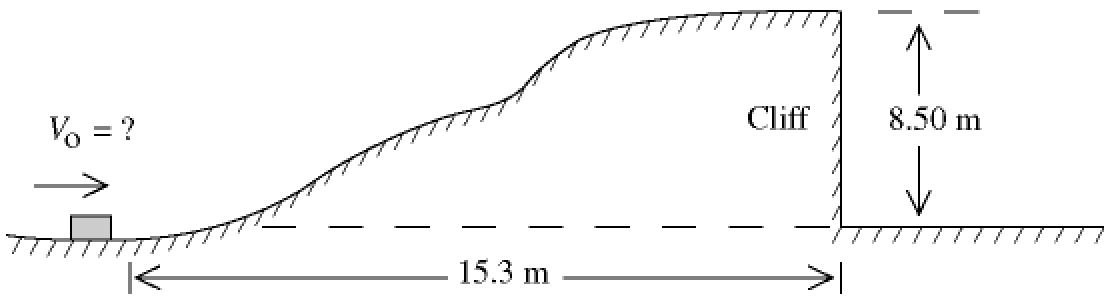
21) A 2.0-kg object is moving without friction along the x-axis. The potential energy curve as a function of position is shown in the figure, and the system is conservative. If the speed of the object at the origin is 4.0 m/s, what will be its speed at 7.0 m along the $+x$-axis?



   A) 4.0 m/s
   B) 4.2 m/s
   C) 4.4 m/s
   D) 4.6 m/s
   E) 9.8 m/s

Answer: B

22) A small hockey puck slides without friction over the icy hill shown in the figure and lands 6.20 m from the foot of the cliff with no air resistance. What was its speed v_0 at the bottom of the hill?



A) 20.8 m/s
B) 17.4 m/s
C) 14.4 m/s
D) 13.7 m/s
E) 4.71 m/s

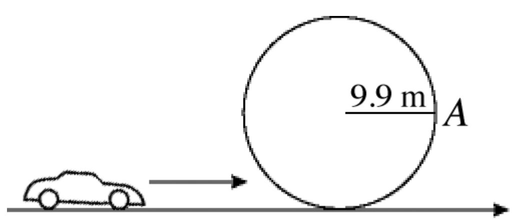
Answer: D

23) An object is attached to a hanging unstretched ideal and massless spring and slowly lowered to its equilibrium position, a distance of 6.4 cm below the starting point. If instead of having been lowered slowly the object was dropped from rest, how far then would it then stretch the spring at maximum elongation?

A) 13 cm
B) 9.1 cm
C) 6.4 cm
D) 18 cm
E) 26 cm

Answer: A

24) In the figure, a stunt car driver negotiates the frictionless track shown in such a way that the car is barely in contact with the track at the top of the loop. The radius of the track is 9.9 m and the mass of the car is 1800 kg. Find the magnitude of the force of the car on the track when the car is at point *A*. You can treat the car as a point mass.



Answer: 53,000 N

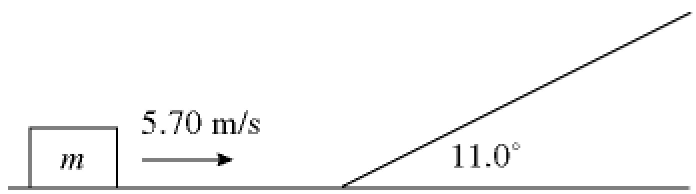
25) A 50.0–kg skier starting from rest travels 200 m down a hill that has a 20.0° slope and a uniform surface. When the skier reaches the bottom of the hill, her speed is 30.0 m/s.
(a) How much work is done by friction as the skier comes down the hill?
(b) What is the magnitude of the friction force if the skier travels directly down the hill?

Answer: (a) -1.10×10^4 J (b) 55.3 N

26) A 5.00–kg object moves clockwise around a 50.0 cm radius circular path. At one location, the speed of the object is 4.00 m/s. When the object next returns to this same location, the speed is 3.00 m/s.
(a) How much work was done by nonconservative (dissipative) forces as the object moved once around the circle?
(b) If the magnitude of the above nonconservative (dissipative) forces acting on the object is constant, what is the value of this magnitude?

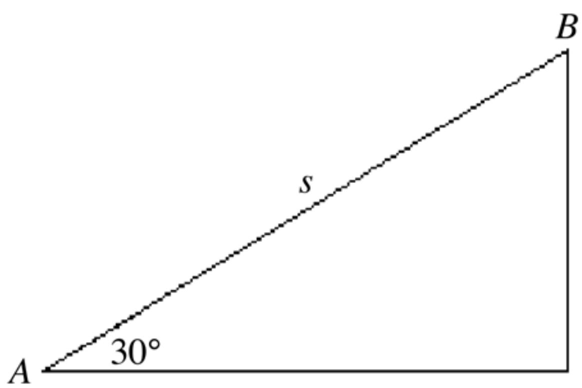
Answer: (a) —17.5 J (b) 5.57 N

27) In the figure, a block of mass *m* is moving along the horizontal frictionless surface with a speed of 5.70 m/s. If the slope is 11.0° and the coefficient of kinetic friction between the block and the incline is 0.260, how far does the block travel up the incline?



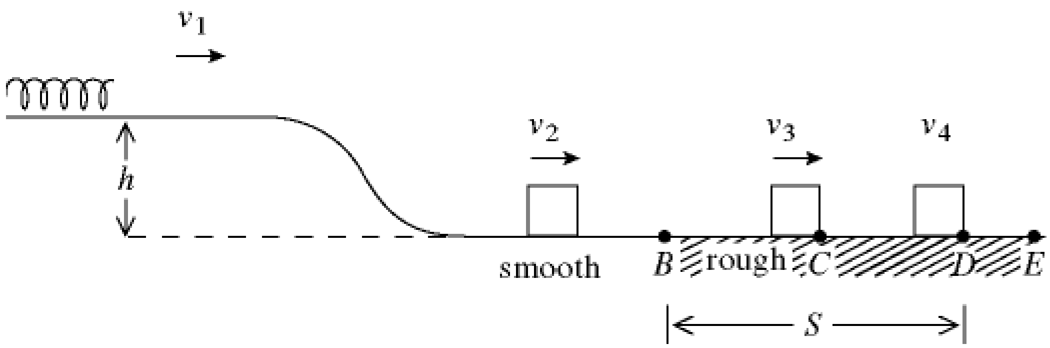
Answer: 3.72 m

28) An object of mass 4.0 kg starts at rest from the top of a rough inclined plane of height 10 m as shown in the figure. If the speed of the object at the bottom of the inclined plane is 10 m/s, how much work does friction do on this object as it slides down the incline?



Answer: –190 J

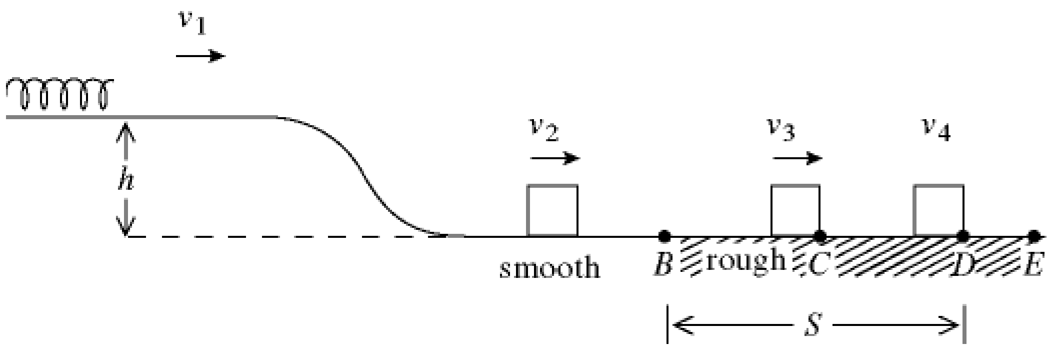
29) An 0.80–kg block is held in place against the spring by a 67–N horizontal external force (see the figure). The external force is removed, and the block is projected with a velocity v_1 = 1.2 m/s upon separation from the spring. The block descends a ramp and has a velocity v_2 = 1.9 m/s at the bottom. The track is frictionless between points *A* and *B*. The block enters a rough section at *B*, extending to *E*. The coefficient of kinetic friction over this section is 0.39. The velocity of the block is v_3 = 1.4 m/s at *C*. The block moves on to *D*, where it stops. The spring constant of the spring is closest to



A) 3900 N/m.
B) 2600 N/m.
C) 2000 N/m.
D) 1600 N/m.
E) 1100 N/m.

Answer: A

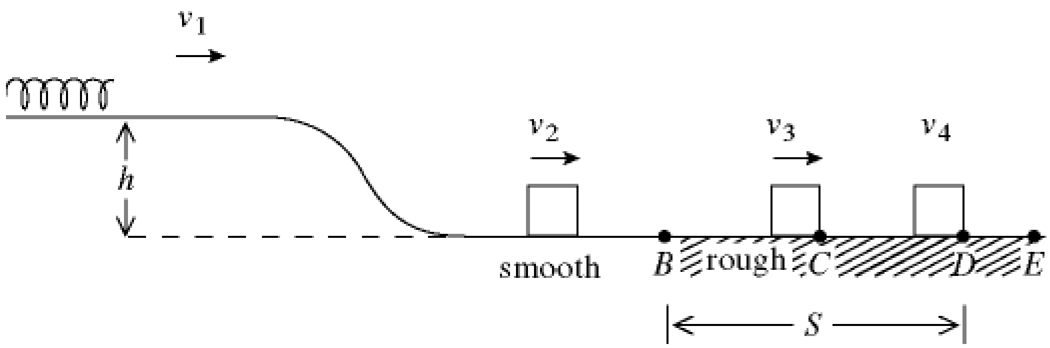
30) A 1.37–kg block is held in place against the spring by a 74–N horizontal external force (see the figure). The external force is removed, and the block is projected with a velocity v_1 = 1.2 m/s upon separation from the spring. The block descends a ramp and has a velocity v_2 = 1.4 m/s at the bottom. The track is frictionless between points A and B. The block enters a rough section at B, extending to E. The coefficient of kinetic friction over this section is 0.24. The velocity of the block is v_3 = 1.4 m/s at C. The block moves on to D, where it stops. The initial compression of the spring is closest to:



A) 2.7 cm.
B) 1.4 cm.
C) 0.96 cm.
D) 5.3 cm.
E) 3.6 cm.

Answer: A

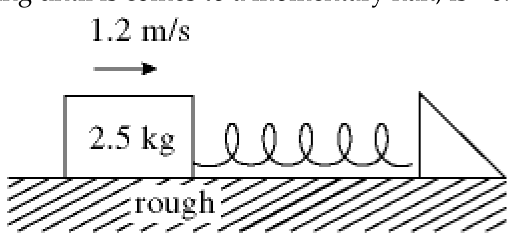
31) A 1.86–kg block is held in place against the spring by a 81–N horizontal external force (see the figure). The external force is removed, and the block is projected with a velocity v_1 = 1.2 m/s upon separation from the spring. The block descends a ramp and has a velocity v_2 = 1.9 m/s at the bottom. The track is frictionless between points A and B. The block enters a rough section at B, extending to E. The coefficient of kinetic friction over this section is 0.28. The velocity of the block is v_3 = 1.4 m/s at C. The block moves on to D, where it stops. The height h of the ramp is closest to



A) 11
B) 7.3
C) 15
D) 17
E) 18

Answer: A

32) A 2.5–kg box, sliding on a rough horizontal surface, has a speed of 1.2 m/s when it makes contact with a spring (see the figure). The block comes to a momentary halt when the compression of the spring is 5.0 cm. The work done by the friction, from the instant the block makes contact with the spring until is comes to a momentary halt, is –0.50 J.



(a) What is the spring constant of the spring?
(b) What is the coefficient of kinetic friction between the box and the rough surface?

Answer: (a) 1040 N/m (b) 0.41

Chapter 8 Gravity

8.1 Conceptual Questions

1) A baseball is located at the surface of the earth. Which statements about it are correct? (There may be more than one correct choice.)
   A) The earth exerts a much greater gravitational force on the ball than the ball exerts on the earth.
   B) The ball exerts a greater gravitational force on the earth than the earth exerts on the ball.
   C) The gravitational force on the ball due to the earth is exactly the same as the gravitational force on the earth due to the ball.
   D) The gravitational force on the ball is independent of the mass of the ball.
   E) The gravitational force on the ball is independent of the mass of the earth.

   Answer: C

2) A very small round ball is located near a large solid sphere of uniform density. The force that the large sphere exerts on the ball
   A) is exactly the same as it would be if all the mass of the sphere were concentrated at the center of the sphere.
   B) is approximately the same as it would be if all the mass of the sphere were concentrated at the center of the sphere.
   C) is independent of the mass of the ball.
   D) is independent of the mass of the sphere.
   E) can only be calculated using calculus.

   Answer: A

3) Planet Z-34 has a mass equal to 1/3 that of Earth, a radius equal to 1/3 that of Earth, and an axial spin rate 1/2 that of Earth. With g representing, as usual, the acceleration due to gravity on the surface of Earth, the acceleration due to gravity on the surface of Z-34 is
   A) $g/3$.
   B) $3g$.
   C) $6g$.
   D) $g/9$.
   E) $9g$.

   Answer: B

4) If the mass of the earth and all objects on it were suddenly doubled, but the size remained the same, the acceleration due to gravity at the surface would become
   A) 4 times what it now is.
   B) 2 times what it now is.
   C) the same as it now is.
   D) 1/2 of what it now is.
   E) 1/4 of what it now is.

   Answer: B

5) Two planets having equal masses are in circular orbit around a star. Planet *A* has a smaller orbital radius than planet *B*. Which statement is true?
   A) Planet *A* has more kinetic energy, less potential energy, and less mechanical energy (potential plus kinetic) than planet *B*.
   B) Planet *A* has more kinetic energy, more potential energy, and more mechanical energy (potential plus kinetic) than planet *B*.
   C) Planet *A* has more kinetic energy, less potential energy, and more mechanical energy (potential plus kinetic) than planet *B*.
   D) Planet *A* and planet *B* have the same amount of mechanical energy (potential plus kinetic).

   Answer: A

6) A certain planet has an escape speed *V*. If another planet of the same size has twice the mass as the first planet, its escape speed will be
   A) $2V$.
   B) $\sqrt{2}V$.
   C) V.
   D) $V/2$.
   E) $V/\sqrt{2}$.

   Answer: B

7) A certain planet has an escape speed *V*. If another planet has twice size and twice the mass of the first planet, its escape speed will be
   A) $2V$.
   B) $\sqrt{2}V$.
   C) V.
   D) $V/2$.
   E) $V/\sqrt{2}$.

   Answer: C

8) A satellite is orbiting the earth. If a payload of material is added until it doubles the satellite's mass, the earth's pull of gravity on this satellite will double but the satellite's orbit will not be affected.
   A) True
   B) False

   Answer: A

9) A satellite in a circular orbit of radius *R* around planet *X* has an orbital period *T*. If Planet *X* had one-fourth as much mass, the orbital period of this satellite in an orbit of the same radius would be
   A) $4T$.
   B) $2T$.
   C) $T\sqrt{2}$
   D) $T/2$.
   E) $T/4$.

   Answer: B

10) A satellite of mass m has an orbital period T when it is in a circular orbit of radius R around the earth. If the satellite instead had mass $4m$, its orbital period would be
A) $4T$.
B) $2T$.
C) T.
D) $T/2$.
E) $T/4$.
Answer: C

11) The reason an astronaut in an earth satellite feels weightless is that
A) the astronaut is beyond the range of the earth's gravity.
B) the astronaut is falling.
C) the astronaut is at a point in space where the effects of the moon's gravity and the earth's gravity cancel.
D) this is a psychological effect associated with rapid motion.
E) the astronaut's acceleration is zero.
Answer: B

8.2 Problems

1) A small-sized 155-kg mass is located 1.50 m from a small-sized 275-kg mass, with both masses fixed in place. Where should you place a third small-sized mass so that the net gravitational force on it due to the original two masses is zero?
Answer: 0.643 m from the 155-kg mass along the line connecting the two given masses

2) An astronaut is in equilibrium when he is positioned 140 km from the center of asteroid X and 581 km from the center of asteroid Y, along the straight line joining the centers of the asteroids. What is the ratio of the masses X/Y of the asteroids?
A) 0.0581
B) 17.2
C) 0.241
D) 4.15
Answer: A

3) Three identical very small 50-kg masses are held at the corners of an equilateral triangle, 0.30 m on each side. If one of the masses is released, what is its initial acceleration if the only forces acting on it are the gravitational forces due to the other two masses? ($G = 6.67 \times 10^{-11}$ N · m^2/kg^2)
A) 3.7×10^{-8} m/s^2
B) 2.5×10^{-8} m/s^2
C) 1.9×10^{-8} m/s^2
D) 4.2×10^{-8} m/s^2
E) 6.4×10^{-8} m/s^2
Answer: E

4) A small planet having a radius of 1000 km exerts a gravitational force of 100 N on an object that is 500 km above its surface. If this object is moved 500 km farther from the planet, the gravitational force on it will be closest to
A) 75 N.
B) 71 N.
C) 56 N.
D) 50 N.
E) 25 N.
Answer: C

5) The gravitational acceleration on a planet's surface is 16.0 m/s^2. What is the gravitational acceleration at an altitude of one planet diameter above the SURFACE of the planet?
A) 5.33 m/s^2
B) 1.78 m/s^2
C) 1.60 m/s^2
D) 4.00 m/s^2
E) 8.00 m/s^2
Answer: B

6) The radius of the earth is R. At what distance above the earth's surface will the acceleration of gravity be 4.9 m/s^2?
A) $0.41R$
B) $0.50R$
C) $1.0R$
D) $1.4R$
E) $2.0R$
Answer: A

7) By how many newtons does the weight of a 100-kg person change when he goes from sea level to an altitude of 5.0 km if we neglect the earth's rotational effects? (The mean radius of the Earth is 6.38×10^6 m, $G = 6.67 \times 10^{-11}$ N • m^2/kg^2.)
A) -0.60 N
B) -1.5 N
C) -2.6 N
D) -3.6 N
E) -5.2 N
Answer: B

8) The weight of spaceman Speff at the surface of planet X, solely due to its gravitational pull, is 389 N. If he moves to a distance of 1.86×10^4 km above the planet's surface, his weight changes to 24.31 N. What is the mass of planet X, if Speff's mass is 75.0 kg? ($G = 6.67 \times 10^{-11}$ N • m^2/kg^2)
A) 2.99×10^{24} kg
B) 2.99×10^{18} kg
C) 2.99×10^{17} kg
D) 1.59×10^{18} kg
Answer: A

9) From what height above the surface of the earth should an object be dropped to initially experience an acceleration of $0.9200g$? The radius of the earth is 6.38×10^6 m.
   A) 272 km
   B) 260 km
   C) 554 km
   D) 510 km

Answer: A

10) An object drops a distance h in a time of 6.3 s on the surface of the earth (neglecting air effects). How long would it take the same object to drop the same distance on the surface of spherical asteroid X having a mass of 1.1×10^{22} kg and a radius of 4.0×10^5 m? ($G = 6.67 \times 10^{-11}$ N • m^2/kg^2, $M_{\text{earth}} = 5.97 \times 10^{24}$ kg, $R_{\text{earth}} = 6.38 \times 10^6$ m)
   A) 9.2 s
   B) 6.3 s
   C) 5.2 s
   D) 12 s
   E) 3.3 s

Answer: A

11) Ekapluto is an unknown planet that has two spherical moons in circular orbits. The table summarizes the hypothetical data about the moons. Both moons have low axial spin rates. ($G = 6.67 \times 10^{-11}$ N • m^2/kg^2)

	Mass	*Radius*	*Orbital radius*	*Orbital period*
Moon A	4.0×10^{20} kg		2.0×10^8 m	4.0×10^6 s
Moon B	1.5×10^{20} kg	2.0×10^5 m	3.0×10^8 m	

The acceleration due to gravity at the surface of Moon B is
   A) 0.10 m/s^2.
   B) 0.15 m/s^2.
   C) 0.20 m/s^2.
   D) 0.25 m/s^2.
   E) 0.30 m/s^2.

Answer: D

12) *Sputnik I* was launched into orbit around Earth in 1957. It had a perigee (the closest approach to Earth, measured from Earth's center) of 6.81×10^6 m and an apogee (the furthest point from Earth's center) of 7.53×10^6 m. What was its speed when it was at its perigee? The mass of Earth is 5.97×10^{24} kg and $G = 6.67 \times 10^{-11}$ N • m^2/kg^2.
   A) 7180 m/s
   B) 7840 m/s
   C) 8230 m/s
   D) 11,000 m/s
   E) 13,400 m/s

Answer: B

13) Beings on spherical asteroid Π have observed that a large rock is approaching their asteroid in a collision course. At 7514 km from the center of the asteroid, the rock has a speed of 136.0 m/s and later at 2823 km it has a speed of 392.0 m/s. Use energy conservation to find the mass of asteroid Π. You can neglect any effects due to the parent star of the asteroid. ($G = 6.67 \times 10^{-11}$ $\text{N} \cdot \text{m}^2/\text{kg}^2$)

A) 4.582×10^{21} kg
B) 9.164×10^{27} kg
C) 6.112×10^{28} kg
D) 4.582×10^{20} kg

Answer: A

14) What is the ratio of the escape speed of a rocket launched from sea level to the escape speed of one launched from Mt. Everest (an altitude of 8.85 km)? The radius of the earth is 6.38×10^6 m.

A) 1.0007
B) 1.0014
C) 1.0001
D) 0.9986
E) 0.9993

Answer: A

15) A huge cannon is assembled on an airless planet having insignificant axial spin. The planet has a radius of 5.00×10^6 m and a mass of 3.95×10^{23} kg. The cannon fires a projectile straight up at 2000 m/s. An observation satellite orbits the planet at a height of 1000 km. What is the projectile's speed as it passes the satellite? ($G = 6.67 \times 10^{-11}$ $\text{N} \cdot \text{m}^2/\text{kg}^2$)

A) 1500 m/s
B) 1380 m/s
C) 1610 m/s
D) 1280 m/s

Answer: A

16) A meteoroid, heading straight for Earth, has a speed of 14.8 km/s relative to the center of Earth as it crosses our moon's orbit, a distance of 3.84×10^8 m from the earth's center. What is the meteroid's speed as it hits the earth? You can neglect the effects of the moon, Earth's atmosphere, and any motion of the earth. ($G = 6.67 \times 10^{-11}$ $\text{N} \cdot \text{m}^2/\text{kg}^2$, $M_{\text{earth}} = 5.97 \times 10^{24}$ kg)

A) 18.5 km/s
B) 21.5 km/s
C) 32.4 km/s
D) 87.3 km/s

Answer: A

17) A certain spherical asteroid has a mass of 3.5×10^{16} kg and a radius of 8.8 km. What is the minimum speed needed to escape from the surface of this asteroid? ($G = 6.67 \times 10^{-11}$ N • m^2/kg^2)
A) 23 m/s
B) 16 m/s
C) 520 m/s
D) 730 m/s
Answer: A

18) A 910-kg object is released from rest at an altitude of 1200 km above the north pole of the earth. If we ignore atmospheric friction, with what speed does the object strike the surface of the earth? ($G = 6.67 \times 10^{-11}$ N • m^2/kg^2, $M_{\text{earth}} = 5.97 \times 10^{24}$ kg, the polar radius of the earth is 6357 km)
A) 4.5 km/s
B) 2.2 km/s
C) 2.7 km/s
D) 3.2 km/s
E) 4.8 km/s
Answer: A

19) A satellite is in circular orbit at an altitude of 1500 km above the surface of a nonrotating planet with an orbital speed of 9.2 km/s. The minimum speed needed to escape from the surface of the planet is 14.9 km/s, and $G = 6.67 \times 10^{-11}$ N • m^2/kg^2. The orbital period of the satellite is closest to
A) 72 min.
B) 65 min.
C) 58 min.
D) 51 min.
E) 44 min.
Answer: A

20) A satellite is in circular orbit at an altitude of 2300 km above the surface of a nonrotating asteroid with an orbital speed of 5.9 km/s. The minimum speed needed to escape from the surface of the asteroid is 14.6 km/s, and $G = 6.67 \times 10^{-11}$ N • m^2/kg^2. The mass of the asteroid is closest to
A) 1.8×10^{24} kg.
B) 8.9×10^{23} kg.
C) 1.3×10^{24} kg.
D) 2.7×10^{24} kg.
E) 3.6×10^{24} kg.
Answer: A

21) An astronaut is standing on the surface of a planetary satellite that has a radius of 1.74×10^6 m and a mass of 7.35×10^{22} kg. An experiment is planned where a projectile needs to be launched straight up from the surface. What must be the minimum initial speed of the projectile so it will reach a height of 2.55×10^6 m above this satellite's surface? ($G = 6.67 \times 10^{-11}$ N • m^2/kg^2)

Answer: 1.83 km/s

22) The International Space Station is orbiting at an altitude of about 370 km above the earth's surface. The mass of the earth is 5.97×10^{24} kg, the radius of the earth is 6.38×10^6 m, and $G = 6.67 \times 10^{-11}$ N • m^2/kg^2. Assuming a circular orbit,
(a) what is the period of the International Space Station's orbit?
(b) what is the speed of the International Space Station in its orbit?

Answer: (a) 5.52×10^3 s (b) 7.69×10^3 m/s

23) A satellite that weighs 4900 N on the launchpad travels around the earth's equator in a circular orbit with a period of 1.667 h. The earth's mass is 5.97×10^{24} kg, its equatorial radius is 6.3×10^6 m, and $G = 6.67 \times 10^{-11}$ N • m^2/kg^2.
(a) Calculate the magnitude of the earth's gravitational force on the satellite.
(b) Determine the altitude of the satellite above the Earth's SURFACE.

Answer: (a) 3910 N (b) 7.55×10^5 m

24) What is the period (in hours) of a satellite circling Mars 100 km above the planet's surface? The mass of Mars is 6.42×10^{23} kg, its radius is 3.40×10^6 m, and $G = 6.67 \times 10^{-11}$ N • m^2/kg^2.
A) 1.75 h
B) 1.25 h
C) 1.15 h
D) 1.00 h
E) 1.45 h

Answer: A

25) Jupiter completes one revolution about its own axis every 9.92 hours. What is the radius of the orbit required for a satellite to revolve about Jupiter with the same period? Jupiter has a mass of 1.90×10^{27} kg and $G = 6.67 \times 10^{-11}$ N • m^2/kg^2.
A) 1.04×10^7 m
B) 2.26×10^9 m
C) 1.60×10^8 m
D) 3.41×10^8 m
E) 7.45×10^8 m

Answer: C

26) The moons of Mars, Phobos (Fear) and Deimos (Terror), are very close to the planet compared to Earth's Moon. Their orbital radii are 9,378 km and 23,459 km respectively. What is the ratio of the orbital speed of Phobos to that of Deimos?
A) 0.2528
B) 0.3998
C) 1.582
D) 2.858
E) 3.956
Answer: C

27) Spaceman Speff orbits spherical asteroid *X* with his spaceship. To remain in a circular orbit at 421 km from the asteroid's center, he should maintain a speed of 80 m/s. What is the mass of planet *X*? ($G = 6.67 \times 10^{-11}$ N • m^2/kg^2)
A) 4.0×10^{19} kg
B) 5.1×10^{17} kg
C) 4.0×10^{16} kg
D) 5.1×10^{14} kg
Answer: A

28) Find the orbital speed of an ice cube in the rings of Saturn. The mass of Saturn is 5.68×10^{26} kg and the rings have an average radius of 100,000 km. ($G = 6.67 \times 10^{-11}$ N • m^2/kg^2)
A) 19.5 km/s
B) 27.5 km/s
C) 13.8 km/s
D) 1.95 km/s
Answer: A

29) You are the science officer on a visit to a distant solar system. Prior to landing on a planet you measure its diameter to be 1.8×10^7 m and its rotation period to be 22.3 hours. You have previously determined that the planet orbits 1.8×10^{11} m from its star with a period of 402 earth days. Once on the surface you find that the acceleration due to gravity is 59.7 m/s^2. What are the mass of (a) the planet and (b) the star? ($G = 6.67 \times 10^{-11}$ N • m^2/kg^2.)
A) (a) 7.2 kg $\times 10^{25}$ kg, (b) 2.9 kg $\times 10^{30}$ kg
B) (a) 1.3 kg $\times 10^{26}$ kg, (b) 2.9 kg $\times 10^{30}$ kg
C) (a) 7.2 kg $\times 10^{25}$ kg, (b) 1.7 kg $\times 10^{30}$ kg
D) (a) 1.3 kg $\times 10^{26}$ kg, (b) 1.7 kg $\times 10^{30}$ kg
Answer: A

30) Suppose we want a satellite to revolve around the earth 5 times a day. What should be the radius of its orbit? (The mass of the earth is 5.97×10^{24} kg, $G = 6.67 \times 10^{-11}$ N • m^2/kg^2, and you can neglect the presence of the moon.)
A) 1.44×10^7 m
B) 0.690×10^7 m
C) 7.22×10^7 m
D) 2.11×10^7 m
Answer: A

31) Ekapluto is an unknown planet that has two moons in circular orbits. The table summarizes the hypothetical data about the moons. ($G = 6.67 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$)

	Mass	*Radius*	*Orbital radius*	*Orbital peric*
Moon A	4.0×10^{20} kg		2.0×10^{8} m	4.0×10^{6} s
Moon B	1.5×10^{20} kg	2.0×10^{5} m	3.0×10^{8} m	

The mass of Ekapluto is closest to

A) 1.0×10^{22} kg.
B) 3.0×10^{22} kg.
C) 1.0×10^{23} kg.
D) 3.0×10^{23} kg.
E) 1.0×10^{24} kg.

Answer: D

32) A man–made satellite of mass 6105 kg is in orbit around the earth, making one revolution in 430 minutes. What is the magnitude of the gravitational force exerted on the satellite by the earth? (The mass of the earth is 6.0×10^{24} kg and $G = 6.67 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$)

Answer: 2.5×10^{3} N

Chapter 9 Systems of Particles

9.1 Conceptual Questions

1) Consider two less-than-desirable options. In the first you are driving 30 mph and crash head-on into an identical car also going 30 mph. In the second option you are driving 30 mph and crash head-on into a stationary brick wall. In neither case does your car bounce off the thing it hits, and the collision time is the same in both cases. Which of these two situations would result in the greatest impact force?
   A) hitting the other car
   B) hitting the brick wall
   C) The force would be the same in both cases.
   D) We cannot answer this question without more information.
   E) None of these is true.

   Answer: C

2) As a tile falls from the roof of a building to the ground its momentum is conserved.
   A) True
   B) False

   Answer: B

3) You are standing on a skateboard, initially at rest. A friend throws a very heavy ball towards you. You can either catch the object or deflect the object back towards your friend (such that it moves away from you with the same speed as it was originally thrown). What should you do in order to MINIMIZE your speed on the skateboard?
   A) Catch the ball.
   B) Deflect the ball.
   C) Your final speed on the skateboard will be the same regardless whether you catch the ball or deflect the ball.

   Answer: A

4) On a smooth horizontal floor, an object slides into a spring which is attached to another mass that is initially stationary. When the spring is most compressed, both objects are moving at the same speed. Ignoring friction, what is conserved during this interaction?
   A) momentum and mechanical energy
   B) momentum only
   C) kinetic energy only
   D) momentum and kinetic energy
   E) momentum and potential energy

   Answer: A

5) A baseball is thrown vertically upward and feels no air resistance. As it is rising
   A) both its momentum and its mechanical energy are conserved.
   B) its momentum is not conserved, but its mechanical energy is conserved.
   C) both its momentum and its kinetic energy are conserved.
   D) its kinetic energy is conserved, but its momentum is not conserved.
   E) its gravitational potential energy is not conserved, buts its momentum is conserved.

   Answer: B

6) A small glider is coasting horizontally when suddenly a very heavy piece of cargo falls out of the bottom of the plane. You can neglect air resistance. Just after the cargo has fallen out
   A) the plane speeds up and the cargo slows down.
   B) the plane speeds up but the cargo does not change speed.
   C) neither the cargo nor the plane change speed.
   D) the cargo slows down but the plane does not change speed.
   E) both the cargo and the plane speed up.

Answer: C

7) A small car has a head-on collision with a large truck. Which of the following statements concerning the magnitude of the average force due to the collision is correct?
   A) The truck experiences the greater average force.
   B) The small car experiences the greater average force.
   C) The small car and the truck experience the same average force.
   D) It is impossible to tell since the masses are not given.
   E) It is impossible to tell since the velocities are not given.

Answer: C

8) In a collision between two objects having unequal masses, how does magnitude of the impulse imparted to the lighter object by the heavier one compare with the magnitude of the impulse imparted to the heavier object by the lighter one?
   A) The lighter object receives a larger impulse.
   B) The heavier object receives a larger impulse.
   C) Both objects receive the same impulse.
   D) The answer depends on the ratio of the masses.
   E) The answer depends on the ratio of the speeds.

Answer: C

9) In a perfectly ELASTIC collision between two perfectly rigid objects
   A) the momentum of each object is conserved.
   B) the kinetic energy of each object is conserved.
   C) the momentum of the system is conserved but the kinetic energy of the system is not conserved.
   D) both the momentum and the kinetic energy of the system are conserved.
   E) the kinetic energy of the system is conserved, but the momentum of the system is not conserved.

Answer: D

10) In an INELASTIC collision between two objects
   A) the momentum of each object is conserved.
   B) the kinetic energy of each object is conserved.
   C) the momentum of the system is conserved but the kinetic energy of the system is not conserved.
   D) both the momentum and the kinetic energy of the system are conserved.
   E) the kinetic energy of the system is conserved, but the momentum of the system is not conserved.

Answer: C

11) A shell explodes into two fragments, one fragment 25 times heavier than the other. If any gas from the explosion has negligible mass, then
   A) the momentum change of the lighter fragment is 25 times as great as the momentum change of the heavier fragment.
   B) the momentum change of the heavier fragment is 25 times as great as the momentum change of the lighter fragment.
   C) the momentum change of the lighter fragment is exactly the same as the momentum change of the heavier fragment.
   D) the kinetic energy change of the heavier fragment is 25 times as great as the kinetic energy change of the lighter fragment.
   E) the kinetic energy change of the lighter fragment is 25 times as great as the kinetic energy change of the heavier fragment.

Answer: C

12) Jacques and George meet in the middle of a lake while paddling in their canoes. They come to a complete stop and talk for a while. When they are ready to leave, Jacques pushes George's canoe with a force $\vec{F}$ to separate the two canoes. What is correct to say about the final momentum and kinetic energy of the system if we can neglect any resistance due to the water?
   A) The final momentum is in the direction of $\vec{F}$ but the final kinetic energy is zero.
   B) The final momentum is in the direction opposite of $\vec{F}$ but the final kinetic energy is zero.
   C) The final momentum is in the direction of $\vec{F}$ and the final kinetic energy is positive.
   D) The final momentum is zero and the final kinetic energy is zero.
   E) The final momentum is zero but the final kinetic energy is positive.

Answer: B

13) A 1.0-kg block and a 2.0-kg block are pressed together on a horizontal frictionless surface with a compressed very light spring between them. They are not attached to the spring. After they are released and have both moved free of the spring
   A) the lighter block will have more kinetic energy than the heavier block.
   B) the heavier block will have more kinetic energy than the lighter block.
   C) both blocks will both have the same amount of kinetic energy.
   D) both blocks will have equal speeds.
   E) the magnitude of the momentum of the heavier block will be greater than the magnitude of the momentum of the lighter block.

Answer: A

14) There must be equal amounts of mass on both side of the center of mass of an object.
   A) True
   B) False

Answer: B

9.2 Problems

1) A time–varying horizontal force $F(t) = At^4 + Bt^2$ acts for 0.500 s on a 12.25–kg object, starting at time $t = 1.00$ s. In the SI system, A has the numerical value 4.50 and B has the numerical value 8.75.
(a) What are the SI units of A and B?
(b) What impulse does this force impart to the object?

Answer: (a) A: N/s^4 = kg • m/s^6 , B: N/s^2 = kg • m/s^4 (b) 12.9 N • s, horizontally

2) A 2.50–kg stone is dropped from rest at a height of 3.75 m. What impulse does gravity impart to this stone from the instant it is dropped until it hits the ground, assuming negligible air resistance?

Answer: 21.4 N • s

3) A firecracker breaks up into several pieces, one of which has a mass of 200 g and flies off along the x–axis with a speed of 82.0 m/s. A second piece has a mass of 300 g and flies off along the y–axis with a speed of 45.0 m/s. What are the magnitude and direction of the total momentum of these two pieces?
A) 361 kg•m/s at 56.3° from the x–axis
B) 93.5 kg•m/s at 28.8° from the x–axis
C) 21.2 kg•m/s at 39.5° from the x–axis
D) 361 kg•m/s at 0.983° from the x–axis
E) 21.2 kg•m/s at 56.3° from the x–axis

Answer: C

4) A stationary 1.67–kg object is struck by a stick. The object experiences a horizontal force given by $F = at - bt^2$, where t is the time in milliseconds from the instant the stick first contacts the object. If a = 1500 N/(ms) and b = 20 N/(ms)^2, what is the speed of the object just after it comes away from the stick at t = 2.74 ms?
A) 3.3 m/s
B) 22 m/s
C) 3.7 m/s
D) 25 m/s

Answer: A

5) During a collision with a wall, the velocity of a 0.200–kg ball changes from 20.0 m/s toward the wall to 12.0 m/s away from the wall. If the time the ball was in contact with the wall was 60.0 ms, what was the magnitude of the average force applied to the ball?
A) 40.0 N
B) 107 N
C) 16.7 N
D) 26.7 N
E) 13.3 N

Answer: B

6) A 0.500–kg ball traveling horizontally on a frictionless surface approaches a very massive stone at 20.0 m/s perpendicular to wall and rebounds with 70.0% of its initial kinetic energy. What is the magnitude of the change in momentum of the stone?
   A) 18.4 kg•m/s
   B) 14.0 kg•m/s
   C) 3.00 kg•m/s
   D) 1.63 kg•m/s
   E) 0.000 kg•m/s

   Answer: A

7) A 620–g object traveling at 2.1 m/s collides head–on with a 320–g object traveling in the opposite direction at 3.8 m/s. If the collision is perfectly elastic, what is the change in the kinetic energy of the 620–g object?
   A) It loses 0.23 J.
   B) It gains 0.69 J.
   C) It loses 0.47 J.
   D) It loses 1.4 J.
   E) It doesn’t lose any kinetic energy because the collision is elastic.

   Answer: A

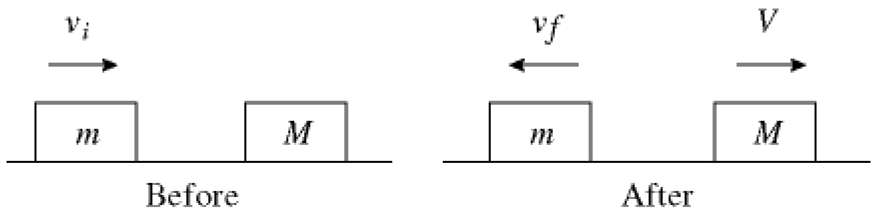
8) A 2.3–kg object traveling at 6.1 m/s collides head–on with a 3.5–kg object traveling in the opposite direction at 4.8 m/s. If the collision is perfectly elastic, what is the final speed of the 2.3–kg object?
   A) 0.48 m/s
   B) 7.1 m/s
   C) 3.8 m/s
   D) 4.3 m/s
   E) 6.6 m/s

   Answer: B

9) A car of mass 1689 kg collides head–on with a parked truck of mass 2000 kg. Spring mounted bumpers ensure that the collision is essentially elastic. If the velocity of the truck is 17 km/h (in the same direction as the car's initial velocity) after the collision, what was the initial speed of the car?
   A) 19 km/h
   B) 38 km/h
   C) 29 km/h
   D) 10 km/h

   Answer: A

10) A block of mass m = 8.40 kg, moving on a horizontal frictionless surface with a speed 4.20 m/s, makes a perfectly elastic collision with a block of mass M at rest. After the collision, the 8.40 block recoils with a speed of 0.400 m/s. In the figure, the blocks are in contact for 0.200 s. The magnitude of the average force on the 8.40-kg block, while the two blocks are in contact, is closest to



A) 193 N
B) 185 N
C) 176 N
D) 168 N
E) 160 N

Answer: A

11) A billiard ball traveling at 3.00 m/s collides perfectly elastically with an identical billiard ball initially at rest on the level table. The initially moving billiard ball deflects 30.0° from its original direction. What is the speed of the initially stationary billiard ball after the collision?

A) 2.00 m/s
B) 0.866 m/s
C) 1.50 m/s
D) 2.59 m/s
E) 0.750 m/s

Answer: C

12) A pool player is attempting a fancy shot. He hits the cue ball giving it a speed of 5.57 m/s and directs its center on a path tangent to the surface of the target ball having the same mass as the cue ball. After the collision (on a frictionless table) the initially-stationary ball moves with a speed of 4.82 m/s. After the collision, the new speed of the cue ball and the relative direction of the balls are closest to

A) 2.79 m/s, at 90° to each other.
B) 2.79 m/s, at 60° to each other.
C) 8.34 m/s, at 90° to each other.
D) 8.34 m/s, at 60° to each other.

Answer: A

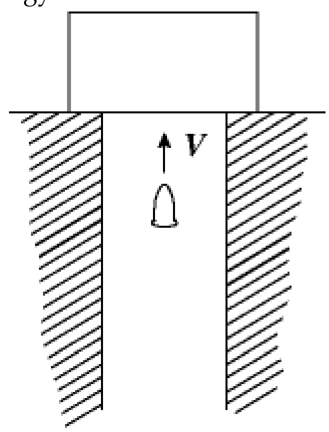
13) A 480-kg car moving at 14.4 m/s hits from behind a 570-kg car moving at 13.3 m/s in the same direction. If the new speed of the heavier car is 14.0 m/s, what is the speed of the lighter car after the collision, assuming that any unbalanced forces on the system are negligibly small?

A) 13.6 m/s
B) 10.5 m/s
C) 19.9 m/s
D) 5.24 m/s

Answer: A

14) A 2.00–kg object traveling east at 20.0 m/s collides with a 3.00–kg object traveling west at 10.0 m/s. After the collision, the 2.00–kg object has a velocity 5.00 m/s to the west. How much kinetic energy was lost during the collision?
A) 0.000 J
B) 458 J
C) 516 J
D) 91.7 J
E) 175 J
Answer: B

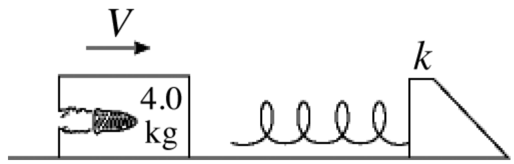
15) A 15–g bullet is shot vertically into an 2–kg block. The block lifts upward 8.0 mm (see the figure). The bullet penetrates the block and comes to rest in it in a time interval of 0.0010 s. Assume the force on the bullet is constant during penetration and that air resistance is negligible. The initial kinetic energy of the bullet is closest to



A) 21 J
B) 14 J
C) 10 J
D) 0.0012 J
E) 0.16 J
Answer: A

16) Two objects of the same mass move along the same line in opposite directions. The first mass is moving with speed v. The objects collide, stick together, and move with speed $0.100v$ in the direction of the velocity of the first mass before the collision. What was the speed of the second mass before the collision?
A) $1.20v$
B) $10.0v$
C) $0.900v$
D) $0.800v$
E) $0.00v$
Answer: D

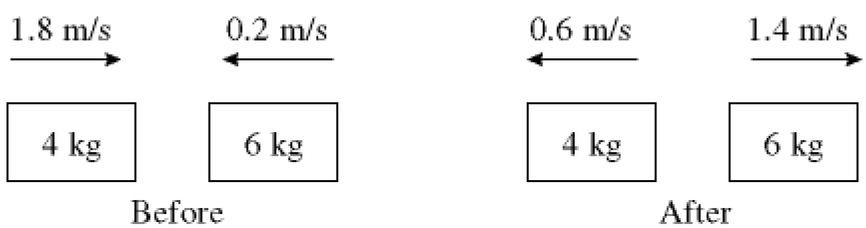
17) An 8.0–g bullet is shot into a 4.0–kg block, at rest on a frictionless horizontal surface (see the figure). The bullet remains lodged in the block. The block moves into an ideal massless spring and compresses it by 8.7 cm. The spring constant of the spring is 2400 N/m. The initial velocity of the bullet is closest to



A) 1100 m/s.
B) 1200 m/s.
C) 900 m/s.
D) 1300 m/s.
E) 1000 m/s.

Answer: A

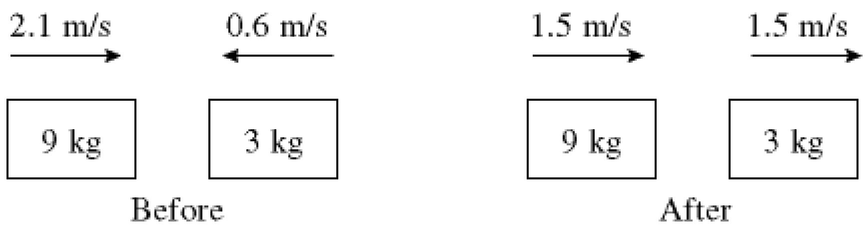
18) In the figure, determine the character of the collision. The masses of the blocks, and the velocities before and after are given. The collision is



A) perfectly elastic.
B) partially inelastic.
C) completely inelastic.
D) characterized by an increase in kinetic energy.
E) not possible because momentum is not conserved.

Answer: A

19) In the figure, determine the character of the collision. The masses of the blocks, and the velocities before and after are given, and no other unbalanced forces act on these blocks. The collision is



A) perfectly elastic.
B) partially inelastic.
C) completely inelastic.
D) characterized by an increase in kinetic energy.
E) not possible because momentum is not conserved.

Answer: E

20) A 5.00–kg ball is hanging from a long but very light flexible wire when it is struck by a 1.50 –kg stone traveling horizontally to the right at 12.0 m/s. The stone rebounds to the left with a speed of 8.50 m/s, and the ball swings to a maximum height h above its original level. The value of h is closest to

A) 0.0563 m.
B) 1.10 m.
C) 1.93 m.
D) 2.20 m.
E) 3.69 m.

Answer: C

21) A 1000–kg car approaches an intersection traveling north at 20.0 m/s. A 1200 –kg car approaches the same intersection traveling east at 22.0 m/s. The two cars collide at the intersection and lock together. Ignoring any external forces that act on the cars during the collision, what is the velocity of the cars immediately after the collision?

A) 29.7 m/s in a direction 47.7° east of north
B) 21.1 m/s in a direction 47.7° west of south
C) 15.1 m/s in a direction 52.8° east of north
D) 21.1 m/s in a direction 52.8° east of north
E) 21.1 m/s in a direction 47.7° east of north

Answer: C

22) Two automobiles traveling at right angles to each other collide and stick together. Car *A* has a mass of 1200 kg and had a speed of 25 m/s before the collision. Car *B* has a mass of 1600 kg. The skid marks show that, immediately after the collision, the wreckage was moving in a direction making an angle of 40° with the original direction of car *A*. What was the speed of car *B* before the collision, assuming that any other unbalanced forces are negligible?
A) 16 m/s
B) 18 m/s
C) 11 m/s
D) 21 m/s
E) 14 m/s

Answer: A

23) A 900-kg car traveling east at 15.0 m/s collides with a 750-kg car traveling north at 20.0 m/s. The cars stick together. Assume that any other unbalanced forces are negligible.
(a) What is the speed of the wreckage just after the collision?
(b) In what direction does the wreckage move just after the collision?

Answer: (a) 12.2 m/s (b) 48.0° N of E

24) A car heading north collides at an intersection with a truck of the same mass as the car heading east. If they lock together and travel at 28 m/s at 46° north of east just after the collision, how fast was the car initially traveling? Assume that any other unbalanced forces are negligible.
A) 40 m/s
B) 20 m/s
C) 80 m/s
D) 30 m/s

Answer: A

25) Two ice skaters push off against one another starting from a stationary position. The 45.0-kg skater acquires a speed of 0.375 m/s. What speed does the 60.0-kg skater acquire? Assume that any other unbalanced forces during the collision are negligible.
A) 0.500 m/s
B) 0.281 m/s
C) 0.375 m/s
D) 0.750 m/s
E) 0.000 m/s

Answer: B

26) On a frictionless horizontal table, two blocks (*A* of mass 2.00 kg and *B* of mass 3.00 kg) are pressed together against an ideal massless spring that stores 75.0 J of elastic potential energy. The blocks are not attached to the spring and are free to move free of it once they are released from rest. The maximum speed achieved by each block is closest to:
A) 6.71 m/s (*A*), 4.47 m/s (*B*)
B) 4.47 m/s (*A*), 6.71 m/s (*B*)
C) 5.48 m/s for both
D) 6.12 m/s (*A*), 5.00 m/s (*B*)
E) 5.00 m/s (*A*), 6.12 m/s (*B*)

Answer: A

27) A 10.0–kg shell is traveling horizontally to the right at 25.0 m/s relative to the ground when it explodes into two fragments, one of mass 3.00 kg and the other of mass 7.00 kg. The lighter fragment goes directly forward, and the explosion releases 1.50×10^3 J of mechanical energy to the fragments. Find the magnitude and direction of the velocity of the heavier fragment relative to the ground just after the explosion. Ignore the effect of any ejected gases.

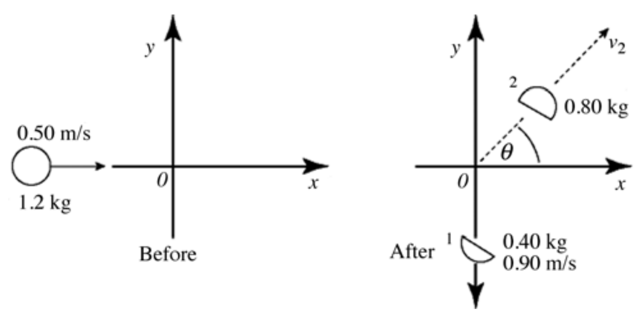
Answer: 13.7 m/s to the right

28) A plate falls vertically to the floor and breaks up into three pieces, which slide along the floor. Immediately after the impact, a 320–g piece moves along the x–axis with a speed of 2.00 m/s and a 355–g piece moves along the y–axis with a speed of 1.50 m/s. The third piece has a mass of 100 g. In what direction does the third piece move? You can neglect any horizontal forces during the crash.

A) 216.9° from the x–axis
B) 219.8° from the x–axis
C) 36.9° from the x–axis
D) 39.9° from the x–axis
E) 39.8° from the x–axis

Answer: B

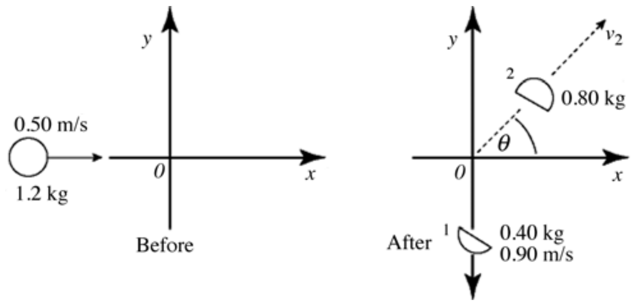
29) A 1.2–kg spring–activated toy bomb slides on a smooth surface along the x–axis with a speed of 0.50 m/s. At the origin 0, the bomb explodes into two fragments. Fragment 1 has a mass of 0.40 kg and a speed of 0.90 m/s along the negative y–axis. In the figure, the angle θ, made by the velocity vector of fragment 2 and the x–axis, is closest to



A) 31°.
B) 37°.
C) 38°.
D) 53°.
E) 59°.

Answer: A

30) A 1.2–kg spring–activated toy bomb slides on a smooth surface along the x–axis with a speed of 0.50 m/s. At the origin 0, the bomb explodes into two fragments. Fragment 1 has a mass of 0.40 kg and a speed of 0.90 m/s along the negative y–axis. In the figure, the energy released by the explosion is closest to



A) 0.20 J.
B) 0.24 J.
C) 0.28 J.
D) 0.32 J.
E) 0.36 J.

Answer: D

31) A 2.00–m rod of negligible mass connects two very small objects at its ends. The mass of one object is 1.00 kg and the mass of the other is unknown. The center of mass of this system is on the rod a distance 1.60 m from the 1.00–kg mass object. What is the mass of the other object?

A) 4.11 kg
B) 3.22 kg
C) 4.00 kg
D) 0.250 kg
E) 0.800 kg

Answer: C

32) A uniform piece of wire, 20 cm long, is bent in a right angle in the center to give it an L–shape. How far from the bend is the center of mass of the bent wire?

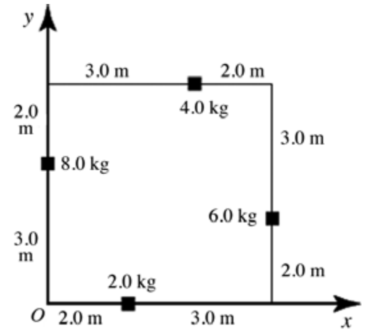
A) 2.5 cm
B) 3.5 cm
C) 4.5 cm
D) 5.0 cm
E) 7.1 cm

Answer: B

33) A long thin rod of length L has a linear density $\lambda(x) = Ax$ where x is the distance from the left end of the rod.
(a) How far is the center of mass of the rod from the left end of the rod?
(b) What is the mass of the rod?

Answer: (a) $2L/3$ (b) $AL^2/2$

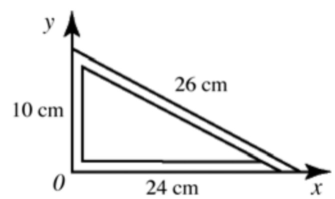
34) In the figure, four point masses are placed as shown. The x and y coordinates of the center of mass are closest to



A) (2.2 m, 2.6 m).
B) (2.2 m, 2.7 m).
C) (2.3 m, 2.6 m).
D) (2.3 m, 2.7 m).
E) (2.3 m, 2.8 m).

Answer: E

35) In the figure, a 60–cm length of uniform wire, of 60 g mass and negligible thickness, is bent into a right triangle. The x and y coordinates of the center of mass, in cm, are closest to



A) (8, 3).
B) (8, 5).
C) (9, 4).
D) (10, 3).
E) (10, 5).

Answer: D

36) A 310–g air track cart is traveling at 1.25 m/s and a 260–g cart traveling in the opposite direction at 1.33 m/s. What is the speed of the center of mass of the two carts?

A) 2.80 m/s
B) 0.0732 m/s
C) 0.131 m/s
D) 1.47 m/s
E) 1.29 m/s

Answer: B

Chapter 10 Rotational Motion

10.1 Conceptual Questions

1) When a rigid body rotates about a fixed axis, all the points in the body have the same
   A) tangential speed.
   B) angular acceleration.
   C) tangential acceleration.
   D) linear displacement.
   E) centripetal acceleration.

   Answer: B

2) A horizontal disk rotates about a vertical axis through its center. Point P is midway between the center and the rim of the disk, and point Q is on the rim. If the disk turns with constant angular velocity, which of the following statements about it are true? (There may be more than one correct choice.)
   A) P and Q have the same linear acceleration.
   B) Q is moving twice as fast as P.
   C) The linear acceleration of Q is twice as great as the linear acceleration of P.
   D) The linear acceleration of P is twice as great as the linear acceleration of Q.
   E) The angular velocity of Q is twice as great as the angular velocity of P.

   Answer: B, C

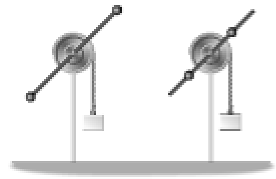
3) A dumbbell-shaped object is composed by two equal masses, m, connected by a rod of negligible mass and length r. If I_1 is the moment of inertia of this object with respect to an axis passing through the center of the rod and perpendicular to it and I_2 is the moment of inertia with respect to an axis passing through one of the masses, it follows that
   A) $I_1 = I_2$.
   B) $I_1 > I_2$.
   C) $I_2 > I_1$.

   Answer: C

4) If two forces of equal magnitude act on an object that is hinged at a pivot, the force acting farther from the pivot must produce the greater torque about the pivot.
   A) true
   B) false
   C) unable to decide without knowing the shape of the object

   Answer: B

5) The two rotating systems shown in the figure differ only in that the two identical movable masses are positioned at different distances from the axis of rotation. If you release the hanging blocks simultaneously from rest, and if the ropes do not slip, which block lands first?



A) The block at the left lands first.
B) The block at the right lands first.
C) Both blocks land at the same time.

Answer: B

6) If an irregularly shaped object (such as a wrench) is dropped from rest in a classroom and feels no air resistance, it will
A) accelerate but will not spin.
B) accelerate and turn until its center of gravity reaches its lowest point.
C) accelerate and turn about its center of gravity with uniform angular speed.
D) accelerate and turn about its center of gravity with uniform angular acceleration.
E) accelerate and spin until its center of gravity reaches its highest point.

Answer: A

7) A tire is rolling along a road, without slipping, with a velocity v. A piece of tape is attached to the tire. When the tape is opposite the road (at the top of the tire), its velocity with respect to the road is
A) $2v$.
B) v.
C) $1.5v$.
D) zero.
E) The velocity depends on the radius of the tire.

Answer: A

8) Consider a uniform solid sphere of radius R and mass M rolling without slipping. Which form of its kinetic energy is larger, translational or rotational?
A) Its translational kinetic energy is larger than its rotational kinetic energy.
B) Its rotational kinetic energy is larger than its translational kinetic energy.
C) Both forms of energy are equal.
D) You need to know the speed of the sphere to tell.

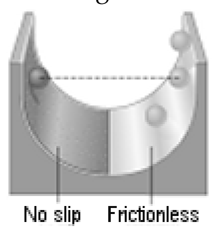
Answer: A

9) A solid sphere, solid cylinder, and a hollow pipe all have equal masses and radii and are of uniform density. If the three are released simultaneously at the top of an inclined plane and roll without slipping, which one will reach the bottom first?
A) solid sphere
B) hollow pipe
C) solid cylinder
D) They all reach the bottom at the same time.

Answer: A

10) A uniform disk, a uniform hoop, and a uniform solid sphere are released at the same time at the top of an inclined ramp. They all roll without slipping. In what order do they reach the bottom of the ramp?
A) disk, hoop, sphere
B) hoop, sphere, disk
C) sphere, disk, hoop
D) sphere, hoop, disk
E) hoop, disk, sphere
Answer: C

11) A ball is released from rest on a no-slip surface, as shown in the figure. After reaching its lowest point, the ball begins to rise again, this time on a frictionless surface as shown in the figure. When the ball reaches its maximum height on the frictionless surface, it is



A) at a greater height as when it was released.
B) at a lesser height as when it was released.
C) at the same height as when it was released.
D) It is impossible to tell without knowing the mass of the ball.
E) It is impossible to tell without knowing the radius of the ball.
Answer: B

10.2 Problems

1) A turbine blade rotates with angular velocity $\omega(t) = 2.00$ rad/s– 2.1.00 rad/s^3 t^2. What is the angular acceleration of the blade at $t = 9.10$ s?
A) –38.2 rad/s^2
B) –19.1 rad/s^2
C) –86.0 rad/s^2
D) –36.2 rad/s^2
E) –172 rad/s^2
Answer: A

2) The angular velocity of a 755–g wheel 15.0 cm in diameter is given by the equation $\omega(t) = (2.00$ rad/s$^2)t + (1.00$ rad/s$^4)t^3$.
(a) Through how many radians does the wheel turn during the first 2.00 s of its motion?
(b) What is the angular acceleration (in rad/s^2) of the wheel at the end of the first 2.00 s of its motion?
Answer: (a) 8.00 rad (b) 14.0 rad/s^2

3) The angular acceleration of a wheel is given in rad/s^2 by $45t^3 - 11t^4$, where t is in seconds. If the wheel starts from rest at t = 0.00 s, when is the next time the wheel is at rest?
   A) 5.1 s
   B) 8.4 s
   C) 6.9 s
   D) 3.6 s

   Answer: A

4) A 1.15–kg grinding wheel 22.0 cm in diameter is spinning counterclockwise at a rate of 20.0 revolutions per second. When the power to the grinder is turned off, the grinding wheel slows with constant angular acceleration and takes 80.0 s to come to a rest.
   (a) What was the angular acceleration (in rad/s^2) of the grinding wheel as it came to rest if we take a counterclockwise rotation as positive?
   (b) How many revolutions did the wheel make during the time it was coming to rest?

   Answer: (a) -1.57 rad/s^2 (b) 800 revolutions

5) A 3.45–kg centrifuge takes 100 s to spin up from rest to its final angular speed with constant angular acceleration. A point located 8.00 cm from the axis of rotation of the centrifuge moves with a speed of 150 m/s when the centrifuge is at full speed.
   (a) What is the angular acceleration (in rad/s^2) of the centrifuge as it spins up?
   (b) How many revolutions does the centrifuge make as it goes from rest to its final angular speed?

   Answer: (a) 18.8 rad/s^2 (b) 1.49×10^4 revolutions

6) When a 2.75–kg fan, having blades 18.5 cm long, is turned off, its angular speed decreases uniformly from 10.0 rad/s to 6.30 rad/s in 5.00 s.
   (a) What is the magnitude of the angular acceleration of the fan?
   (b) Through what angle (in degrees) does it turn while it is slowing down during the 5.00 s?
   (c) If its angular acceleration does not change, how long after it is turned off does it take the fan to stop.

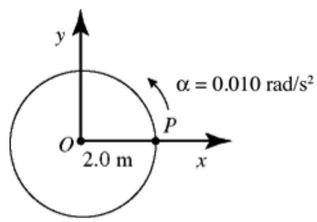
   Answer: (a) 0.740 rad/s^2 (b) 2330° (c) 13.5 s

7) A 4.50–kg wheel that is 34.5 cm in diameter rotates through an angle of 13.8 rad as it slows down uniformly from 22.0 rad/s to 13.5 rad/s. What is the magnitude of the angular acceleration of the wheel?
   A) 0.616 rad/s^2
   B) 5.45 rad/s^2
   C) 111 rad/s^2
   D) 22.5 rad/s^2
   E) 10.9 rad/s^2

   Answer: E

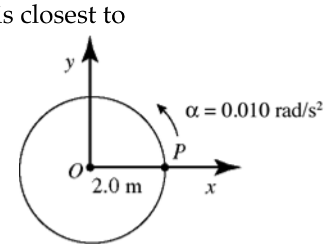
8) A machinist turns the power on to a grinding wheel, which is at rest at time $t = 0.00$ s. The wheel accelerates uniformly for 10 s and reaches the operating angular velocity of 25 rad/s. The wheel is run at that angular velocity for 37 s and then power is shut off. The wheel decelerates uniformly at 1.5 rad/s^2 until the wheel stops. In this situation, the time interval of angular deceleration (slowing down) is closest to:
A) 17 s
B) 15 s
C) 19 s
D) 21 s
E) 23 s
Answer: A

9) In the figure, point P is at rest when it is on the x–axis. The linear speed of point P when it reaches the y–axis is closest to



A) 0.18 m/s.
B) 0.24 m/s.
C) 0.35 m/s.
D) 0.49 m/s.
E) 0.71 m/s.
Answer: C

10) In the figure, point P is at rest when it is on the x–axis. The time t, when P returns to the original position on the x–axis, is closest to



A) 13 s.
B) 18 s.
C) 25 s.
D) 35 s.
E) 50 s.
Answer: D

11) A 1.25–kg ball begins rolling from rest with constant angular acceleration down a hill. If it takes 3.60 s for it to make the first complete revolution, how long will it take to make the next complete revolution?
Answer: 1.49 s

12) A piece of thin uniform wire of mass m and length $3b$ is bent into an equilateral triangle. Find the moment of inertia of the wire triangle about an axis perpendicular to the plane of the triangle and passing through one of its vertices.

A) $\frac{2}{3}mb^2$

B) $\frac{7}{4}mb^2$

C) $\frac{1}{3}mb^2$

D) $\frac{7}{12}mb^2$

E) $\frac{1}{2}mb^2$

Answer: E

13) A slender uniform rod 100.00 cm long is used as a meter stick. Two parallel axes that are perpendicular to the rod are considered. The first axis passes through the 50-cm mark and the second axis passes through the 30-cm mark. What is the ratio of the moment of inertia through the second axis to the moment of inertia through the first axis?

A) $I_2/I_1 = 1.5$
B) $I_2/I_1 = 1.7$
C) $I_2/I_1 = 1.9$
D) $I_2/I_1 = 2.1$
E) $I_2/I_1 = 2.3$

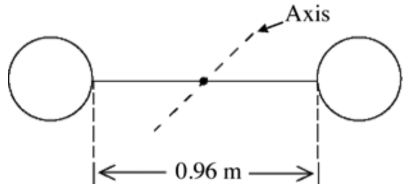
Answer: A

14) A uniform solid sphere has a moment of inertia I about an axis tangent to its surface. What is the moment of inertia of this sphere about an axis through its center?

A) 1/7 I
B) 2/7 I
C) 2/5 I
D) 3/5 I
E) 7/5 I

Answer: B

15) In the figure, a weightlifter's barbell consists of two identical uniform spherical masses each with radius 0.17 m and mass of 50 kg. The weights are connected by a 0.96-m uniform steel rod with a mass of 12 kg. Find the moment of inertia of the barbell about the axis through the center (see figure).



Answer: 44 kg∙m^2

16) An extremely light rod 1.00 m long has a 2.00–kg mass attached to one end and a 3.00–kg mass attached to the other. The system rotates at a constant angular speed about a fixed axis perpendicular to the rod that passes through the rod 30.0 cm from the end with the 3.00–kg mass attached. The kinetic energy of the system is measured to be 100.0 J.
(a) What is the moment of inertia of this system about the fixed axis?
(b) What is the angular speed (in revolutions per second) of this system?

Answer: (a) 1.25 $kg \cdot m^2$ (b) 2.01 rev/s

17) A uniform solid sphere of mass M and radius R rotates with an angular speed ω about an axis through its center. A uniform solid cylinder of mass M, radius R, and length $2R$ rotates through an axis running through the central axis of the cylinder. What must be the angular speed of the cylinder so it will have the same rotational kinetic energy as the sphere?
A) $2\omega/5$
B) $\sqrt{2/5}\,\omega$
C) $4\omega/5$
D) $2\omega/\sqrt{5}$
E) $\omega/\sqrt{5}$

Answer: D

18) While spinning down from 500.0 rpm to rest, a solid uniform flywheel does 5.1 kJ of work. If the radius of the disk is 1.2 m, what is its mass?
A) 5.2 kg
B) 4.4 kg
C) 6.0 kg
D) 6.8 kg

Answer: A

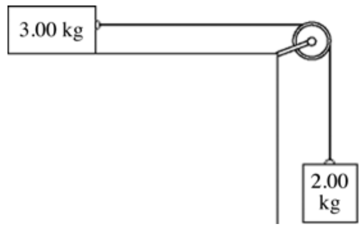
19) At any angular speed, a certain uniform solid sphere of diameter D has half as much rotational kinetic energy as a certain uniform thin–walled hollow sphere of the same diameter when both are spinning about an axis through their centers. If the mass of the solid sphere is M, the mass of the hollow sphere is
A) 3/5 M.
B) 5/3 M.
C) 5/6 M.
D) 6/5 M.
E) 2 M.

Answer: D

20) A futuristic design for a car is to have a large solid disk–shaped flywheel within the car storing kinetic energy. The uniform flywheel has mass 370 kg with a radius of 0.500 m and can rotate up to 230 rev/s. Assuming all of this stored kinetic energy could be transferred to the linear velocity of the 1600–kg car, find the maximum attainable speed of the car.

Answer: 246 m/s

21) In the figure, two blocks, of masses 2.00 kg and 3.00 kg, are connected by a light string that passes over a frictionless pulley of moment of inertia 0.00400 kg $\cdot$ m^2 and radius 5.00 cm. The coefficient of friction for the tabletop is 0.300. The blocks are released from rest. Using energy methods, find the speed of the upper block just as it has moved 0.600 m.



A) 1.22 m/s
B) 5.44 m/s
C) 3.19 m/s
D) 1.95 m/s
E) 1.40 m/s

Answer: E

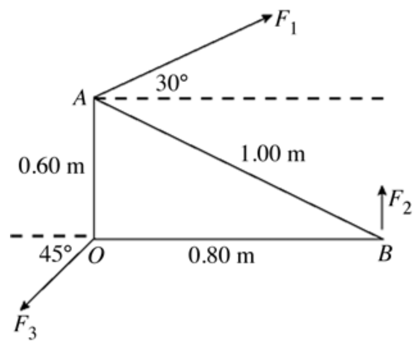
22) A 1.10–kg wrench is acting on a nut trying to turn it. The length of the wrench lies directly to the east of the nut. A force 150.0 N acts on the wrench at a position 15.0 cm from the center of the nut in a direction 30.0° north of east. What is the magnitude of the torque about the center of the nut?
A) 22.5 N•m
B) 11.3 N•m
C) 19.5 N•m
D) 2250 N•m
E) 1949 N•m

Answer: B

23) A 95 N force exerted at the end of a 0.50 m long torque wrench gives rise to a torque of 15 N • m. What is the angle (assumed to be less than 90°) between the wrench handle and the direction of the applied force?
A) 18°
B) 14°
C) 22°
D) 25°

Answer: A

24) A light triangular plate *OAB* is in a horizontal plane. Three forces, F_1 = 6.0 N, F_2 = 9.0 N, and F_3 = 7.0 N, act on the plate, which is pivoted about a vertical axes through point *O*. In the figure, $\vec{F}_2$ is perpendicular to *OB*. Consider the counterclockwise sense as positive. The sum of the torques about the vertical axis through point *O*, acting on the plate due to forces F_1, F_2, and F_3, is closest to



A) 4.1 N • m
B) 5.4 N • m
C) −4.1 N • m
D) −5.4 N • m
E) zero

Answer: A

25) A 72.0–kg person pushes on a small doorknob with a force of 5.00 N perpendicular to the surface of the door. The doorknob is located 0.800 m from axis of the frictionless hinges of the door. The door begins to rotate with an angular acceleration of 2.00 rad/s^2. What is the moment of inertia of the door about the hinges?

A) 4.28 kg•m^2
B) 7.52 kg•m^2
C) 1.88 kg•m^2
D) 0.684 kg•m^2
E) 2.74 kg•m^2

Answer: C

26) A torque of 12 N • m is applied to a solid, uniform disk of radius 0.50 m, causing the disk to accelerate at 5.7 rad/s^2. What is the mass of the disk?

A) 17 kg
B) 13 kg
C) 8.5 kg
D) 4.3 kg

Answer: A

27) In an experiment, a student brings up the rotational speed of a piece of laboratory apparatus to 30.0 rpm. She then allows the apparatus to slow down uniformly on its own, and counts 240 revolutions before the apparatus comes to a stop. The moment of inertia of the apparatus is known to be 0.0850 kg∙m^2. What is the magnitude of the retarding torque on the apparatus?

A) 0.0425 N∙m
B) 0.159 N∙m
C) 0.0787 N∙m
D) 0.000278 N∙m
E) 0.0000136 N∙m

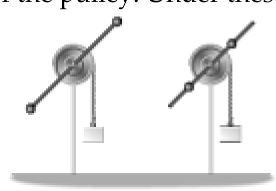
Answer: D

28) A string is wrapped around a pulley with a radius of 2.0 cm and no appreciable friction in its axle. The pulley is initially not turning. A constant force of 50 N is applied to the string, which does not slip, causing the pulley to rotate and the string to unwind. If the string unwinds 1.2 m in 4.9 s, what is the moment of inertia of the pulley?

A) 0.17 kg∙m^2
B) 17 kg∙m^2
C) 14 kg∙m^2
D) 0.20 kg∙m^2
E) 0.017 kg∙m^2

Answer: D

29) The rotating systems shown in the figure differ only in that the two identical movable masses are positioned a distance r from the axis of rotation (left), or a distance $r/2$ from the axis of rotation (right). You release the hanging blocks simultaneously from rest, and call t_L the time taken by the block on the left and t_R the time taken by the block on the right to reach the bottom, respectively. The bar, pulley, and rope have negligible mass, the rope does not slip, and there is no friction in the axle of the pulley. Under these conditions



A) $t_L = \frac{1}{2} t_R$.
B) $t_L = t_R$.
C) $t_L = \sqrt{2}\, t_R$.
D) $t_L = 2t_R$.
E) $t_l = 4t_R$.

Answer: D

30) A solid uniform sphere of mass 1.85 kg and diameter 45.0 cm spins about an axle through its center. Starting with an angular velocity of 2.40 rev/s, it stops after turning through 18.2 rev with uniform acceleration. The net torque acting on this sphere as it is slowing down is closest to

A) 0.00593 N m.
B) 0.0372 N • m.
C) 0.0466 N • m.
D) 0.0620 N • m.
E) 0.149 N • m.

Answer: B

31) A very thin uniform rod, 2.40 m long and of weight 135 N, has a frictionless hinge at its lower end. It starts out vertically from rest and falls, pivoting about the hinge. Just as it has rotated through an angle of 55.0°, what is the downward acceleration of the end farthest from the hinge?

A) 5.02 m/s^2
B) 8.03 m/s^2
C) 9.80 m/s^2
D) 12.0 m/s^2
E) 19.6 m/s^2

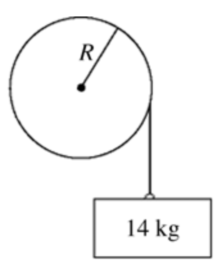
Answer: D

32) A very thin horizontal, 2.00–m long, 5.00–kg uniform beam that lies along the east–west direction is acted on by two forces. At the east end of the beam, a 200–N force pushes downward. At the west end of the beam, a 200–N force pushes upward. What is the angular acceleration of the beam?

A) 240 rad/s^2 north
B) 1.33×10^2 rad/s^2 north
C) zero
D) 240 rad/s^2 south
E) 1.33×10^2 rad/s^2 south

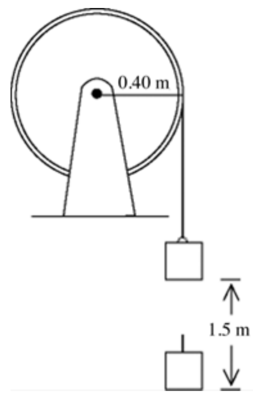
Answer: A

33) In the figure, a very light rope is wrapped around a wheel of radius R = 2.0 meters and does not slip. The wheel is mounted with frictionless bearings on an axle through its center. A block of mass 14 kg is suspended from the end of the rope. When the system is released from rest it is observed that the block descends 10 meters in 2.0 seconds. What is the moment of inertia of the wheel?



Answer: 54 kg • m^2

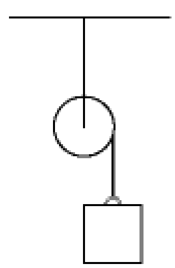
34) A wheel has a radius of 0.40 m and is mounted on frictionless bearings. A block is suspended from a rope that is wound on the wheel and attached to it (see figure). The wheel is released from rest and the block descends 1.5 m in 2.00 s without any slipping of the rope. The tension in the rope during the descent of the block is 20 N. What is the moment of inertia of the wheel?



A) 3.5 kg • m^2
B) 3.7 kg • m^2
C) 3.9 kg • m^2
D) 4.1 kg • m^2
E) 4.3 kg • m^2

Answer: E

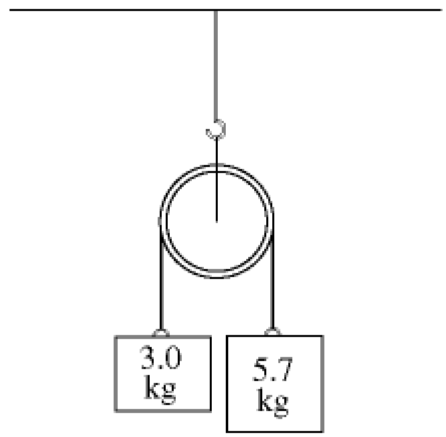
35) In the figure, a mass of 31.77 kg is attached to a light string that is wrapped around a cylindrical spool of radius 10.0 cm and moment of inertia 4.00 kg • m^2. The spool is suspended from the ceiling, and the mass is then released from rest a distance 5.70 m above the floor. How long does it take to reach the floor?



A) 3.98 s
B) 3.83 s
C) 1.14 s
D) 5.59 s
E) 7.89 s

Answer: A

36) For the apparatus shown in the figure, there is no slipping between the cord and the surface of the pulley. The blocks have mass of 3.0 kg and 5.7 kg, and the pulley has a radius of 0.12 m and a mass of 10.3 kg. At the instant the 5.7 kg mass has fallen 1.5 m starting from rest, find the speed of each block. (Assume the pulley is in the shape of a uniform solid disk and has no friction in its axle.)



Answer: 2.4 m/s

37) A uniform solid sphere of mass 1.5 kg and diameter 30.0 cm starts from rest and rolls without slipping down a 35° incline that is 7.0 m long.
(a) Calculate the linear speed of the center of the sphere when it reaches the bottom of the incline.
(b) Determine the angular speed of the sphere about its center at the bottom of the incline.
(c) Through what angle (in radians) does this sphere turn as it rolls down the incline?
(d) Does the linear speed in (a) depend on the radius or mass of the sphere? Does the angular speed in (b) depend on the radius or mass of the sphere?

Answer: (a) 7.5 m/s (b) 50 rad/s (c) 47 rad
(d) The linear speed depends on neither the radius nor the mass of the sphere. The angular speed depends on the radius of the sphere.

38) A uniform solid 5.25–kg cylinder is released from rest and rolls without slipping down an inclined plane inclined at 18° to the horizontal. How fast is it moving after it has rolled 2.2 m down the plane?
A) 4.3 m/s
B) 5.2 m/s
C) 3.0 m/s
D) 3.7 m/s
E) 2.6 m/s

Answer: C

39) A uniform solid cylinder of radius R and a thin uniform spherical shell of radius R both roll without slipping. If both objects have the same mass and the same kinetic energy, what is the ratio of the linear speed of the cylinder to the linear speed of the spherical shell?

A) $\sqrt{3} / 2$
B) $\sqrt{10} / 2$
C) $\sqrt{4 / 3}$
D) $4 / \sqrt{3}$
E) $4 / 3$

Answer: B

40) A uniform solid sphere is rolling without slipping along a horizontal surface with a speed of 5.50 m/s when it starts up a ramp that makes an angle of 25.0° with the horizontal. What is the speed of the sphere after it has rolled 3.00 m up the ramp, measured along the surface of the ramp?

A) 4.01 m/s
B) 8.02 m/s
C) 1.91 m/s
D) 2.16 m/s
E) 3.53 m/s

Answer: E

41) A solid, uniform sphere of mass 2.0 kg and radius 1.7 m rolls from rest without slipping down an inclined plane of height 7.0 m. What is the angular velocity of the sphere at the bottom of the inclined plane?

A) 5.8 rad/s
B) 9.9 rad/s
C) 11 rad/s
D) 7.0 rad/s

Answer: A

42) A uniform solid disk of radius 1.60 m and mass 2.30 kg rolls without slipping to the bottom of an inclined plane. If the angular velocity of the disk is 5.35 rad/s at the bottom, what is the height of the inclined plane?

A) 5.61 m
B) 4.21 m
C) 4.94 m
D) 6.73 m

Answer: A

Chapter 11 Rotational Vectors and Angular Momentum

11.1 Conceptual Questions

1) If two vectors are perpendicular to each other, their cross product must be zero.
A) True
B) False
Answer: B

2) If two vectors point in opposite directions, their cross product must be zero.
A) True
B) False
Answer: A

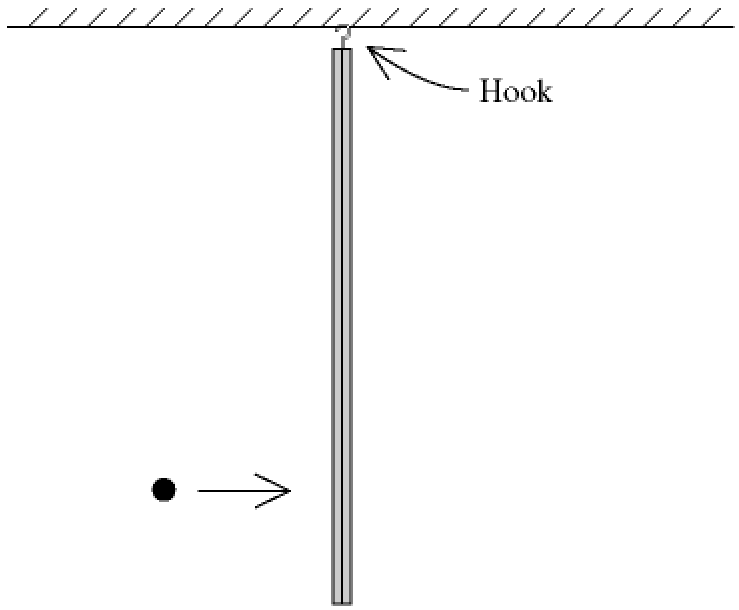
3) If $\vec{A}$ and $\vec{B}$ are nonzero vectors for which $\vec{A} \cdot \vec{B} = 0$, it must follow that
A) $\vec{A} \times \vec{B} = 0$.
B) $\vec{A}$ is parallel to $\vec{B}$.
C) $|\vec{A} \times \vec{B}| = AB$.
D) $|\vec{A} \times \vec{B}| = 1$.
Answer: C

4) As you are leaving a building, the door opens outward. If the hinges on the door are on your right, what is the direction of the angular velocity of the door as you open it?
A) up
B) down
C) to your left
D) to your right
E) forwards
Answer: B

5) When you ride a bicycle, in what direction is the angular velocity of the wheels?
A) to your left
B) to your right
C) forwards
D) backwards
E) up
Answer: A

6) The angular momentum of a system remains constant
A) when the total kinetic energy is constant.
B) when no net external force acts on the system.
C) when the linear momentum and the energy are constant.
D) when no torque acts on the system.
E) all the time since it is a conserved quantity.
Answer: D

7) A metal bar is hanging from a hook in the ceiling when it is suddenly struck by a ball that is moving horizontally (see figure). The ball is covered with glue, so it sticks to the bar. During this collision



A) the angular momentum of the system (ball and bar) is conserved about the hook because only gravity is acting on the system.
B) the angular momentum of the system (ball and bar) is not conserved because the hook exerts a force on the bar.
C) the angular momentum of the system (ball and bar) is conserved about the hook because neither the hook nor gravity exerts any torque on this system about the hook.
D) both the angular momentum of the system (ball and bar) and its kinetic energy are conserved.
E) both the linear momentum and the angular momentum of the system (ball and bar) are conserved.

Answer: C

11.2 Problems

1) What is the vector product of $\vec{A} = 2.00\,\hat{i} + 3.00\,\hat{j} + 1.00\,\hat{k}$ and $\vec{B} = 1.00\,\hat{i} - 3.00\,\hat{j} - 2.00\,\hat{k}$?
A) $-3.00\,\hat{i} + 5.00\,\hat{j} - 9.00\,\hat{k}$
B) $-5.00\,\hat{i} + 2.00\,\hat{j} - 6.00\,\hat{k}$
C) $-9.00\,\hat{i} - 3.00\,\hat{j} - 3.00\,\hat{k}$
D) $-4.00\,\hat{i} + 3.00\,\hat{j} - 1.00\,\hat{k}$
E) $2.00\,\hat{i} - 9.00\,\hat{j} - 2.00\,\hat{k}$

Answer: A

2) What is the magnitude of the cross product of a vector of magnitude 2.00 m pointing east and a vector of magnitude 4.00 m pointing 30.0° west of north?
   A) 6.93
   B) −6.93
   C) 4.00
   D) −4.00
   E) 8.00

Answer: A

3) If the magnitude of the cross product of two vectors is one−half the dot product of the same vectors, what is the angle between the two vectors?

Answer: 26.6°

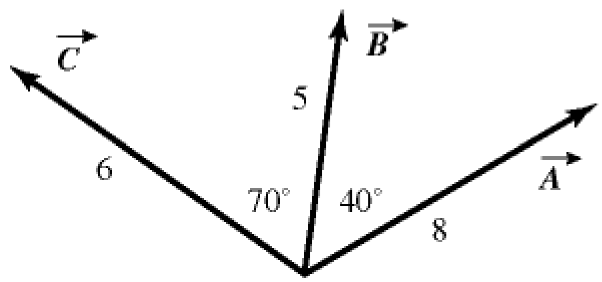
4) If $\vec{C} = -4\hat{i} - 2\hat{j} - 3\hat{k}$, what is $\vec{C} \times \hat{j}$?
   A) $+3\hat{i} - 4\hat{k}$
   B) $+3\hat{i} + 4\hat{k}$
   C) $-3\hat{i} + 4\hat{k}$
   D) $+3\hat{i} + 2\hat{j} - 4\hat{k}$
   E) $-3\hat{i} - 2\hat{j} + 4\hat{k}$

Answer: A

5) If $\vec{B} = -2\hat{i} - 6\hat{j} + 2\hat{k}$ and $\vec{C} = -2\hat{i} - 2\hat{j} - 3\hat{k}$, which of the following numbers is closest to the magnitude of $\vec{C} \times \vec{B}$?
   A) 25
   B) 21
   C) 17
   D) 13
   E) 9

Answer: A

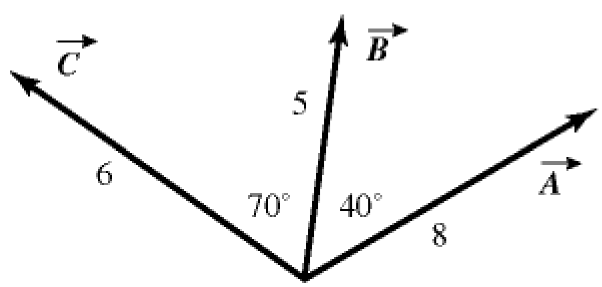
6) For the vectors shown in the figure, find the magnitude and direction of $\vec{B} \times \vec{A}$, assuming that the quantities shown are accurate to two significant figures.



A) 26, directed into the plane
B) 26, directed out of the plane
C) 31, directed on the plane
D) 31, directed into the plane
E) 31, directed out of the plane

Answer: A

7) For the vectors shown in the figure, find the magnitude and direction of the vector product $\vec{A} \times \vec{C}$, assuming that the quantities shown are accurate to two significant figures.



A) 16, directed into the plane
B) 16, directed out of the plane
C) 45, directed on the plane
D) 45, directed into the plane
E) 45, directed out of the plane

Answer: E

8) A force $\vec{F} = 3.00\text{ N}\,\hat{i} - 2.00\text{ N}\,\hat{j}$ acts at a location $\vec{r} = 1.00\text{ m}\,\hat{i} + 2.00\text{ m}\,\hat{j}$ on an object. What is the torque that this force applies about an axis through the origin perpendicular to the xy–plane?

A) -1.00 N•m $\hat{k}$
B) 7.00 N•m $\hat{k}$
C) -3.00 N•m $\hat{k}$
D) 5.00 N•m $\hat{k}$
E) -8.00 N•m $\hat{k}$

Answer: E

9) What is the torque about the origin on a particle located at $\vec{r} = 3\text{ m}\,\hat{i} + 4\text{ m}\,\hat{j} - 2\text{ m}\,\hat{k}$ if a force $\vec{F} = 5\text{ N}\,\hat{i} - 2\text{ N}\,\hat{j} + 3\text{ N}\,\hat{k}$ acts on the particle?
A) $(8\hat{i} + \hat{j} - 26\hat{k})$ N•m
B) $(8\hat{i} - 19\hat{j} - 26\hat{k})$ N•m
C) $(8\hat{i} + 2\hat{j} + \hat{k})$ N•m
D) $(16\hat{i} - 19\hat{j} - 26\hat{k})$ N•m
E) $(8\hat{i} - 2\hat{j} + \hat{k})$ N•m
Answer: B

10) Three solid, uniform, cylindrical flywheels, each of mass 65.0 kg and radius 1.47 m rotate independently around a common axis. Two of the flywheels rotate in one direction at 3.83 rad/s; the other rotates in the opposite direction at 3.42 rad/s. Calculate the magnitude of the net angular momentum of the system.
A) 298 kg•m^2/s
B) 778 kg•m^2/s
C) 257 kg•m^2/s
D) 222 kg•m^2/s
Answer: A

11) A potter's wheel, with rotational inertia 46 kg•m^2, is spinning freely at 40 rpm. The potter drops a lump of clay onto the wheel, where it sticks a distance 1.2 m from the rotational axis. If the subsequent angular speed of the wheel and clay is 32 rpm what is the mass of the clay?
A) 8.0 kg
B) 5.4 kg
C) 7.0 kg
D) 8.8 kg
Answer: A

12) A bicycle is traveling north at 5.0 m/s. The mass of the wheel, 2.0 kg, is uniformly distributed along the rim, which has a radius of 20 cm. What are the magnitude and direction of the angular momentum of the wheel about its axle?
A) 2.0 kg•m^2/s towards the west
B) 5.0 kg•m^2/s vertically upwards
C) 2.0 kg•m^2/s towards the east
D) 5.0 kg•m^2/s towards the east
E) 5.0 kg•m^2/s towards the west
Answer: A

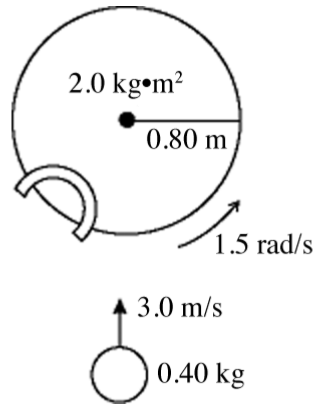
13) A 500–g particle is located at the point $\vec{r}$ = 4m $\hat{i}$ + 3m $\hat{j}$ – 2m $\hat{k}$ and is moving with a velocity $\vec{v}$ = 5 m/s $\hat{i}$ –2 ms $\hat{j}$ + 4 m/s $\hat{k}$. What is the angular momentum of this particle about the origin?
A) (24 $\hat{i}$ – 6 $\hat{j}$ – 8 $\hat{k}$) kg•m^2/s
B) (12 $\hat{i}$ – 3 $\hat{j}$ – 4 $\hat{k}$) kg•m^2/s
C) (8 $\hat{i}$ + 14 $\hat{j}$ – 13 $\hat{k}$) kg•m^2/s
D) (10 $\hat{i}$ – $\hat{j}$ + 2 $\hat{k}$) kg•m^2/s
E) (4 $\hat{i}$ – 13 $\hat{j}$ – 11.5 $\hat{k}$) kg•m^2/s
Answer: E

14) A figure skater rotating at 5.00 rad/s with arms extended has a moment of inertia of 2.25 kg •m^2. If the arms are pulled in so the moment of inertia decreases to 1.80 kg•m^2, what is the final angular speed?
A) 2.25 rad/s
B) 4.60 rad/s
C) 6.25 rad/s
D) 1.76 rad/s
E) 0.810 rad/s
Answer: C

15) A 5.0–m radius playground merry–go–round with a moment of inertia of 2000 kg•m^2 is rotating freely with an angular speed of 1.0 rad/s. Two people, each having a mass of 60 kg, are standing right outside the edge of the merry–go–round and step on it with negligible speed. What is the angular speed of the merry–go–round right after the two people have stepped on?
A) 0.20 rad/s
B) 0.40 rad/s
C) 0.60 rad/s
D) 0.80 rad/s
E) 0.67 rad/s
Answer: B

16) A record is dropped vertically onto a freely rotating (undriven) turntable. Frictional forces act to bring the record and turntable to a common angular speed. If the rotational inertia of the record is 0.54 times that of the turntable, what percentage of the initial kinetic energy is lost?
A) 35%
B) 18%
C) 46%
D) 60%
Answer: A

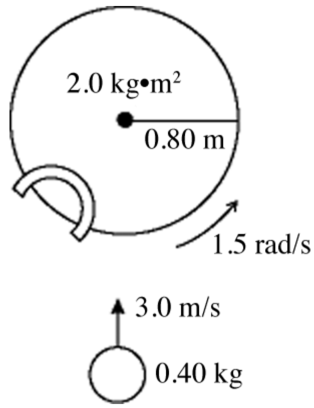
17) A turntable has a radius of 0.80 m and a moment of inertia of 2.0 kg $\cdot$ m^2. The turntable is rotating with an angular velocity of 1.5 rad/s about a vertical axis though its center on frictionless bearings. A very small 0.40-kg ball is projected horizontally toward the turntable axis with a velocity of 3.0 m/s. The ball is caught by a very small and very light cup-shaped mechanism on the rim of the turntable (see figure). What is the angular velocity of the turntable just after the ball is caught?



A) 2.1 rad/s
B) 1.3 rad/s
C) 0.94 rad/s
D) 0.75 rad/s
E) 0.30 rad/s

Answer: B

18) A turntable has a radius of 0.80 m and a moment of inertia of 2.0 kg • m^2. The turntable is rotating with an angular velocity of 1.5 rad/s about a vertical axis though its center on frictionless bearings. A very small 0.40–kg ball is projected horizontally toward the turntable axis with a velocity of 3.0 m/s. The ball is caught by a very small and very light cup–shaped mechanism on the rim of the turntable (see figure). The percent of the initial kinetic energy of the system that is lost during the capture of the ball is closest to



A) 45%.
B) 51%.
C) 55%.
D) 60%.
E) 65%.

Answer: B

19) A uniform disk has a mass of 3.7 kg and a radius of 0.40 m. The disk is mounted on frictionless bearings and is used as a turntable. The turntable is initially rotating at 30 rpm. A thin–walled hollow cylinder has the same mass and radius as the disk. It is released from rest, just above the turntable, and on the same vertical axis. The hollow cylinder slips on the turntable for 0.20 s until it acquires the same final angular velocity as the turntable. What is the final angular momentum of the system?

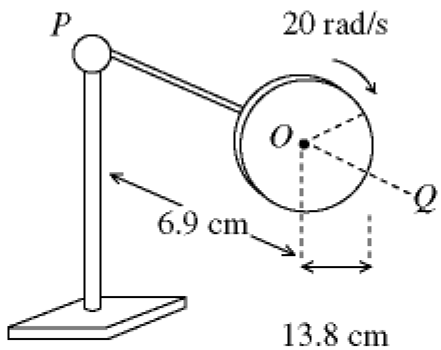
A) 0.93 kg • m^2/s
B) 1.1 kg • m^2/s
C) 1.3 kg • m^2/s
D) 1.6 kg • m^2/s
E) 1.9 kg • m^2/s

Answer: A

20) An object is rotating with an angular momentum 4.00 kg $\cdot$m^2/s $\hat{k}$ while being acted on by a constant torque 3.00 N$\cdot$m $\hat{i}$. What is the angular speed of precession of the angular velocity of the object?
A) 1.33 rad/s
B) 0.750 rad/s
C) 12.0 rad/s
D) zero
E) It depends on the moment of inertia of the object.

Answer: B

21) In the figure, the rotor of a gyroscope is a uniform disk that has a radius of 13.8 cm and a moment of inertia about its axis of 4.0×10^{-3} kg$\cdot$m^2. The length of the rotor shaft is 6.9 cm. The ball pivot at *P* is frictionless. At a given instant, the rotor shaft is horizontal and the rotor is rotating with an angular velocity of 90 rad/s about its axis *OP*, as shown. The rotor is viewed from point *Q* on the axis. The precessional linear velocity of point *O*, including the direction seen from point *Q*, is closest to



A) 0.054 m/s, leftward
B) 0.054 m/s, upward
C) 0.054 m/s, rightward
D) 0.11 m/s, downward
E) 0.11 m/s, rightward

Answer: A

22) 61) A bicycle wheel of radius 0.36 m and mass 3.2 kg is set spinning at 4.00 rev/s. A very light bolt is attached to extend the axle in length, and a string is attached to the axle at a distance of 0.10 m from the wheel. Initially the axle of the spinning wheel is horizontal, and the wheel is suspended only from the string. We can ignore the mass of the axle and spokes. At what rate will the wheel process about the vertical?
A) 2.9 rpm
B) 1.9 rpm
C) 18 rpm
D) 0.30 rpm
E) 0.77 rpm

Answer: A

Chapter 12 Static Equilibrium

12.1 Conceptual Questions

1) If the torque on an object adds up to zero
   A) the forces on it also add up to zero.
   B) the object is at rest.
   C) the object cannot be turning.
   D) the object could be accelerating linearly but it could not be turning.
   E) the object could be both turning and accelerating linearly.

   Answer: E

2) A heavy boy and a lightweight girl are balanced on a massless seesaw. If they both move forward so that they are one-half their original distance from the pivot point, what will happen to the seesaw? Assume that both people are small enough compared to the length of the seesaw to be thought of as point masses.
   A) It is impossible to say without knowing the masses.
   B) It is impossible to say without knowing the distances.
   C) The side the boy is sitting on will tilt downward.
   D) Nothing will happen; the seesaw will still be balanced.
   E) The side the girl is sitting on will tilt downward.

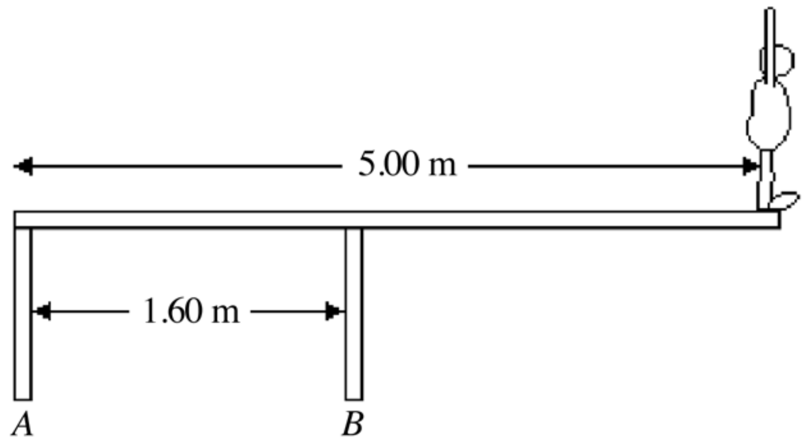
   Answer: D

12.2 Problems

1) A light board, 10 m long, is supported by two sawhorses, one at one edge of the board and a second at the midpoint. A small 40–N weight is placed between the two sawhorses, 3.0 m from the edge and 2.0 m from the center. What forces are exerted by the sawhorses on the board?

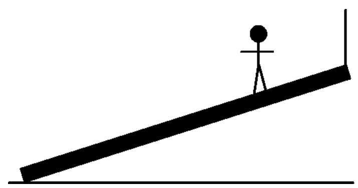
   Answer: 16 N at the end and 24 N at the midpoint

2) An 82.0 kg–diver stands at the edge of a light 5.00–m diving board, which is supported by two narrow pillars 1.60 m apart, as shown in the figure. Find the magnitude and direction of the force exerted on the diving board
(a) by pillar *A*.
(b) by pillar *B*.



Answer: (a) 1.71 kN downwards (b) 2.51 kN upwards

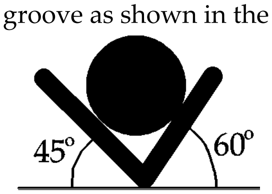
3) A 20.0–kg uniform plank is supported by the floor at one end and by a vertical rope at the other as shown in the figure. A 50.0–kg mass person stands on the plank a distance three–fourths of the length plank from the end on the floor.



(a) What is the tension in the rope?
(b) What is the magnitude of the force that the floor exerts on the plank?

Answer: (a) 466 N (b) 220 N

4) A 3.00–kg ball rests in a frictionless groove as shown in the figure.



(a) What is the magnitude of the force that the left side of the groove exerts on the ball?
(b) What is the magnitude of the force that the right side of the groove exerts on the ball?

Answer: (a) 26.4 N (b) 21.5 N

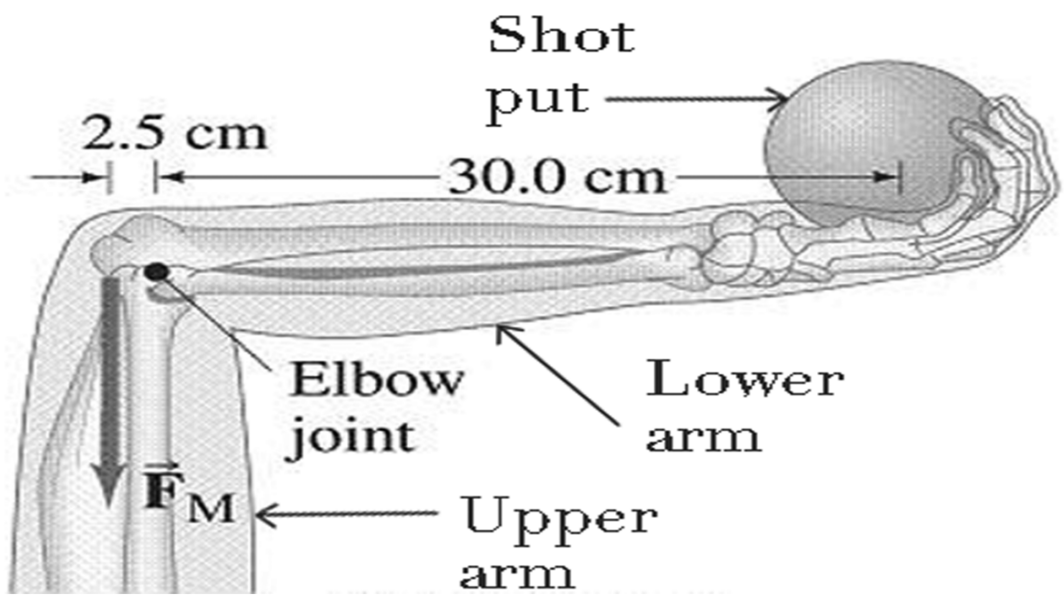
5) A nonuniform, 80.0-g, meterstick balances when the support is placed at the 51.0-cm mark. At what location on the meterstick should a 5.00-g tack be placed so that the stick will balance at the 50.0 cm mark?
   A) 16.0 cm
   B) 67.0 cm
   C) 66.0 cm
   D) 35.0 cm
   E) 34.0 cm

   Answer: E

6) A 30.0-kg child sits on one end of a long uniform beam having a mass of 20.0 kg, and a 40.0-kg child sits on the other end. The beam balances when a fulcrum is placed below the beam a distance 1.10 m from the 30.0-kg child. How long is the beam?
   A) 2.12 m
   B) 1.98 m
   C) 1.93 m
   D) 2.07 m
   E) 2.20 m

   Answer: B

7) In the figure, the horizontal lower arm has a mass of 2.8 kg and its center of gravity is 12 cm from the elbow joint pivot. How much force F_M must the vertical extensor muscle in the upper arm exert on the lower arm to hold a 7.5 kg shot put?

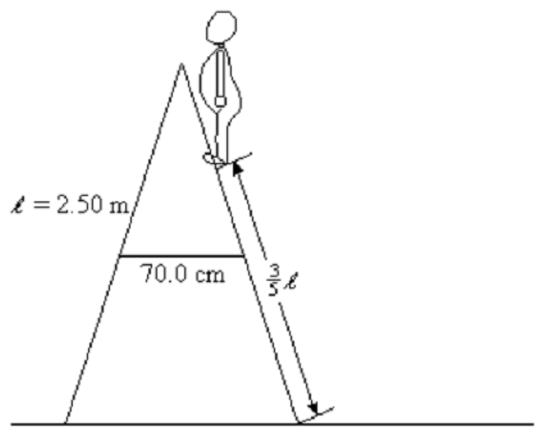


   A) 100 N
   B) 500 N
   C) 750 N
   D) 1000 N
   E) 1500 N

   Answer: D

8) A 5.0–m long, 12–kg uniform ladder rests against a smooth vertical wall with the bottom of the ladder 3.0 m from the wall. The coefficient of static friction between the floor and the ladder is 0.28. What distance, measured along the ladder from the bottom, can a 60 –kg person climb before the ladder starts to slip?
A) 4.0 m
B) 3.7 m
C) 1.7 m
D) 1.3 m
E) 3.3 m
Answer: C

9) A stepladder consists of two halves, hinged at the top, and connected by a tie rod that keeps the two halves from spreading apart. In this particular instance, the two halves are 2.50 m long, the tie rod is connected to the center of each half and is 70.0 cm long. An 800 –N person stands 3/5 of the way up the stepladder, as shown in the figure. Neglecting the weight of the ladder, and assuming that the ladder is resting on a smooth floor, what is the tension in the tie rod? ***Note:*** To solve this problem you must "cut" the ladder in half and consider the equilibrium of forces and torques acting on each half of the ladder.



A) 140 N
B) 240 N
C) 280 N
D) 360 N
E) 560 N
Answer: A

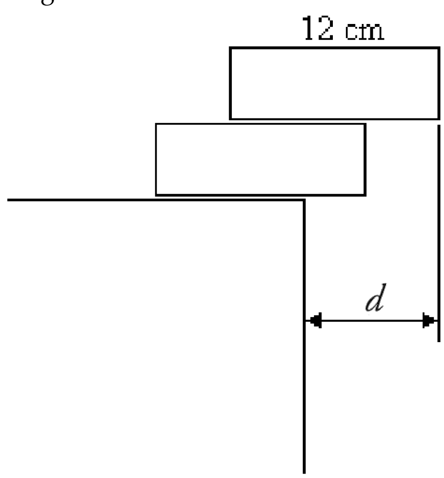
10) Two identical ladders are 3.0 m long and weigh 600 N each. They are connected by a hinge at the top and are held together by a horizontal rope, 1.0 m above the smooth floor forming a symmetric "A" arrangement. The angle between the ladders is 60° and both ladders have their center of gravity at their midpoint. What is the tension in the rope?
A) 240 N
B) 300 N
C) 220 N
D) 260 N
E) 280 N
Answer: E

11) A 120-kg refrigerator, 2.00 m tall and 85.0 cm wide, has its center of mass at its geometrical center. You are attempting to slide it along the floor by pushing horizontally on the side of the refrigerator. The coefficient of static friction between the floor and the refrigerator is 0.300. Depending on where you push, the refrigerator may start to tip over before it starts to slide along the floor. What is the highest distance above the floor that you can push the refrigerator so that it won't tip before it begins to slide?

A) 0.710 m
B) 1.00 m
C) 1.21 m
D) 1.42 m
E) 1.63 m

Answer: D

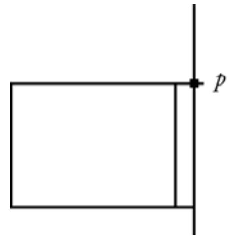
12) A child is trying to stack two uniform wooden blocks, 12 cm in length, so they will protrude as much as possible over the edge of a table, without tipping over, as shown in the figure. What is the maximum possible overhang distance d?



A) 5 cm
B) 6 cm
C) 7 cm
D) 8 cm
E) 9 cm

Answer: E

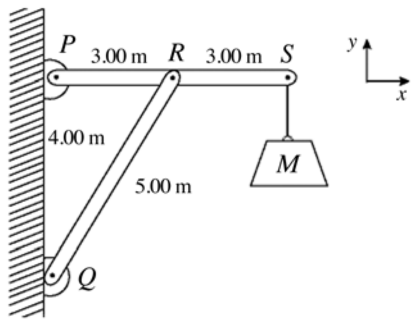
13) A uniform sign is supported against a wall at point P as shown in the figure. If the sign is a square 0.40 m on a side and its mass is 4.0 kg, what is the magnitude of the horizontal force that the wall at P experiences?



A) 20 N
B) 0.00 N
C) 7.8 N
D) 98 N

Answer: A

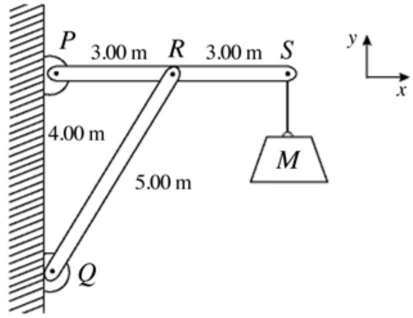
14) A uniform 300–kg beam, 6.00 m long, is freely pivoted at P, as shown in the figure. The beam is supported in a horizontal position by a light strut, 5.00 m long, which is freely pivoted at Q and is loosely pinned to the beam at R. A load of mass is suspended from the end of the beam at S. A maximum compression of 23,000 N in the strut is permitted, due to safety. The maximum mass M of the load is closest to



A) 789 kg.
B) 554 kg.
C) 1020 kg.
D) 1090 kg.
E) 1320 kg.

Answer: A

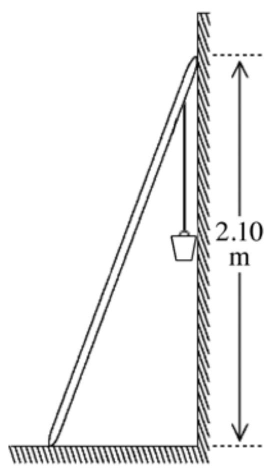
15) A uniform 300–kg beam, 6.00 m long, is freely pivoted at P, as shown in the figure. The beam is supported in a horizontal position by a light strut, 5.00 m long, which is freely pivoted at Q and is loosely pinned to the beam at R. A load of mass is suspended from the end of the beam at S. A maximum compression of 23,000 N in the strut is permitted, due to safety. Under maximum load, find the magnitude of the x component of the force exerted on the beam by the pivot at P.



A) 13,800 N
B) 12,800 N
C) 11,200 N
D) 14,400 N
E) 16,000 N

Answer: A

16) A 10.0–kg uniform ladder that is 2.50 m long is placed against a smooth vertical wall and reaches to a height of 2.10 m, as shown in the figure. The base of the ladder rests on a rough horizontal floor whose coefficient of static friction with the ladder is 0.800. An 80.0–kg bucket of concrete is suspended from the top rung of the ladder, right next to the wall, as shown in the figure. What is the magnitude of the friction force that the floor exerts on the ladder?



A) 538 N
B) 706 N
C) 1290 N
D) 833 N
E) 601 N

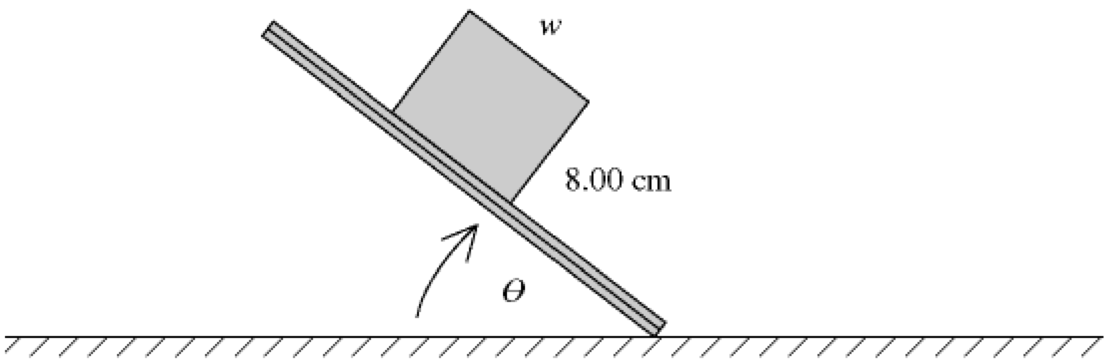
Answer: A

17) A dump truck has a large cubical concrete block in its bed. The coefficients of friction between this block and the floor of the bed are $\mu_k = 0.450$ and $\mu_s = 0.650$. As the bed is slowly tilted above the horizontal, will the brick first begin to slide or will it first tip over?

A) It will first tip over.
B) It will first begin to slide.
C) It will tip over just as it begins to slide.
D) It is impossible to answer without knowing the mass of the block.
E) It is impossible to answer without knowing the dimensions of the block.

Answer: B

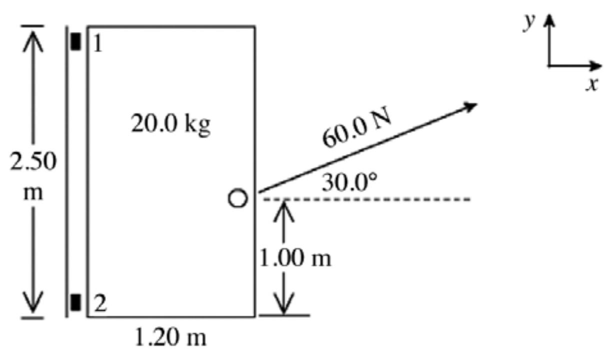
18) A solid uniform brick is placed on a sheet of wood. When one end of the sheet is raised (see figure), you observe that the maximum that the angle θ can be without tipping over the brick is 49.6°. There is enough friction to prevent the brick from sliding. What is the width w of the brick?



A) 5.18 cm
B) 6.09 cm
C) 6.81 cm
D) 9.40 cm
E) 10.5 cm

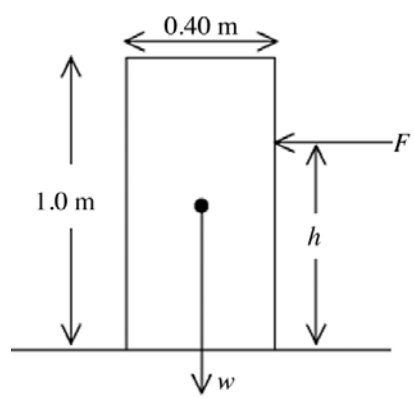
Answer: D

19) A 20.0–kg uniform door has a width of 1.20 m and a height of 2.50 m. The door is mounted on a post by a pair of hinges, marked 1 and 2 in the figure, at the top and bottom of the door. An external force of 60.0 N, at an angle of 30.0° above the horizontal, is applied to the small doorknob, as shown in the figure. The doorknob is 1.00 m above the bottom of the door.
(a) Find the x component of the force that hinge 1 exerts on the door at the top.
(b) Find the SUM of the y components of the forces that hinges 1 and 2 together exert on the door.



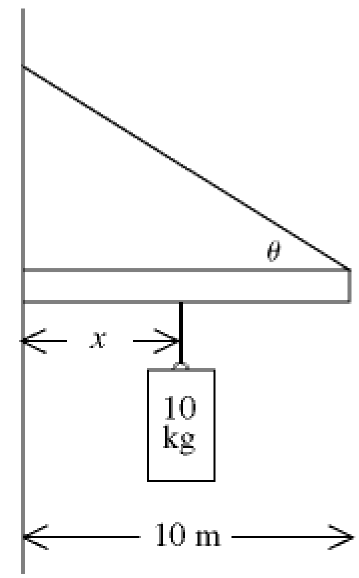
Answer: (a) -53.4 N (b) 166 N

20) In the figure, a uniform rectangular crate 0.40 m wide and 1.0 m tall rests on a horizontal surface. The crate weighs 930 N, and its center of gravity is at its geometric center. A horizontal force F is applied at a distance h above the floor. If h = 0.61 m, what minimum value of F is required to make the crate start to tip over? Static friction is large enough that the crate does not start to slide.



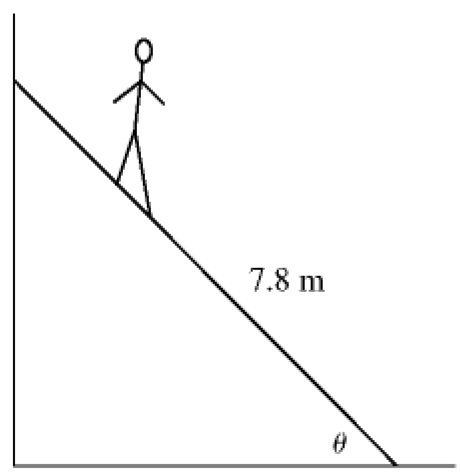
Answer: 305 N

21) In the figure, a 10.0–m long bar is attached by a frictionless hinge to a wall and held horizontal by a rope that makes an angle θ of 53° with the bar. The bar is uniform and weighs 39.9 N. How far from the hinge should a 10.0–kg mass be suspended for the tension T in the rope to be 125 N?



Answer: 8.15 m from the hinge

22) In the figure, a uniform ladder 12 meters long rests against a vertical frictionless wall. The ladder weighs 400 N and makes an angle θ of 79° with the floor. A man weighing 790 N climbs slowly up the ladder When he has climbed to a point that is 7.8 m from the base of the ladder, the ladder starts to slip. What is the coefficient of static friction between the floor and the ladder?



Answer: 0.12

Chapter 13 Oscillatory Motion

13.1 Conceptual Questions

1) The position x of an object varies with time t. For which of the following equations relating x and t is the motion of the object simple harmonic motion? (There may be more than one correct choice.)

A) $x = 5 \sin^2 3t$
B) $x = 8 \cos 3t$
C) $x = 4 \tan 2t$
D) $x = 5 \sin 3t$
E) $x = 2 \cos(3t - 1)$

Answer: B, D, E

2) A restoring force of magnitude F acts on a system with a displacement of magnitude x. In which of the following cases will the system undergo simple harmonic motion?

A) $F \propto \sqrt{x}$
B) $F \propto \sin x$
C) $F \propto x^2$
D) $F \propto x$
E) $F \propto 1/x$

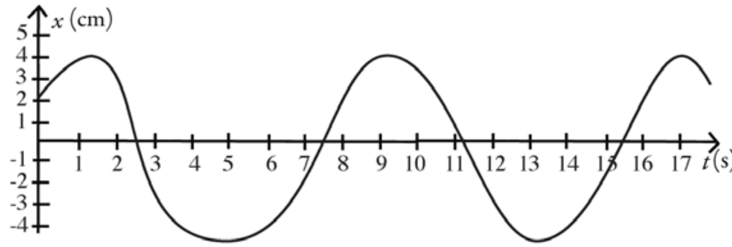
Answer: D

3) An object is executing simple harmonic motion. What is true about the acceleration of this object? (There may be more than one correct choice.)

A) The acceleration is a maximum when the displacement of the object is a maximum.
B) The acceleration is a maximum when the speed of the object is a maximum.
C) The acceleration is a maximum when the displacement of the object is zero.
D) The acceleration is zero when the speed of the object is a maximum.
E) The acceleration is a maximum when the object is instantaneously at rest.

Answer: A, D, E

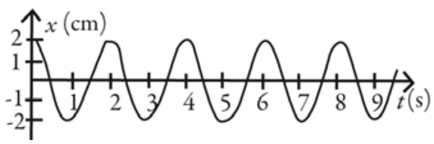
4) The simple harmonic motion of an object is described by the graph shown in the figure. What is the equation for the position $x(t)$ of the object as a function of time t?

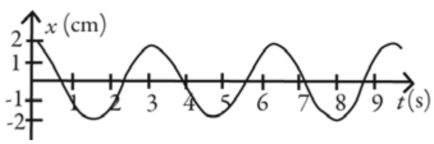


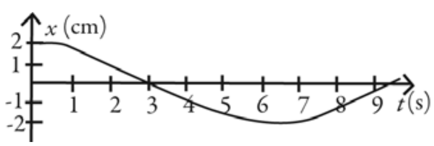
A) $x(t) = (4.0\text{ m})\sin[(2\pi/8.0\text{ s})t + \pi/3.0]$
B) $x(t) = (4.0\text{ m})\cos[(2\pi/8.0\text{ s})t + 2\pi/3.0]$
C) $x(t) = (4.0\text{ m})\cos[(2\pi/8.0\text{ s})t + \pi/3.0]$
D) $x(t) = (4.0\text{ m})\cos[(2\pi/8.0\text{ s})t - \pi/3.0]$
E) $x(t) = (8.0\text{ m})\cos[(2\pi/8.0\text{ s})t + \pi/3.0]$

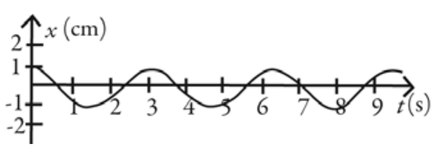
Answer: D

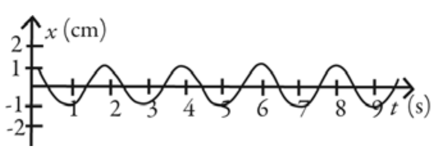
5) Which of following graphs describes simple periodic motion with amplitude 2.00 cm and angular frequency 2.00 rad/s?

A)


B)


C)


D)


E)


Answer: B

6) A mass M is attached to an ideal massless spring. When this system is set in motion with amplitude A, it has a period T. What is the period if the amplitude of the motion is increased to $2A$?
   A) $2T$
   B) $T/2$
   C) $\sqrt{2}T$
   D) $4T$
   E) T

   Answer: E

7) A mass M is attached to an ideal massless spring. When this system is set in motion, it has a period T. What is the period if the mass is doubled to $2M$?
   A) $2T$
   B) $T/2$
   C) $\sqrt{2}T$
   D) $4T$
   E) T

   Answer: C

8) In simple harmonic motion, the speed is greatest at that point in the cycle when
   A) the magnitude of the acceleration is a maximum.
   B) the displacement is a maximum.
   C) the magnitude of the acceleration is a minimum.
   D) the potential energy is a maximum.
   E) the kinetic energy is a minimum.

   Answer: C

9) If we double only the amplitude of a vibrating ideal mass-and-spring system, the mechanical energy of the system
   A) increases by a factor of $\sqrt{2}$.
   B) increases by a factor of 2.
   C) increases by a factor of 3.
   D) increases by a factor of 4.
   E) does not change.

   Answer: D

10) If we double only the mass of a vibrating ideal mass-and-spring system, the mechanical energy of the system
   A) increases by a factor of $\sqrt{2}$.
   B) increases by a factor of 2.
   C) increases by a factor of 3.
   D) increases by a factor of 4.
   E) does not change.

   Answer: E

11) If we double only the spring constant of a vibrating ideal mass-and-spring system, the mechanical energy of the system
   A) increases by a factor of $\sqrt{2}$.
   B) increases by a factor of 2.
   C) increases by a factor of 3.
   D) increases by a factor of 4.
   E) does not change.

   Answer: B

12) An object is attached to a vertical ideal massless spring and bobs up and down between the two extreme points A and B. When the kinetic energy of the object is a minimum, the object is located
   A) at either A or B.
   B) midway between A and B.
   C) 1/3 of the distance from A to B.
   D) 1/4 of the distance from A to B.
   E) $1/\sqrt{2}$ times the distance from A to B.

   Answer: A

13) A frictionless pendulum released from 65 degrees with the vertical will vibrate with the same frequency as if it were released from 5 degrees with the vertical because the period is independent of the amplitude and mass.
   A) True
   B) False

   Answer: B

14) A certain frictionless simple pendulum having a length L and mass M swings with period T. If both L and M are doubled, what is the new period?
   A) $4T$
   B) $2T$
   C) $\sqrt{2}T$
   D) T
   E) $T/4$

   Answer: C

15) A frictionless pendulum clock on the surface of the earth has a period of 1.00 s. On a distant planet, the length of the pendulum must be shortened slightly to have a period of 1.00 s. What is true about the acceleration due to gravity on the distant planet?
   A) The gravitational acceleration on the planet is slightly greater than g.
   B) The gravitational acceleration on the planet is slightly less than g.
   C) The gravitational acceleration on the planet is equal to g.
   D) We cannot tell because we do not know the mass of the pendulum.

   Answer: B

16) In designing buildings to be erected in an area prone to earthquakes, what relationship should the designer try to achieve between the natural frequency of the building and the typical earthquake frequencies?
A) The natural frequency of the building should be exactly the same as typical earthquake frequencies.
B) The natural frequency of the building should be very different from typical earthquake frequencies.
C) The natural frequency of the building should be almost the same as typical earthquake frequencies but slightly higher.
D) The natural frequency of the building should be almost the same as typical earthquake frequencies but slightly lower.

Answer: B

13.2 Problems

1) A sewing machine needle moves up and down in simple harmonic motion with an amplitude of 1.27 cm and a frequency of 2.55 Hz.
(a) What is the maximum speed of the needle?
(b) What is the maximum acceleration of the needle?

Answer: (a) 20.3 cm/s (b) 326 cm/s^2

2) An object is undergoing simple harmonic motion with frequency f = 9.7 Hz and an amplitude of 0.12 m. At t = 0.00 s the object is at x = 0.00 m. How long does it take the object to go from x = 0.00 m to x = 0.048 m?

Answer: 0.0068 seconds

3) A simple harmonic oscillator has an amplitude of 3.50 cm and a maximum speed of 26.0 cm/s. What is its speed when the displacement is 1.75 cm?
A) 12.0 cm/s
B) 22.5 cm/s
C) 14.2 cm/s
D) 15.0 cm/s
E) 17.0 cm/s

Answer: B

4) The position of an object that is oscillating on an ideal spring is given by the equation $x = (12.3 \text{ cm}) \cos[(1.26 s^{-1})t]$. At time t = 0.815 s,
(a) how fast is the object moving?
(b) what is the magnitude of the acceleration of the object?

Answer: (a) 13.3 cm/s (b) 10.1 cm/s^2

5) A machine part is vibrating along the x–axis in simple harmonic motion with a period of 0.27 s and a range (from the maximum in one direction to the maximum in the other) of 3.0 cm. At time $t = 0$ it is at its central position and moving in the $+x$ direction. What is its position when $t = 55$ s?
A) $x = -0.43$ cm
B) $x = -0.51$ cm
C) $x = +0.51$ cm
D) $x = -1.3$ cm
E) $x = -1.4$ cm

Answer: E

6) The x component of the velocity of an object vibrating along the x–axis obeys the equation $v_x(t) = (0.445 \text{ m/s}) \sin[(25.4 \text{ rad/s})t + 0.223]$.
(a) What is the amplitude of the motion of this object?
(b) What is the maximum acceleration of the vibrating object?

Answer: (a) 0.0175 m (b) 11.3 m/s^2

7) A 12.0–N object is oscillating in simple harmonic motion at the end of an ideal vertical spring. Its vertical position y as a function of time t is given by $y(t) = 4.50 \text{ cm} \cos[(19.5 \text{ s}^{-1})t - \pi/8]$.
(a) What is the spring constant of the spring?
(b) What is the maximum acceleration of the object?
(c) What is the maximum speed that the object reaches?
(d) How long does it take the object to go from its highest point to its lowest point?

Answer: (a) 466 N/m (b) 17.1 m/s^2 (c) 0.878 m/s (d) 0.161 s

8) An object of mass 8.0 kg is attached to an ideal massless spring and allowed to hang in the Earth's gravitational field. The spring stretches 3.6 cm before it reaches its equilibrium position. If this system is allowed to oscillate, what will be its frequency?
A) 2.6 Hz
B) 0.0045 Hz
C) 0.67 Hz
D) 2.1 Hz

Answer: A

9) An object that weighs 2.450 N is attached to an ideal massless spring and undergoes simple harmonic oscillations with a period of 0.640 s. What is the spring constant of the spring?
A) 2.45 N/m
B) 12.1 N/m
C) 24.1 N/m
D) 0.102 N/m
E) 0.610 N/m

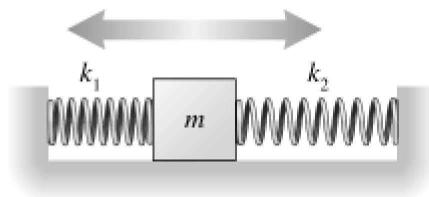
Answer: C

10) A 2.25–kg object is attached to a horizontal an ideal massless spring on a frictionless table. What should be the spring constant of this spring so that the maximum acceleration of the object will be g when it oscillates with amplitude of 4.50 cm?

Answer: 490 N/m

11) A 56 kg bungee jumper jumps off a bridge and undergoes simple harmonic motion. If the period of oscillation is 11.2 s, what is the spring constant of the bungee cord, assuming it has negligible mass compared to that of the jumper?
A) 17.6 N/m
B) 21.1 N/m
C) 28.2 N/m
Answer: A

12) A 2.0 kg block on a frictionless table is connected to two ideal massless springs with spring constants k_1 and k_2 whose opposite ends are fixed to walls, as shown in the figure. What is angular frequency of the oscillation if k_1= 7.6 N/m and k_2 = 5.0 N/m?

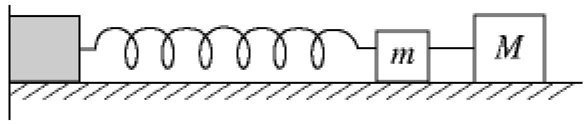


A) 2.5 rad/s
B) 3.5 rad/s
C) 0.40 rad/s
D) 0.56 rad/s
Answer: A

13) A 1.6-kg block on a horizontal frictionless surface is attached to an ideal massless spring whose spring constant is 190 N/m. The block is pulled from its equilibrium position at x = 0.00 m to a displacement x = +0.080 m and is released from rest. The block then executes simple harmonic motion along the horizontal x-axis. What is the velocity of the block at time t = 0.40 s?
A) 0.82 m/s
B) -0.82 m/s
C) 0.30 m/s
D) -0.30 m/s
E) 0.00 m/s
Answer: A

14) A 0.28-kg block on a horizontal frictionless surface is attached to an ideal massless spring whose spring constant is 500 N/m. The block is pulled from its equilibrium position at x = 0.00 m to a displacement x = +0.080 m and is released from rest. The block then executes simple harmonic motion along the horizontal x-axis. When the displacement is x = -0.052 m, find the acceleration of the block.
A) 92 m/s^2
B) 46 m/s^2
C) 69 m/s^2
D) 230 m/s^2
E) 280 m/s^2
Answer: A

15) In the figure, two masses, $M = 16$ kg and $m = 12.8.0$ kg, are connected to a very light rigid bar and are attached to an ideal massless spring of spring constant 100 N/m. The system is set into oscillation with an amplitude of 78 cm. At the instant when the acceleration is at its maximum, the 16–kg mass separates from the 12.8.0–kg mass, which then remains attached to the spring and continues to oscillate. What will be the amplitude of oscillation of the 12.8.0–kg mass?



A) 78 cm
B) 62 cm
C) 35 cm
D) 98 cm
E) 180 cm

Answer: A

16) A 2.00–kg object is attached to an ideal massless horizontal spring of spring constant 100.0 N/m and is at rest on a frictionless horizontal table. The spring is aligned along the x–axis and is fixed to a peg in the table. Suddenly this mass is struck by another 2.00–kg object traveling along the x–axis at 3.00 m/s, and the two masses stick together. What are the amplitude and period of the oscillations that result from this collision?
A) 0.300 m, 1.26 s
B) 0.300 m, 0.889 s
C) 0.424 m, 0.889 s
D) 0.424 m, 1.26 s
E) 0.424 m, 5.00 s

Answer: A

17) A 0.25 kg ideal harmonic oscillator has a total mechanical energy of 4.0 J. If the oscillation amplitude is 20.0 cm, what is the oscillation frequency?
A) 4.5 Hz
B) 1.4 Hz
C) 2.3 Hz
D) 3.2 Hz

Answer: A

18) A 0.50–kg object is attached to an ideal massless spring of spring constant 20 N/m along a horizontal, frictionless surface. The object oscillates in simple harmonic motion and has a speed of 1.5 m/s at the equilibrium position.
(a) What is the amplitude of vibration?
(b) At what location are the kinetic energy and the potential energy of the system the same?

Answer: (a) 0.24 m (b) $x = 0.17$ m

19) A 1.5–kg mass attached to an ideal massless spring with a spring constant of 20.0 N/m oscillates on a horizontal, frictionless track. At time $t = 0.00$ s, the mass is released from rest at $x = 10.0$ cm. (That is, the spring is stretched by 10.0 cm.)
(a) Find the frequency of the oscillations.
(b) Determine the maximum speed of the mass. At what point in the motion does the maximum speed occur?
(c) What is the maximum acceleration of the mass? At what point in the motion does the maximum acceleration occur?
(d) Determine the total energy of the oscillating system.
(e) Express the displacement x as a function of time t.

Answer: (a) 0.58 Hz (b) 0.37 m/s, at the equilibrium position
(c) 1.3 m/s^2, at maximum displacement
(d) 0.10 J
(e) $x = (0.10 \text{ m}) \cos(3.7t)$

20) A 0.025–kg block on a horizontal frictionless surface is attached to an ideal massless spring whose spring constant is 150 N/m. The block is pulled from its equilibrium position at $x = 0.00$ m to a displacement $x = +0.080$ m and is released from rest. The block then executes simple harmonic motion along the horizontal x–axis. When the displacement is $x = 0.024$ m, what is the kinetic energy of the block?
A) 0.44 J
B) 0.41 J
C) 0.46 J
D) 0.49 J
E) 0.52 J

Answer: A

21) An object of mass 6.8 kg is attached to an ideal massless spring of spring constant 1690 N/m. The object is Calculate the maximum speed the object reaches during its motion.

Answer: 5.5 m/s

22) An object weighing 44.1 N hangs from a vertical massless ideal spring. When set in vertical motion, the object obeys the equation $y(t) = (6.20 \text{ cm}) \cos[(2.74 \text{ rad/s})t - 1.40]$.
(a) Find the time for this object to vibrate one complete cycle.
(b) What are the maximum speed and maximum acceleration of the object.
(c) What is the TOTAL distance the object moves through in one cycle.
(d) Find the maximum kinetic energy of the object.
(e) What is the spring constant of the spring.

Answer: (a) 2.29 s (b) 0.170 m/s, 0.465 m/s^2
(c) 24.8 cm (d) 0.0649 J (e) 33.8 N/m

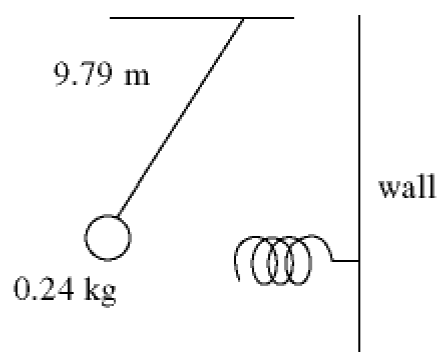
23) A frictionless simple pendulum on Earth has a period of 1.75 s. On Planet X its period is 2.14 s. What is the acceleration due to gravity on Planet X?

Answer: 6.55 m/s^2

24) The angle that a swinging simple pendulum makes with the vertical obeys the equation $\Theta(t) = (0.150 \text{ rad}) \cos[(2.85 \text{ rad/s})t + 1.66]$.
(a) What is the length of the pendulum?
A) 0.15 m
B) 0.83 m
C) 1.21 m
D) 2.02 m
E) It cannot be determined from the information given.
(b) What is the mass of the swinging bob at the end of the pendulum?
A) 2.85 kg
B) 1.66 kg
C) 0.454 kg
D) 0.150 kg
E) It cannot be determined from the information given.

Answer: (a) C (b) E

25) In the figure, a 0.24–kg ball is suspended from a very light string 9.79 m long and is pulled slightly to the left. As the ball swings without friction through the lowest part of its motion it encounters an ideal massless spring attached to the wall. The spring pushes against the ball and eventually the ball is returned to its original starting position. Find the time for one complete cycle of this motion if the spring constant of the spring is 21 N/m. (Assume that once the pendulum ball hits the spring there is no effect due to the vertical movement of the ball.)



Answer: 3.5 s

26) A long thin uniform rod of length 1.50 m is to be suspended from a frictionless pivot located at some point along the rod so that its pendulum motion takes 3.00 s. How far from the center of the rod should the pivot be located?
A) 7.98 cm
B) 7.52 cm
C) 8.73 cm
D) 8.40 cm
E) 23.4 cm

Answer: C

27) A uniform meter stick is freely pivoted about the 0.20-m mark. If it is allowed to swing in a vertical plane with a small amplitude and friction, what is the frequency of its oscillations?
A) 0.55 Hz
B) 0.66 Hz
C) 0.92 Hz
D) 1.1 Hz
E) 1.3 Hz

Answer: B

28) A large stick is pivoted about one end and allowed to swing back and forth with no friction as a physical pendulum. The mass of the stick is 5.40 kg and its center of gravity (found by finding its balance point) is 1.80 m from the pivot. If the period of the swinging stick is 6.90 seconds, what is the moment of inertia of the stick about an axis through the pivot?

Answer: 115 kg • m^2

29) The amplitude of a lightly damped harmonic oscillator decreases from 60.0 cm to 40.0 cm in 10.0 s. What will be the amplitude of the harmonic oscillator after another 10.0 s passes?
A) 20.0 cm
B) 167 cm
C) 30.0 cm
D) 0.00 cm
E) 26.7 cm

Answer: E

30) A lightly damped harmonic oscillator, with a damping force proportional to its speed, is oscillating with an amplitude of 0.500 cm at time $t = 0$. When $t = 8.20$ s, the amplitude has died down to 0.400 cm. At what value of t will the oscillations have an amplitude of 0.250 cm?
A) 18.5 s
B) 20.5 s
C) 16.5 s
D) 25.5 s
E) 5.13 s

Answer: D

31) An ideal massless spring with a spring constant of 2.00 N/m is attached to an object of 75.0 g. The system has a small amount of damping. If the amplitude of the oscillations decreases from 10.0 mm to 5.00 mm in 15.0 s, what is the magnitude of the damping constant b?
A) 0.00693 kg/s
B) 0.0462 kg/s
C) 0.00762 kg/s
D) 0.0100 kg/s
E) 0.00857 kg/s

Answer: A

32) A 2.15 kg lightly damped harmonic oscillator has an angular oscillation frequency of 0.261 rad/s. If the maximum displacement of 2.0 m occurs when $t = 0.00$ s, and the damping constant b is 0.74 kg/s what is the object's displacement when $t = 4.01$ s?
A) 0.50 m
B) 0.43 m
C) 0.58 m
D) 0.65 m

Answer: A

33) A 25 kg object is undergoing lightly damped harmonic oscillations. If the maximum displacement of the object from its equilibrium point drops to 1/3 its original value in 1.8 s, what is the value of the damping constant b?
A) 31 kg/s
B) 34 kg/s
C) 37 kg/s
D) 40 kg/s

Answer: A

34) A 5.0–kg block is attached to an ideal massless spring whose spring constant is 125 N/m. The block is pulled from its equilibrium position at $x = 0.00$ m to a position at $x = +0.687$ m and is released from rest. The block then executes lightly damped oscillation along the x–axis, and the damping force is proportional to the velocity. When the block first returns to $x = 0.00$ m, its x component of velocity is -2.0 m/s and its x component of acceleration is +5.6 m/s^2.
(a) What is the magnitude of the acceleration of the block upon release at $x = +0.687$ m.
(b) Find the damping constant b.

Answer: (a) 17.2 m/s^2 (b) 14 kg/s

35) An object of mass of 2.0 kg hangs from an ideal massless spring with a spring constant of 50 N/m. An oscillating force $F = (4.8 \text{ N}) \cos[(3.0 \text{ rad/s})t]$ is applied to the object. What is the amplitude of the resulting oscillations? You can neglect damping.
A) 0.15 m
B) 0.30 m
C) 1.6 m
D) 2.4 m
E) 0.80 m

Answer: A

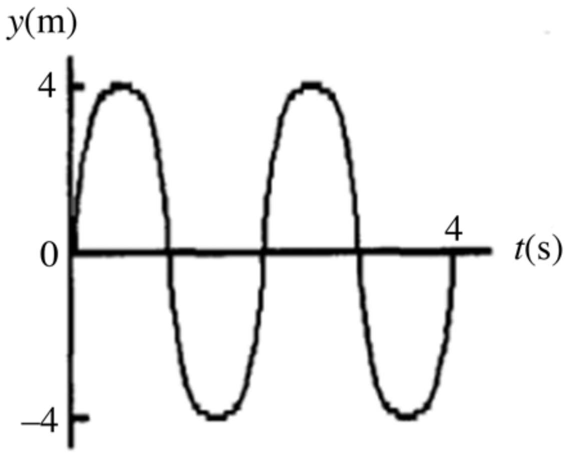
Chapter 14 Wave Motion

14.1 Conceptual Questions

1) Four traveling waves are described by the following equations, where all quantities are measured in SI units and y represents the displacement.
   I: $y = 0.12 \cos(3x - 21t)$
   II: $y = 0.15 \sin(6x + 42t)$
   III: $y = 0.13 \cos(6x + 21t)$
   IV: $y = -0.27 \sin(3x - 42t)$
   Which of these waves have the same period?
   A) I and III, and also II and IV
   B) I and IV, and also II and III
   C) I and II, and also III and IV
   D) All of them have the same period.
   E) They all have different periods.
   Answer: A

2) Four traveling waves are described by the following equations, where all quantities are measured in SI units and y represents the displacement.
   I: $y = 0.12 \cos(3x + 2t)$
   II: $y = 0.15 \sin(6x - 3t)$
   III: $y = 0.23 \cos(3x + 6t)$
   IV: $y = -0.29 \sin(1.5x - t)$
   Which of these waves have the same speed?
   A) I and III
   B) I and IV
   C) II and III
   D) I and II
   E) III and IV
   Answer: B

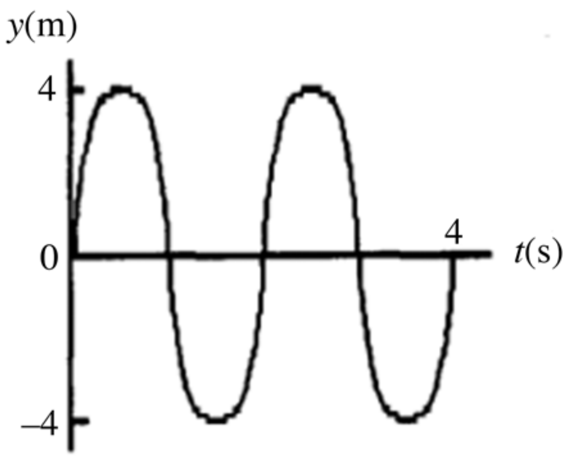
3) For the wave shown in the figure, the wavelength is



A) 8 m.
B) 4 m.
C) 2 m.
D) 1 m.
E) unable to be determined from the given information.

Answer: E

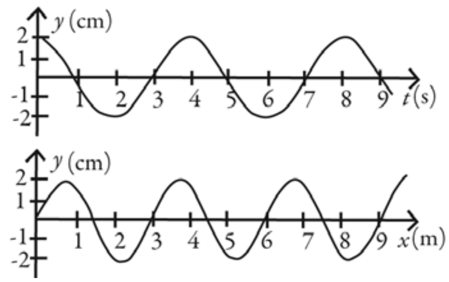
4) For the wave shown in the figure, the frequency is



A) 0.5 Hz.
B) 1 Hz.
C) 2 Hz.
D) 4 Hz.
E) unable to be determined from the given information.

Answer: A

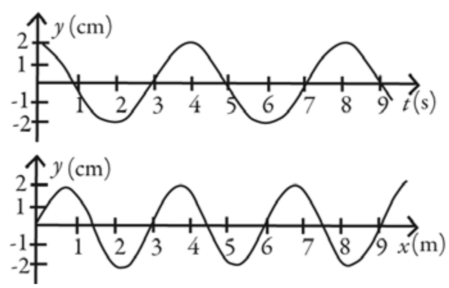
5) The figure shows the displacement y of a traveling wave at a given position as a function of time and the displacement of the same wave at a given time as a function of position. Determine the wavelength of the wave.



A) 2.0 cm
B) 3.0 m
C) 2.0 m
D) 4.0 m
E) 1.5 m

Answer: B

6) The figure shows the displacement y of a wave at a given position as a function of time and the displacement of the same wave at a given time as a function of position. Determine the frequency of the wave.



A) 4.0 Hz
B) 0.50 Hz
C) 3.0 Hz
D) 0.33 Hz
E) 0.25 Hz

Answer: E

7) When a weight W is hanging from a light vertical string, the speed of pulses on the string is V. If a second weight W is added without stretching the string, the speed of pulses on this string will now become

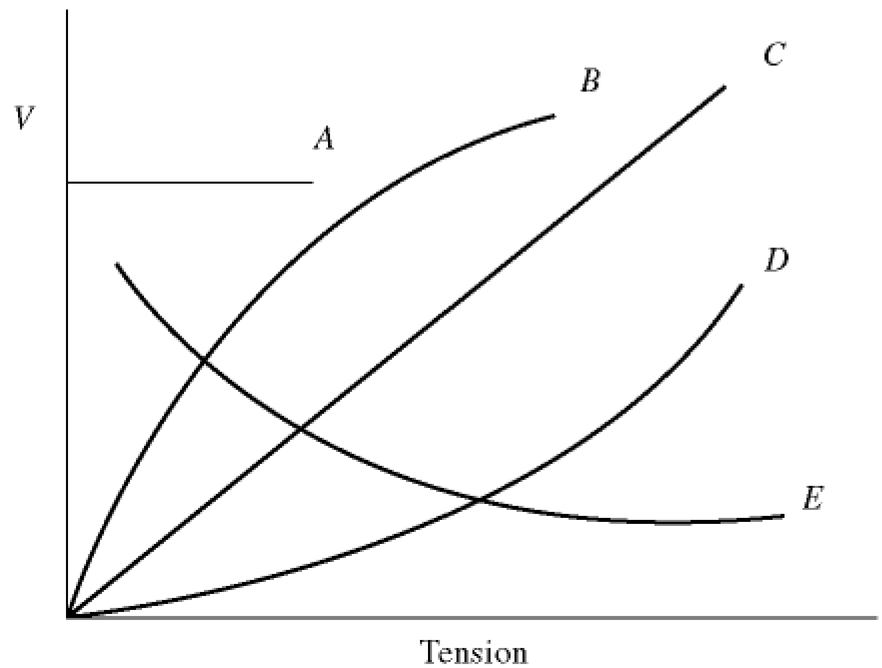
A) $2V$.
B) $\sqrt{2}V$.
C) V.
D) $V/\sqrt{2}$.
E) $V/2$

Answer: B

8) You are generating traveling waves on a stretched string by wiggling one end. If you suddenly begin to wiggle more rapidly without appreciably affecting the tension, you will cause the waves to move down the string
   A) faster than before.
   B) slower than before.
   C) at the same speed as before.

   Answer: C

9) In the figure, which of the curves best represents the variation of wave speed as a function of tension for transverse waves on a stretched string?



   A) A
   B) B
   C) C
   D) D
   E) E

   Answer: B

10) A transverse wave traveling along a string transports energy at a rate r. If we want to double this rate, we could
   A) increase the amplitude of the wave by a factor of 8.
   B) increase the amplitude of the wave by a factor of 4.
   C) increase the amplitude of the wave by a factor of 2.
   D) increase the amplitude by a factor of $\sqrt{2}$.
   E) increase the amplitude by a factor of $\sqrt{8}$.

   Answer: D

11) A wave pulse traveling to the right along a thin cord reaches a discontinuity where the rope becomes thinner and lighter. What is the orientation of the reflected and transmitted pulses?
   A) Both pulses are right side up.
   B) The reflected pulse returns right side up while the transmitted pulse is inverted.
   C) The reflected pulse returns inverted while the transmitted pulse is right side up.
   D) Both pulses are inverted.

   Answer: A

12) A wave pulse traveling to the right along a thin cord reaches a discontinuity where the rope becomes thicker and heavier. What is the orientation of the reflected and transmitted pulses?
   A) Both pulses are right side up.
   B) The reflected pulse returns right side up while the transmitted pulse is inverted.
   C) The reflected pulse returns inverted while the transmitted pulse is right side up.
   D) Both pulses are inverted.

   Answer: C

13) A guitar string is fixed at both ends. If you tighten it to increase its tension
   A) the frequencies of its vibrational modes will increase but its wavelengths will not be affected.
   B) the wavelength increases but the frequency is not affected.
   C) both the frequency and the wavelength increase.

   Answer: A

14) A tube open at one end and closed at the other end produces sound having a fundamental frequency of 350 Hz. If you now open the closed end, the fundamental frequency becomes
   A) 87.5 Hz.
   B) 175 Hz.
   C) 350 Hz.
   D) 700 Hz.
   E) 1400 Hz.

   Answer: B

15) Consider the waves on a vibrating guitar string and the sound waves the guitar produces in the surrounding air. The string waves and the sound waves must have the same
   A) wavelength.
   B) velocity.
   C) frequency.
   D) amplitude.
   E) More than one of the above is true.

   Answer: C

16) What characteristic of sound determines the "pitch" of a musical note?
   A) amplitude
   B) wavelength
   C) frequency
   D) phase
   E) intensity

   Answer: C

17) Which one of the following statements is true?
   A) Both the intensity level (in dB) and the sound intensity can never be negative.
   B) The intensity level (in dB) obeys an inverse-square distance law, but the sound intensity does not.
   C) Both intensity level (in dB) and sound intensity obey inverse-square distance laws.
   D) The sound intensity can never be negative, but the intensity level (in dB) can be negative.
   E) Both the intensity level (in dB) and the sound intensity can be negative.

Answer: D

18) A pipe that is 120 cm long resonates to produce sound of wavelengths 480 cm, 160 cm, and 96 cm but does not resonate at any wavelengths longer than these. This pipe is
   A) open at both ends.
   B) open at one end and closed at the other end.
   C) closed at both ends.
   D) We cannot tell because we do not know the frequency of the sound.

Answer: B

19) Consider a pipe of length L that is open at both ends. What are the wavelengths of the three lowest-pitch tones produced by this pipe?
   A) $4L$, $2L$, L
   B) $2L$, L, $L/2$
   C) $2L$, L, $2L/3$
   D) $4L$, $4L/3$, $4L/5$
   E) $2L$, L, $L/2$

Answer: C

20) The lowest-pitch tone to resonate in a pipe of length L that is open at both ends is 200 Hz. Which one of the following frequencies will NOT resonate in the same pipe?
   A) 400 Hz
   B) 600 Hz
   C) 800 Hz
   D) 900 Hz
   E) 1000 Hz

Answer: D

21) In a resonating pipe that is open at both ends, there
   A) are displacement nodes at each end.
   B) are displacement antinodes at each end.
   C) is a displacement node at one end and a displacement antinode at the other end.
   D) None of the above are possible.

Answer: B

22) In a resonating pipe that is open at one end and closed at the other end, there
   A) are displacement nodes at each end.
   B) are displacement antinodes at each end.
   C) is a displacement node at the open end and a displacement antinode at the closed end.
   D) is a displacement node at the closed end and a displacement antinode at the open end.

Answer: D

23) The lowest-pitch tone to resonate in a pipe of length L that is closed at one end and open at the other end is 200 Hz. Which one of the following frequencies will NOT resonate in the same pipe?
A) 400 Hz
B) 600 Hz
C) 1000 Hz
D) 1400 Hz
E) 1800 Hz

Answer: A

24) Two pure tones are sounded together and a particular beat frequency is heard. What happens to the beat frequency if the frequency of one of the tones is increased?
A) It increases.
B) It decreases.
C) It does not change.
D) It becomes zero.
E) We cannot tell from the information given.

Answer: E

25) When a rocket is traveling toward a mountain at 100 m/s, the sound waves from this rocket's engine approach the mountain at speed V. If the rocket doubles its speed to 200 m/s, the sound waves from the engine will now approach the mountain at speed
A) $4V$.
B) $2V$.
C) $\sqrt{2}V$.
D) V.

Answer: D

26) A plane flies toward a stationary siren at 1/4 the speed of sound. Then the plane stands still on the ground and the siren is driven toward it at 1/4 the speed of sound. In both cases, a person sitting in the plane will hear the same frequency of sound from the siren.
A) True
B) False

Answer: B

27) A stationary siren emits sound of frequency 1000 Hz and wavelength 0.343 m. An observer who is moving toward the siren will measure a frequency f and wavelength λ for this sound such that
A) $f > 1000$ Hz and $\lambda > 0.343$ m.
B) $f > 1000$ Hz and $\lambda = 0.343$ m.
C) $f > 1000$ Hz and $\lambda < 0.343$ m.
D) $f = 1000$ Hz and $\lambda < 0.343$ m.

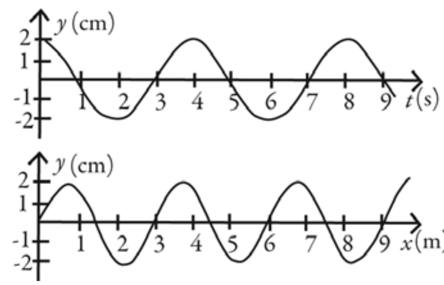
Answer: B

28) Shock waves occur when
A) the frequency of the waves is the resonant frequency of the system.
B) the amplitude of waves exceeds the critical shock value.
C) two waves from different sources collide with each other.
D) the wave source is traveling at a speed greater than the wave speed.
E) the period of the waves matches the lifetime of the waves.

Answer: D

14.2 Problems

1) The figure shows the displacement y of a traveling wave at a given position as a function of time and the displacement of the same wave at a given time as a function of position. How fast is the wave traveling?



A) 3.0 m/s
B) 0.75 m/s
C) 0.66 m/s
D) 1.5 m/s
E) 2.0 m/s

Answer: B

2) Ocean tides are waves that have a period of 12 hours, an amplitude (in some places) of 1.50 m, and a speed of 750 km/hr. What is the distance between adjacent crests of these waves?
A) 9000 km
B) 32,400 km
C) 9000 m
D) 32,400 m
E) 2500 m

Answer: A

3) The vertical displacement $y(x,t)$ of a string stretched along the horizontal x–axis is given by $y(x,t) = (6.00 \text{ mm}) \cos[(3.25 \text{ m}^{-1})x - (7.22 \text{ rad/s})t]$.
(a) What is the minimum time for each complete cycle of the wave?
(b) What is the distance between adjacent crests of the wave?
(c) How fast does this wave travel?

Answer: (a) 0.870 s (b) 1.93 m (c) 2.22 m/s

4) A transverse wave is traveling on a string stretched along the horizontal x–axis. The equation for the vertical displacement y of the string is given by $y = 0.0020 \cos[\pi(15x - 52t)]$, where all quantities are in SI units. The maximum speed of a particle of the string is closest to
A) 0.33 m/s.
B) 0.43 m/s.
C) 0.53 m/s.
D) 0.64 m/s.
E) 0.74 m/s.

Answer: A

5) Find the speed of an ocean wave whose vertical displacement y as a function of time t is given by $y(x,t) = 3.7 \cos(2.2x - 5.6t)$, where all quantities are in SI units.
A) 2.5 m/s
B) 1.9 m/s
C) 3.5 m/s
D) 4.5 m/s

Answer: A

6) You and your surfing buddy are waiting to catch a wave a few hundred meters off the beach. The waves are conveniently sinusoidal, and you notice that when you're on the top of one wave and moving toward your friend, she is exactly halfway between you and the trough of the wave. 1.50 seconds later, your friend is at the top of the wave. You estimate the horizontal distance between you and your friend at 8.00 m.
(a) What is the frequency of the waves?
(b) Find the speed of the waves.

Answer: (a) 0.167 Hz (b) 5.33 m/s

7) Waves travel along a 100–m length of string which has a mass of 55 g and is held taut with a tension of 75 N. What is the speed of the waves?
A) 3700 m/s
B) 370 m/s
C) 37 m/s
D) 0.37 m/s
E) 3.7 m/s

Answer: B

8) A 6.00–m long rope is under a tension of 600 N. Waves travel along this rope at 40.0 m/s. What is the mass of the rope?
A) 1.00 kg
B) 1.25 kg
C) 2.25 kg
D) 2.50 kg
E) 1.12 kg

Answer: C

9) The density of aluminum is 2700 kg/m^3. If transverse waves propagate at 34 m/s in a 4.6–mm diameter aluminum wire, what is the tension on the wire?
A) 52 N
B) 31 N
C) 42 N
D) 62 N
Answer: A

10) A 6.0–m wire with a mass of 50 g, is under tension. A transverse wave, for which the frequency is 810 Hz, the wavelength is 0.40 m, and the amplitude is 4.0 mm, is propagating on the wire. The time for a crest of this wave to travel the length of the wire is closest to
A) 19 ms.
B) 16 ms.
C) 21 ms.
D) 23 ms.
E) 25 ms.
Answer: A

11) A 8.0–m long wire with a mass of 10 g is under tension. A transverse wave for which the frequency is 570 Hz, the wavelength is 0.10 m, and the amplitude is 3.7 mm is propagating on the wire. The maximum transverse acceleration of a point on a wire is closest to
A) 47,000 m/s^2.
B) 41,000 m/s^2.
C) 35,000 m/s^2.
D) 29,000 m/s^2.
E) 53,000 m/s^2.
Answer: A

12) A heavy stone of mass *m* is hung from the ceiling by a thin 8.25–g wire that is 65.0 cm long. When you gently pluck the upper end of the wire, a pulse travels down the wire and returns 7.84 ms later, having reflected off the lower end. The stone is heavy enough to prevent the lower end of the wire from moving. What is the mass *m* of the stone?
A) 8.90 kg
B) 23.1 kg
C) 35.6 kg
D) 227 kg
E) 349 kg
Answer: C

13) Two people are talking at a distance of 3.0 m from where you are and you measure the sound intensity as 1.1×10^{-7} W/m^2. Another student is 4.0 m away from the talkers. What sound intensity does the other student measure? Assume that the sound spreads out uniformly and undergoes no significant reflections or absorption.

A) 6.2×10^{-8} W/m^2
B) 1.5×10^{-7} W/m^2
C) 8.3×10^{-8} W/m^2
D) 7.8×10^{-7} W/m^2
E) 2.5×10^{-8} W/m^2

Answer: A

14) Calculate the light intensity 1.51 m from a light bulb that emits 100 W of visible light, assuming that the light radiates uniformly in all directions.

A) 3.49 W/m^2
B) 4.01 W/m^2
C) 43.9 W/m^2
D) 50.5 W/m^2

Answer: A

15) The intensity of sunlight falling on the earth is about 1.4 kW/m^2 (before any gets absorbed by our atmosphere). At what rate does the sun emit light energy? (The earth–sun distance = 1.5×10^8 km and the earth's radius = 6.4×10^3 km.)

A) 4.0×10^{26} W
B) 3.2×10^{22} W
C) 7.2×10^{14} W
D) 7.6×10^8 W

Answer: A

16) Observer *A* is 3.0 m from a tiny light bulb and observer *B* is 12.0 m from the same bulb. Assume that the light spreads out uniformly and undergoes no significant reflections or absorption. If observer *B* sees a light of intensity *I*, the light intensity that *A* sees is

A) *I*.
B) 9*I*.
C) 16*I*.
D) 36*I*.
E) 144*I*.

Answer: C

17) A tiny vibrating source sends waves uniformly in all directions. An area of 3.25 cm^2 on a sphere of radius 2.50 m centered on the source receives energy at a rate of 4.20 J/s.
(a) What is the intensity of the waves at 2.50 m from the source and at 10.0 m from the source?
(b) At what rate is energy leaving the vibrating source of the waves?

Answer: (a) 12,900 W/m^2 (at 2.50 m), 808 W/m^2 (at 10.0 m)
(b) 1.01×10^6 W

18) A 2.00–m long piano wire with a mass per unit length of 12.0 g/m is under a tension of 8.00 kN. What is the frequency of the fundamental mode of vibration of this wire?
A) 204 Hz
B) 102 Hz
C) 408 Hz
D) 510 Hz
E) 153 Hz

Answer: A

19) A platinum wire that is 1.20 m long has a radius of 0.500 mm and is fixed at both ends. In its third harmonic it vibrates at 512 Hz. The density of platinum is 21.4×10^3 kg/m^3. What is the tension in the wire?
A) 4.00 kN
B) 2.00 kN
C) 2.82 kN
D) 1.41 kN
E) 1.00 kN

Answer: C

20) A thin taut string is fixed at both ends and stretched along the horizontal x–axis with its left end at $x = 0$. It is vibrating in its third OVERTONE, and the equation for the vertical displacement of any point on the string is $y(x,t) = (1.22\text{ cm}) \sin[(14.4\text{ m}^{-1})x] \cos[(166\text{ rad/s})t]$.
(a) What are the frequency and wavelength of the fundamental mode of this string?
(b) How long is the string?
(c) How fast do waves travel on this string?

Answer: (a) 6.60 Hz, 1.75 m (b) 0.873 m (c) 11.5 m/s

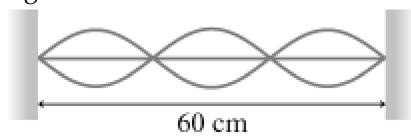
21) A thin 2.00–m string of mass 50.0 g is fixed at both ends and under a tension of 70.0 N. If it is set into small–amplitude oscillation, what is the frequency of the first harmonic mode?
A) 6.61 Hz
B) 13.2 Hz
C) 26.5 Hz
D) 52.9 Hz

Answer: B

22) A guitar string 0.650 m long has a tension of 61.0 N and a mass per unit length of 3.00 g/m.
(a) What is the speed of waves on the string when it is plucked?
(b) What is the string's fundamental frequency of vibration when plucked?

Answer: (a) 143 m/s (b) 110 Hz

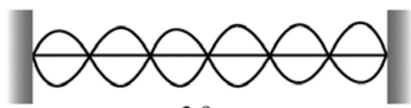
23) A standing wave is oscillating at 690 Hz on a string, as shown in the figure. What is the speed of traveling waves on this string?



A) 280 m/s
B) 410 m/s
C) 210 m/s
D) 140 m/s

Answer: A

24) A 2.0–m string is fixed at both ends and tightened until the wave speed is 78 m/s. What is the frequency of the standing wave shown in the figure?



A) 120 Hz
B) 230 Hz
C) 350 Hz
D) 470 Hz

Answer: A

25) A 1.0–g string that is 0.64 m long is fixed at both ends and is under tension. This string produces a 100–Hz tone when it vibrates in the third harmonic. The speed of sound in air is 344 m/s. The tension in the string, in is closest to

A) 2.8 N.
B) 2.3 N.
C) 1.8 N.
D) 3.4 N.
E) 3.9 N.

Answer: A

26) A heavy stone of mass *m* is hung from the ceiling by a thin 8.25–g wire that is 65.0 cm long. When you gently pluck the upper end of the wire, a pulse travels down the wire and returns 7.84 ms later, having reflected off the lower end. The speed of sound in the room is 344 m/s, and the stone is heavy enough to prevent the lower end of the wire from moving. If the wire is vibrating in its second overtone, what is the frequency of the sound it will produce?

A) 128 Hz
B) 191 Hz
C) 255 Hz
D) 383 Hz
E) 765 Hz

Answer: D

27) A heavy stone of mass m is hung from the ceiling by a thin 8.25-g wire that is 65.0 cm long. When you gently pluck the upper end of the wire, a pulse travels down the wire and returns 7.84 ms later, having reflected off the lower end. The speed of sound in the room is 344 m/s, and the stone is heavy enough to prevent the lower end of the wire from moving. If the wire is vibrating in its second overtone, what is the wavelength of the sound it will produce?
A) 0.217 m
B) 0.433 m
C) 0.650 m
D) 0.899 m
E) 1.35 m

Answer: D

28) Two violinists are trying to tune their instruments in an orchestra. One is producing the desired frequency of 440.0 Hz. The other is producing a frequency of 448.4 Hz. By what percentage should the out-of-tune musician change the tension in his string to bring his instrument into tune at 440.0 Hz?
A) +1.9%
B) -1.9%
C) +3.7%
D) -3.7%
E) +8.4%

Answer: D

29) Standing waves of frequency 57 Hz are produced on a string that has mass per unit length 0.0160 kg/m. With what tension must the string be stretched between two supports if adjacent nodes in the standing wave are to be 0.71 meters apart?

Answer: 100 N

30) A certain source of sound waves radiates uniformly in all directions. At a distance of 20 m from the source the intensity level is 51 db. What is the total acoustic power output of the source, in watts? (Note: The reference intensity I_0 is 1.0×10^{-12} W/m^2.)

Answer: 6.3×10^{-4} W

31) A howler monkey is the loudest land animal and, under some circumstances, can be heard up to a distance of 5.0 km. Assume the acoustic output of a howler to be uniform in all directions and that the threshold of hearing is 1.0×10^{-12} W/m^2. The acoustic power emitted by the howler is closest to
A) 0.31 mW.
B) 0.11 mW.
C) 1.1 mW.
D) 3.2 mW.
E) 11 mW.

Answer: A

32) The howler monkey is the loudest land animal and, under some circumstances, can be heard up to a distance of 8.9 km. Assume the acoustic output of a howler to be uniform in all directions and that the threshold of hearing is 1.0×10^{-12} W/m^2. A juvenile howler monkey has an acoustic output of 63 μW. What is the ratio of the acoustic intensity produced by the juvenile howler to the reference intensity I_0, at a distance of 210 m?

A) 110
B) 230
C) 76
D) 170
E) 300

Answer: A

33) An enclosed chamber with sound absorbing walls has a 2.0 m × 1.0 m opening for an outside window. A loudspeaker is located outdoors,, 78 m away and facing the window. The intensity level of the sound entering the window space from the loudspeaker is 79 dB. Assume the acoustic output of the loudspeaker is uniform in all directions and that the acoustic energy incident upon the ground is completely absorbed and therefore is not reflected into the window. The threshold of hearing is 1.0×10^{-12} W/m^2. The acoustic power entering through the window space is closest to

A) 160 μW.
B) 79 μW.
C) 320 μW.
D) 790 μW.
E) 1600 μW.

Answer: A

34) An enclosed chamber with sound absorbing walls has a 2.0 m × 1.0 m opening for an outside window. A loudspeaker is located outdoors, 84 m away and facing the window. The intensity level of the sound entering the window space from the loudspeaker is 56 dB. Assume the acoustic output of the loudspeaker is uniform in all directions and that acoustic energy incident upon the ground is completely absorbed and therefore is not reflected into the window. The threshold of hearing is 1.0×10^{-12} W/m^2. The acoustic power output of the loudspeaker is closest to

A) 0.035 W.
B) 0.070 W.
C) 0.18 W.
D) 0.35 W.
E) 0.70 W.

Answer: A

35) A sound source emits 20.0 W of acoustical power spread equally in all directions. The threshold of hearing is 1.0×10^{-12} W/m^2. What is the sound intensity level 30.0 m from the source?

A) 92.5 dB
B) 81.5 dB
C) 1.77×10^{-3} dB
D) 1.77×10^{-3} W
E) –27.5 dB

Answer: A

36) The sound level at 1.0 m from a certain talking person talking is 60 dB. You are surrounded by five such people, all 1.0 m from you and all talking equally loud at the same time. The threshold of hearing is 1.0×10^{-12} W/m^2. What sound level are you being exposed to? You can neglect any absorption, reflection, or interference of the sound. The threshold of hearing is 1.0×10^{-12} W/m^2.

A) 300 dB
B) 60 dB
C) 74 dB
D) 67 dB
E) 81 dB

Answer: D

37) A certain crying baby emits sound with an intensity of 8.0×10^{-8} W/m^2. What is the intensity level due to a set of five such crying babies, all crying with the same intensity? You can neglect any absorption, reflection, or interference of the sound. The lowest detectable intensity is 1.0×10^{-12} W/m^2.

A) 79 dB
B) 69 dB
C) 56 dB
D) 49 dB
E) 36 dB

Answer: C

38) The intensity level of a "Super-Silent" power lawn mower at a distance of 1.0 m is 100 dB. You wake up one morning to find that four of your neighbors are all mowing their lawns using identical "Super-Silent" mowers. When they are each 20 m from your open bedroom window, what is the intensity level of the sound in your bedroom? You can neglect any absorption, reflection, or interference of the sound. The lowest detectable intensity is 1.0×10^{-12} W/m^2.

A) 80 dB
B) 104 dB
C) 400 dB
D) 50 dB
E) 40 dB

Answer: A

39) If the intensity level at distance d of one trombone is 70 dB, what is the intensity level of 76 identical trombones, all at distance d?

A) 146 dB
B) 89 dB
C) 5320 dB
D) 76 dB
E) 82 dB

Answer: B

40) At a distance of 2.00 m from a point source of sound, the intensity level is 80.0 dB. What will be the intensity level at a distance of 4.00 m from this source? The lowest detectable intensity is 1.0×10^{-12} W/m^2.

A) 77.0 dB
B) 74.0 dB
C) 60.0 dB
D) 40.0 dB
E) 20.0 dB

Answer: B

41) The speed of sound in the air inside a 0.640–m long gas column is 340 m/s. What is the fundamental resonant frequency of this air column if it is
(a) open at one end and closed at the other end?
(b) open at both ends?

Answer: (a) 133 Hz (b) 266 Hz

42) A 1.30–m long gas column that is open at one end and closed at the other end has a fundamental resonant frequency 80.0 Hz. What is the speed of sound in this gas?

A) 104 m/s
B) 61.5 m/s
C) 26.0 m/s
D) 246 m/s
E) 416 m/s

Answer: E

43) An air column, open at one end and closed at the other, is being designed so that its second lowest resonant frequency is 440 Hz. What should be the length of the column if the speed of sound in air is 340 m/s?

A) 0.386 m
B) 0.772 m
C) 1.16 m
D) 0.193 m
E) 0.580 m

Answer: E

44) One of the harmonics of a column of air open at one end and closed at the other has a frequency of 448 Hz and the next higher harmonic has a frequency of 576 Hz. What is the fundamental frequency of the air column?

A) 32 Hz
B) 64 Hz
C) 88 Hz
D) 128 Hz
E) 256 Hz

Answer: B

45) A violin with string length 32 cm and string density 1.5 g/cm resonates with the first overtone from a 2.0–m long organ pipe with one end closed and the other end open. What is the tension in the string?
A) 1000 N
B) 110 N
C) 450 N
D) 4100 N
E) 56 N

Answer: A

46) 50) A 0.25–m string, vibrating in its sixth harmonic, excites a 0.96–m pipe that is open at both ends into its second overtone resonance. The speed of sound in air is 345 m/s. The common resonant frequency of the string and the pipe is closest to
A) 540 Hz.
B) 360 Hz.
C) 450 Hz.
D) 630 Hz.
E) 700 Hz.

Answer: A

47) A string, 0.28 m long and vibrating in its third harmonic, excites an open pipe that is 0.82 m long into its second overtone resonance. The speed of sound in air is 345 m/s. The speed of transverse waves on the string is closest to
A) 120 m/s.
B) 110 m/s.
C) 100 m/s.
D) 98 m/s.
E) 91 m/s.

Answer: A

48) A pipe that is 0.46 m long and open at both ends vibrates in the second overtone with a frequency of 1150 Hz. In this situation, the distance from the center of the pipe to the nearest antinode is closest to
A) 7.7 cm.
B) 3.8 cm.
C) 12 cm.
D) 15 cm.
E) zero.

Answer: A

49) A pipe is 0.90 m long and is open at one end but closed at the other end. If it resonates with a tone whose wavelength is 0.72 m, what is the wavelength of the next higher overtone in this pipe?
A) 0.36 m
B) 0.40 m
C) 0.45 m
D) 0.51 m
E) 0.58 m

Answer: D

50) An organ pipe open at both ends has two successive harmonics with frequencies of 210 Hz and 240 Hz. What is the length of the pipe? The speed of sound is 344 m/s in air.
A) 5.25 m
B) 5.73 m
C) 2.76 m
D) 4.90 m
E) 3.62 m

Answer: B

51) A string 40.0 cm long of mass 8.50 g is fixed at both ends and is under a tension of 425 N. When this string is vibrating in its third OVERTONE, you observe that it causes a nearby pipe, open at both ends, to resonate in its third HARMONIC. The speed of sound in the room is 344 m/s.
(a) How long is the pipe?
(b) What is the fundamental frequency of the pipe?

Answer: (a) 0.730 m (b) 236 Hz

52) The sound from a single source can reach point *O* by two different paths. One path is 20.0 m long and the second path is 21.0 m long. The sound destructively interferes at point *O*. What is the minimum frequency of the source if the speed of sound is 340 m/s?
A) 340 Hz
B) 6800 Hz
C) 520 Hz
D) 680 Hz
E) 170 Hz

Answer: E

53) Two in–phase loudspeakers that emit sound with the same frequency are placed along a wall and are separated by a distance of 5.00 m. A person is standing 12.0 m away from the wall, equidistant from the loudspeakers. When the person moves 1.00 m parallel to the wall, she experiences destructive interference for the first time. What is the frequency of the sound? The speed of sound in air is 343 m/s.
A) 211 Hz
B) 256 Hz
C) 422 Hz
D) 512 Hz
E) 674 Hz

Answer: C

54) Two in–phase loudspeakers that emit sound with the same frequency are placed along a wall and are separated by a distance of 8.00 m. A person is standing 12.0 m away from the wall, equidistant from the loudspeakers. When the person moves 3.00 m parallel to the wall, she experiences destructive interference for the second time. What is the frequency of the sound? The speed of sound in the room is 343 m/s. CAREFUL! The distance to the wall is NOT much greater than the distance between the speakers.
A) 278 Hz
B) 422 Hz
C) 452 Hz
D) 562 Hz
E) 694 Hz

Answer: A

55) Two stereo speakers mounted 4.52 m apart on a wall emit identical in–phase sound waves. You are standing at the opposite wall of the room at a point directly between the two speakers. You walk 2.11 m parallel to the wall, to a location where you first notice that the sound intensity drops to zero. If the wall along which you are walking is 10.7 m from the wall with the speakers, what is the wavelength of the sound waves? CAREFUL! The distance to the wall is NOT much greater than the distance between the speakers.
A) 1.7 m
B) 2.1 m
C) 2.6 m
D) 2.9 m

Answer: A

56) Radio station KBOB broadcasts at a frequency of 85.7 MHz on your dial using radio waves that travel at 3.00×10^8 m/s. Since most of the station's audience is due south of the transmitter, the managers of KBOB don't want to waste any energy broadcasting to the east and west. They decide to build two towers, transmitting in phase at exactly the same frequency, aligned on an east–west axis. For engineering reasons, the two towers must be AT LEAST 10.0 m apart. What is the shortest distance between the towers that will eliminate all broadcast power to the east and west?

Answer: 12.3 m

57) Two loudspeakers placed 6.0 m apart are driven in phase by an audio oscillator whose frequency range is 2193 Hz to 2967 Hz. A point P is located 4.4 m from one loudspeaker and 3.6 m from the other. The speed of sound is 344 m/s. The frequency produced by the oscillator, for which constructive interference of sound occurs at point P, is closest to
A) 2580 Hz.
B) 2903 Hz.
C) 2473 Hz.
D) 2795 Hz.
E) 2688 Hz.

Answer: A

58) Two identical loudspeakers that are 5.00 m apart and face toward each other are driven in phase by the same oscillator at a frequency of 875 Hz. The speed of sound in the room is 344 m/s. If you start out standing midway between the speakers, find the shortest distance you can walk toward either speaker in order to hear a minimum of sound.
A) 0.0983 m
B) 0.197 m
C) 0.295 m
D) 0.393 m
E) 0.590 m

Answer: A

59) A person is hearing two sound waves simultaneously. One has a period of 1.50 ms and the other one a period of 1.54 ms. What is the period of the beat due to these two waves?
A) 0.040 ms
B) 1.5 ms
C) 3.0 ms
D) 58 ms
E) 330 ms

Answer: D

60) Two harmonic sound waves reach an observer simultaneously. The observer hears the sound intensity rise and fall with a time of 0.200 s between the maximum intensity and the succeeding minimum intensity. What is the difference in frequency of the two sound waves?
A) 10.0 Hz
B) 0.200 Hz
C) 5.00 Hz
D) 2.50 Hz
E) 1.25 Hz

Answer: D

61) Two motors in a factory are running at slightly different rates. One runs at 825 rpm and the other at 786 rpm. You hear the sound intensity increase and then decrease periodically due to wave interference. How much time elapses between successive maxima of the sound intensity?
A) 1.5 s
B) 1.4 s
C) 1.7 s
D) 1.8 s

Answer: A

62) The tension in each of two strings is adjusted so that both vibrate at exactly 666 Hz. The tension in one of the strings is then increased slightly. As a result, six beats per second are heard when both strings vibrate. What is the new frequency of the string that was tightened?
A) 672 Hz
B) 660 Hz
C) 669 Hz
D) 663 Hz

Answer: A

63) Two strings of identical material and radius are stretched with the same tension with their ends fixed, but one string is 8.0 mm longer than the other. Waves on these strings propagate at 420 m/s. The fundamental frequency of the longer string is 528 Hz. What is the beat frequency when each string is vibrating at its fundamental frequency?
A) 22 Hz
B) 11 Hz
C) 16 Hz
D) 5.5 Hz
E) 27 Hz
Answer: B

64) A woman is riding a bicycle at 18.0 m/s along a straight road that runs parallel to and right next to some railroad tracks. She hears the whistle of a train that is behind. The frequency emitted by the train is 840 Hz, but the frequency the woman hears is 778 Hz. Take the speed of sound to be 340 m/s.
(a) What is the speed of the train, and is the train traveling away from or toward the bicycle?
(b) What frequency is heard by a stationary observer located between the train and the bicycle?
Answer: (a) 7.67 m/s, away from the bicycle (b) 821 Hz

65) A factory siren indicating the end of a shift has a frequency of 90.0 Hz. The speed of sound is 343 m/s.
(a) What frequency is perceived by the occupant of a car traveling towards the factory at 25.0 m/s?
(b) What frequency is perceived by the occupant of a car traveling away from the factory at 30.0 m/s?
Answer: (a) 96.6 Hz (b) 82.1 Hz

66) As you stand by the side of the road, a car approaches you at a constant speed, sounding its horn, and you hear a frequency of 80.0 Hz. After the car goes by, you hear a frequency of 60.0 Hz. What is the speed of the car? The speed of sound in the air is 343 m/s.
A) 64.0 m/s
B) 49.0 m/s
C) 16.0 m/s
D) 36.0 m/s
E) 25.0 m/s
Answer: B

67) A boy on a bicycle approaches a brick wall as he sounds his horn at a frequency 400.00 Hz. The sound he hears reflected back from the wall is at a frequency 408.00 Hz. At what is the speed is the boy riding his bicycle toward the wall? Assume the speed of sound in air is 340 m/s.
A) 3.68 m/s
B) 333 m/s
C) 6.67 m/s
D) 6.80 m/s
E) 3.37 m/s
Answer: E

68) You are driving along a highway at 35.0 m/s when you hear the siren of a police car approaching you from behind and you perceive the frequency as 1370 Hz. You are relieved that he is in pursuit of a different speeder when he continues past you, but now you perceive the frequency as 1330 Hz. What is the speed of the police car? The speed of sound in air is 343 m/s.
A) 38.4 m/s
B) 30.0 m/s
C) 39.2 m/s
D) 40.0 m/s
E) 41.7 m/s

Answer: D

69) You are driving along a highway at 35.0 m/s when you hear the siren of a police car approaching you from behind and you perceive the frequency as 1310 Hz. You are relieved that he is in pursuit of a different speeder when he continues past you, but now you perceive the frequency as 1240 Hz. What is the frequency of the siren in the police car? The speed of sound in air is 343 m/s.
A) 1300 Hz
B) 1320 Hz
C) 1270 Hz
D) 1360 Hz
E) 1370 Hz

Answer: C

70) A bat emits a sound at a frequency of 30.0 kHz as it approaches a wall. The bat detects beats such that the frequency of the echo is 900 Hz higher than the frequency the bat is emitting. The speed of sound in air is 340 m/s. The speed of the bat is closest to
A) 20.0 m/s.
B) 530 m/s.
C) 10.0 m/s.
D) 30.0 m/s.
E) 5.02 m/s.

Answer: E

71) Two in–phase loudspeakers are some distance apart. They emit sound with a frequency of 1536 Hz. You move between the speakers, along the line joining them, at a constant speed of 2.8 m/s. What beat frequency do you observe? The speed of sound in the room is 330 m/s.
A) 13 Hz
B) 431 Hz
C) 26 Hz
D) 4.7 Hz
E) 118 Hz

Answer: C

72) A policeman in a stationary car measures the speed of approaching cars by means of an ultrasonic device that emits a sound with a frequency of 41.2 kHz. A car is approaching him at a speed of 33.0 m/s. The wave is reflected by the car and interferes with the emitted sound producing beats. What is the frequency of the beats? The speed of sound in air is 330 m/s.
A) 9.2 kHz
B) 4.1 kHz
C) 4.6 kHz
D) 1.2 kHz
E) 8.2 kHz

Answer: A

73) A carousel that is 5.00 m in radius has a pair of 600−Hz sirens mounted on posts at opposite ends of a diameter. The carousel rotates with an angular velocity of 0.800 rad/s. A stationary listener is located at a distance from the carousel. The speed of sound is 350 m/s. The longest wavelength reaching the listener from the sirens is closest to
A) 57.0 cm.
B) 57.7 cm.
C) 58.3 cm.
D) 59.0 cm.
E) 59.6 cm.

Answer: D

74) A carousel that is 5.00 m in radius has a pair of 600−Hz sirens mounted on posts at opposite ends of a diameter. The carousel rotates with an angular velocity of 0.800 rad/s. A stationary listener is located at a distance from the carousel. The speed of sound is 350 m/s. The maximum beat frequency of the sirens at the position of the listener is closest to
A) 6 Hz.
B) 8 Hz.
C) 10 Hz.
D) 12 Hz.
E) 14 Hz.

Answer: E

75) An airplane flying faster than the speed of sound of 340 m/s produces a shock wave that makes an angle of 50° with the direction the plane is flying. What is the speed of the plane?
A) 490 m/s
B) 530 m/s
C) 390 m/s
D) 440 m/s
E) 405 m/s

Answer: D

76) A supersonic plane passes overhead at a speed of 500 m/s. If you hear the sonic boom (shock wave) 4.00 s after the plane is directly overhead, at what altitude is the plane flying? Assume the speed of sound in air is 340 m/s.
A) 1.36 km
B) 2.16 km
C) 1.85 km
D) 2.45 km
E) The plane is not flying fast enough to produce a shock wave.

Answer: C

77) A jet aircraft, in level flight at constant speed, is observed directly overhead. A sonic boom is heard 7.0 s later, at which time the line of sight to the aircraft forms a 56° angle with respect to the horizontal. The speed of sound is 325 m/s. What is the Mach number (the ratio of the speed of the jet to the speed of sound) for the aircraft?
A) 1.2
B) 1.8
C) 1.9
D) 2.1
E) 2.2

Answer: A

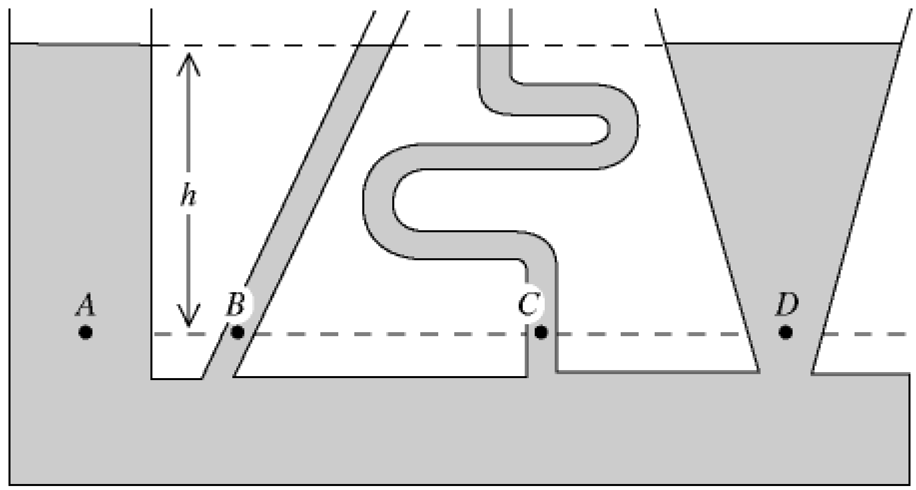
78) A jet aircraft, in level flight at constant speed, is observed directly over head. A sonic boom is heard 13.0 s later, at which time the line of sight to the aircraft forms a 51° angle with respect to the horizontal. The speed of sound is 325 m/s. The altitude of the aircraft is closest to
A) 6700 m.
B) 5400 m.
C) 8300 m.
D) 2700 m.
E) 13,000 m.

Answer: A

Chapter 15 Fluid Motion

15.1 Conceptual Questions

1) Fluid fills the container shown in the figure. At which of the indicated points is the pressure greatest?



A) A
B) B
C) C
D) D
E) The pressure is the same at each of the labeled points.

Answer: E

2) At a certain depth in the ocean, the absolute pressure is p. If you go to twice that depth (treating the water as incompressible)
A) the absolute pressure will be $2p$.
B) the absolute pressure will be less than $2p$.
C) the absolute pressure will be greater than $2p$.
D) the gauge pressure will not change.
E) the gauge pressure will increase but will not double.

Answer: B

3) If you double the pressure on the surface of a can of water, the buoyant force on a stone placed in that water will
A) increase, but not double.
B) double.
C) decrease, but not by one-half.
D) not change.

Answer: D

4) A cup of water containing an ice cube at 0°C is filled to the brim. The tip of the ice cube sticks out of the surface. As the ice melts, you observe that
   A) the cup overflows.
   B) the cup might overflow but it depends on the actual mass of the ice cube.
   C) the water level remains the same.
   D) the water level actually goes down.
   E) There is not enough information to answer this question.

   Answer: C

5) Salt water is more dense than fresh water. A ship floats in both fresh water and salt water. Compared to the fresh water, the volume of salt water displaced by the ship is
   A) greater than the volume of fresh water.
   B) less than the volume of fresh water.
   C) the same as the volume of fresh water.

   Answer: B

6) A 50-cm^3 block of wood is floating partially submerged in water, and a 50-cm^3 block of iron is totally submerged in water. Which block has the greater buoyant force on it?
   A) the wood
   B) the iron
   C) Both have the same buoyant force.
   D) The answer cannot be determined without knowing the densities of the blocks.

   Answer: B

7) A rock is under water in a shallow lake. As the rock sinks deeper and deeper into water, the buoyant force on it
   A) increases.
   B) decreases.
   C) remains constant.

   Answer: C

8) A piece of wood is floating in a bathtub. A second piece of wood sits on top of the first piece, and does not touch the water. If the top piece is taken off and placed in the water, what happens to the water level in the tub?
   A) It goes up.
   B) It goes down.
   C) It does not change.
   D) This cannot be determined without knowing the volume of the top piece of wood.

   Answer: C

9) Water flows through a pipe having a varying width. More water flows per second through the wide section than through the narrow section because there is more room for it to flow.
   A) True
   B) False

   Answer: B

10) As the speed of a moving fluid increases, the pressure in the fluid
   A) increases.
   B) remains constant.
   C) decreases.
   D) may increase or decrease, depending on the density of the fluid.

   Answer: C

11) When you blow some air above the upper face of a paper strip, the paper rises. This occurs because
   A) the air above the upper face of the paper moves faster, which makes the pressure higher than at the lower face.
   B) the air above the upper face of the paper moves faster, which makes the pressure lower than at the lower face.
   C) the air above the upper face of the paper moves faster but the pressure remains constant.
   D) the air above the upper face of the paper moves slower, which makes the pressure higher than at the lower face.
   E) the air above the upper face of the paper moves slower, which makes the pressure lower than at the lower face.

   Answer: B

12) You are driving a late model convertible car at the 65 mph speed limit with its soft flexible roof closed up and the windows closed. You observe that the roof
   A) bows inward.
   B) is no different from when the car was at rest.
   C) bows outward.
   D) bows inward only when you are driving uphill.
   E) bows inward only when you are driving downhill.

   Answer: C

15.2 Problems

1) A certain coin has a diameter of 21.21 mm, a thickness of 1.95 mm, and weighs 0.04905 N. What is its density?
   A) 29.1×10^3 kg/m^3
   B) 7.26×10^3 kg/m^3
   C) 9.25×10^3 kg/m^3
   D) 2.31×10^3 kg/m^3
   E) 71.2×10^3 kg/m^3

   Answer: B

2) What is the radius of a sphere that has a density of 5000 kg/m^3 and a mass of 6.00 kg?
   A) 4.98 cm
   B) 1.27 cm
   C) 6.59 cm
   D) 1.56 cm
   E) 7.22 cm

   Answer: C

3) A sphere is constructed of two concentric parts. The inner part is a solid sphere of radius 10.0 cm made of a material with density 4000 kg/m^3. The outer part is a spherical shell with inner radius 10.0 cm and outer radius 20.0 cm. The material in the outer shell has a density 9000 kg/m^3.
(a) What is the mass of the sphere?
(b) What is the average density of this sphere?

Answer: (a) 281 kg (b) 8.38×10^3 kg/m^3

4) One of the dangers of tornados and hurricanes is the rapid drop in air pressure that is associated with such storms. Assume that the air pressure inside of a sealed house is 1.02 atm when a hurricane hits. The hurricane rapidly decreases the external air pressure to 0.910 atm. A square window in an outside wall of the house measures 2.02 m on each side. What net force (directed outwards) is exerted on this window? (1 atm = 1.01×10^5 Pa.)

A) 4.53×10^4 N
B) 5.14×10^4 N
C) 4.78×10^5 N
D) 5.37×10^5 N

Answer: A

5) A cubical box, 5.00 cm on each side, is immersed in a fluid. The gauge pressure at the top surface of the box is 594 Pa and the gauge pressure on the bottom surface is 1133 Pa. What is the density of the fluid?

A) 1000 kg/m^3
B) 1100 kg/m^3
C) 1220 kg/m^3
D) 2340 kg/m^3
E) 12,000 kg/m^3

Answer: B

6) The weight of a car of mass 1.20×10^3 kg is supported equally by the four tires, which are inflated to the same gauge pressure. What gauge pressure in the tires is required so the area of contact of each tire with the road is 1.00×10^2 cm^2? (1 atm = 1.01×10^5 Pa.)

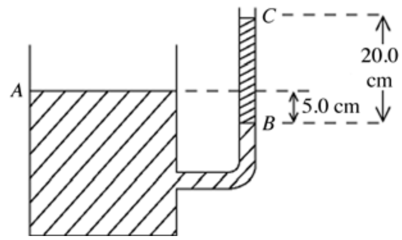
A) 11.6×10^5 Pa
B) 11.6×10^4 Pa
C) 2.94×10^5 Pa
D) 2.94×10^4 Pa
E) 2.94×10^3 Pa

Answer: C

7) On planet *X*, the absolute pressure at a depth of 2.00 m below the surface of a liquid nitrogen lake is 5.00×10^5 N/m^2. At a depth 5.00 m below the surface, the absolute pressure is 8.00×10^5 N/m^2. The density of liquid nitrogen is 808 kg/m^3.
(a) What is the atmospheric pressure on planet *X*?
(b) What is the acceleration due to gravity on planet *X*?

Answer: (a) 3.00×10^5 N/m^2 (b) 124 m/s^2

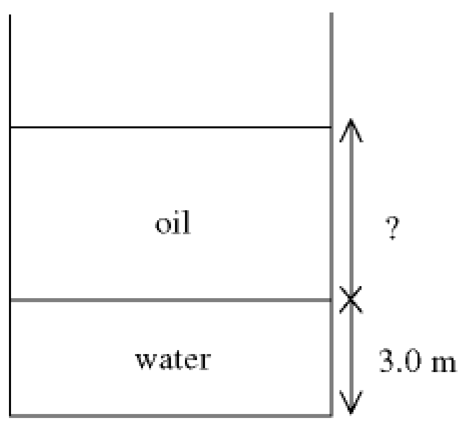
8) As shown in the figure, a container has a vertical tube, whose inner radius is 32.00 mm, connected to it at its side. An unknown liquid reaches level *A* in the container and level *B* in the tube—level *A* being 5.0 cm higher than level *B*. The liquid supports a 20.0–cm high column of oil, between levels *B* and *C*, whose density is 460 kg/m^3. What is the density of the unknown liquid?



A) 1800 kg/m^3
B) 2000 kg/m^3
C) 1400 kg/m^3
D) 1600 kg/m^3
E) 1700 kg/m^3

Answer: A

9) In the figure, an open tank contains a layer of oil floating on top of a layer of water (of density 1000 kg/m^3) that is 3.0 m thick, as shown. What must be the thickness of the oil layer if the gauge pressure at the bottom of the tank is to be 5.0×10^4 Pa? The density of the oil is 510 kg/m^3.



Answer: 4.1 m

10) The small piston of a hydraulic lift has a diameter of 8.0 cm, and its large piston has a diameter of 40 cm. The lift raises a load of 15,000 N.
(a) Determine the force that must be applied to the small piston.
(b) Determine the pressure applied to the fluid in the lift.

Answer: (a) 600 N (b) 1.2×10^5 Pa

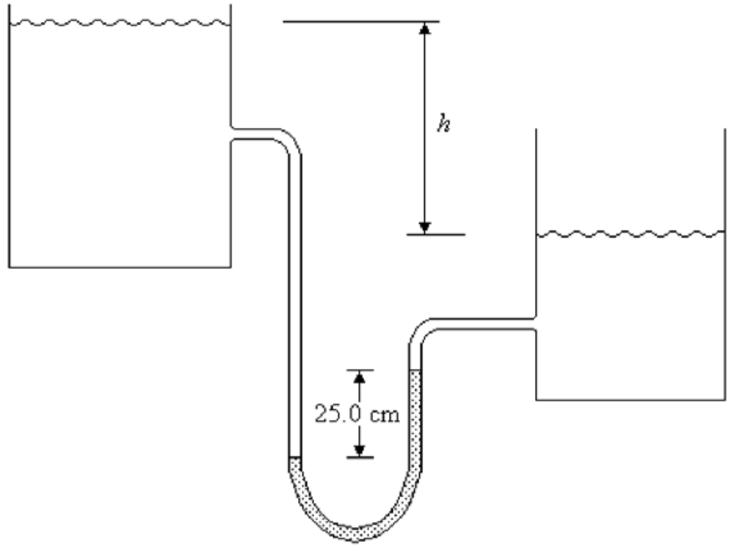
11) A 12,000–N car is raised using a hydraulic lift, which consists of a U–tube with arms of unequal areas, filled with incompressible oil and capped at both ends with tight–fitting pistons. The wider arm of the U–tube has a radius of 18.0 cm and the narrower arm has a radius of 5.00 cm. The car rests on the piston on the wider arm of the U–tube. The pistons are initially at the same level. What is the initial force that must be applied to the smaller piston in order to start lifting the car? (For purposes of this problem, you can neglect the weight of the pistons.)
    A) 727 N
    B) 926 N
    C) 2900 N
    D) 3330 N
    E) 1.20 kN

    Answer: B

12) A 12,000–N car is raised using a hydraulic lift, which consists of a U–tube with arms of unequal areas, filled with incompressible oil with a density of 800 kg/m^3 and capped at both ends with tight–fitting pistons. The wider arm of the U–tube has a radius of 18.0 cm and the narrower arm has a radius of 5.00 cm. The car rests on the piston on the wider arm of the U–tube. The pistons are initially at the same level. What is the force that must be applied to the smaller piston in order to lift the car after it has been raised 1.20 m? (For purposes of this problem, you can neglect the weight of the pistons.)
    A) 0.954 kN
    B) 1.88 kN
    C) 1.96 kN
    D) 3.67 kN
    E) 1.20 kN

    Answer: C

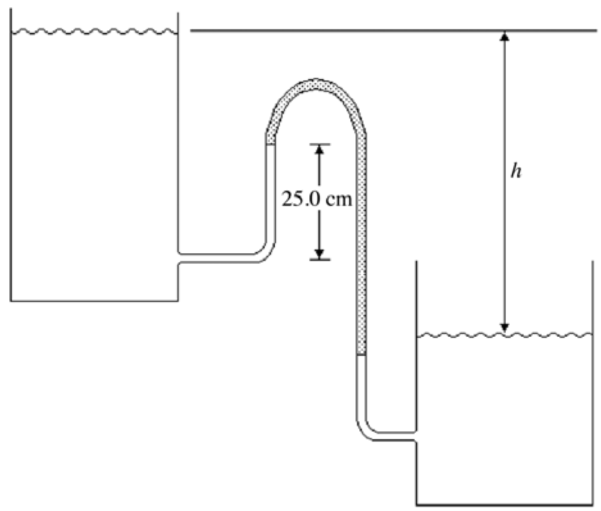
13) The two water reservoirs shown in the figure are open to the atmosphere, and the water has density 1000 kg/m^3. The manometer contains incompressible mercury with a density of 13,600 kg/m^3. What is the difference in elevation h if the manometer reading m is 25.0 cm?



A) 1.58 m
B) 4.20 m
C) 3.75 m
D) 3.40 m
E) 3.15 m

Answer: E

14) The two water reservoirs shown in the figure are open to the atmosphere, and the water has density 1000 kg/m^3. The manometer contains incompressible oil with a density of 820 kg/m^3. What is the difference in elevation h if the manometer reading m is 25.0 cm?



A) 0.045 m
B) 0.025 m
C) 0.065 m
D) 0.115 m
E) 0.205 m

Answer: A

15) A wooden raft has a mass of 50 kg. When empty it floats in water (density 1000 kg/m^3) with 69% of its volume submerged. What mass of sand can be put on the raft without it sinking?

Answer: 22 kg

16) A board that is 20.0 cm wide, 5.00 cm thick, and 3.00 m long has a density 350 kg/m^3. The board is floating partially submerged in water of density 1000 kg/m^3. What fraction of the volume of the board is above the surface of the water?

A) 0.350
B) 0.650
C) zero
D) 0.200
E) The answer depends on which edge of the board is vertical.

Answer: B

17) A rock is suspended from a scale reads 20.0 N. A beaker of water (having a density of 1000 kg/m^3) is raised up so the rock is totally submerged in the water. The scale now reads 12.5 N. What is the density of the rock?
A) 1.60×10^3 kg/m^3
B) 2.50×10^3 kg/m^3
C) 2.33×10^3 kg/m^3
D) 3.00×10^3 kg/m^3
E) 2.67×10^3 kg/m^3
Answer: E

18) A person who weighs 550 N empties her lungs as much as possible and is then completely immersed in water (of density 1000 kg/m^3) while suspended from a harness. Her apparent weight is now 21.2 N. What is her density?
A) 1050 kg/m^3
B) 1040 kg/m^3
C) 1030 kg/m^3
D) 960 kg/m^3
E) 56.1 kg/m^3
Answer: B

19) A barge is 15.0 m wide and 75.0 m long and has vertical sides. The bottom of the hull is 1.20 m below the water surface. What is the weight of the barge and its cargo, if it is floating in fresh water of density 1000 kg/m^3?
A) 22.6 MN
B) 13.2 MN
C) 1.35 MN
D) 1.13 MN
E) 11.3 MN
Answer: B

20) A hollow steel ball of diameter 3.0 m barely floats in water. What is the thickness of the wall of the ball? The density of iron is 7.87 g/cm^3 and that of water is 1000 kg/m^3.
A) 6.6 cm
B) 37 cm
C) 131 cm
D) 79 cm
Answer: A

21) A 7.8-kg solid sphere, made of metal whose density is 2500 kg/m^3, is suspended by a cord. When the sphere is immersed in water (of density 1000 kg/m^3), what is the tension in the cord?
A) 46 N
B) 61 N
C) 76 N
D) 92 N
E) 110 N
Answer: A

22) A 6.1–kg solid sphere, made of metal whose density is 2600 kg/m^3, is suspended by a cord. When the sphere is immersed in a liquid of unknown density, the tension in the cord is 26 N. Find the density of the liquid.
A) 1500 kg/m^3
B) 1400 kg/m^3
C) 1300 kg/m^3
D) 1200 kg/m^3
E) 1100 kg/m^3
Answer: A

23) A circular cylinder of height 1.20 m having faces of diameter 0.620 m is immersed in water of density 1.00×10^3 kg/m^3 with its axis vertical so that its faces are parallel to the surface of the water. The upper face is 2.50 m below the surface of the water. The net force on this cylinder is observed to be 1120 N downward. Atmospheric pressure is 1.01×10^5 Pa. What net force does the water exert on the lower face of the cylinder?
A) 7.40×10^3 N
B) 1.09×10^4 N
C) 3.79×10^4 N
D) 4.14×10^4 N
E) 1.37×10^5 N
Answer: D

24) A circular cylinder of height 1.20 m having faces of diameter 0.620 m is immersed in water of density 1.00×10^3 kg/m^3 with its axis vertical so that its faces are parallel to the surface of the water. The upper face is 2.50 m below the surface of the water. The net force on this cylinder is observed to be 1120 N downward. Atmospheric pressure is 1.01×10^5 Pa. What is the weight of the cylinder?
A) 2430 N
B) 3550 N
C) 4670 N
D) 10,900 N
E) 12,100 N
Answer: C

25) An incompressible fluid flows steadily through a pipe that has a change in diameter. The fluid speed at a location where the pipe diameter is 8.0 cm is 1.28 m/s. What is the fluid speed at a location where the diameter has narrowed to 4.0 cm?
A) 0.32 m/s
B) 0.64 m/s
C) 1.28 m/s
D) 2.56 m/s
E) 5.12 m/s
Answer: E

26) Water, of density 1000 kg/m^3, is flowing in a drainage channel of rectangular cross–section. The width of the channel is 15 m, the depth of the water is 8.0 m and the speed of the flow is 2.5 m/s. At what rate is water flowing in this channel?
A) 2.0×10^5 kg/s
B) 2.0×10^3 kg/s
C) 3.0×10^5 kg/s
D) 3.0×10^3 kg/s
E) 3.0×10^2 kg/s
Answer: C

27) Water flowing through a pipe suddenly comes to a section of pipe where the pipe diameter decreases to 86% of its previous value. If the speed of the water in the larger section of the pipe was 36 m/s, what is its speed in this smaller section?
A) 49 m/s
B) 42 m/s
C) 31 m/s
D) 27 m/s
Answer: A

28) Water is flowing in a horizontal pipe of diameter d. If you want to change the diameter of this pipe so that the speed of the water would be half as great as it was, what should be the new diameter?
A) $d/4$
B) $d/2$
C) $d/\sqrt{2}$
D) $d\sqrt{2}$
E) $2d$
Answer: D

29) Incompressible water flows out of a large reservoir through a pipe that opens to the atmosphere 5.70 m below the level of the water in the reservoir. What is the speed of the water as it comes out of the pipe?
A) 1.72 m/s
B) 7.47 m/s
C) 55.8 m/s
D) 10.6 m/s
E) 27.9 m/s
Answer: D

30) A horizontal tube consists of a 7.0–cm diameter pipe that narrows to a 2.0–cm–diameter throat. In the pipe, the water pressure is twice atmospheric pressure and the water flows with a speed of 0.40 m/s. What is the pressure in the throat, assuming that the water behaves like an ideal fluid? The density of water is 1000 kg/m^3, and atmospheric pressure is 1.01×10^5 Pa.
A) 1.9 atm
B) 0.12 atm
C) 2.1 atm
D) 2.0 atm
Answer: A

31) A large cylindrical water tank is mounted on a platform with its central axis vertical. The water level is 3.75 m above the base of the tank, and base is 6.50 m above the ground. A small hole 2.22 mm in diameter has formed in the base of the tank. Both the hole and the top of the tank are open to the air. We can ignore air resistance and treat water as an ideal fluid with a density of 1000 kg/m^3.
(a) How many cubic meters of water per second is this tank losing?
(b) How fast is the water from the hole moving just as it reaches the ground?

Answer: (a) 3.26×10^{-5} m^3/s (b) 14.2 m/s

32) Air is flowing through a rocket nozzle. Inside the rocket the air has a density of 5.25 kg/m^3 and a speed of 1.20 m/s. The interior diameter of the rocket is 15.0 cm. At the nozzle exit, the diameter is 2.50 cm and the density is 1.29 kg/m^3. What is the speed of the air when it leaves the nozzle?
A) 123 m/s
B) 176 m/s
C) 88.0 m/s
D) 45.7 m/s
E) 29.3 m/s

Answer: B

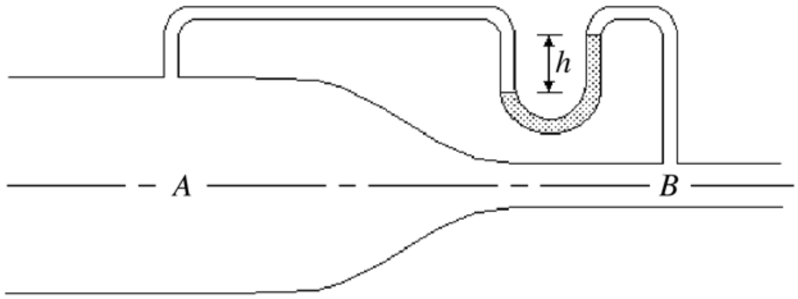
33) A level pipe contains a nonviscous, incompressible fluid with a density 1200 kg/m^3 that is flowing steadily. At one position within the pipe, the pressure is 300 kPa and the speed of the flow is 20.0 m/s. At another position, the pressure is 200 kPa. What is the speed of the flow at this second position?
A) 567 m/s
B) 16.2 m/s
C) 32.9 m/s
D) 23.8 m/s
E) 186 m/s

Answer: D

34) In a section of horizontal pipe with a diameter of 3.00 cm the pressure is 5.21 kPa and water is flowing with a speed of 1.50 m/s. The pipe narrows to 2.50 cm. What is the pressure in the narrower region if water behaves like an ideal fluid of density 1000 kg/m^3?
A) 4.00 kPa
B) 7.50 kPa
C) 5.82 kPa
D) 6.42 kPa
E) 4.61 kPa

Answer: A

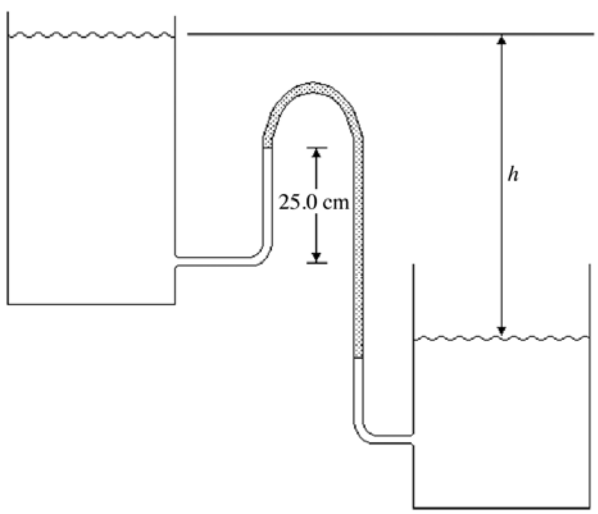
35) Water flows in the horizontal pipe shown in the figure. At point A the area is 25.0 cm^2 and the speed of the water is 2.00 m/s. At B the area is 16.0 cm^2. The fluid in the manometer is mercury, which has a density of 13,600 kg/m^3. We can treat water as an ideal fluid having a density of 1000 kg/m^3. What is the manometer reading h?



A) 0.546 cm
B) 1.31 cm
C) 2.81 cm
D) 2.16 cm
E) 3.36 cm

Answer: D

36) Water flows in the horizontal pipe shown in the figure. At A the diameter is 5.00 cm and at B the diameter is 4.00 cm The fluid in the manometer is mercury, which has a density of 13,600 kg/m^3. The manometer reading h is 4.40 cm. We can treat water as an ideal fluid having a density of 1000 kg/m^3. What volume of water is flowing through the pipe per second?

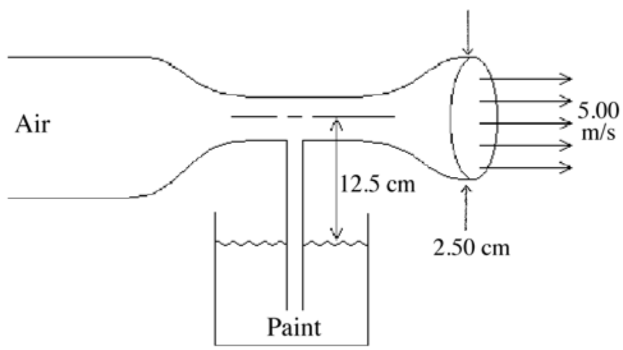


A) 0.0206 m^3/s
B) 0.0426 m^3/s
C) 0.00560 m^3/s
D) 0.372 m^3/s
E) 0.186 m^3/s

Answer: C

37) Consider a very small hole in the bottom of a tank 20.0 cm in diameter filled with water to a height of 50.0 cm. Find the speed at which the water exits the tank through the hole.
A) 3.13 m/s
B) 9.80 m/s
C) 31.8 m/s
D) 34.9 m/s
Answer: A

38) A paint sprayer pumps air through a constriction in a 2.50-cm diameter pipe, as shown in the figure. The flow causes the pressure in the constricted area to drop and paint rises up the feed tube and enters the air stream. The speed of the air stream in the 2.50-cm diameter sections is 5.00 m/s. The density of the air is 1.29 kg/m^3, and the density of the paint is 1200 kg/m^3. We can treat the air and paint as incompressible ideal fluids. What is the maximum diameter of the constriction that will allow the sprayer to operate?



A) 8.07 mm
B) 4.05 mm
C) 12.2 mm
D) 9.65 mm
E) 14.3 mm
Answer: A

Chapter 16 Temperature and Heat

16.1 Conceptual Questions

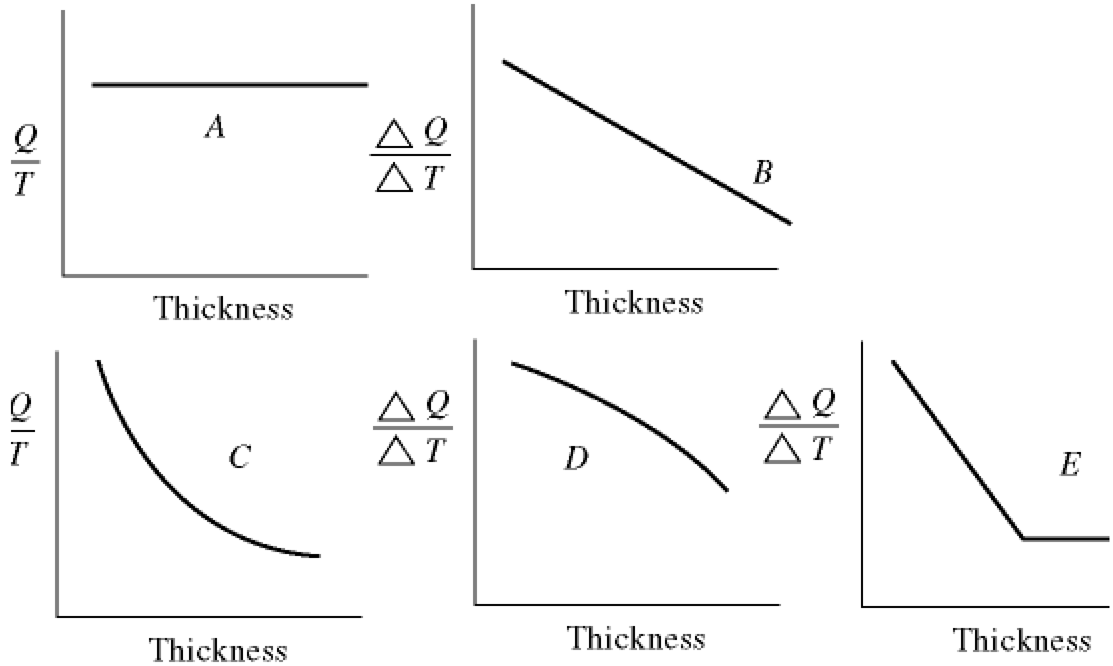
1) It is a well-known fact that water has a higher specific heat than iron. Now, consider equal masses of water and iron that are initially in thermal equilibrium. The same amount of heat, 30 calories, is added to each one. Which statement is true?
   A) They remain in thermal equilibrium.
   B) They are no longer in thermal equilibrium; the iron is warmer.
   C) They are no longer in thermal equilibrium; the water is warmer.
   D) It is impossible to say without knowing the exact mass involved.
   E) It is impossible to say without knowing the exact specific heats.

   Answer: B

2) A thermally isolated system is made up of a hot piece of aluminum and a cold piece of copper; the aluminum and the copper are in thermal contact. The specific heat of aluminum is more than double that of copper. Which object experiences the greater temperature change during the time the system takes to reach thermal equilibrium?
   A) The copper experiences a greater temperature change.
   B) The aluminum experiences a greater temperature change.
   C) Neither; both objects experience the same magnitude temperature change.
   D) It is impossible to tell without knowing the masses.
   E) It is impossible to tell without knowing the volumes.

   Answer: D

3) An architect is interested in estimating the heat loss (in kcal/s) through a sheet of insulating material as a function of the thickness of the sheet. Assuming fixed temperatures on the two faces of the sheet, which one of the graphs in the figure best represents the rate of heat transfer as a function of the thickness of the insulating sheet?



A) A
B) B
C) C
D) D
E) E

Answer: C

16.2 Problems

1) (a) Internal human body temperature is often stated to be normal at 98.6°F. What is this temperature on the Celsius and Kelvin scales?
(b) Gallium boils at 2205°C. What is the corresponding temperature in the Fahrenheit and Kelvin scales?
(c) The boiling point of liquid nitrogen is 77.0 K. What is the corresponding temperature in the Fahrenheit and Celsius scales?

Answer: (a) 37.0°C, 310 K (b) 4001°F, 2478 K (c) -321°F, -196°C

2) It is necessary to determine the specific heat of an unknown object. The mass of the object is measured to be 199.0 g. It is determined experimentally that it takes 16.0 J to raise the temperature 10.0°C. Find the specific heat of the object.
A) 8.04 J/kg • K
B) 1600 J/kg • K
C) 0.00120 J/kg • K
D) 3.18×10^6 J/kg • K

Answer: A

3) A 648–g empty iron kettle is put on a stove. How much heat. in joules. must it absorb to raise its temperature from 15.0°C to 37.0°C? (The specific heat for iron is 113 cal/kg•C°, 1 cal = 4.190 J)
   A) 6740 J
   B) 11,300 J
   C) 1610 J
   D) 16,100 J

   Answer: A

4) If we use 67 W of power to heat 148 g of water, how long will it take to raise the temperature of the water from 15°C to 25°C? The specific heat of water is 4190 J/kg•K.
   A) 93 s
   B) 5.3 s
   C) 22 s
   D) 114 h

   Answer: A

5) A 905–g meteor impacts the earth at a speed of 1629 m/s. If all of its energy is entirely converted to heat in the meteor, what will be the resulting temperature rise of the meteor, assuming it does not melt? The specific heat for the meteor material is 472 J/kg•K, which is about the same as that of iron.
   A) 2810°C
   B) 2,540,000°C
   C) 3.10°C
   D) 11,700°C

   Answer: A

6) A person pours 330 g of water at 45°C into an 855–g aluminum container with an initial temperature of 10°C. The specific heat of aluminum is 900 J/(kg•K) and that of water is 4190 J/(kg•K). What is the final temperature of the system, assuming no heat is exchanged with the surroundings?
   A) 28°C
   B) 32°C
   C) 31°C
   D) 33°C
   E) 35°C

   Answer: B

7) A 400–g piece of metal at 120.0°C is dropped into a cup containing 450 g of water at 15.0°C. The final temperature of the system is measured to be 40.0°C. What is the specific heat of the metal, assuming no heat is exchanged with the surroundings or the cup? The specific heat of water is 4190 J/(kg•K).
   A) 1470 J/(kg • K)
   B) 2830 J/(kg • K)
   C) 3420 J/(kg • K)
   D) 3780 J/(kg • K)
   E) 4280 J/(kg • K)

   Answer: A

8) An 80-g aluminum calorimeter contains 380 g of water at an equilibrium temperature of 20°C. A 120-g piece of metal, initially at 352°C, is added to the calorimeter. The final temperature at equilibrium is 32°C. Assume there is no external heat exchange. The specific heats of aluminum and water are 910 J/kg•K and 4190 J/kg•K, respectively. The specific heat of the metal is closest to
   A) 520 J/kg • K.
   B) 480 J/kg • K.
   C) 390 J/kg • K.
   D) 350 J/kg • K.
   E) 560 J/kg • K.

   Answer: A

9) A copper cylinder with a mass of 125 g and temperature of 345°C is cooled by dropping it into a glass beaker containing 565 g of water initially at 20.0°C. The mass of the beaker is 50.0 g and the specific heat of the glass is 840 J/kg•K. What is the final equilibrium temperature of the system, assuming the cooling takes place very quickly, so that no energy is lost to the air? The specific heat of copper is 385 J/kg•K and that of water is 4190 J/kg•K.

   Answer: 26.4°C

10) What is the steady state rate of heat flow through a pane of glass that is 40.0 cm by 30.0 cm with a thickness of 4.00 mm when the outside temperature of the glass is -10.0°C and its inside temperature is 25.0°C? The thermal conductivity of glass is 0.105 W/(m•K), the specific heat of glass is 0.180 cal/(g•°C), and 1 cal = 4.190 J.
   A) 24.2 W
   B) 3.81 W
   C) 18.6 W
   D) 47.3 W
   E) 110 W

   Answer: E

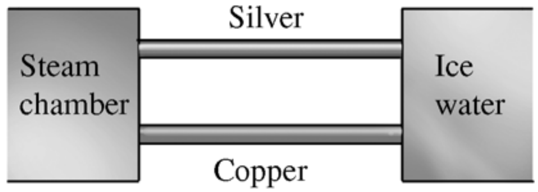
11) Under steady state conditions, a piece of wood 350 mm by 350 mm and 15 mm thick conducts heat through its thickness and loses no appreciable heat through its well-insulated sides. The rate of heat flow is measured to be 14.0 W when the temperature difference across its thickness is 28 C°. Determine the thermal conductivity of this wood.
   A) 9.2×10^{-4} W/(m•C°)
   B) 270 W/(m•C°)
   C) 16 W/(m•C°)
   D) 0.061 W/(m•C°)
   E) 33 W/(m•C°)

   Answer: D

12) A solid concrete wall 4.0 m by 2.4 m and 30 cm thick, with a thermal conductivity of 1.3 W/(m •K), separates a basement at 18°C from the ground outside at 6°C. Under steady state conditions, how much heat flows through the wall in one hour?
   A) 1.8 MJ
   B) 1.8 kJ
   C) 500 J
   D) 5.0 MJ
   E) 5.0 kJ

   Answer: A

13) Two metal rods, one silver and the other copper, are both attached to a steam chamber as shown in the figure, with a temperature of 100°C, at one end, and an ice water bath, with a temperature of 0°C, at the other. The rods are 5.0 cm long and have a square cross–section, 2.0 cm on a side. When steady state has been reached, how much heat flows through the two rods in 1.0 min? The thermal conductivity of silver is 417 W/(m•K), and that of copper is 395 W/(m •K). No heat is exchanged between the rods and the surroundings, except at their ends.



A) 20 kJ
B) 39 kJ
C) 47 kJ
D) 49 kJ
E) 11 kJ

Answer: B

14) A heat conducting rod, 0.90 m long, is made of an aluminum section that is 0.10 m long, and a copper section that is 0.80 m long. Both sections have cross–sectional areas of 0.00040 m^2. The aluminum end is maintained at a temperature of 40°C and the copper end is at 150°C.. The thermal conductivity of aluminum is 205 W/m•K and of copper is 385 W/m•K. Steady state has been reached, and no heat is lost through the well–insulated sides of the rod. The temperature of the aluminum–copper junction in the rod is closest to

A) 61°C.
B) 58°C.
C) 56°C.
D) 54°C.
E) 52°C.

Answer: A

15) A heat conducting rod, 1.40 m long, is made of an aluminum section that is 0.50 m long and a copper section that is 0.90 m long. Both sections have cross–sectional areas of 0.00040 m^2. The aluminum end and the copper end are maintained at temperatures of 40°C and 280°C, respectively. The thermal conductivity of aluminum is 205 W/m•K of copper is 385 W/m•K. The rate at which heat is conducted in the rod is closest to

A) 20 W.
B) 18 W.
C) 23 W.
D) 25 W.
E) 28 W.

Answer: A

16) Some properties of glass are listed here.

Density:	2300 kg/m^3
Specific heat:	840 J/kg•C°
Coefficient of linear thermal expansion:	8.5×10^{-6} $(C°)^{-1}$
Thermal conductivity:	0.80 W/(m•C°)

A glass window pane is 2.7 m high, 2.4 m wide, and 2.0 mm thick. The temperature at the inner surface of the glass is 22°C and at the outer surface 4.0°C. How much heat is lost each hour through the window under steady state conditions?

A) 1.7×10^8 J
B) 1.7×10^5 J
C) 4.7×10^4 J
D) 4.7×10^1 J
E) 1.7×10^6 J

Answer: A

17) A cylindrical bar that us well insulated around its sides connects hot and cold reservoirs and conducts heat at a rate of 10.0 J/s under steady state conditions. If all of its linear dimensions (diameter and length) are reduced by half, the rate at which it will now conduct heat between the same reservoirs is closest to

A) 80.0 J/s.
B) 20.0 J/s.
C) 5.00 J/s.
D) 2.50 J/s.
E) 1.25 J/s.

Answer: C

18) A concrete wall of a cold storage room measures 3.0 m high, 5.0 m wide, and 20 cm thick. The room temperature is maintained at -10°C and the outside temperature is 20°C The inside wall is to be covered by a layer of wood in order to reduce the rate of heat loss through the wall BY 90 percent. The thermal conductivities of concrete and wood are 0.80 W/m•K and 0.040 W/m•K, respectively. Under steady state conditions, the thickness of the layer of wood required is closest to

A) 60 mm.
B) 70 mm.
C) 80 mm.
D) 90 mm.
E) 100 mm.

Answer: D

19) The filament in a light bulb has a diameter of 0.050 mm and an emissivity of 1.0. The temperature of the filament is 3000°C. What should be the length of the filament so it will radiate 60 W of power? The Stefan–Boltzmann constant is 5.670×10^{-8} $W/m^2 \cdot K^4$.

A) 11 cm
B) 9.4 cm
C) 8.6 cm
D) 7.2 cm
E) 5.9 cm

Answer: E

20) A blacksmith is flattening a steel plate that measures 10 cm × 15 cm × 1 mm. He has heated the plate to 900 K. If the emissivity of the plate is 0.75, what is the total rate at which it radiates energy? The Stefan–Boltzmann constant is 5.670×10^{-8} $W/m^2 \cdot K^4$. Ignore any heat it receives from the surroundings.
A) 360 W
B) 760 W
C) 790 W
D) 850 W
E) 880 W

Answer: D

21) Betelgeuse is a red supergiant star in the constellation Orion. It radiates heat at the rate of 2.70×10^{30} W and has a surface temperature of 3000 K. Assuming that it is a perfect emitter, what is the radius of Betelgeuse? The Stefan–Boltzmann constant is 5.670×10^{-8} $W/m^2 \cdot K^4$.
A) 7.80×10^{10} m
B) 8.70×10^{10} m
C) 1.40×10^{11} m
D) 1.90×10^{11} m
E) 2.16×10^{11} m

Answer: E

22) A cube at 100.0°C radiates heat at a rate of 80.0 J/s. If the length of each side is cut in half, the rate at which it will now radiate is closest to
A) 56.6 J/s.
B) 40.0 J/s.
C) 28.3 J/s.
D) 20.0 J/s.
E) 10.0 J/s.

Answer: D

23) A cube at 100°C radiates heat at a rate of 80.0 J/s. If its surface temperature is increased to 200°C, the rate at which it will now radiate is closest to
A) 160 J/s.
B) 207 J/s.
C) 320 J/s.
D) 640 J/s.
E) 1280 J/s.

Answer: B

Chapter 17 The Thermal Behavior of Matter

17.1 Conceptual Questions

1) If the temperature of an iron sphere is increased
   A) its density will increase.
   B) its volume will decrease.
   C) its density will decrease.
   D) its mass will decrease.
   E) its density will remain unchanged.

   Answer: C

2) A machinist needs to remove a tight fitting pin of material *A* from a hole in a block made of material *B*. The machinist heats both the pin and the block to the same high temperature and removes the pin easily. What statement relates the coefficient of thermal expansion of material *A* to that of material *B*?
   A) Material *B* has a greater coefficient of expansion than does material *A*.
   B) The situation is not possible because heating block *B* will shrink the hole in the material as the material expands with increasing temperature.
   C) Material *B* has the same coefficient of expansion as does material *A*.
   D) Material *A* has a greater coefficient of expansion than does material *B*.

   Answer: A

3) Two steel spheres are made of the same material and have the same diameter, but one is solid and the other is hollow. If their temperature is increased by the same amount
   A) the solid sphere becomes bigger than the hollow one.
   B) the hollow sphere becomes bigger than the solid one.
   C) the two spheres remain of equal size.
   D) the solid sphere becomes heavier and the hollow one becomes lighter.
   E) the solid sphere becomes lighter and the hollow one becomes heavier.

   Answer: C

4) When a solid melts
   A) the temperature of the substance increases.
   B) the temperature of the substance decreases.
   C) heat energy leaves the substance.
   D) heat energy enters the substance.

   Answer: D

5) When a vapor condenses
   A) the temperature of the substance increases.
   B) the temperature of the substance decreases.
   C) heat energy leaves the substance.
   D) heat energy enters the substance.

   Answer: C

6) A chunk of ice (T = -20°C) is added to a thermally insulated container of cold water (T = 0°C). What happens in the container?
   A) The ice melts until thermal equilibrium is established.
   B) The water cools down until thermal equilibrium is established.
   C) Some of the water freezes and the chunk of ice gets larger.
   D) None of the above things happen.

   Answer: C

7) A fixed amount of ideal gas is held in a rigid container that expands negligibly when heated. At 20°C the gas pressure is p. If we add enough heat to increase the temperature from 20°C to 40°C, the pressure will be
   A) impossible to determine since we do not know the number of moles of gas in the container.
   B) greater than $2p$.
   C) less than $2p$.
   D) equal to $2p$.
   E) impossible to determine since we do not know the volume of gas in the container.

   Answer: C

8) For a fixed amount of gas, if the absolute temperature of the gas is doubled, what happens to the pressure of the gas?
   A) The answer cannot be determined without volume information.
   B) The pressure of the gas becomes double the original pressure.
   C) The pressure of the gas becomes eight times the original pressure.
   D) The pressure of the gas becomes one half the original pressure.
   E) The pressure of the gas becomes four times the original pressure.

   Answer: A

9) The number of molecules in one mole of a substance
   A) depends on the molecular weight of the substance.
   B) depends on the atomic weight of the substance.
   C) depends on the density of the substance.
   D) depends on the temperature of the substance.
   E) is the same for all substances.

   Answer: E

10) Which contains more moles of material: 80 grams of helium gas (He, having atomic weight 4.0 g/mol) or 400 grams of argon gas (Ar, having atomic weight 40 g/mol)?
   A) helium
   B) argon
   C) Both contain the same number of moles.

   Answer: A

11) If the temperature of a fixed amount of an ideal gas is increased, it NECESSARILY follows that
   A) the pressure of the gas will increase.
   B) the volume of the gas will increase.
   C) the speed of the gas molecules will increase.
   D) All of the above statements are correct.

   Answer: C

12) A mole of oxygen (O_2) molecules and a mole of carbon dioxide (CO_2) molecules at the same temperature and pressure have

A) the same average molecular speeds.
B) the same number of atoms.
C) different average kinetic energy per molecule.
D) the same number of molecules.
E) different volumes.

Answer: D

13) The average molecular kinetic energy of a gas can be determined by knowing

A) only the number of molecules in the gas.
B) only the volume of the gas.
C) only the pressure of the gas.
D) only the temperature of the gas.
E) All of the above quantities must be known to determine the average molecular kinetic energy.

Answer: D

14) A sample of an ideal gas is slowly compressed to one-half its original volume with no change in temperature. What happens to the average speed of the molecules in the sample?

A) It does not change.
B) It becomes 4 times as great.
C) It becomes 2 times as great.
D) It becomes 1/2 as great.
E) It becomes 1/4 as great.

Answer: A

15) A sample of an ideal gas is slowly compressed to one-half its original volume with no change in pressure. If the original root-mean-square speed (thermal speed) of the gas molecules was V, the new speed is

A) V.
B) $2V$.
C) $\sqrt{2}V$.
D) $V/2$.
E) $V/\sqrt{2}$

Answer: E

16) If we double the root-mean-square speed (thermal speed) of the molecules of a gas, then

A) its temperature must increase by a factor of 4.
B) its temperature must increase by a factor of 2.
C) its temperature must increase by a factor of $\sqrt{2}$.
D) its pressure must increase by a factor of 2.
E) its pressure must increase by a factor of 4.

Answer: A

17) A container is filled with a mixture of helium (light molecules) and oxygen (heavy molecules) gases. A thermometer in the container reads 22°C. Which gas molecules have the greater average kinetic energy?
A) It is the same for both of the gases because the temperatures are the same.
B) The oxygen molecules do because they are diatomic.
C) The oxygen molecules do because they are more massive.
D) The helium molecules do because they are less massive.
E) The helium molecules do because they are monatomic.

Answer: A

18) A container is filled with a mixture of helium (light molecules) and oxygen (heavy molecules) gases. A thermometer in the reads 22°C. Which gas molecules have the greater average speed?
A) It is the same for both of the gases because the temperatures are the same.
B) The oxygen molecules do because they are diatomic.
C) The oxygen molecules do because they are more massive.
D) The helium molecules do because they are less massive.
E) The helium molecules do because they are monatomic.

Answer: D

17.2 Problems

1) A rod has a length 2.00000 m at 10.0°C. The length of the rod increases to 2.00060 m when the temperature increases to 30.0°C. What is the coefficient of linear expansion of the material from which the rod is made?
A) 2.0×10^{-5}/K
B) 2.5×10^{-5}/K
C) 1.5×10^{-5}/K
D) 1.0×10^{-3}/K
E) 1.0×10^{-5}/K

Answer: C

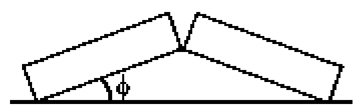
2) Suppose that a steel bridge, 1000 m long, was built without any expansion joints and that only one end of the bridge was held fixed. What would the difference in the length of the bridge be between winter and summer, taking a typical winter temperature as 0.00°C, and a typical summer temperature as 40°C? The coefficient of thermal expansion of steel is $10.5 \times 10^{-6}\ K^{-1}$.
A) 0.42 m
B) 0.11 mm
C) 0.11 m
D) 0.42 mm
E) 0.37 cm

Answer: A

3) The exterior of a supersonic airplane is made of aluminum, which has a coefficient of linear expansion of 24×10^{-6} K^{-1}. At 15°C, the plane measures 62.1 m in length. When the plane is in flight, friction with the air increases the temperature of the exterior skin to 200°C. What is the change in the length of the outer skin of the plane?
   A) 20 cm
   B) 24 cm
   C) 28 cm
   D) 32 cm
   E) 36 cm

   Answer: C

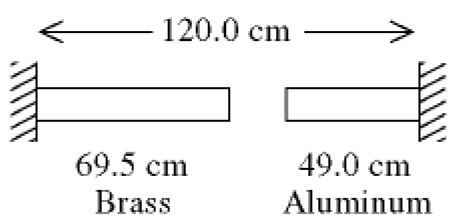
4) Two identical concrete slabs lie flat and in contact with each other as shown in the figure. If the temperature increases by 40°C, the lower edges opposite the contact edges remained fixed in position, and the lower edges of the contact side remain in contact, at what angle will the slabs be tilted? The coefficient of thermal expansion of the concrete is 10×10^{-6}/K.



   A) 19°
   B) 0.028°
   C) 15°
   D) 1.6°
   E) The answer depends on the length of the slabs.

   Answer: D

5) A brass rod is 40.1 cm long and an aluminum rod is 79.3 cm long when both rods are at an initial temperature of 0°C. The rods are placed in line with a gap of 0.60 cm between them, as shown in the figure. The distance between the far ends of the rods is maintained at 120.0 cm throughout. The temperature of both rods is raised until the two rods are barely in contact. The coefficients of linear expansion of brass and aluminum are 2.0×10^{-5} K^{-1} and 2.4×10^{-5} K^{-1}, respectively. The temperature at which contact of the rods barely occurs is closest to



   A) 220°C.
   B) 210°C.
   C) 200°C.
   D) 230°C.
   E) 240°C.

   Answer: A

6) You want to insert an aluminum rod, which at 20°C has a radius of 1.000200 cm into a copper tube which has a radius of 1.000100 cm at the same temperature. You decide to put both of them in the refrigerator. At what temperature will the rod just fit if both are cooled to the same temperature? The coefficient of thermal expansion for aluminum is 2.4×10^{-5} K^{-1}, and that of copper is 1.7×10^{-5} K^{-1}.
A) 7.8°C
B) 6.3°C
C) 9.2°C
D) 15°C
E) 5.7°C
Answer: E

7) The hole for a bolt in a brass plate has a diameter of 1.200 cm at 20°C. What is the diameter of the hole when the plate is heated to 220°C? The coefficient of linear thermal expansion for brass is 19×10^{-6}/C°. (Express your answer to 4 significant figures.)
A) 1.205 cm
B) 1.125 cm
C) 1.195 cm
D) 1.200 cm
E) 1.210 cm
Answer: A

8) 1.000 L of water at 20.00°C will occupy what volume if it is heated to 80.00°C? Water has a volume expansion coefficient of 210×10^{-6}/C°. (Express your answer to 4 significant figures.)
A) 1.600 L
B) 1.326 L
C) 1.013 L
D) 0.9870 L
E) 0.9987 L
Answer: C

9) A glass flask has a volume of 500 mL at a temperature of 20°C. The flask contains 492 mL of mercury at 20°C. The temperature of the mercury and flask is raised until the mercury reaches the 500 mL reference mark. The coefficients of volume expansion of mercury and glass are 18×10^{-5} K^{-1} and 2.0×10^{-5} K^{-1}, respectively. The temperature at which this occurs is closest to
A) 122°C.
B) 112°C.
C) 102°C.
D) 110°C.
E) 132°C.
Answer: A

10) The coefficient of linear expansion of aluminum is 24×10^{-6} K^{-1} and the coefficient of volume expansion of olive oil is 0.68×10^{-3} K^{-1}. A novice cook, in preparation for deep-frying some potatoes, fills a 1.00-L aluminum pot to the brim and heats the oil and the pot from an initial temperature of 15°C to 190°C. To his consternation some olive oil spills over the top. How much?
A) 0.11 L
B) 0.12 L
C) 0.13 L
D) 0.14 L
E) 0.15 L

Answer: A

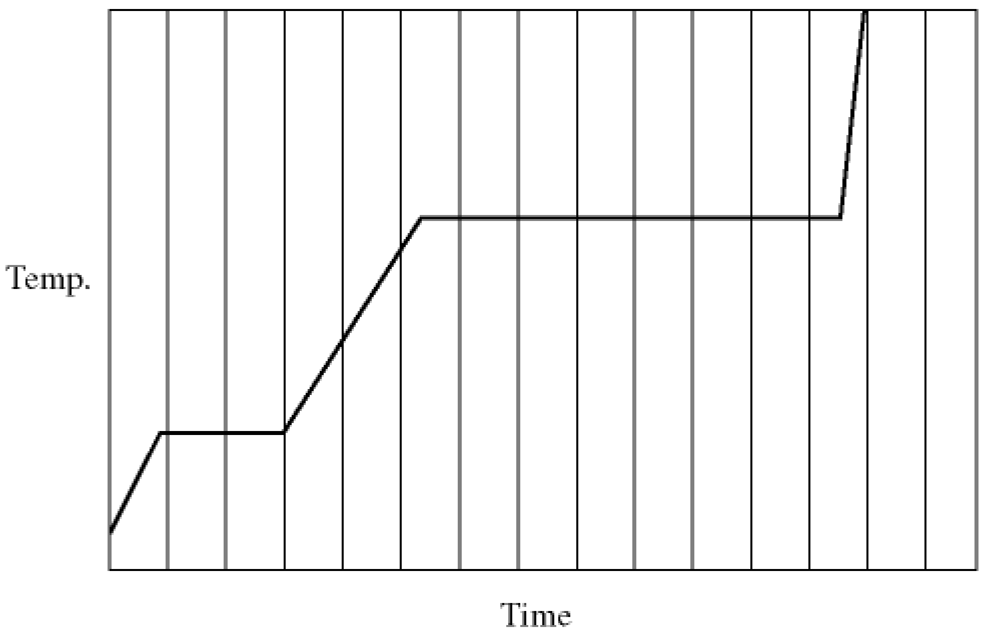
11) The coefficient of volume expansion of olive oil is 0.68×10^{-3} K^{-1}. A 1.00-L glass beaker is filled to the brim with olive oil at room temperature. The beaker is placed on a range and the temperature of the oil and beaker increases by 25 C°. As a result, 0.0167 L of olive oil spill over the top of the beaker. What is the coefficient of linear expansion of the glass?
A) 1.0×10^{-6} K^{-1}
B) 4.0×10^{-6} K^{-1}
C) 1.0×10^{-5} K^{-1}
D) 2.0×10^{-5} K^{-1}
E) 3.0×10^{-5} K^{-1}

Answer: B

12) A certain metal has a coefficient of linear expansion of 2.00×10^{-5} K^{-1}. It has been kept in a laboratory oven at 325°C for a long time. It is now removed from the oven and placed in a freezer at -145°C. After it has reached freezer temperature, the percent change in its density during this process is closest to
A) +2.90%.
B) -2.90%.
C) +2.74%.
D) -2.74%.
E) It is not possible to tell without knowing the mass and original volume of the metal.

Answer: A

13) Heat is added to a pure substance in a closed container at a constant rate. The figure shows a graph of the temperature of the substance as a function of time. If L_f = latent heat of fusion and L_v = latent heat of vaporization, what is the value of the ratio L_v / L_f for this substance?



A) 5.0
B) 4.5
C) 7.2
D) 3.5
E) 1.5

Answer: D

14) A substance has a melting point of 20°C and a heat of fusion of 3.9×10^4 J/kg. The boiling point is 150°C and the heat of vaporization is 7.8×10^4 J/kg at a pressure of 1.0 atm. The specific heats for the solid, liquid, and gaseous phases are 600 J/(kg•K), 1000 J/(kg•K), and 400 J/(kg•K), respectively. The quantity of heat required to raise the temperature of 3.80 kg of the substance from –6°C to 128°C, at a pressure of 1.0 atm, is closest to

A) 620 kJ.
B) 470 kJ.
C) 560 kJ.
D) 210 kJ.
E) 770 kJ.

Answer: A

15) A substance has a melting point of 20°C and a heat of fusion of 3.5×10^4 J/kg. The boiling point is 150°C and the heat of vaporization is 7.0×10^4 J/kg at a pressure of 1.0 atm. The specific heats for the solid, liquid, and gaseous phases are 600 J/(kg•K), 1000 J/(kg•K), and 400 J/(kg•K), respectively. The quantity of heat given up by 0.50 kg of the substance when it is cooled from 170°C to 88°C, at a pressure of 1.0 atmosphere, is closest to

A) 70 kJ.
B) 14 kJ.
C) 21 kJ.
D) 30 kJ.
E) 44 kJ.

Answer: A

16) If 2.0 g of water at 0.00°C is to be vaporized, how much heat must be added to it? The specific heat of water is 1.0 cal/g•K, its heat of fusion is 80 cal/g, and its heat of vaporization is 539 cal/g.

A) 1100 cal
B) 1100 kcal
C) 1200 cal
D) 1300 cal
E) 1500 cal

Answer: D

17) If you add 700 kJ of heat to 700 g of water at 70.0°C, how much water is left in the container? The latent heat of vaporization of water is 2.26×10^6 J/kg and its specific heat is is 4190 J/(kg •K).

A) 429 g
B) 258 g
C) 340 g
D) 600 g
E) none

Answer: A

18) Heat is added to a 2.0 kg piece of ice at a rate of 793.0 kW. How long will it take for the ice to melt if it was initially at 0.00°C? (The latent heat of fusion for water is 334 kJ/kg and its latent heat of vaporization is 2260 kJ/kg.)

A) 0.84 s
B) 530,000 s
C) 4.7 s
D) 670 s

Answer: A

19) A 406.0 kg copper bar is put into a smelter for melting. The initial temperature of the copper is 300.0 K. How much heat must the smelter produce to completely melt the copper bar? (The specific heat for copper is 386 J/kg•K, the heat of fusion for copper is 205 kJ/kg, and its melting point is 1357 K.)

A) 2.49×10^5 kJ
B) 1.66×10^{11} kJ
C) 1.66×10^8 kJ
D) 2.96×10^5 kJ

Answer: A

20) Two experimental runs are performed to determine the calorimetric properties of an alcohol that has a melting point of -10°C. In the first run, a 200-g cube of frozen alcohol, at the melting point, is added to 300 g of water at 20°C in a styrofoam container. When thermal equilibrium is reached, the alcohol-water solution is at a temperature of 5.0°C. In the second run, an identical cube of alcohol is added to 500 g of water at 20°C and the temperature at thermal equilibrium is 10°C. The specific heat of water is 4190 J/kg•K. Assume that no heat is exchanged with the styrofoam container and with the surroundings. The heat of fusion of the alcohol is closest to

A) 5.5×10^4 J/kg
B) 6.3×10^4 J/kg
C) 7.1×10^4 J/kg
D) 7.9×10^4 J/kg
E) 8.7×10^4 J/kg

Answer: B

21) Two experimental runs are performed to determine the calorimetric properties of an alcohol that has a melting point of -10°C. In the first run, a 200-g cube of frozen alcohol, at the melting point, is added to 300 g of water at 20°C in a styrofoam container. When thermal equilibrium is reached, the alcohol-water solution is at a temperature of 5.0°C. In the second run, an identical cube of alcohol is added to 500 g of water at 20°C and the temperature at thermal equilibrium is 10°C. The specific heat of water is 4190 J/kg•K. Assume that no heat is exchanged with the styrofoam container and with the surroundings. The specific heat of the alcohol is closest to

A) 1700 J/kg•K.
B) 1900 J/kg•K.
C) 2100 J/kg•K.
D) 2300 J/kg•K.
E) 2500 J/kg•K.

Answer: C

22) A person makes ice tea by adding ice to 1.8 kg of hot tea, initially at 80°C. How many kilograms of ice, initially at 0.00°C, are required to bring the mixture to 10°C? The heat of fusion of ice is 334 kJ/kg, and we can assume that tea has essentially the same thermal properties as water, so its specific heat is 4190 J/(kg•K).
A) 1.0 kg
B) 1.2 kg
C) 1.4 kg
D) 1.5 kg
E) 1.7 kg

Answer: C

23) A block of ice at 0.000°C is added to a well–insulated 147–g aluminum calorimeter cup that holds 200 g of water at 10.0°C. The water and aluminum cup are in thermal equilibrium, and the specific heat of aluminum is 910 J/(kg•K). If all but 2.00 g of ice melt, what was the original mass of the block of ice? The specific heat of water is 4190 J/(kg•K), its latent heat of fusion is 334 kJ/kg, and its latent heat of vaporization is 2260 kJ/kg.
A) 31.1 g
B) 35.6 g
C) 38.8 g
D) 42.0 g
E) 47.6 g

Answer: A

24) A 200–g metal container, insulated on the outside, holds 100 g of water in thermal equilibrium at 22.00°C. A 21–g ice cube, at the melting point, is dropped into the water, and when thermal equilibrium is reached the temperature is 15.00°C. Assume there is no heat exchange with the surroundings. For water, the specific heat is 4190 J/kg • K and the heat of fusion is 3.34×10^5 J/kg. The specific heat for the metal is closest to
A) 3850 J/kg • K.
B) 2730 J/kg • K.
C) 4450 J/kg • K.
D) 4950 J/kg • K.
E) 5450 J/kg • K.

Answer: A

25) How many grams of ice at –13°C must be added to 711 grams of water that is initially at a temperature of 87°C to produce water at a final temperature of 10.0°C? Assume that no heat is lost to the surroundings and that the container has negligible mass. The specific heat of liquid water is 4190 J/kg•C° and of ice is 2050 J/kg•C°. For water the normal melting point is 0.00°C and the heat of fusion is 334×10^3 J/kg. The normal boiling point is 100°C and the heat of vaporization is 2.26×10^6 J/kg.

Answer: 570 g

26) The walls of an ice chest are made of 2.00-mm-thick insulation having a thermal conductivity 0.00300 W/m•K. The total surface area of the ice chest is 1.20 m^2. If 4.00 kg of ice at 0.00°C are placed in the chest and the temperature of the outside surface of the chest is 20.0°C, how long does it take the ice to melt under steady state conditions? The latent heat of fusion of water is 79.6 cal/g = 334 kJ/kg.

A) 4.22 h
B) 22.1 h
C) 17.6 h
D) 1.33 d
E) 10.3 h

Answer: E

27) A rod, with sides insulated to prevent heat loss, has one end immersed in boiling water 100°C and the other end in a water-ice mixture at 0.00°C. The rod has uniform cross-sectional area of 4.04 cm^2 and length of 91 cm. Under steady state conditions, the heat conducted by the rod melts the ice at a rate of 1.0 g every 34 seconds. What is the thermal conductivity of the rod? (The heat of fusion of water is 3.34×10^5 J/kg.)

Answer: 220 W/m • K

28) A spherical object 25.0 cm in diameter having an emissivity of 0.800 is held at a temperature of 275°C by an internal heater. This object is embedded in a very large vat of water at 100.0°C and atmospheric pressure. At what maximum rate (in g/min) is the water evaporating in the vat due to the radiated heat it receives from the object? You can ignore any heat radiated by the water. The latent heat of fusion for water is 33,400 J/kg, its latent heat of vaporization is 2.26×10^6 J/kg, and the Stefan-Boltzmann constant is 5.670×10^{-8} W/m^2 • K^4.

Answer: 21.3 g/min

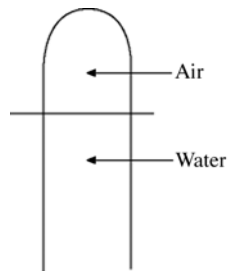
29) 2.0 L of a ideal nitrogen gas (N_2) are at 0.00°C and 1.0 atm. The ideal gas constant is R = 8.314 J/mol • K = 0.0821 L • atm/mol • K, Avogadro's number is 6.022×10^{23} molecules/mol, and the ATOMIC mass of nitrogen is 14 g/mol.
(a) Determine the number of moles of N_2.
(b) How many molecules of N_2 are present?
(c) What is the mass of this gas?

Answer: (a) 0.089 mol (b) 5.4×10^{23} molecules (c) 2.5 g

30) If a certain sample of an ideal gas has a temperature of 109°C and exerts a pressure of 1.2×10^4 Pa on the walls of its container, how many gas molecules are present in each cubic centimeter of volume? The ideal gas constant is 8.314 J/mol • K and Avogadro's number is 6.022×10^{23} molecules/mol.

Answer: 2.3×10^{18} molecules

31) A vertical tube that is closed at the upper end and open at the lower end contains an air pocket. The open end of the tube is under the water of a lake, as shown in the figure. When the lower end of the tube is just under the surface of the lake, where the temperature is 37°C and the pressure is 1.0×10^5 Pa, the air pocket occupies a volume of 630 cm^3. Suppose now that the lower end of the tube is at a depth of 86 m in the lake, where the temperature is 7.0°C. What is the volume of the air pocket under these conditions? The density of the water in the lake is 1000 kg/m^3.



Answer: 60 cm^3

32) A sealed 89-m^3 tank is filled with 6000 moles of oxygen gas (O_2) at an initial temperature of 270 K. The gas is heated to a final temperature of 350 K. The ATOMIC mass of oxygen is 16.0 g/mol, and the ideal gas constant is $R = 8.314$ J/mol • K = 0.0821 L • atm/mol • K. The initial pressure of the gas is closest to

A) 0.15 MPa.
B) 0.17 MPa.
C) 0.19 MPa.
D) 0.13 MPa.
E) 0.11 MPa.

Answer: A

33) A sealed 26-m^3 tank is filled with 2000 moles of oxygen gas (O_2) at an initial temperature of 270 K. The gas is heated to a final temperature of 460 K. The ATOMIC mass of oxygen is 16.0 g/mol, and the ideal gas constant is $R = 8.314$ J/mol • K = 0.0821 L • atm/mol • K. The final pressure of the gas is closest to

A) 0.29 MPa.
B) 0.31 MPa.
C) 0.33 MPa.
D) 0.34 MPa.
E) 0.36 MPa.

Answer: A

34) A 3.2-L volume of neon gas (Ne) is at a pressure of 3.3 atm and a temperature of 330 K. The atomic mass of neon is 20.2 g/mol, Avogadro's number is 6.022 10^{23} molecules/mol, and the ideal gas constant is R = 8.314 J/mol • K = 0.0821 L • atm/mol • K. The mass of the neon gas is closest to

A) 7.9×10^{-3} kg.
B) 4.6×10^{-3} kg.
C) 3.8 kg.
D) 7.8 kg.
E) 7.8×10^{2} kg.

Answer: A

35) A weather balloon contains 12.0 m^3 of hydrogen gas when the balloon is released from a location at which the temperature is 22.0°C and the pressure is 101 kPa. The balloon rises to a location where the temperature is -30.0°C and the pressure is 20.0 kPa. If the balloon is free to expand so that the pressure of the gas inside is equal to the ambient pressure, what is the new volume of the balloon? Assume that in both cases the hydrogen gas is in thermal equilibrium with the outside air.

A) 14.0 m^3
B) 2.38 m^3
C) 49.9 m^3
D) 82.6 m^3
E) 4.16 m^3

Answer: C

36) A sealed container holds 0.020 moles of nitrogen (N_2) gas, at a pressure of 1.5 atmospheres and a temperature of 290 K. The atomic mass of nitrogen is 14.0 g/mol. The Boltzmann constant is 1.38×10^{-23} J/K and the ideal gas constant is R = 8.314 J/mol • K = 0.0821 L • atm/mol • K. The mass density of the gas is closest to

A) 0.90 kg/m^3.
B) 1.3 kg/m^3.
C) 1.8 kg/m^3.
D) 2.2 kg/m^3.
E) 2.6 kg/m^3.

Answer: C

37) An ideal gas is at a pressure 1.00×10^5 N/m^2 and occupies a volume 2.00 m^3. If the gas is compressed to a volume 1.00 m^3 while the temperature remains constant, what will be the new pressure in the gas?

A) 0.500×10^5 N/m^2
B) 4.00×10^5 N/m^2
C) 1.00×10^5 N/m^2
D) 2.00×10^5 N/m^2
E) The answer depends on the mass of the gas particles.

Answer: D

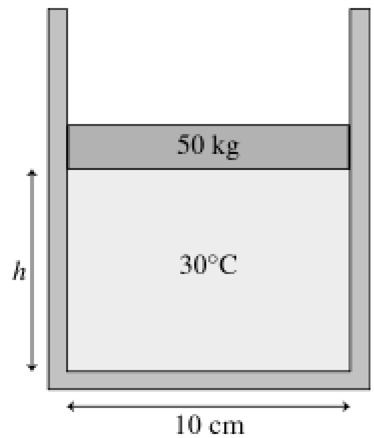
38) Sometimes an experiment requires a certain pure gas to be used at reduced pressure. One way to achieve this is to purchase a sealed glass container filled with the gas, and to introduce the gas into a vacuum by attaching the glass container to the vacuum chamber and breaking the tip of the glass container using a metallic bean and a magnet. If the volume of the glass container is 1.0 L and it is at a pressure of 1.0×10^5 Pa and if the vacuum chamber has a volume of 2.0 L, what will the pressure be after the gas, which is to be assumed to be an ideal gas, is released into the vacuum chamber and the temperature has returned to its original value? (Note that the glass container remains part of the system.)
A) 33 kPa
B) 50 kPa
C) 300 kPa
D) 200 kPa
Answer: A

39) A bag of potato chips contains 2.00 L of air when it is sealed at sea level at a pressure of 1.00 atm and a temperature of 20.0°C. What will be the volume of the air in the bag if you take it with you, still sealed, to the mountains where the temperature is 7.00°C and atmospheric pressure is 70.0 kPa? Assume that the bag behaves like a balloon and that the air in the bag is in thermal equilibrium with the outside air. (1 atm = 1.01×10^5 Pa)
A) 4.13 L
B) 1.01 L
C) 1.38 L
D) 2.76 L
Answer: D

40) A cold trap is set up to cause molecules to linger near the suction in a vacuum system. If the cold trap has an effective volume of 0.200 L and is maintained at 13.0 K, how many molecules are in it at 10.0 Pa of pressure? (Avogadro's number is 6.022×10^{23} molecules/mol, and the universal gas constant is 8.314 J/mol•K. Assume the behavior of an ideal gas.)
A) 1.11×10^{19} molecules
B) 1.10×10^{22} molecules
C) 7.71×10^{20} molecules
D) 7.71×10^{23} molecules
Answer: A

41) A hot air balloon has a volume of 2.00×10^3 m^3 when fully inflated, and the air inside the balloon is always at atmospheric pressure of 1.01×10^5 Pa because of the large opening used to fill the balloon and heat the air inside it. What is the mass of hot air inside the balloon if its temperature is 120°C? The universal gas constant is 8.314 J/mol•K. (Assume a molecular weight of 28.8 g/mol for air.)
A) 1780 kg
B) 5850 kg
C) 203 kg
D) 62.0 kg
Answer: A

42) The figure shows a 50-kg frictionless cylindrical piston that floats on 0.68 mol of compressed air at 30°C. How far does the piston move if the temperature is increased to 300°C?



A) 120 cm
B) 250 cm
C) 130 cm
D) 1300 cm

Answer: A

43) 3.00 moles of an ideal gas at a pressure of 250 kPa are held in a container of volume of 25.0 L. The ideal gas constant is R = 8.314 J/mol•K = 0.0821 L • atm/mol • K, and 1 atm = 1.01 x 10^5 Pa. The temperature of this gas is closest to

A) 240°C.
B) -180°C.
C) 480°C.
D) -1.0°C.
E) -22°C.

Answer: E

44) How many moles of water (H_2O) molecules are in a 4.00 m^3 container at a pressure 8.00 × 10^5 N/m^2 and temperature 600°C? The ideal gas constant is R = 8.314 J/mol•K = 0.0821 L • atm/mol • K.

A) 7.72 × 10^{26} mol
B) 641 mol
C) 441 mol
D) 3.86 × 10^{26} mol
E) 2.65 × 10^{26} mol

Answer: C

45) The interior of a refrigerator has a volume of 0.600 m^3. The temperature inside the refrigerator in 282 K, and the pressure is 101 kPa. If the molecular weight of air is 29 g/mol, what is the mass of air inside the refrigerator? The ideal gas constant is $R = 8.314$ J/mol•K = 0.0821 L • atm/mol • K.
A) 500 g
B) 560 g
C) 140 g
D) 270 g
E) 750 g
Answer: E

46) What is the mass density of argon gas at pressure 1.00×10^5 N/m^2 and at temperature 300 K? The mean atomic mass of argon is 39.948 g/mol and the ideal gas constant is $R = 8.314$ J/mol •K = 0.0821 L • atm/mol • K.
A) 1.40 kg/m^3
B) 1.00 kg/m^3
C) 1.20 kg/m^3
D) 1.60 kg/m^3
E) 1.80 kg/m^3
Answer: D

47) A 25-L container holds ideal hydrogen (H_2) gas at a gauge pressure of 0.25 atm and a temperature of 0°C. What mass of hydrogen gas is in this container? The ATOMIC mass of hydrogen is 1.0 g/mol, the ideal gas constant is $R = 8.314$ J/mol•K = 0.0821 L • atm/mol • K, and 1.00 atm = 101 kPa.
A) 1.4 g
B) 2.8 g
C) 4.2 g
D) 5.6 g
E) 6.3 g
Answer: B

48) What is the total translational kinetic energy in a test chamber filled with nitrogen (N_2) at 2.16×10^5 Pa and 20.7°C? The dimensions of the chamber are 4.00 m × 5.70 m × 7.40 m. The ATOMIC weight of nitrogen is 28.0 g/mol, Avogadro's number is 6.022×10^{23} molecules/mol and the Boltzmann constant is 1.38×10^{-23} J/K.
Answer: 5.47×10^7 J

49) A 5.0–liter gas tank holds 1.4 moles of helium (He) and 0.70 moles of oxygen (O_2), at a temperature of 260 K. The atomic masses of helium and oxygen are 4.0 g/mol and 16.0 g/mol, respectively. Avogadro's number is 6.022×10^{23} molecules/mol and the Boltzmann constant is 1.38×10^{-23} J/K. The total random translational kinetic energy of the gas in the tank is closest to

A) 6.8 kJ.
B) 6.1 kJ.
C) 7.6 kJ.
D) 8.3 kJ.
E) 9.1 kJ.

Answer: A

50) A 5.0–liter gas tank holds 1.7 moles of monatomic helium (He) and 1.10 mole of diatomic oxygen (O_2), at a temperature of 260 K. The ATOMIC masses of helium and oxygen are 4.0 g/mol and 16.0 g/mol, respectively. What is the ratio of the root–mean–square (thermal) speed of helium to that of oxygen?

A) 1.4
B) 2.0
C) 2.8
D) 4.0
E) 5.6

Answer: C

51) An ideal gas is kept in a rigid container that expands negligibly when heated. The gas starts at a temperature of 20.0°C, and heat is added to increase its temperature. At what temperature will its root–mean–square speed (thermal speed) be double its value at 20.0°C?

A) 40.0°C
B) 141°C
C) 313°C
D) 400°C
E) 899°C

Answer: E

52) The root–mean–square speed (thermal speed) for a certain gas at 100°C is 0.500 km/s. If the temperature of the gas is now increased to 200°C, the root–mean–square (thermal) speed will be closest to

A) 563 m/s.
B) 634 m/s.
C) 707 m/s.
D) 804 m/s.
E) 1000 m/s.

Answer: A

53) A 0.10-m^3 gas tank holds 5.0 moles of nitrogen gas (N_2), at a temperature of 370 K. The atomic mass of nitrogen is 14 g/mol, the molecular radius is 3.0×10^{-10} m, and the Boltzmann constant is 1.38×10^{-23} J/K. The root-mean-square speed (thermal speed) of the molecules is closest to
A) 570 m/s.
B) 810 m/s.
C) 410 m/s.
D) 22 m/s.
E) 99 m/s.
Answer: A

54) What is the average translational kinetic energy per molecule of an ideal gas at a temperature of 300 K? The Boltzmann constant is 1.38×10^{-23} J/K.
A) 1.7×10^{-21} J
B) 8.3×10^{-21} J
C) 6.2×10^{-21} J
D) 2.1×10^{-21} J
E) 4.1×10^{-21} J
Answer: C

55) The root-mean-square speed (thermal speed) of a certain sample of carbon dioxide molecules, with a molecular weight of 44 g/mol, is 396 m/s. What is the root-mean-square speed (thermal speed) of water vapor molecules, with a molecular weight of 18 g/mol, at the same temperature?
A) 253 m/s
B) 396 m/s
C) 421 m/s
D) 506 m/s
E) 619 m/s
Answer: E

56) The root-mean-square speed (thermal speed) of the molecules of a gas is 200 m/s at a temperature 23.0°C. What is the mass of the individual molecules? The Boltzmann constant is 1.38×10^{-23} J/K.
A) 2.13×10^{-25} kg
B) 2.45×10^{-25} kg
C) 5.66×10^{-25} kg
D) 1.78×10^{-25} kg
E) 3.11×10^{-25} kg
Answer: E

57) A sealed container holds 0.020 moles of nitrogen (N_2) gas at a pressure of 1.5 atmospheres and a temperature of 290 K. The atomic mass of nitrogen is 14 g/mol. The Boltzmann constant is 1.38×10^{-23} J/K and the ideal gas constant is $R = 8.314$ J/mol•K = 0.0821 L • atm/mol • K. The average translational kinetic energy of a nitrogen molecule is closest to

A) 4.0×10^{-21} J.
B) 6.0×10^{-21} J.
C) 8.0×10^{-21} J.
D) 10×10^{-21} J.
E) 12×10^{-21} J.

Answer: B

58) At 50.0°C, the average translational kinetic energy of a gas molecule is K. If the temperature is now increased to 100.0°C, the average translational kinetic energy of a molecule will be closest to

A) 1.07K.
B) 1.15K.
C) 1.41K.
D) 2.00K.
E) 4.00K.

Answer: B

59) The root-mean-square speed (thermal speed) of the molecules of a gas is 200 m/s at 23.0°C. At 227°C the root-mean-square speed (thermal speed) of the molecules will be closest to

A) 160 m/s
B) 330 m/s
C) 260 m/s
D) 630 m/s
E) 2000 m/s

Answer: C

60) A cubic box with sides of 20.0 cm contains 2.00×10^{23} molecules of helium with a root-mean-square speed (thermal speed) of 200 m/s. The mass of a helium molecule is 3.40×10^{-27} kg. What is the average pressure exerted by the molecules on the walls of the container? The Boltzmann constant is 1.38×10^{-23} J/K and the ideal gas constant is $R = 8.314$ J/mol•K = 0.0821 L • atm/mol • K.

A) 3.39 kPa
B) 1.13 kPa
C) 570 Pa
D) 2.26 kPa
E) 9.10 Pa

Answer: B

61) At what temperature would the root-mean-square speed (thermal speed) of oxygen molecules be 13.0 m/s? Assume that oxygen approximates an ideal gas. The mass of one O_2 molecule is 5.312×10^{-26} kg. The Boltzmann constant is 1.38×10^{-23} J/K.
A) 0.217 K
B) 1800 K
C) 5410 K
D) 0.0666 K
Answer: A

62) What is the average kinetic energy of an ideal gas molecule at 569°C? (The Boltzmann constant is 1.38×10^{-23} J/K.)
A) 1.74×10^{-20} J
B) 5.81×10^{-21} J
C) 1.18×10^{-17} J
D) 3.93×10^{-19} J
Answer: A

63) Dust particles are pulverized rock, which has density 2500 kg/m^3. They are approximately spheres 20 μm in diameter. Treating dust as an ideal gas, what is the root-mean-square speed (thermal speed) of a dust particle at 400°C? (The Boltzmann constant is 1.38×10^{-23} J/K.)
A) 5.2×10^{-5} m/s
B) 1.7×10^{-5} m/s
C) 3.0×10^{-5} m/s
D) 7.3×10^{-5} m/s
Answer: A

64) An oxygen molecule falls in a vacuum. From what height must it fall so that its kinetic energy at the bottom equals the average energy of an oxygen molecule at 800 K? (The Boltzmann constant is 1.38×10^{-23} J/K, the molecular weight of oxygen is 32.0 g/mol, and Avogadro's number is 6.022×10^{23} molecules/mol.)
A) 31.8 km
B) 10.6 km
C) 21.1 km
D) 42.3 km
Answer: A

Chapter 18 Heat, Work, and the First Law of Thermodynamics

18.1 Conceptual Questions

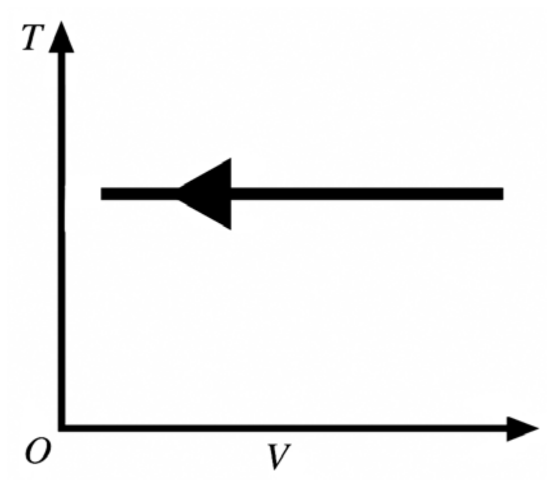
1) When a gas undergoes an isothermal process, there is
   A) no change in the pressure of the gas.
   B) no change in the temperature of the gas.
   C) no change in the volume of the gas.
   D) no work done by (or on) the gas.
   E) no heat added to the gas.

Answer: B

2) An ideal gas is compressed in a well-insulated chamber using a well-insulated piston. This process is
   A) isochoric.
   B) isothermal.
   C) adiabatic.
   D) isobaric.

Answer: C

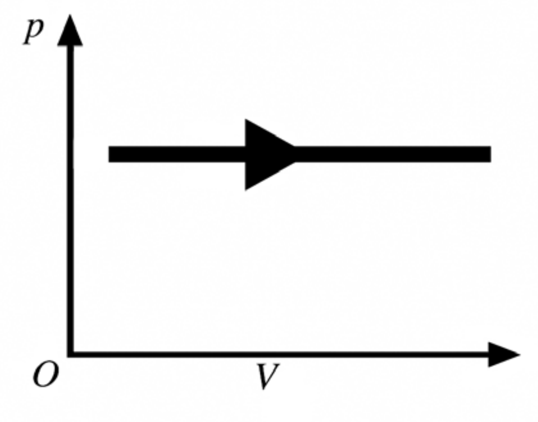
3) The process shown in the T-V diagram in the figure is an



   A) adiabatic compression.
   B) isothermal compression.
   C) isochoric compression.
   D) isobaric compression.
   E) isothermal expansion.

Answer: B

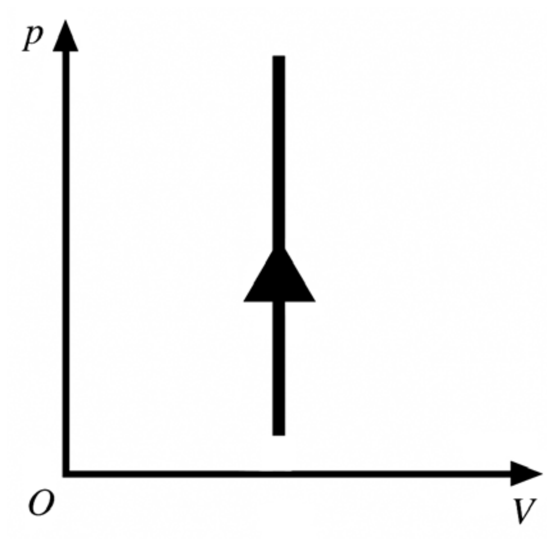
4) The process shown in the pV diagram in the figure is an



A) adiabatic expansion.
B) isothermal expansion.
C) isochoric expansion.
D) isobaric expansion.
E) isochoric compression.

Answer: D

5) The process shown in the pV diagram in the figure is



A) adiabatic.
B) isothermal.
C) isochoric.
D) isobaric.

Answer: C

6) Consider two cylinders of gas identical in all respects except that one contains oxygen O_2 and the other helium He. Both cylinders initially contain the same volume of gas at 0°C and 1 atm of pressure and are closed by a movable piston at one end. Both gases are now compressed adiabatically to one-third their original volume.
(a) Which gas will show the greater temperature increase?
A) the O_2
B) the He
C) Neither; both will show the same increase.
D) It is impossible to tell from the information given.
(b) Which gas will show the greater pressure increase?
A) the O_2
B) the He
C) Neither; both will show the same increase.
D) It is impossible to tell from the information given.

Answer: (a) B (b) B

7) When a fixed amount of ideal gas goes through an isothermal expansion
A) its internal (thermal) energy does not change.
B) the gas does no work.
C) no heat enters or leaves the gas.
D) its temperature must decrease.
E) its pressure must increase.

Answer: A

8) When a fixed amount of ideal gas goes through an adiabatic expansion
A) its internal (thermal) energy does not change.
B) the gas does no work.
C) no heat enters or leaves the gas.
D) its temperature cannot change.
E) its pressure must increase.

Answer: C

9) When a fixed amount of ideal gas goes through an isobaric expansion
A) its internal (thermal) energy does not change.
B) the gas does no work.
C) no heat enters or leaves the gas.
D) its temperature must increase.
E) its pressure must increase.

Answer: D

10) When a fixed amount of ideal gas goes through an isochoric process
A) its internal (thermal) energy does not change.
B) the gas does no work.
C) no heat enters or leaves the gas.
D) its temperature must increase.
E) its pressure must increase.

Answer: B

11) An ideal gas increases in temperature from 22°C to 42°C by two different processes. In one process, the temperature increases at constant volume, and in the other process the temperature increases at constant pressure. Which of the following statements about this gas are correct? (There may be more than one correct choice.)
   A) The heat required to cause this temperature change is the same for both the constant-volume and the constant-pressure processes.
   B) More heat is required for the constant-pressure process than for the constant-volume process.
   C) The change in the internal (thermal) energy of the gas is the same for both the constant-volume and the constant-pressure processes.
   D) The root-mean-square (thermal) speed of the gas molecules increases more during the constant-volume process than during the constant-pressure process.

   Answer: B, C

12) A container of ideal gas has a movable frictionless piston. This container is placed in a very large water bath and slowly compressed so that the temperature of the gas remains constant and equal to the temperature of the water. Which of the following statements about this gas are true for this process? (There may be more than one correct choice.)
   A) Heat leaves the gas during the compression.
   B) Since the gas and water are at the same temperature, no heat can flow between them, which makes this an adiabatic compression.
   C) The internal (thermal) energy of the gas does not change during the compression.
   D) The internal energy of the gas increases during the compression because work is done on the gas.
   E) Since the temperature of the gas remains constant, the pressure of the gas must also remain constant.

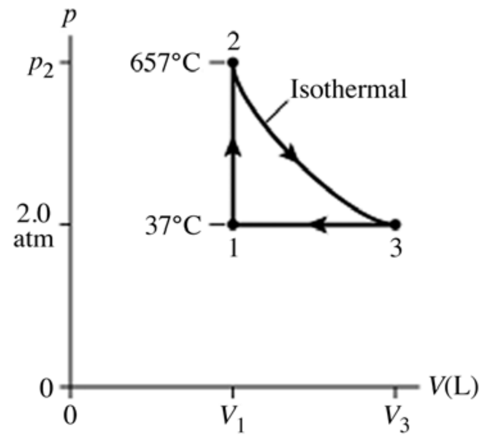
   Answer: A, C

13) When an ideal gas increases in volume at constant pressure, the average kinetic energy of the gas molecules
   A) increases.
   B) decreases.
   C) does not change.
   D) may either increase or decrease, depending on whether or not the process is carried out adiabatically.
   E) may or may not change, but insufficient information is given to make such a determination.

   Answer: A

18.2 Problems

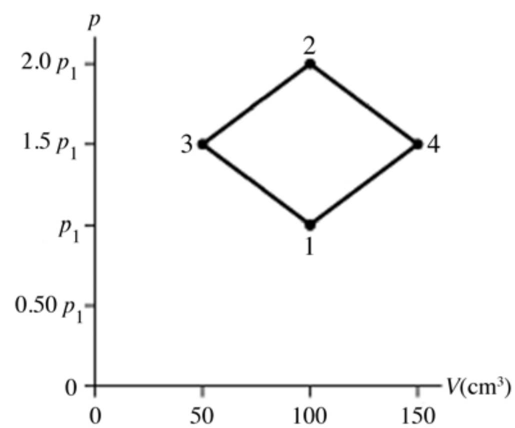
1) The figure (not to scale) shows a pV diagram for 1.8 g of helium gas (He) that undergoes the process $1 \rightarrow 2 \rightarrow 3$. Find the value of V_3. The ideal gas constant is R = 8.314 J/mol • K = 0.0821 L • atm/mol • K, and the atomic weight of helium is 4.0 g/mol.



A) 17 L
B) 69 L
C) 34 L
D) 8.6 L

Answer: A

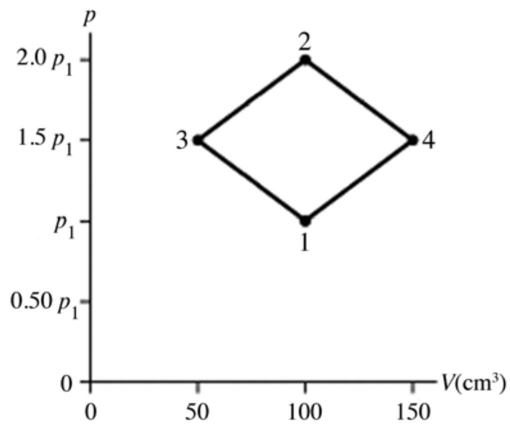
2) The figure shows a pV diagram for 8.3 g of nitrogen gas (N_2) in a sealed container. The temperature T_1 of the gas in state 1 is 79°C. What are (a) the pressure p_1 of the gas in state 1 and (b) the temperature T_2 of the gas in state 2? The ideal gas constant is R = 8.314 J/mol • K = 0.0821 L • atm/mol • K, and the ATOMIC weight of nitrogen is 14 g/mol.



A) (a) 86 atm, (b) 700°C.
B) (a) 19 atm, (b) 700°C.
C) (a) 86 atm, (b) 160°C.
D) (a) 19 atm, (b) 160°C.

Answer: A

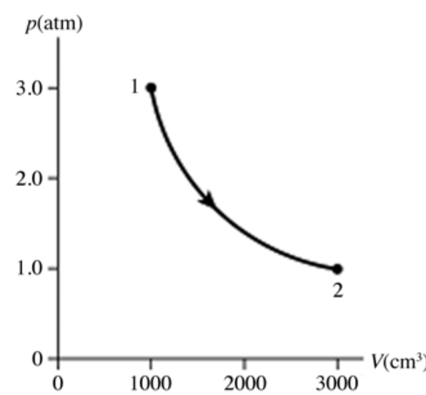
3) The figure shows a *pV* diagram for 4.3 g of oxygen gas (O_2) in a sealed container. The temperature T_1 of the gas in state 1 is 21°C. What are the temperatures T_3 and T_4 of the gas in states 3 and 4? The ideal gas constant is R = 8.314 J/mol • K = 0.0821 L • atm/mol • K, and the ATOMIC weight of oxygen is 16 g/mol.



A) –52°C, 390°C
B) 16°C, 47°C
C) 220°C, 660°C
D) 11°C, 32°C

Answer: A

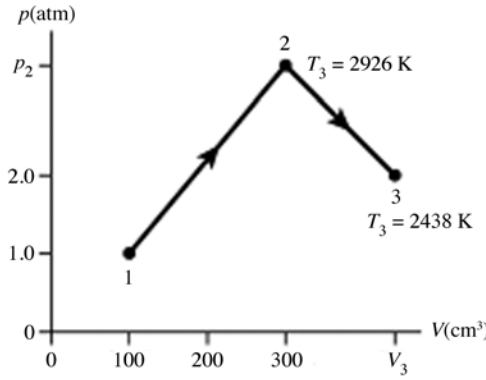
4) The figure shows a *pV* diagram for 0.95 mol of gas that undergoes the process 1 → 2. The gas then undergoes an isochoric heating from point 2 until the pressure is restored to the value it had at point 1. What is the final temperature of the gas? The ideal gas constant is R = 8.314 J/mol • K = 0.0821 L • atm/mol • K.



A) –160°C
B) 15°C
C) 390°C
D) 120°C

Answer: A

5) The figure shows a pV diagram for 0.0066 mol of gas that undergoes the process 1 → 2 → 3. What is the pressure p_2. The ideal gas constant is R = 8.314 J/mol • K = 0.0821 L • atm/mol • K.



A) 5.3 atm
B) 5.3×10^5 atm
C) 16 atm
D) 1.6×10^6 atm
Answer: A

6) How much work is done by 3.00 mol of ideal gas when it triples its volume at a constant temperature of 127°C? The ideal gas constant is R = 8.314 J/mol • K.
A) 12.7 kJ
B) 9.97 kJ
C) 11.0 kJ
D) 15.3 kJ
E) 1.20 kJ
Answer: C

7) An ideal gas in a balloon is kept in thermal equilibrium with its constant-temperature surroundings. How much work is done by the gas if the outside pressure is slowly reduced, allowing the balloon to expand to 6.0 times its original size? The balloon initially has a pressure of 645.0 Pa and a volume of 0.10 m^3. The ideal gas constant is R = 8.314 J/mol • K.
A) 120 J
B) 390 J
C) -330 J
D) 6.0 J
Answer: A

8) A steel container, equipped with a piston, contains 21 mol of an ideal gas at 465 K. The container is compressed isothermally to 90% of its original volume. How much work is done on the gas? The ideal gas constant is R = 8.314 J/mol • K.
A) 8600 J
B) -73,300 J
C) -8500 J
D) 11 J
Answer: A

9) A certain amount of ideal monatomic gas is maintained at constant volume as it is cooled from 455K to 405 K. This feat is accomplished by removing 400 J of heat from the gas. How much work is done by the gas during this process? The ideal gas constant is R = 8.314 J/mol • K.
A) 0.00 J
B) 200 J
C) 400 J
D) -400 J
E) -200 J

Answer: A

10) An ideal monatomic gas cools from 455.0 K to 405.0 K at constant volume as 831 J of energy is removed from it. How many moles of gas are in the sample? The ideal gas constant is R = 8.314 J/mol • K.
A) 2.50 mol
B) 2.15 mol
C) 1.50 mol
D) 1.33 mol
E) 0.725 mol

Answer: D

11) 3.0 moles of an ideal gas with a molar heat capacity at constant volume of 4.9 cal/(mol •K) and a molar heat capacity at constant pressure of 6.9 cal/(mol•K) starts at 300 K and is heated at constant pressure to 320 K, then cooled at constant volume to its original temperature. How much heat flows into the gas during this two–step process?
A) 710 cal
B) -720 cal
C) 0.00 cal
D) 120 cal
E) -120 cal

Answer: D

12) A quantity of ideal gas requires 800 kJ to raise the temperature of the gas by 10.0 K when the gas is maintained at constant volume. The same quantity of gas requires 900 kJ to raise the temperature of the gas by 10.0 K when the gas is maintained at constant pressure. What is the adiabatic constant γ for this gas?
A) 0.889
B) 1.13
C) 1.22
D) 1.67
E) 1.40

Answer: B

13) The temperature of an ideal gas in a sealed 0.40-m^3 rigid container is reduced from 350 K to 270 K. The final pressure of the gas is 60 kPA. The molar heat capacity at constant volume of the gas is 28.0 J/mol • K. The heat absorbed by the gas is closest to
A) -24 kJ.
B) -31 kJ.
C) 24 kJ.
D) 31 kJ.
E) 0.00 kJ.
Answer: A

14) The temperature of an ideal gas in a sealed 0.40 m^3 container is reduced from 400 K to 270 K. The final pressure of the gas is 30 kPA. The molar heat capacity at constant volume of the gas is 28.0 J/mol • K. The work done by the gas is closest to
A) 0.00 kJ.
B) -19 kJ.
C) -25 kJ.
D) 19 kJ.
E) 25 kJ.
Answer: A

15) A compression, at a constant pressure of 190 kPa, is performed on 5.0 moles of an ideal monatomic gas. The compression reduces the volume of the gas from 0.19 m^3 to 0.12 m^3. The ideal gas constant is R = 8.314 J/mol • K. The work done by the gas is closest to
A) -13 kJ.
B) 13 kJ.
C) -33 kJ.
D) 33 kJ.
E) 0.00 kJ.
Answer: A

16) A monatomic ideal gas undergoes an isothermal expansion at 300 K, as the volume increased from 0.03 m^3 to 0.21 m^3. The final pressure of the gas is 60 kPa. The ideal gas constant is R = 8.314 J/mol • K. The change in the internal (thermal) energy of the gas is closest to
A) 0.00 kJ.
B) 12 kJ.
C) 25 kJ.
D) -12 kJ.
E) -25 kJ.
Answer: A

17) A monatomic ideal gas undergoes an isothermal expansion at 300 K, as the volume increased from 0.020 m^3 to 0.040 m^3. The final pressure is 120 kPa. The ideal gas constant is R = 8.314 J/mol • K. The heat transfer to the gas is closest to
A) 3.3 kJ.
B) 1.7 kJ.
C) -3.3 kJ.
D) -1.7 kJ.
E) 0.00 kJ.
Answer: A

18) An expansion process on an ideal diatomic gas has a linear path between the initial and final states on a *pV* diagram. The initial pressure is 300 kPa, the initial volume is 0.060 m^3, and the initial temperature is 390 K. The ideal gas constant is R = 8.314 J/mol • K. The final pressure is 150 kPa and the final temperature is 260 K. The work done by the gas is closest to
A) 4500 J.
B) 2300 J.
C) 3400 J.
D) 5600 J.
E) 6800 J.
Answer: A

19) An expansion process on an ideal diatomic gas has a linear path between the initial and final states on a *pV* diagram. The initial pressure is 300 kPa, the initial volume is 0.020 m^3, and the initial temperature is 390 K. The final pressure is 160 kPa and the final temperature is 310 K. The change in the internal (thermal) energy of the gas is closest to
A) -3100 J.
B) -1800 J.
C) 3100 J.
D) 1800 J.
E) 0.00 J.
Answer: A

20) An adiabatic compression is performed on an ideal gas. The final pressure is equal to 0.560 times the initial pressure and the final volume equals 1.50 times the initial volume. What is the adiabatic constant for the gas?
A) 1.33
B) 1.43
C) 1.48
D) 1.52
E) 1.67
Answer: B

21) An ideal gas with γ = 1.67 is initially at 0°C in a volume of 10.0 L at a pressure of 1.00 atm. It is then expanded adiabatically to a volume of 10.4 L. What is the final temperature of the gas?
A) -7.1°C
B) 2.5°C
C) -23°C
D) 68°C
E) -20°C
Answer: A

22) During an isothermal process, 5.0 J of heat is removed from an ideal gas. What is the change in internal (thermal) energy of the gas?
A) 0.00 J
B) 2.5 J
C) 5.0 J
D) 7.5 J
E) 10 J
Answer: A

23) During an isothermal process, 5.0 J of heat is removed from an ideal gas. How much work does the gas do during this process?
A) 0.00 J
B) 2.0 J
C) 5.0 J
D) -5.0 J
E) 10 J

Answer: D

24) During an adiabatic process, an ideal gas does 25 J of work. What is the change in the internal (thermal) energy of the gas during this process?
A) 0.00 J
B) 50 J
C) 25 J
D) -25 J
E) -50 J

Answer: D

25) In an isochoric process, the internal (thermal) energy of an ideal gas decreases by 50 J. How much work does the gas do during this process?
A) 0.00 J
B) 25 J
C) 50 J
D) -25 J
E) -50 J

Answer: A

26) In an isochoric process, the internal (thermal) energy of an ideal gas decreases by 50 J. How much heat is exchanged with the gas during this process?
A) 0.00 J
B) 25 J
C) 50 J
D) -25 J
E) -50 J

Answer: E

27) A system has a heat source supplying heat to an ideal gas at a rate of 187.0 W and the gas is doing work at a rate of 130.9 W. At what rate is the internal (thermal) energy of the gas changing?
A) 56.1 W
B) 318 W
C) -56.1 W
D) 187 W

Answer: A

28) The gas in a perfectly insulated system does work at a rate of 13 W. At what rate is the internal (thermal) energy of the gas changing?
A) –13 W
B) 13 W
C) 0.00 W
D) 6.5 W
Answer: A

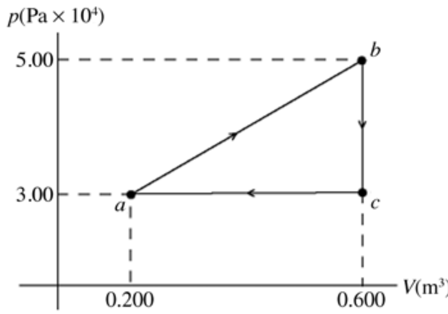
29) An ideal gas is allowed to expand slowly at constant temperature to twice its original volume. During the expansion, the gas absorbs 200 kJ of heat.
(a) What is the change in the internal (thermal) energy of the gas during the expansion?
(b) How much work does the gas do during the expansion?
Answer: (a) zero (b) 200 kJ

30) An ideal gas initially at 300 K and occupying a volume of 20 L is adiabatically compressed. If its final temperature is 400 K and $\gamma = 1.30$, what is its final volume?
A) 7.7 L
B) 14 L
C) 22 L
D) 52 L
Answer: A

31) A container with rigid walls is filled with 4 mol of air with $C_V = 2.5R$. How much does the internal (thermal) energy change if the temperature of the air rises from 16°C to 437°C? The ideal gas constant is $R = 8.314$ J/mol • K.
A) 35 kJ
B) 421 J
C) 3.5 kJ
D) 8.75 kJ
Answer: A

32) An ideal gas with $\gamma = 1.30$ occupies 7.0 L at 300 K and 200 kPa pressure. It is compressed adiabatically to 1/7 of its original volume, then cooled at constant volume to 300 K, and finally allowed to expand isothermally to 7.0 L. How much work does the gas do during this process? The ideal gas constant is $R = 8.314$ J/mol • K = 0.0821 L • atm/mol • K.
A) -980 J
B) 6400 J
C) -270,000 J
D) -6400 J
E) 980 J
Answer: A

33) The pV diagram shown is for 7.50 moles of an ideal diatomic gas taken through a cycle from a to b to c. The ideal gas constant is R = 8.314 J/mol • K.



(a) What is the highest temperature reached by the gas during the cycle?
(b) What *net* work does the gas do during the cycle?
(c) How much heat is exchanged with the gas during part bc of the cycle? Does it enter or leave the gas?
(d) What is the change in the internal (thermal) energy of the gas during part bc of the cycle?
(e) What is the change in the internal (thermal) energy of the gas during the entire cycle?

Answer: (a) 208°C (b) 4.00 kJ (c) 30.0 kJ, leaves the gas
(d) -30.0 kJ (e) 0.00 J

34) A cylinder contains 23 moles of an ideal gas at a temperature of 300 K. The gas is compressed at constant pressure until the final volume equals 0.43 times the initial volume. The molar heat capacity at constant volume of the gas is 24.0 J/mol • K and the ideal gas constant is R = 8.314 J/mol • K. The heat absorbed by the gas is closest to

A) –130 kJ.
B) –94 kJ.
C) 130 kJ.
D) 94 kJ.
E) –33 kJ.

Answer: A

35) A cylinder contains 24.0 moles of an ideal gas at a temperature of 300 K. The gas is compressed at constant pressure until the final volume equals 0.63 times the initial volume. The molar heat capacity at constant volume of the gas is 24.0 J/mol • K and the ideal gas constant is R = 8.314 J/mol • K. The change in the internal (thermal) energy of the gas is closest to

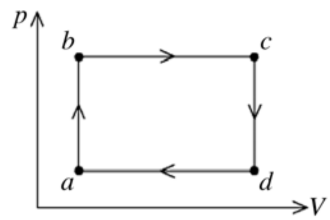
A) –64 kJ.
B) –86 kJ.
C) 64 kJ.
D) 86 kJ.
E) –22 kJ.

Answer: A

36) During an adiabatic process, 20 moles of a monatomic ideal gas undergo a temperature change from 450 K to 320 K starting from an initial pressure is 400 kPa. The ideal gas constant is R = 8.314 J/mol • K.
(a) What is the final volume of the gas?
(b) How much heat does the gas exchange during this process?
(c) What is the change in the internal (thermal) energy of the gas during this process?

Answer: (a) 0.31 m^3 (b) 0.00 J (c) -32 kJ

37) The figure shows the pV diagram for a certain thermodynamic process. In this process, 1500 J of heat flows into a system, and at the same time the system expands against a constant external pressure of 9.00×10^4 Pa. If the volume of the system increases from 0.020 m^3 to 0.050 m^3, calculate the change in internal (thermal) energy of the system. If the internal (thermal) energy change is nonzero, be sure to indicate whether this energy change is positive or negative.



Answer: +−1200 J

38) A fixed amount of ideal gas goes through a process abc. In state a, the temperature of the gas is 152°C, its pressure is 1.25 atm, and it occupies a volume of 0.250 m^3. It then undergoes an isothermal expansion to state b that doubles its volume, followed by an isobaric compression back to its original volume at state c. (*Hint:* First show this process on a pV diagram.) The ideal gas constant is 8.314 J/mol • K, and 1.00 atm = 1.01×10^5 Pa.
(a) How many moles does this gas contain?
(b) What is the change in the internal energy of the gas between states a and b?
(c) What is the *net* work done on (or by) this gas during the entire process?
(d) What is the temperature of the gas in state c?

Answer: (a) 8.93 moles (b) 0.00 J (c) 6.10×10^3 J (d) 213 K

39) A cylinder contains 1.2 moles of ideal gas, initially at a temperature of 116°C. The cylinder is provided with a frictionless piston, which maintains a constant pressure of 6.4×10^5 Pa on the gas. The gas is cooled until its temperature has decreased to 27°C. For the gas C_V = 11.65 J/mol • K, and the ideal gas constant R = 8.314 J/mol • K.
(a) Find the work done by (or on) the gas during this process. Is the work done by or on the gas?
(b) What is the change in the internal (thermal) energy of the gas during this process?
(c) How much heat is transferred to (or from) the gas during this process? Does this heat flow into or out of the gas?

Answer: (a) W = −890 J (the negative sign means that work is done on the gas)
(b) −1200 J
(c) Q = −2100 J (the negative sign means that heat flows out of the gas)

40) In a thermodynamic process involving 7.8 moles of an ideal gas, the gas is at an initial temperature of 24°C and has an initial volume of 0.040 m^3. The gas expands adiabatically to a volume of 0.080 m^3. For this gas, C_V = 12.27 J/mol • K, and the ideal gas constant is R = 8.314 J/mol • K. Calculate the work done by the gas during this expansion.

Answer: 11 kJ

Chapter 19 The Second Law of Thermodynamics

19.1 Conceptual Questions

1) Is it possible to transfer heat from a hot reservoir to a cold reservoir?
   A) No; this is forbidden by the second law of thermodynamics.
   B) Yes; this will happen naturally.
   C) Yes, but work will have to be done.
   D) Theoretically yes, but it hasn't been accomplished yet.

   Answer: B

2) Is it possible to transfer heat from a cold reservoir to a hot reservoir?
   A) No; this is forbidden by the second law of thermodynamics.
   B) Yes; this will happen naturally.
   C) Yes, but work will have to be done.
   D) Theoretically yes, but it hasn't been accomplished yet.

   Answer: C

3) An engine manufacturer makes the claim that the engine they have developed will, on each cycle, take 100 J of heat out of boiling water at 100°C, do mechanical work of 80 J, and exhaust 20 J of heat at 10°C. What, if anything, is wrong with this claim?
   A) The heat exhausted must always be greater than the work done according to the second law of thermodynamics.
   B) This engine violates the first law of thermodynamics because 100 J + 20 J $\neq$ 80 J.
   C) An engine would operate by taking in heat at the lower temperature and exhausting heat at the higher temperature.
   D) The efficiency of this engine is greater than the ideal Carnot cycle efficiency.
   E) There is nothing wrong with this claim because 100 J = 20 J + 80 J.

   Answer: D

4) The entropy of an isolated system must be conserved, so it never changes.
   A) True
   B) False

   Answer: B

5) As a result of any natural process, the total entropy of any system plus that of its environment
   A) never decreases.
   B) sometimes decreases.
   C) never increases.
   D) always stays the same.

   Answer: A

6) According to the second law of thermodynamics, the entropy of any system always increases.
   A) True
   B) False

   Answer: B

7) A hot piece of iron is thrown into the ocean and its temperature eventually stabilizes. Which of the following statements concerning this process is correct? (There may be more than one correct choice.)
A) The entropy lost by the iron is equal to the entropy gained by the ocean.
B) The entropy gained by the iron is equal to the entropy lost by the ocean.
C) The change in the entropy of the iron-ocean system is zero.
D) The ocean gains more entropy than the iron loses.
E) The ocean gains less entropy than the iron loses.

Answer: D

8) The second law of thermodynamics leads us to conclude that
A) the total energy of the universe is constant.
B) disorder in the universe is increasing with the passage of time.
C) it is theoretically impossible to convert work into heat with 100% efficiency.
D) the total energy in the universe is increasing with time.
E) the total energy in the universe is decreasing with time.

Answer: B

9) An ice cube at 0°C is placed in a very large bathtub filled with water at 30°C and allowed to melt, causing no appreciable change in the temperature of the bath water. Which one of the following statements is true?
A) The entropy gained by the ice cube is equal to the entropy lost by the water.
B) The entropy lost by the ice cube is equal to the entropy gained by the water.
C) The net entropy change of the system (ice plus water) is zero because no heat was added to the system.
D) The entropy of the system (ice plus water) increases because the process is irreversible.
E) The entropy of the water does not change because its temperature did not change.

Answer: D

19.2 Problems

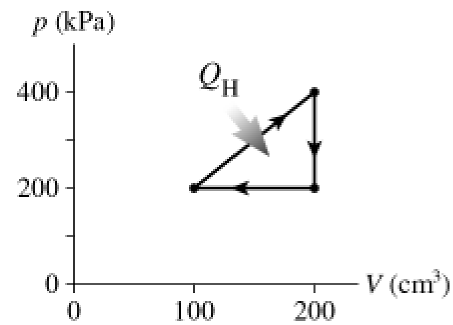
1) A nuclear fission power plant has an actual efficiency of 39%. If 0.25 MW of power are produced by the nuclear fission, how much electric power does the power plant output?
A) 0.098 MW
B) 9.8 MW
C) 35 MW
D) 0.35 MW

Answer: A

2) An automobile engine takes in 4000 J of heat and performs 1100 J of mechanical work in each cycle.
(a) Calculate the engine's efficiency.
(b) How much heat is "wasted" in each cycle?

Answer: (a) 27.5% (b) 2900 J

3) The graph in the figure shows a cycle for a heat engine for which Q_H=35 J. What is the thermal efficiency of this engine?



A) 29 %
B) 57 %
C) 14 %
D) 23 %

Answer: A

4) A certain engine extracts 1300 J of heat from a hot temperature reservoir and discharges 700 J of heat to a cold temperature reservoir. What is the efficiency of this engine?
A) 46%
B) 54%
C) 86%
D) 27%
E) 13%

Answer: A

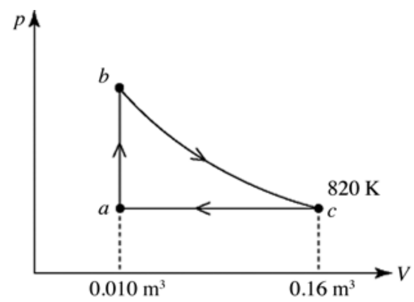
5) A heat engine with an efficiency of 30.0% performs 2500 J of work. How much heat is discharged to the lower temperature reservoir?
A) 5830 J
B) 8330 J
C) 750 J
D) 1350 J
E) 7080 J

Answer: A

6) A real (non–Carnot) heat engine, operating between heat reservoirs at temperatures of 650 K and 270 K, performs 4.3 kJ of net work and rejects 8.0 kJ of heat in a single cycle. The thermal efficiency of this heat engine is closest to
A) 0.35
B) 0.31
C) 0.28
D) 0.38
E) 0.42

Answer: A

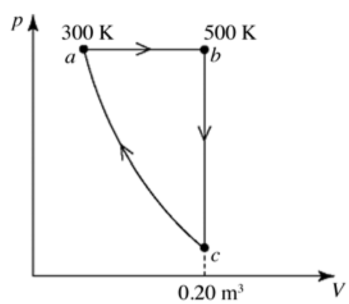
7) A heat engine takes 2.0 moles of an ideal gas through the reversible cycle *abca*, on the *pV* diagram shown in the figure. The path *bc* is an isothermal process. The temperature at *c* is 820 K, and the volumes at *a* and *c* are 0.010 m^3 and 0.16 m^3, respectively. The molar heat capacity at constant volume, of the gas, is 37 J/mol•K, and the ideal gas constant is R = 8.314 J/(mol•K). The thermal efficiency of the engine is closest to



A) 0.26.
B) 0.026.
C) 0.33.
D) 0.40.
E) 0.53.

Answer: A

8) A heat engine performs the reversible cycle *abca* with 9.0 moles of an ideal gas, as shown in the figure. Path *ca* is an adiabatic process. The temperatures at points *a* and *b* are 300 K and 500 K, respectively. The volume at point *c* is 0.20 m^3. The adiabatic constant of the gas is 1.60. The thermal efficiency of this engine is closest to



A) 0.070.
B) 0.10.
C) 0.13.
D) 0.16.
E) 0.19.

Answer: C

9) A refrigerator has a coefficient of performance equal to 4.2. How much work must be done on the refrigerator in order to remove 250 J of heat from the interior?
A) 60 J
B) 120 J
C) 250 J
D) 480 J
E) 1050 J

Answer: A

10) A refrigerator removes heat from the freezing compartment at the rate of 20 kJ and ejects 24 kJ into a room per cycle. How much work is required in each cycle?
A) 4 kJ
B) 20 kJ
C) 22 kJ
D) 24 kJ
E) 44 kJ

Answer: A

11) During each cycle of operation, a refrigerator absorbs 230 J of heat from the freezer and expels 356 J of heat to the room. How much work input is required in each cycle?
A) 712 J
B) 586 J
C) 460 J
D) 310 J
E) 126 J

Answer: E

12) An ideal reversible refrigerator keeps its inside compartment at 9.0°C. What is the high temperature, T_h, needed to give this refrigerator a coefficient of performance of 3.7?
A) 85°C
B) 1052°C
C) 11°C
D) 42°C

Answer: A

13) A refrigerator has a coefficient of performance of 1.15, and it extracts 7.95 J of heat from the cold reservoir during each cycle.
(a) How much work is done on the gas in each cycle?
(b) How much heat is exhausted into the hot reservoir in each cycle?

Answer: (a) 6.91 J (b) 14.9 J

14) An air conditioner with a coefficient of performance of 3.5 uses 30 kW of power. How much power is it discharging to the outdoors?
A) 30 kW
B) 75 kW
C) 105 kW
D) 135 kW
E) 210 kW

Answer: D

15) A certain Carnot heat pump transfers energy from the outside of a house, where the temperature is -15°C, to the inside of a room where the temperature is 21°C. If this heat pump runs off of electricity, what is the minimum rate at which it uses electrical energy to deliver 150 W to the inside room?

Answer: 18 W

16) A Carnot engine operates between a high temperature reservoir at 435 K and a river with water at 280 K. If it absorbs 3700 J of heat each cycle, how much work per cycle does it perform?
A) 1318 J
B) 2382 J
C) 1449 J
D) 2251 J

Answer: A

17) A Carnot engine operating between a reservoir of liquid mercury at its melting point (233 K) and a colder reservoir extracts 10.0 J of heat from the mercury and does 8.0 J of work during each cycle. What is the temperature of the colder reservoir?
A) 47 K
B) 186 K
C) 163 K
D) 207 K

Answer: A

18) What is the maximum theoretical efficiency possible for a heat engine operating between a reservoir in which ice and water coexist, and a reservoir in which water and steam coexist? The pressure is constant at 1.0 atmosphere for both reservoirs.
A) 27%
B) 45%
C) 73%
D) 17%

Answer: A

19) A Carnot engine operates between reservoirs at 550K and 300K, discarding 1500 J of heat in each cycle.
(a) What is the engine's efficiency?
(b) How much heat is supplied to the engine by the hot reservoir in each cycle?

Answer: (a) 45.5% (b) 2750 J

20) A Carnot cycle engine operates between a low temperature reservoir at 20°C and a high temperature reservoir at 800°C. If the engine is required to output 20.0 kJ of work per cycle, how much heat must the high temperature reservoir transfer to the engine during each cycle?
A) 27.5 kJ
B) 73.2 kJ
C) 39.2 kJ
D) 800 kJ
E) 20.5 kJ

Answer: A

21) A perfect Carnot engine operates between the temperatures of 300K and 700K, drawing 60 kJ of heat from the 700K reservoir in each cycle. How much heat is dumped into the 300K reservoir in each cycle?
A) 38 kJ
B) 34 kJ
C) 30 kJ
D) 26 kJ
E) 42 kJ

Answer: D

22) One of the most efficient engines built so far has the following characteristics:

combustion chamber temperature = 1900°C
exhaust temperature = 430°C
7.0×10^9 cal of fuel produces 1.4×10^{10} J of work in one hour, where 1 cal = 4.19 J

(a) What is the actual efficiency of this engine?
(b) What is the Carnot efficiency of the engine?
(c) What is the power output of this engine?

Answer: (a) 48% (b) 68% (c) 3.9 MW

23) A coal-fired plant generates 600 MW of electric power. The plant uses 4.8×10^6 kg of coal each day. The heat produced by the combustion of coal is 3.3×10^7 J/kg. The steam that drives the turbines is at a temperature of 300°C, and the exhaust water is at 37°C.
(a) What is the overall efficiency of the plant for generating electric power?
(b) What is the maximum efficiency that this plant could possibly have using the same temperature extremes that it presently uses?
(c) How much thermal energy is exhausted each day by this plant?

Answer: (a) 33% (b) 46% (c) 1.1×10^{14} J

24) You want to design an ideal Carnot heat engine that wastes only 35.0% of the heat that goes into it. The lowest cold-reservoir temperature available to you is +15.0°C. If 150.0 J of work is done per cycle, the heat input per cycle is closest to
A) 203 J
B) 231 J
C) 248 J
D) 429 J
E) 760 J

Answer: B

25) An ideal Carnot engine operates between reservoirs having temperatures of 125°C and -20°C. Each cycle the heat expelled by this engine is used to melt 30.0 g of ice at 0.00°C. The heat of fusion of water is 3.34×10^5 J/kg and the heat of vaporization of water is 2.25×10^6 J/kg.
(a) How much work does this engine do each cycle?
(b) How much heat per cycle does this engine absorb at the hot reservoir?

Answer: (a) 5740 J (b) 15,800 J

26) A Carnot refrigerator takes heat from water at 0°C and rejects heat to a room at 12°C. Suppose that 92.0 grams of water at 0°C are converted to ice at 0°C by the refrigerator. Calculate the mechanical energy that must be supplied to the refrigerator. The heat of fusion of water is 3.34×10^5 J/kg.

Answer: 1350 J

27) A Carnot refrigerator has a coefficient of performance of 2.5. The refrigerator consumes 50 W of power. How much heat is removed from the interior of the refrigerator in 1 hour?

A) 7.5 kJ
B) 450 kJ
C) 180 kJ
D) 720 kJ
E) 72 kJ

Answer: B

28) A Carnot air conditioner operates between an indoor temperature of 20°C and an outdoor temperature of 39°C. How much energy does it need to remove 2000 J of heat from the interior of the house?

A) 105 J
B) 130 J
C) 780 J
D) 520 J
E) 340 J

Answer: B

29) The compressor in a certain Carnot refrigerator performs 480 J of work to remove 150 J of heat from the interior of the refrigerator. How much heat must the coils behind the refrigerator discharge into the kitchen?

A) 110 J
B) 150 J
C) 330 J
D) 480 J
E) 630 J

Answer: E

30) The temperature inside a Carnot refrigerator placed in a kitchen at 22.0°C is 2.0°C. The heat extracted from the refrigerator is 89 MJ/h. What power is needed to operate this refrigerator?

A) 1.7 kW
B) 1.8 kW
C) 1.5 kW
D) 1.9 kW
E) 1.6 kW

Answer: B

31) A Carnot engine is operated as a heat pump to heat a room in the winter. The heat pump delivers heat to the room at the rate of 34 kJ per second and maintains the room at a temperature of 293 K when the outside temperature is 229 K. The power requirement for the heat pump under these operating conditions is closest to
A) 7500 W.
B) 6000 W.
C) 17,000 W.
D) 13,000 W.
E) 9600 W.

Answer: A

32) A system consists of two very large thermal reservoirs in contact with each other, one at temperature 300°C and the other at temperature 200°C. When 600 J of heat transfers from the 300°C reservoir to the 200°C reservoir, what is the change in entropy of this system?
A) 0.221 J/K
B) 1.00 J/K
C) 5.00 J/K
D) -1.00 J/K
E) -2.31 J/K

Answer: A

33) A 2.0–kg block of aluminum at 50°C is dropped into 5.0 kg of water at 20°C and the temperature is allowed to stabilize. What is the total change in entropy during this process, assuming no heat is exchanged with the environment? The specific heat of aluminum is 910 J/(kg•K) and the specific heat of water is 4190 J/(kg•K).
A) 8.2 J/K
B) 10 J/K
C) 3.3×10^{-2} J/K
D) 3.8×10^{-3} J/K
E) 2.4×10^{-3} J/K

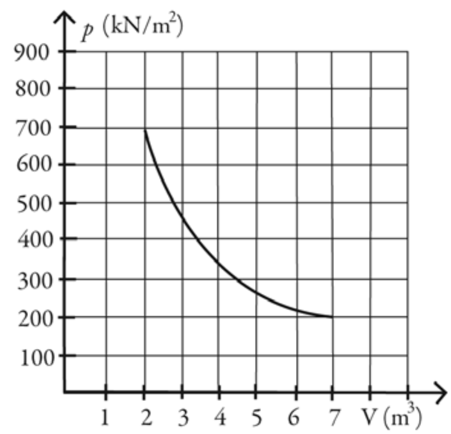
Answer: A

34) A 2.00 kg piece of lead at 40.0°C is placed in a very large quantity of water at 10.0°C, and thermal equilibrium is eventually reached. Calculate the entropy change of the lead that occurs during this process. The specific heat of lead is 130 J/(kg•K).
A) -12.5 J/K
B) 86.0 J/K
C) -26.2 J/K
D) -86.0 J/K
E) -6.24 J/K

Answer: C

35) A 2.00 kg piece of lead at 40.0°C is placed in a very large quantity of water at 10.0°C, and thermal equilibrium is eventually reached. Calculate the TOTAL change in entropy that occurs during this process. The specific heat of lead is 130 J/(kg•K).
A) 190 J/K
B) 100 J/K
C) 6.6 J/K
D) 6.2 J/K
E) 1.4 J/K
Answer: E

36) What is the change in entropy of 10.0 moles of *ideal* monatomic gas that reversibly undergoes the isothermal expansion shown in the figure? The ideal gas constant is R = 8.314 J/(mol•K).



A) 221 J/K
B) 104 J/K
C) 63.1 J/K
D) 45.2 J/K
E) 90.8 J/K

Answer: B

37) A 610-g quantity of an ideal gas undergoes a reversible isothermal compression at a temperature of 330 K. The compression reduces the volume of the gas from 0.40 m^3 initially, to 0.21 m^3 finally. The molecular mass of the gas is 33.0 g/mol, and the ideal gas constant is R = 8.314 J/(mol•K). The entropy change for the gas is closest to
A) -99 J/K.
B) -81 J/K.
C) 99 J/K.
D) 81 J/K.
E) 0.00 J/K.
Answer: A

38) A 810-g quantity of ethanol, in the liquid state at its melting point of −114°C, is frozen at atmospheric pressure. The heat of fusion of ethanol is 1.04×10^5 J/kg, the molecular mass is 46.1 g/mol, and the ideal gas constant is R = 8.314 J/(mol•K). The change in the entropy of the ethanol as it freezes is closest to

A) −540 J/K.
B) −490 J/K.
C) −600 J/K.
D) 490 J/K.
E) 540 J/K.

Answer: A

39) A 2.00-kg block of ice at 0.00°C is dropped into a very large lake at 25.0°C and completely melts. For water, the heat of fusion is 3.35×10^5 J/kg, the heat of vaporization is 2.25×10^5 J/kg, and the specific heat is 4190 J/kg•K. The net change in entropy of the system consisting of the ice and the lake due to this melting process is closest to

A) 2.45×10^3 J/K.
B) 2.24×10^3 J/K.
C) 2.06×10^2 J/K.
D) -2.45×10^3 J/K.
E) -2.06×10^2 J/K.

Answer: C

40) At atmospheric pressure, 45 moles of liquid helium are vaporized at its boiling point of 4.22 K. The heat of vaporization of helium, at atmospheric pressure, is 2.09×10^4 J/kg, and the atomic weight of helium is 4.00 g/mol. The change in the entropy of the helium, as it vaporizes, is closest to

A) 890 J/K.
B) 14,000 J/K.
C) 18,000 J/K.
D) -9400 J/K.
E) -14,000 J/K.

Answer: A

41) A brass rod, 75.0 cm long and having a cross-sectional area of 2.50 cm^2, conducts heat from a large furnace at 375°C into a very large cold water bath at 10.0°C without losing any heat at the lateral surface of the rod. Steady state has been established, and the thermal conductivity of brass is 109 W/m•K. The rate at which the entropy of the system (furnace plus water) is changing is closest to

A) 2.05×10^{-2} W/K.
B) 2.64×10^{-2} W/K.
C) 3.54×10^{-2} W/K.
D) 4.69×10^{-2} W/K.
E) 6.74×10^{-2} W/K.

Answer: B

Chapter 20 Electric Charge, Force, and Field

20.1 Conceptual Questions

1) *X* and *Y* are two uncharged metal spheres on insulating stands, and are in contact with each other. A positively charged rod *R* is brought close to *X* as shown in Figure (a).

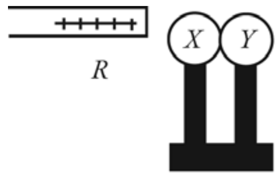


Figure (a)

Sphere *Y* is now moved away from *X*, as in Figure (b).

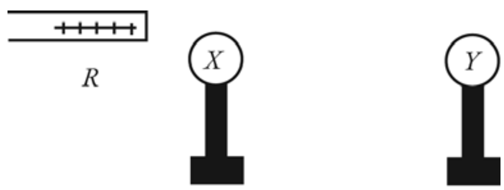


Figure (b)

What are the final charge states of *X* and *Y*?
A) Both *X* and *Y* are neutral.
B) *X* is positive and *Y* is neutral.
C) *X* is neutral and *Y* is positive.
D) *X* is negative and *Y* is positive.
E) Both *X* and *Y* are negative.

Answer: D

2) Two identical small charged spheres are a certain distance apart, and each one initially experiences an electrostatic force of magnitude *F* due to the other. With time, charge gradually leaks off of both spheres. When each of the spheres has lost half its initial charge, the magnitude of the electrostatic force will be
A) 1/16 *F*.
B) 1/8 *F*.
C) 1/4 *F*.
D) 1/2 *F*.

Answer: C

3) When two point charges are a distance d part, the electric force that each one feels from the other has magnitude F. In order to make this force twice as strong, the distance would have to be changed to
   A) $2d$.
   B) $\sqrt{2}d$.
   C) $d/\sqrt{2}$
   D) $d/2$.
   E) $d/4$.

   Answer: C

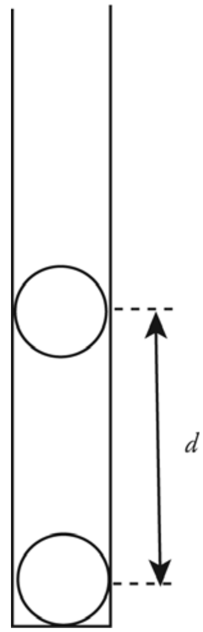
4) A point charge Q is located a short distance from a point charge $3Q$, and no other charges are present. If the electrical force on Q is F, what is the electrical force on $3Q$?
   A) $F/3$
   B) $F/\sqrt{3}$
   C) F
   D) $\sqrt{3}F$
   E) $3F$

   Answer: C

5) A positive point charge Q is fixed on a very large horizontal frictionless tabletop. A second positive point charge q is released from rest near the stationary charge and is free to move. Which statement best describes the motion of q after it is released?
   A) Its speed will be greatest just after it is released.
   B) Its acceleration is zero just after it is released.
   C) As it moves farther and farther from Q, its acceleration will keep increasing.
   D) As it moves farther and farther from Q, its speed will decrease.
   E) As it moves farther and farther from Q, its speed will keep increasing.

   Answer: E

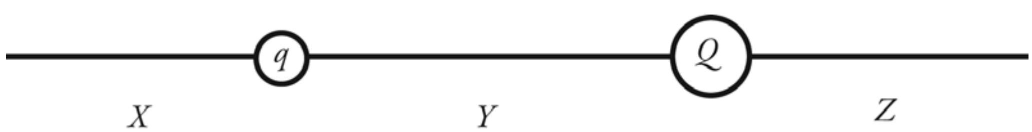
6) One very small uniformly charged plastic ball is located directly above another such charge in a test tube as shown in the figure. The balls are in equilibrium a distance d apart. If the charge on each ball is doubled, the distance between the balls in the test tube would become



A) $\sqrt{2}d$.
B) $2d$.
C) $4d$.
D) $8d$.

Answer: B

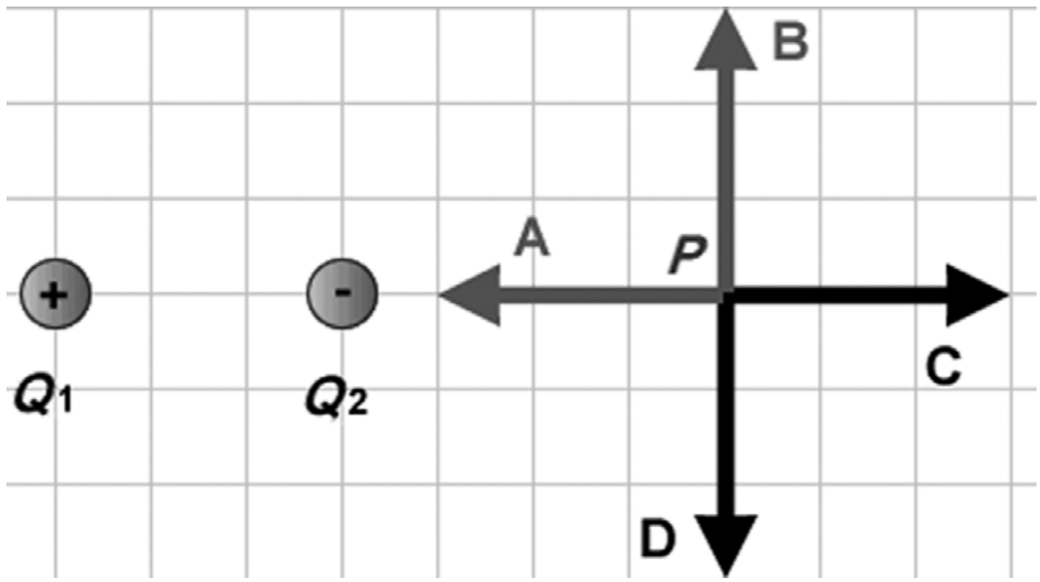
7) The figure shows two unequal point charges, q and Q, of opposite sign. Charge Q has greater magnitude than charge q. In which of the regions X, Y, Z will there be a point at which the net electric field due to these two charges is zero?



A) only regions X and Z
B) only region X
C) only region Y
D) only region Z
E) all three regions

Answer: B

8) Two point charges Q_1 and Q_2 of equal magnitudes and opposite signs are positioned as shown in the figure. Which of the arrows best represents the net electric field at point P due to these two charges?



A) A
B) B
C) C
D) D
E) The field is equal to zero at point P.

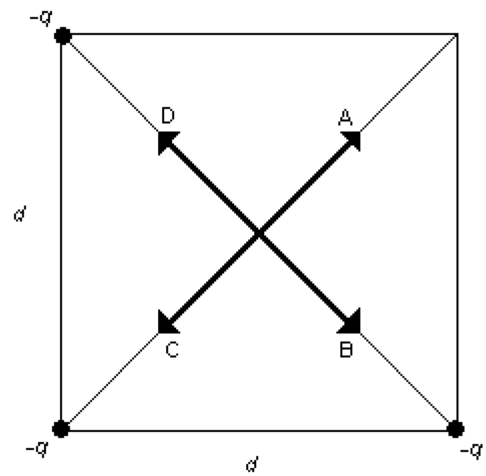
Answer: A

9) Four equal negative point charges are located at the corners of a square, their positions in the xy-plane being (1, 1), (-1, 1), (-1, -1), (1, -1). The electric field on the x-axis at (1, 0) points in the same direction as

A) $\hat{j}$.
B) $\hat{i}$.
C) $-\hat{i}$
D) $\hat{k}$.
E) $-\hat{j}$.

Answer: C

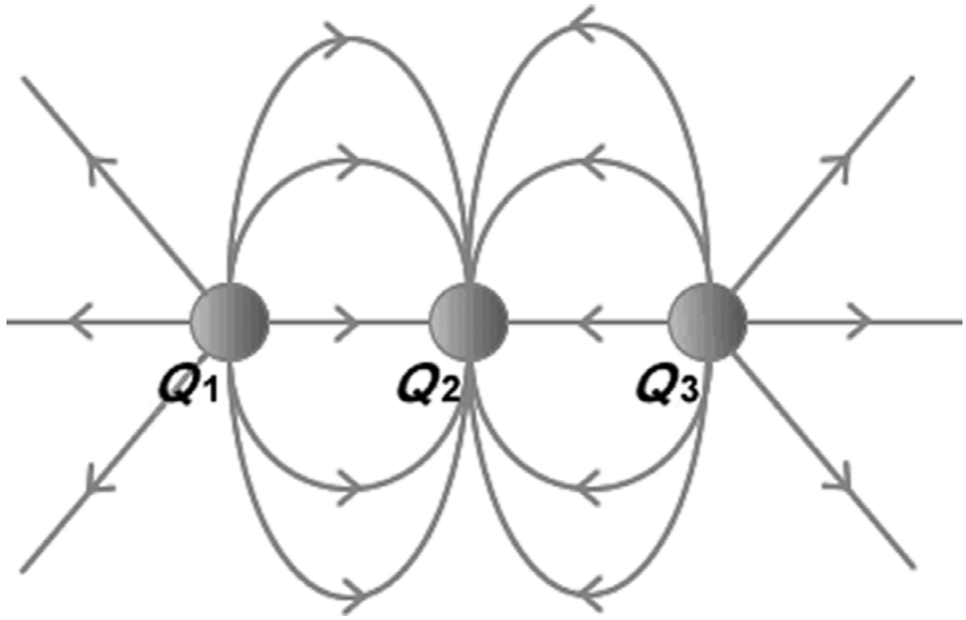
10) Three equal negative point charges are placed at three of the corners of a square of side *d* as shown in the figure. Which of the arrows represents the direction of the net electric field at the center of the square?



A) A
B) B
C) C
D) D
E) The field is equal to zero at point *P*.

Answer: C

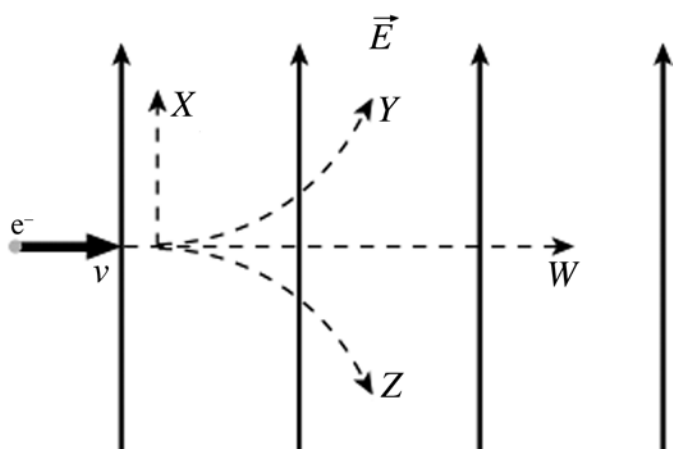
11) The figure shows three electric charges labeled Q_1, Q_2, Q_3, and some electric field lines in the region surrounding the charges. What are the signs of the three charges?



A) Q_1 is positive, Q_2 is negative, Q_3 is positive.
B) Q_1 is negative, Q_2 is positive, Q_3 is negative.
C) Q_1 is positive, Q_2 is positive, Q_3 is negative.
D) All three charges are negative.
E) All three charges are positive.

Answer: A

12) An electron is initially moving to the right when it enters a uniform electric field directed upwards. Which trajectory shown below will the electron follow?



A) trajectory W
B) trajectory X
C) trajectory Y
D) trajectory Z

Answer: D

20.2 Problems

1) A piece of plastic has a net charge of +2.00 μC. How many more protons than electrons does this piece of plastic have? ($e = 1.60 \times 10^{-19}$ C)
   A) 1.25×10^{13}
   B) 1.25×10^{19}
   C) 2.50×10^{13}
   D) 2.50×10^{19}

   Answer: A

2) A 1.0-C point charge is 15 m from a second point charge, and the electric force on one of them due to the other is 1.0 N. What is the magnitude of the second charge? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)
   A) 25 C
   B) 1.0 C
   C) 10 nC
   D) 0.025 C
   E) 25 nC

   Answer: E

3) When two point charges are 2.0 cm apart, each one experiences a 1.0-N electric force due to the other charge. If they are moved to a new separation of 8.0 cm, the electric force on each of them is closest to
   A) 1.0 N.
   B) 4.0 N.
   C) 16 N.
   D) 0.25 N.
   E) 0.063 N.

   Answer: E

4) Two identical small conducting spheres are separated by 0.60 m. The spheres carry different amounts of charge and each sphere experiences an attractive electric force of 10.8N. The total charge on the two spheres is -24 μC. The two spheres are now connected by a slender conducting wire, which is then removed. The electric force on each sphere is closest to
   A) zero.
   B) 3.6 N, attractive.
   C) 5.4 N, attractive.
   D) 3.6 N, repulsive.
   E) 5.4 N, repulsive.

   Answer: D

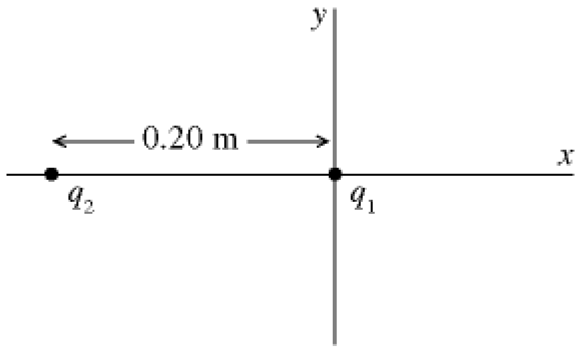
5) Three point charges are placed on the x-axis. A charge of +2.0 μC is placed at the origin, -2.0 μC to the right at x = 50 cm, and +4.0 μC at the 100 cm mark. What are the magnitude and direction of the electrostatic force that acts on the charge at the origin? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

   Answer: 0.072 N, toward the right

6) Charge Q_1 = 6.0 nC is at (0.30 m, 0), charge Q_2 = -1.0 nC is at (0, 0.10 m), and charge Q_3 = 5.0 nC is at (0, 0). What are the magnitude and direction of the net electrostatic force on the 5.0–nC charge due to the other charges? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

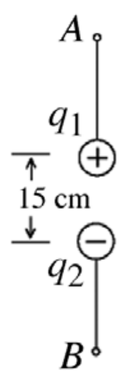
Answer: 5.4×10^{-6} N, 56° above -x–axis

7) In the figure, charge $q_1 = 3.1 \times 10^{-6}$ C is placed at the origin and charge $q_2 = -8.7 \times 10^{-6}$ C is placed on the x–axis, at x = –0.20 m. Where along the x–axis can a third charge Q = –8.3 μC be placed such that the resultant force on this third charge is zero?



Answer: 0.30 m

8) Two small insulating spheres are attached to silk threads and aligned vertically as shown in the figure. These spheres have equal masses of 40 g, and carry charges q_1 and q_2 of equal magnitude 2.0 μC but opposite sign. The spheres are brought into the positions shown in the figure, with a vertical separation of 15 cm between them. Note that you cannot neglect gravity. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2) The tension in the lower thread is closest to



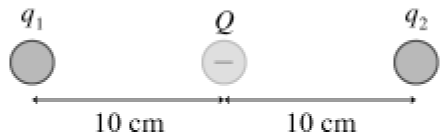
A) 1.2 N.
B) 1.4 N.
C) 1.6 N.
D) 1.8 N.
E) 2.0 N.

Answer: A

9) A +7.00 μC point charge and −9.00 μC point charge are placed along the x−axis at $x = 0.000$ cm and $x = 40.0$ cm, respectively. Where must a third charge, q, be placed along the x−axis so that it does not experience any net electric force due to the other two charges?
A) −0.200 m
B) 2.99 m
C) −0.187 m
D) −2.99 m
E) 0.187 m

Answer: D

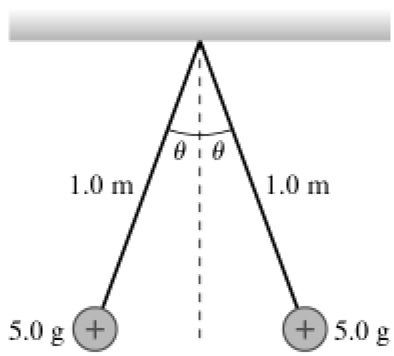
10) In the figure, all the charges are point charges and the charge in the middle is $Q = -3.1$ nC. For what charge q_1 will charge q_2 be in static equilibrium?



A) 12 nC
B) 6.2 nC
C) 3.1 nC
D) 25 nC

Answer: A

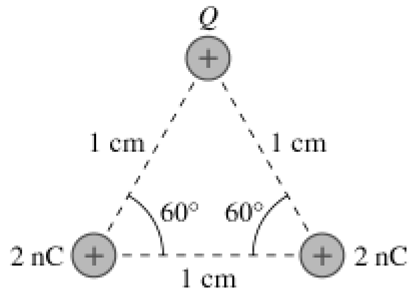
11) The figure shows two tiny 5.0−g spheres suspended from two very thin 1.0−m−long threads. The spheres repel each other after being charged to +91 nC and hang at rest as shown. What is the angle θ? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)



A) 4.1°
B) 8.2°
C) 12°
D) 16°

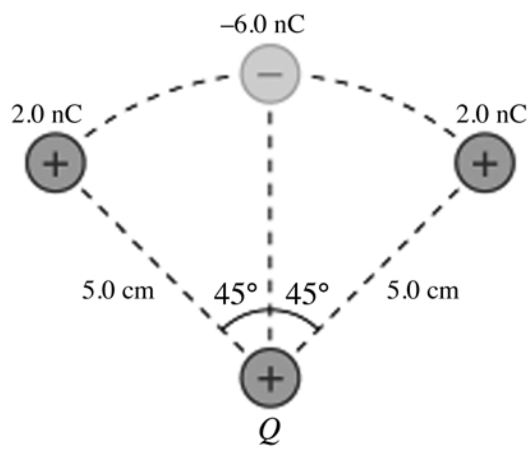
Answer: A

12) In the figure $Q = 5.8$ nC and all other quantities are accurate to 2 significant figures. What is the magnitude of the force on the charge Q? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)



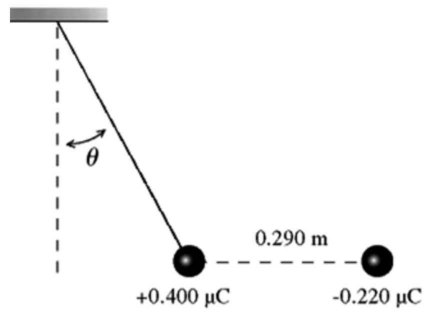
A) 1.8×10^{-3} N
B) 1.0×10^{-3} N
C) 9.0×10^{-4} N
D) 1.2×10^{-3} N
Answer: A

13) The point charge at the bottom of the figure is $Q = +17$ nC, and the curve is a circular arc. What is the magnitude of the force on the charge Q due to the other point charges shown? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)



A) 1.9×10^{-4} N
B) 1.2×10^{-4} N
C) 1.6×10^{-4} N
D) 2.3×10^{-4} N
Answer: A

14) In the figure, a small spherical insulator of mass 6.00×10^{-2} kg and charge +0.400 μC is hung by a thin wire of negligible mass. A charge of -0.220 μC is held 0.290 m away from the sphere and directly to the right of it, so the wire makes an angle θ with the vertical, as shown. What is the angle θ? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)



A) 0.917°
B) 1.10°
C) 1.30°
D) 1.50°
E) 1.70°

Answer: A

15) An atomic nucleus has a charge of +40*e*. What is the magnitude of the electric field at a distance of 1.0 m from the center of the nucleus? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2, $e = 1.60 \times 10^{-19}$ C)

A) 5.4×10^{-8} N/C
B) 5.6×10^{-8} N/C
C) 5.8×10^{-8} N/C
D) 6.0×10^{-8} N/C
E) 6.2×10^{-8} N/C

Answer: C

16) A small glass bead has been charged to 8.0 nC. What is the magnitude of the electric field 2.0 cm from the center of the bead? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

A) 1.8×10^5 N/C
B) 3.6×10^3 N/C
C) 1.4×10^{-3} N/C
D) 3.6×10^{-6} N/C

Answer: A

17) The electric field 1.5 cm from a very small charged object points toward the object with a magnitude of 180,000 N/C. What is the charge on the object? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)
   A) –4.5 nC
   B) +4.5 nC
   C) –5.0 nC
   D) +5.0 nC
   Answer: A

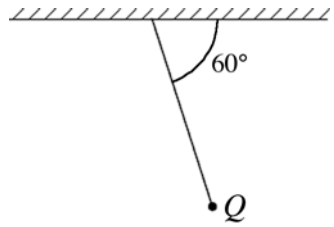
18) A metal sphere of radius 10 cm carries a charge of +2.0 μC uniformly distributed over its surface. What is the magnitude of the electric field due to this sphere at a point 5.0 cm outside the sphere's surface? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)
   A) 4.0×10^5 N/C
   B) 8.0×10^5 N/C
   C) 4.2×10^6 N/C
   D) 4.0×10^7 N/C
   E) 8.0×10^7 N/C
   Answer: B

19) A proton is placed in an electric field of intensity 700 N/C. What are the magnitude and direction of the acceleration of this proton due to this field? ($m_{proton} = 1.67 \times 10^{-27}$ kg, $e = 1.60 \times 10^{-19}$ C)
   A) 6.71×10^9 m/s^2 opposite to the electric field
   B) 6.71×10^{10} m/s^2 opposite to the electric field
   C) 6.71×10^{10} m/s^2 in the direction of the electric field
   D) 67.1×10^{10} m/s^2 opposite to the electric field
   E) 67.1×10^{10} m/s^2 in the direction of the electric field
   Answer: C

20) A small sphere with a mass of 441 g is moving upward along the vertical $+y$–axis when it encounters an electric field of 5.00 N/C $\hat{i}$. If, due to this field, the sphere suddenly acquires a horizontal acceleration of 13.0 m/s^2 $\hat{i}$, what is the charge that it carries?
   A) 1.15 C
   B) -1.15 C
   C) 1150 C
   D) -1150 C
   Answer: A

21) What is the minimum magnitude of an electric field that balances the weight of a plastic sphere of mass 6.4 g that has been charged to –3.0 nC?
   A) 2.1×10^7 N/C
   B) 2.4×10^6 N/C
   C) 4.5×10^6 N/C
   D) 6.4×10^6 N/C
   Answer: A

22) A point charge Q of mass 8.50 g hangs from the horizontal ceiling by a light 25.0-cm thread. When a horizontal electric field of magnitude 1750 N/C is turned on, the charge hangs away from the vertical as shown in the figure. The magnitude of Q is closest to



A) 27.5 μC.
B) 47.6 μC.
C) 55.0 μC.
D) 3.0 μC.
E) 3.5 μC.

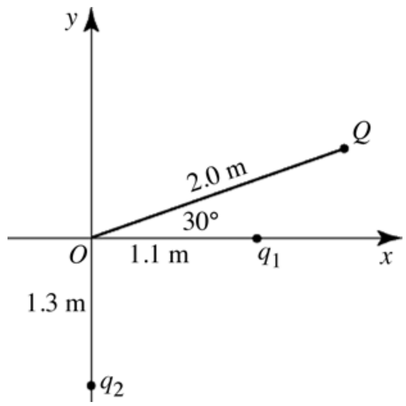
Answer: A

23) Two point charges of +20.0 μC and -8.00 μC are separated by a distance of 20.0 cm. What is the magnitude of electric field due to these charges at a point midway between them? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2$)

A) 25.2×10^6 N/C directed toward the negative charge
B) 25.2×10^6 N/C directed toward the positive charge
C) 25.2×10^5 N/C directed toward the negative charge
D) 25.2×10^5 N/C directed toward the positive charge
E) 25.2×10^4 N/C directed toward the negative charge

Answer: A

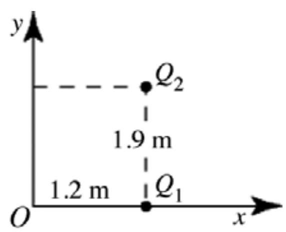
24) A point charge Q = -500 nC and two unknown point charges, q_1 and q_2, are placed as shown in the figure. The electric field at the origin O, due to charges Q, q_1 and q_2, is equal to zero. The charge q_1 is closest to



A) 130 nC.
B) 76 nC.
C) 150 nC.
D) -76 nC.
E) -130 nC.

Answer: A

25) Two point charges, Q_1 = -1.0 μC and Q_2 = + 4.0 μC, are placed as shown in the figure. ($k = 1/4 \pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2) The y component of the electric field, at the origin O, is closest to



A) 6.0×10^{-3} N/C.
B) -6.0×10^{-3} N/C.
C) 3.8×10^{-3} N/C.
D) -3.8×10^{-3} N/C.
E) 7.1×10^{-3} N/C.

Answer: A

26) Three +3.0-μC point charges are at the three corners of a square of side 0.50 m. The last corner is occupied by a -3.0-μC charge. Find the magnitude of the electric field at the center of the square. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

Answer: 4.3×10^5 N/C

27) Three equal negative point charges are placed at three of the corners of a square of side d. What is the magnitude of the net electric field at the center of the square? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

Answer: $E = 2kq/d^2$

28) A 5.0-μC point charge is placed at the 0.00 cm mark of a meter stick and a -4.0-μC point charge is placed at the 50 cm mark. At what point on a line joining the two charges is the electric field due to these charges equal to zero?

Answer: 4.7 m from the 0.00-cm mark

29) A 3.0-μC positive point charge is located at the origin and a 2.0 μC positive point charge is located at x = 0.00 m, y = 1.0 m. Find the coordinates of the point where the net electric field strength due to these charges is zero.

A) x = 0.00 m, y = 0.55 m
B) x = 0.00 m, y = 0.67 m
C) x = 0.00 m, y = 1.5 m
D) x = 0.00 m, y = 0.60 m

Answer: A

30) A very long wire carries a uniform linear charge density of 7.0 nC/m. What is the electric field strength 16.0 m from the center of the wire at a point on the wire's perpendicular bisector? ($\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)

A) 7.9 N/C
B) 3.9 N/C
C) 0.49 N/C
D) 0.031 N/C

Answer: A

31) At a distance of 4.3 cm from the center of a very long uniformly charged wire, the electric field has magnitude 2000 N/C and is directed toward the wire. What is the charge on a 1.0 cm length of wire near the center? ($\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)

A) -0.048 nC
B) -0.052 nC
C) -0.044 nC
D) -0.056 nC

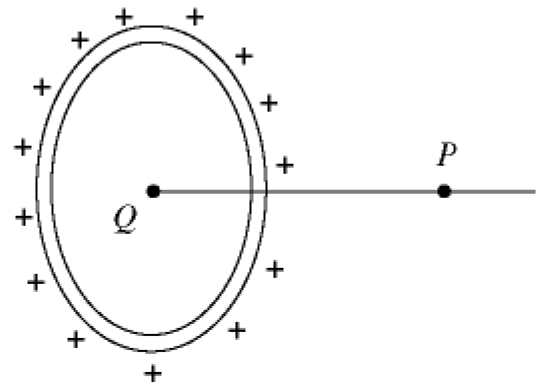
Answer: A

32) A long, thin rod parallel to the y-axis is located at x = -1.0 cm and carries a uniform linear charge density of +1.0 nC/m. A second long, thin rod parallel to the z-axis is located at x = +1.0 cm and carries a uniform linear charge density of -1.0 nC/m. What is the net electric field due to these rods at the origin? ($\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)

A) (-3.6×10^3 N/C) $\hat{\boldsymbol{i}}$
B) (1.8×10^3 N/C) $\hat{\boldsymbol{j}}$
C) (-1.8×10^3 N/C) $\hat{\boldsymbol{k}}$
D) (3.6×10^3 N/C) $\hat{\boldsymbol{i}}$
E) zero

Answer: D

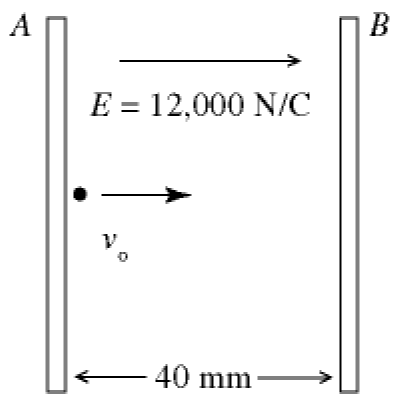
33) In the figure, a ring 0.71 m in radius carries a charge of + 580 nC uniformly distributed over it. A point charge Q is placed at the center of the ring. The electric field is equal to zero at field point P, which is on the axis of the ring, and 0.73 m from its center. ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$) The point charge Q is closest to



A) -210
B) -300
C) -420
D) 210
E) 300

Answer: A

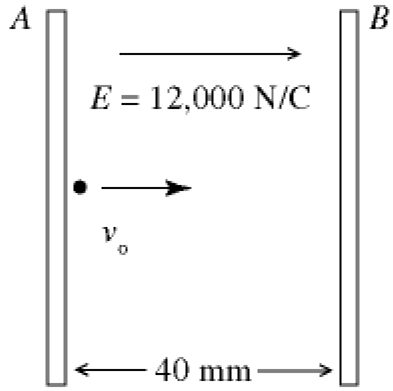
34) A pair of charged conducting plates produces a uniform field of 12,000 N/C, directed to the right, between the plates. The separation of the plates is 40 mm. An electron is projected from plate A, directly toward plate B, with an initial velocity of $v_o = 2.0 \times 10^7$ m/s, as shown in the figure. ($e = 1.60 \times 10^{-19}$ C, $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$, $m_{el} = 9.11 \times 10^{-31}$ kg) The velocity of the electron as it strikes plate B is closest to



A) 1.2×10^7 m/s.
B) 1.5×10^7 m/s.
C) 1.8×10^7 m/s.
D) 2.1×10^7 m/s.
E) 2.4×10^7 m/s.

Answer: B

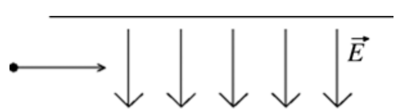
35) A pair of charged conducting plates produces a uniform field of 12,000 N/C, directed to the right, between the plates. The separation of the plates is 40 mm. An electron is projected from plate *A*, directly toward plate *B*, with an initial velocity of $v_0 = 1.0 \times 10^7$ m/s, as shown in the figure. ($e = 1.60 \times 10^{-19}$ C, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$, $m_{el} = 9.11 \times 10^{-31}$ kg) The distance of closest approach of the electron to plate *B* is nearest to



A) 16 mm.
B) 18 mm.
C) 20 mm.
D) 22 mm.
E) 24 mm.

Answer: A

36) In the figure, a proton is projected horizontally midway between two parallel plates that are separated by 0.50 cm. The electrical field due to the plates has magnitude 610,000 N/C between the plates away from the edges. If the plates are 5.60 cm long, find the minimum speed of the proton if it just misses the lower plate as it emerges from the field. ($e = 1.60 \times 10^{-19}$ C, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$, $m_{el} = 9.11 \times 10^{-31}$ kg)



Answer: 6.06×10^6 m/s

37) A dipole with a positive charge of 2.0 μC and a negative charge of −2.0 μC is centered at the origin and oriented along the x−axis with the positive charge located to the right of the origin. The charge separation is 0.0010 m. Find the electric field due to this dipole at the point $x = 4.0$ m, $y = 0.0$ m. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ $N \cdot m^2/C^2$)

A) $0.56\,\hat{i}$ N/C
B) $-0.56\,\hat{i}$ N/C
C) $0.28\,\hat{i}$ N/C
D) $-0.28\,\hat{i}$ N/C

Answer: A

38) An electric dipole is made of two charges of equal magnitudes and opposite signs. The positive charge, $q = 1.0\ \mu C$, is located at the point $(x, y, z) = (0.00$ cm, 1.0 cm, 0.00 cm$)$, while the negative charge is located at the point $(x, y, z) = (0.00$ cm, -1.0 cm, 0.00 cm$)$. How much work will be done by an electric field $\vec{E} = (3.0 \times 10^6\ \text{N/C})\,\hat{i}$ to bring the dipole to its stable equilibrium position?

A) 0.060 J
B) 0.030 J
C) 0.00 J
D) 0.020 J
E) 0.12 J

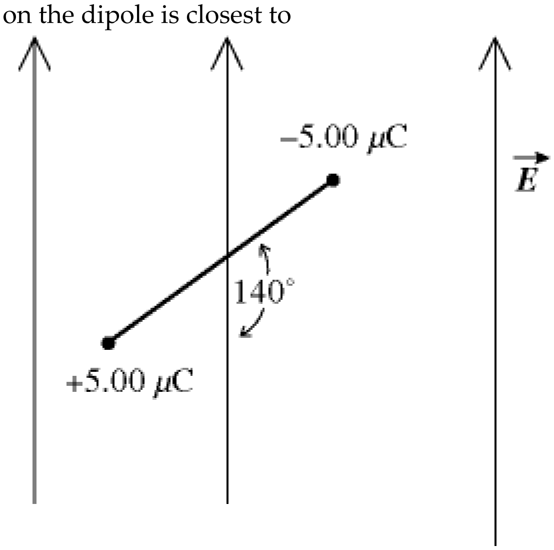
Answer: A

39) An initially-stationary electric dipole of dipole moment $\vec{p} = (5.00 \times 10^{-10}\ \text{C} \cdot \text{m})\,\hat{i}$ placed in an electric field $\vec{E} = (2.00 \times 10^6\ \text{N/C})\,\hat{i} + (2.00 \times 10^6\ \text{N/C})\,\hat{j}$. What is the magnitude of the maximum torque that the electric field exerts on the dipole?

A) 2.00×10^{-3} N • m
B) 1.40×10^{-3} N • m
C) 2.80×10^{-3} N • m
D) 0.00 N • m
E) 1.00×10^{-3} N • m

Answer: E

40) An electric dipole consists of charges ±5.00 μC separated by 1.20 mm. It is placed in a vertical electric field of magnitude 525 N/C oriented as shown in the figure. The magnitude of the net torque this field exerts on the dipole is closest to



A) 2.02×10^{-6} N • m.
B) 3.15×10^{-6} N • m.
C) 2.41×10^{-6} N • m.
D) 1.01×10^{-6} N • m.
E) 1.21×10^{-6} N • m.

Answer: A

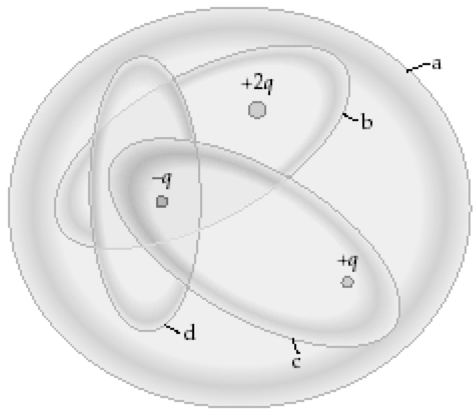
Chapter 20 Gauss's Law

21.1 Conceptual Questions

1) If the electric flux through a closed surface is zero, the electric field at points on that surface must be zero.
   A) True
   B) False

   Answer: B

2) The figure shows four Gaussian surfaces surrounding a distribtuion of charges.



   (a) Which Gaussian surfaces have an electric flux of $+q/\varepsilon_0$ through them?

   (b) Which Gaussian surfaces have no electric flux through them?

   Answer: (a) b (b) c

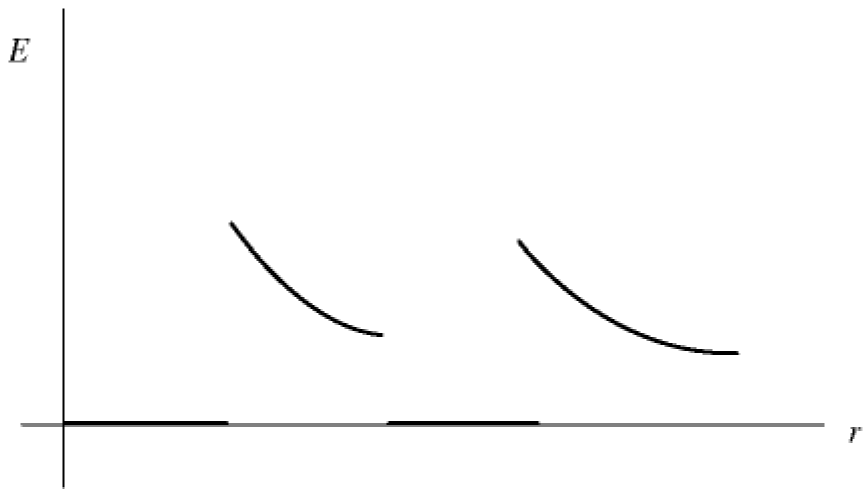
3) Which of the following statements about Gauss's law are correct? (There may be more than one correct choice.)
   A) Gauss's law is valid only for symmetric charge distributions, such as spheres and cylinders.
   B) If there is no charge inside of a Gaussian surface, the electric field must be zero at points of that surface.
   C) Only charge enclosed within a Gaussian surface can produce an electric field at points on that surface.
   D) If a Gaussian surface is completely inside an electrostatic conductor, the electric field must always be zero at all points on that surface.
   E) The electric flux passing through a Gaussian surface depends only on the amount of charge inside that surface, not on its size or shape.

   Answer: D, E

4) Consider a spherical Gaussian surface of radius R centered at the origin. A charge Q is placed inside the sphere. To maximize the magnitude of the flux of the electric field through the Gaussian surface, the charge should be located
A) at $x = 0$, $y = 0$, $z = R/2$.
B) at the origin.
C) at $x = R/2$, $y = 0$, $z = 0$.
D) at $x = 0$, $y = R/2$, $z = 0$.
E) The charge can be located anywhere, since flux does not depend on the position of the charge as long as it is inside the sphere.

Answer: E

5) The graph in the figure shows the electric field strength (*not* the field lines) as a function of distance from the center for a pair of concentric uniformly charged spheres. Which of the following situations could the graph plausibly represent? (There may be more than one correct choice.)



A) a positively charged conducting sphere within another positively charged conducting sphere
B) a positively charged conducting sphere within an uncharged conducting sphere
C) a solid nonconducting sphere, uniformly charged throughout its volume, inside of a positively charged conducting sphere
D) a positively charged nonconducting thin-walled spherical shell inside of a positively charged conducting sphere
E) a positively charged nonconducting thin-walled spherical shell inside of another positively charged nonconducting thin-walled spherical shell

Answer: A, D

6) Two long straight parallel lines, #1 and #2, carry uniform positive linear charge densities. The charge density on line #2 is twice as great as the charge density on line #1. The locus of points where the electric field due to these lines is zero is
A) along a line between the lines closer to line #2 than line #1.
B) at a point midway between the lines.
C) along a line perpendicular to lines #1 and #2.
D) along a line between the lines closer to line #1 than line #2.

Answer: D

7) At a distance D from a very long (essentially infinite) uniform line of charge, the electric field strength is 1000 N/C. At what distance from the line will the field strength to be 2000 N/C?
   A) $2D$
   B) $\sqrt{2}D$
   C) $D/\sqrt{2}$
   D) $D/2$
   E) $D/4$

Answer: D

8) A charge Q is uniformly spread over one surface of a very large nonconducting square elastic sheet having sides of length d. At a point P that is 1.25 cm outside the sheet, the magnitude of the electric field due to the sheet is E. If the sheet is now stretched so that its sides have length $2d$, what is the magnitude of the electric field at P?
   A) $4E$
   B) $2E$
   C) E
   D) $E/2$
   E) $E/4$

Answer: E

9) An uncharged conductor has a hollow cavity inside of it. Within this cavity there is a charge of +10 μC that does not touch the conductor. There are no other charges in the vicinity. Which statement about this conductor is true? (There may be more than one correct choice.)
   A) The inner surface of the conductor carries a charge of −10 μC and its outer surface carries no excess charge.
   B) The inner and outer surfaces of the conductor each contain charges of −5 μC.
   C) The net electric field within the material of the conductor points away from the +10 μC charge.
   D) The outer surface of the conductor contains +10 μC of charge and the inner surface contains −10 μC.
   E) Both surfaces of the conductor carry no excess charge because the conductor is uncharged.

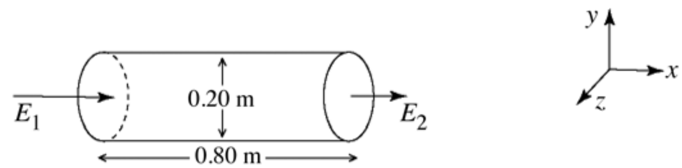
Answer: D

10) Under electrostatic conditions, the electric field just outside the surface of any charged conductor
   A) is always parallel to the surface.
   B) is always zero because the electric field is zero inside conductors.
   C) is always perpendicular to the surface of the conductor.
   D) is perpendicular to the surface of the conductor only if it is a sphere, a cylinder, or a flat sheet.
   E) can have nonzero components perpendicular to and parallel to the surface of the conductor.

Answer: C

21.2 Problems

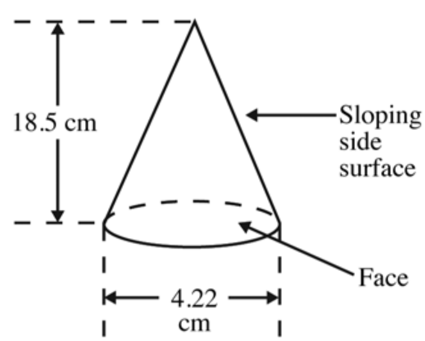
1) A nonuniform electric field is directed along the x–axis at all points in space. This magnitude of the field varies with x, but not with respect to y or z. The axis of a cylindrical surface, 0.80 m long and 0.20 m in diameter, is aligned parallel to the x–axis, as shown in the figure. The electric fields E_1 and E_2, at the ends of the cylindrical surface, have magnitudes of 6000 N/C and 1000 N/C respectively, and are directed as shown. What is the net electric flux passing through the cylindrical surface?



A) -160 N • m^2/C
B) -350 N • m^2/C
C) 0.00 N • m^2/C
D) +350 N • m^2/C
E) +160 N • m^2/C

Answer: A

2) A cone is resting on a tabletop as shown in the figure with its face horizontal. A uniform electric field of magnitude 4550 N/C points vertically upward. How much electric flux passes through the sloping side surface area of the cone?

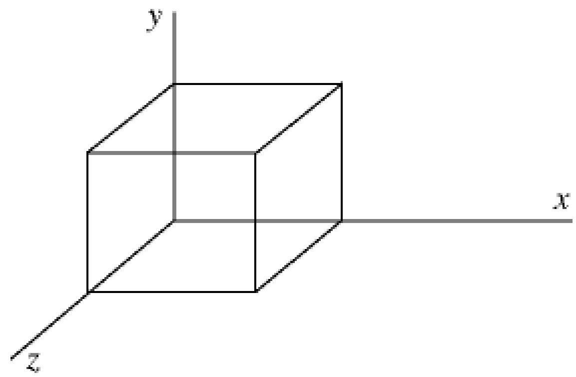


Answer: 6.36 N • m^2/C

3) If a rectangular area is rotated in a uniform electric field from the position where the maximum electric flux goes through it to an orientation where only half the flux goes through it, what has been the angle of rotation?
A) 45°
B) 26.6°
C) 90°
D) 30°
E) 60°

Answer: E

4) The cube of insulating material shown in the figure has one corner at the origin. Each side of the cube has length 0.080 m so the top face of the cube is parallel to the xz–plane and is at y = 0.080 m. It is observed that there is an electric field $\vec{E}$ = (3280 N/C • m)$y\,\hat{j}$ that is in the +y direction and whose magnitude depends only on y. Use Gauss's law to calculate the net charge enclosed by the cube. ($\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)



Answer: 1.5 x 10^{-11} C

5) A charge q = 2.00 μC is placed at the origin in a region where there is already a uniform electric field $\vec{E}$ = (100 N/C) $\hat{i}$. Calculate the flux of the net electric field through a Gaussian sphere of radius R = 10.0 cm centered at the origin. ($\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)

A) 5.52 × 10^5 N • m^2/C
B) 1.13 × 10^5 N • m^2/C
C) 2.26 × 10^5 N • m^2/C
D) zero

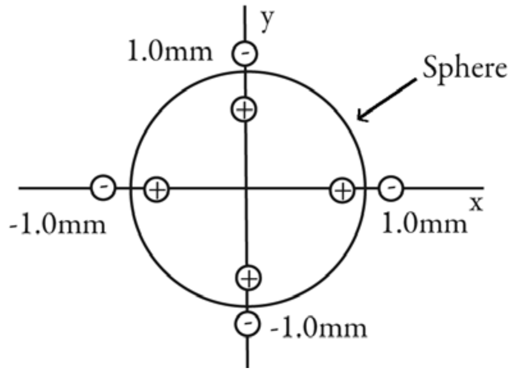
Answer: C

6) A charge of 1.0 × 10^{-6} μC is located inside a sphere, 1.25 cm from its center. What is the electric flux through the sphere due to this charge? ($\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)

A) 0.11 N • m^2/C
B) 8.9 N • m^2/C
C) 0.028π N • m^2/C
D) It cannot be determined without knowing the radius of the sphere.

Answer: A

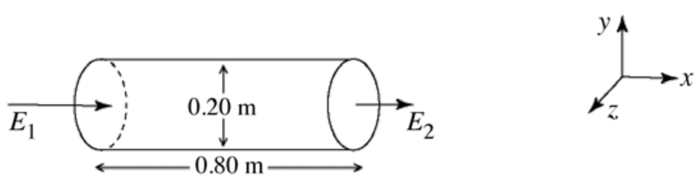
7) Four dipoles, each consisting of a +10-μC charge and a -10-μC charge, are located in the xy-plane with their centers 1.0 mm from the origin, as shown. A sphere passes through the dipoles, as shown in the figure. What is the electric flux through the sphere due to these dipoles? ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)



A) $4.5 \times 10^6\ N \cdot m^2/C$
B) $0.00\ N \cdot m^2/C$
C) $9.0 \times 10^6\ N \cdot m^2/C$
D) $11 \times 10^5\ N \cdot m^2/C$

Answer: A

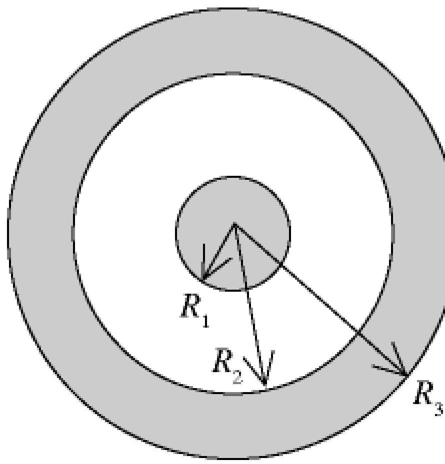
8) A nonuniform electric field is directed along the x-axis at all points in space. This magnitude of the field varies with x, but not with respect to y or z. The axis of a cylindrical surface, 0.80 m long and 0.20 m in diameter, is aligned parallel to the x-axis, as shown in the figure. The electric fields E_1 and E_2, at the ends of the cylindrical surface, have magnitudes of 9000 N/C and 5000 N/C respectively, and are directed as shown. ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$) The charge enclosed by the cylindrical surface is closest to



A) -1.1 nC.
B) 1.1 nC.
C) -2.4 nC.
D) -4.8 nC.
E) 4.8 nC.

Answer: A

9) Two concentric spheres are shown in the figure. The inner sphere is a solid nonconductor and carries a charge of +5.00 μC uniformly distributed over its outer surface. The outer sphere is a conducting shell that carries a net charge of -8.00 μC. No other charges are present. The radii shown in the figure have the values R_1 = 10.0 cm, R_2 = 20.0 cm, and R_3 = 30.0 cm. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)
(a) Find the total excess charge on the inner and outer surfaces of the conducting sphere.
(b) Find the magnitude and direction of the electric field at the following distances r from the center of the inner sphere: (i) r = 9.5 cm, (ii) r = 15.0 cm, (iii) r = 27.0 cm, (iv) r = 35.0 cm.



Answer: (a) –5.00 μC (inner surface), –3.00 μC (outer surface)
(b) (i) 0; (ii) 2.00×10^6 N/C, radially outward; (iii) 0; (iv) 2.20×10^5 N/C, radially inward

10) Two concentric conducting spherical shells produce a radially outward electric field of magnitude 49,000 N/C at a point 4.10 m from the center of the shells. The outer surface of the larger shell has a radius of 3.75 m. If the inner shell contains an excess charge of -5.30 μC, find the amount of charge on the outer surface of the larger shell. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

Answer: 91.6 μC

11) A solid nonconducting sphere of radius R carries a uniform charge density throughout its volume. At a radial distance $r_1 = R/4$ from the center, the electric field has a magnitude E_0. What is the magnitude of the electric field at a radial distance $r_2 = 2R$?

A) $E_0/4$
B) zero
C) $E_0/2$
D) E_0
E) $2E_0$

Answer: D

12) A solid nonconducting sphere of radius R carries a charge Q distributed uniformly throughout its volume. At a certain distance r_1 ($r_1 < R$) from the center of the sphere, the electric field has magnitude E. If the same charge Q were distributed uniformly throughout a sphere of radius $2R$, the magnitude of the electric field at the same distance r_1 from the center would be equal to

A) $E/8$.
B) $E/2$.
C) $2E$.
D) $8E$.
E) E.

Answer: A

13) A spherical, non-conducting shell of inner radius r_1= 10 cm and outer radius r_2= 15 cm carries a total charge Q = 15 μC distributed uniformly throughout the volume of the shell. What is the magnitude of the electric field at a distance r = 12 cm from the center of the shell? ($k = 1/4\pi\varepsilon_0$ = 8.99×10^9 N • m^2/C^2)

A) 5.75×10^3 N/C
B) zero
C) 2.87×10^6 N/C
D) 5.75×10^6 N/C
E) 2.87×10^3 N/C

Answer: C

14) A non-conducting sphere of radius R = 7.0 cm carries a charge Q = 4.0 mC distributed uniformly throughout its volume. At what distance, measured from the center of the sphere, does the electric field reach a value equal to half its maximum value?

A) 3.5 cm only
B) 4.9 cm only
C) 3.5 cm and 9.9 cm
D) 3.5 cm and 4.9 cm
E) 9.9 cm only

Answer: C

15) Electric charge is uniformly distributed inside a nonconducting sphere of radius 0.30 m. The electric field at a point P, which is 0.50 m from the center of the sphere, is 15,000 N/C and is directed radially outward. At what distance from the center of the sphere does the electric field have the same magnitude as it has at P?

A) 0.11 m
B) 0.13 m
C) 0.15 m
D) 0.17 m
E) at no other point

Answer: A

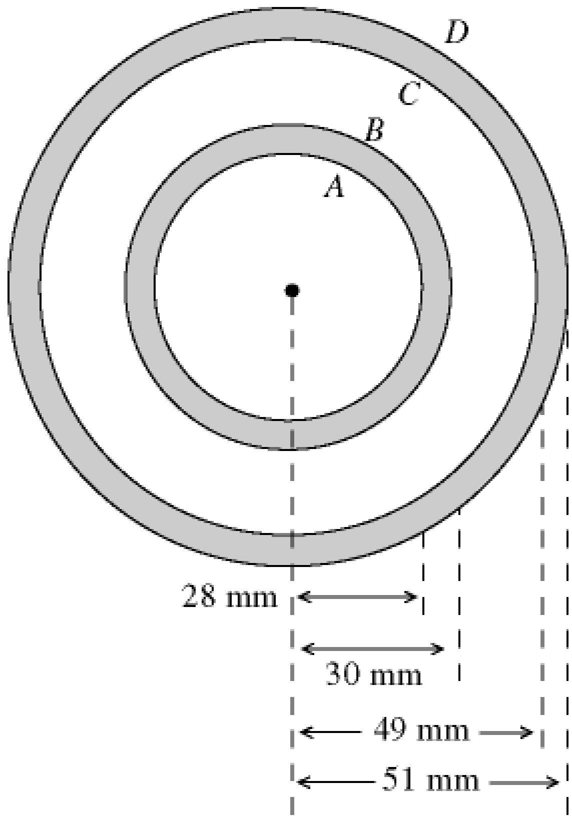
16) Electric charge is uniformly distributed inside a nonconducting sphere of radius 0.30 m. The electric field at a point *P*, which is 0.50 m from the center of the sphere, is 15,000 N/C and is directed radially outward. What is the maximum magnitude of the electric field due to this sphere?
A) 25,000 N/C
B) 30,000 N/C
C) 36,000 N/C
D) 42,000 N/C
E) 48,000 N/C
Answer: D

17) A nonconducting spherical shell of inner radius R_1 and outer radius R_2 contains a uniform volume charge density ρ throughout the shell. Use Gauss's law to derive an equation for the magnitude of the electric field at the following radial distances r from the center of the sphere. Your answers should be in terms of ρ, R_1, R_2, r, ε_0, and π.
(a) $r < R_1$
(b) $R_1 < r < R_2$
(c) $r > R_2$

Answer: (a) $E = 0$ (b) $E = \dfrac{\rho}{3\varepsilon_0 r^2}\left(r^3 - R_1{}^3\right)$ (c) $E = \dfrac{\rho}{3\varepsilon_0 r^2}\left(R_2{}^3 - R_1{}^3\right)$

18) An infinitely long nonconducting cylinder of radius $R = 2.00$ cm carries a uniform volume charge density of 18.0 μC/ m^3. Calculate the electric field at distance $r = 1.00$ cm from the axis of the cylinder. ($\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$)
A) 2.50×10^3 N/C
B) 5.10×10^3 N/C
C) zero
D) 2.00×10^3 N/C
E) 10.2×10^3 N/C
Answer: E

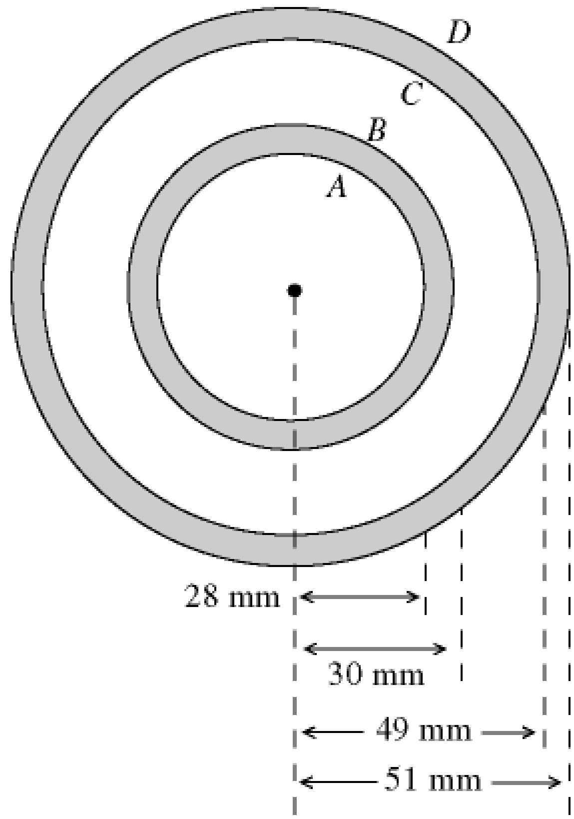
19) The cross section of a long coaxial cable is shown in the figure, with radii as given. The linear charge density on the inner conductor is −30 nC/m and the linear charge density on the outer conductor is −70 nC/m. The inner and outer cylindrical surfaces are respectively denoted by *A*, *B*, *C*, and *D*, as shown. ($\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$)The radial component of the electric field at a point that 34 mm from the axis is closest to



A) −16,000 N/C.
B) +16,000 N/C.
C) −37,000 N/C.
D) +37,000 N/C.
E) zero

Answer: A

20) The cross section of a long coaxial cable is shown in the figure, with radii as given. The linear charge density on the inner conductor is −40 nC/m and the linear charge density on the outer conductor is −50 nC/m. The inner and outer cylindrical surfaces are respectively denoted by *A*, *B*, *C*, and *D*, as shown. ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)The magnitude of the electric field at a point that is 94 mm from the axis is closest to



A) 17,000 N/C.
B) 15,000 N/C.
C) 13,000 N/C.
D) 11,000 N/C.
E) 9600 N/C.

Answer: A

21) Charge is distributed uniformly throughout a large insulating cylinder of radius *R*. The charge per unit length in the cylindrical volume is λ.
(a) Use Gauss's law to find the magnitude of the electric field at a distance *r* from the central axis of the cylinder for $r < R$. Your answer should be in terms of r, R, λ, ε_0, and π.
(b) Check the reasonableness of your answer by evaluating it at the surface of the cylinder.

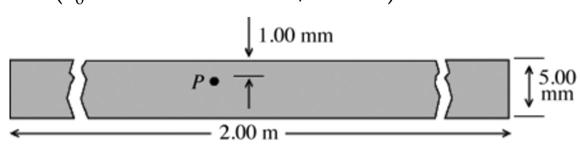
Answer: (a) $E = \dfrac{\lambda r}{2\pi\varepsilon_0 R^2}$

(b) At $r = R$, $E = \lambda/2\pi\varepsilon_0 R$, which is reasonable.

22) A very large sheet of a conductor carries a uniform charge density of 4.00 pC/mm^2 on its surfaces. What is the electric field strength 3.00 mm outside the surface of the conductor? ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)
A) 4.52×10^5 N/C
B) 2.26×10^5 N/C
C) 9.04×10^5 N/C
D) 0.452 N/C
E) 0.226 N/C
Answer: A

23) A huge (essentially infinite) horizontal nonconducting sheet 10.0 cm thick has charge uniformly spread over both faces. The upper face carries +95.0 nC/m^2 while the lower face carries -25.0 nC/ m^2. What is the magnitude of the electric field at a point within the sheet 2.00 cm below the upper face? ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)
A) 0.00 N/C
B) 3.95×10^3 N/C
C) 6.78×10^3 N/C
D) 7.91×10^3 N/C
E) 1.36×10^4 N/C
Answer: C

24) As shown in the figure, a square insulating slab 5.0 mm thick measuring 2.0 m × 2.0 m has a charge of 8.0×10^{-11} C distributed uniformly throughout its volume. Use Gauss's law to determine the electric field at point *P*, which is located within the slab beneath its center, 1.0 mm from one of the faces. ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)



A) 0.68 N/C
B) 14 N/C
C) 23 N/C
D) 34 N/C
E) 57 N/C
Answer: A

25) Two extremely large nonconducting horizontal sheets each carry uniform charge density on the surfaces facing each other. The upper sheet carries +5.00 $\mu C/m^2$. The electric field midway between the sheets is 4.25×10^5 N/C pointing downward. What is the surface charge density on the lower sheet? ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)

Answer: -2.52 $\mu C/m^2$

26) Consider two closely spaced and oppositely charged parallel metal plates. The plates are square with sides of length *L* and carry charges *Q* and -*Q* on their facing surfaces. What is the magnitude of the electric field in the region between the plates?

A) $E = \dfrac{Q}{\varepsilon_0 L^2}$

B) $E = \dfrac{2Q}{\varepsilon_0 L^2}$

C) E = 0

D) $E = \dfrac{4Q}{\varepsilon_0 L^2}$

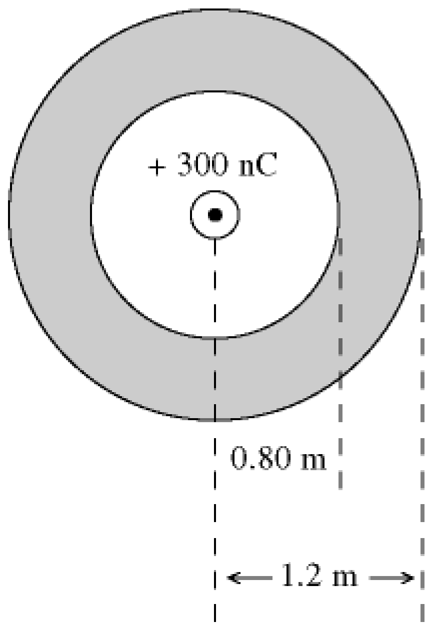
E) $E = \dfrac{Q}{2\varepsilon_0 L^2}$

Answer: A

27) A neutral hollow spherical conducting shell of inner radius 1.00 cm and outer radius 3.00 cm has a +2.00–μC point charge placed at its center. Find the surface charge density
(a) on the inner surface of the shell.
(b) on the outer surface of the shell.

Answer: (a) -1590 $\mu C/m^2$ (b) +177 $\mu C/m^2$

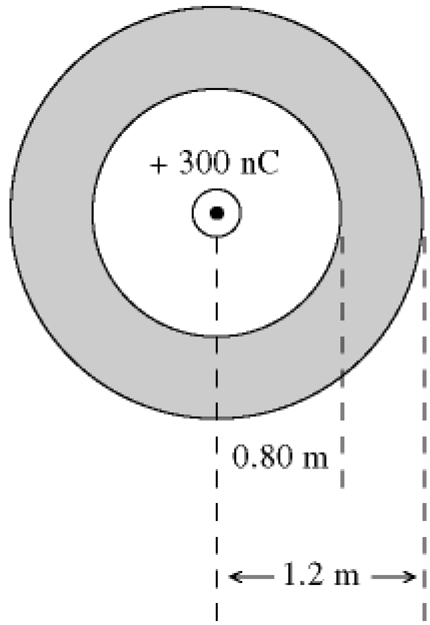
28) A hollow conducting spherical shell has radii of 0.80 m and 1.20 m, as shown in the figure. The sphere carries an excess charge of −500 nC. A point charge of +300 nC is present at the center. The surface charge density on the inner spherical surface is closest to



A) zero.
B) $+4.0 \times 10^{-8}$ C/m^2.
C) $+6.0 \times 10^{-8}$ C/ m^2.
D) -4.0×10^{-8} C/ m^2.
E) -6.0×10^{-8} C/ m^2.

Answer: D

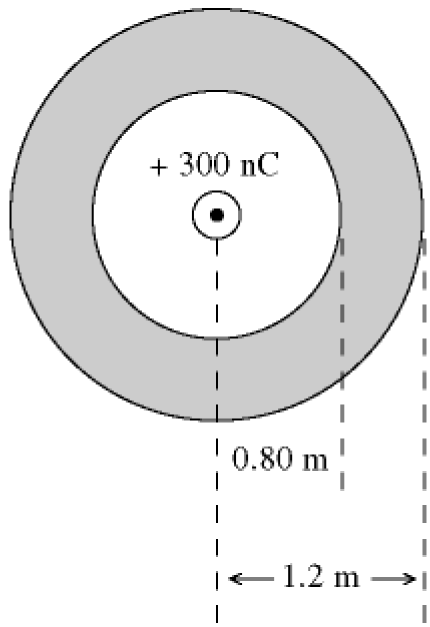
29) A hollow conducting spherical shell has radii of 0.80 m and 1.20 m, as shown in the figure. The sphere carries a net excess charge of -500 nC. A point charge of +300 nC is present at the center. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C}$) The radial component of the electric field at a point that is 0.60 m from the center is closest to



A) zero.
B) +5000 N/C.
C) +7500 N/C.
D) -5000 N/C.
E) -7500 N/C.

Answer: C

30) A hollow conducting spherical shell has radii of 0.80 m and 1.20 m, as shown in the figure. The sphere carries a net excess charge of -500 nC. A point charge of +300 nC is present at the center. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C) The radial component of the electric field at a point that is 1.50 m from the center is closest to



A) +1200 N/C.
B) +2000 N/C.
C) -800 N/C.
D) -1600 N/C.
E) -2000 N/C.

Answer: C

31) An irregular conductor carries a surface charge density of -6.75 μC/m^2 at and in the vicinity of a point *P* on the surface. An electron is released just above *P* outside the conductor. What are the magnitude and direction of its acceleration the instant after it is released? ($\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2, $e = 1.60 \times 10^{-19}$ C, $m_{el} = 9.11 \times 10^{-31}$ kg)

Answer: 1.34×10^{17} m/s^2, away from *P*

Chapter 21 Electric Potential

22.1 Conceptual Questions

1) If the electric field is zero everywhere inside a region of space, the potential must also be zero in that region.
   A) True
   B) False

   Answer: B

2) When the electric field is zero at a point, the potential must also be zero there.
   A) True
   B) False

   Answer: B

3) If the electrical potential in a region is constant, the electric field must be zero everywhere in that region.
   A) True
   B) False

   Answer: A

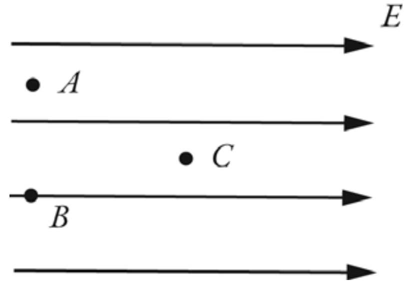
4) If the electric potential at a point in space is zero, then the electric field at that point must also be zero.
   A) True
   B) False

   Answer: B

5) A negative charge, if free, will tend to move
   A) from high potential to low potential.
   B) from low potential to high potential.
   C) toward infinity.
   D) away from infinity.
   E) in the direction of the electric field.

   Answer: B

6) Suppose a region of space has a uniform electric field, directed towards the right, as shown in the figure. Which statement about the electric potential is true?



A) The potential at all three locations (*A*, *B*, *C*) is the same because the field is uniform.
B) The potential at points *A* and *B* are equal, and the potential at point *C* is higher than the potential at point *A*.
C) The potential at points *A* and *B* are equal, and the potential at point *C* is lower than the potential at point *A*.
D) The potential at point *A* is the highest, the potential at point *B* is the second highest, and the potential at point *C* is the lowest.

Answer: C

7) Which statements are true for an electron moving in the direction of an electric field? (There may be more than one correct choice.)
A) Its electric potential energy increases as it goes from high to low potential.
B) Its electric potential energy decreases as it goes from high to low potential.
C) Its potential energy increases as its kinetic energy decreases.
D) Its kinetic energy decreases as it moves in the direction of the electric field.
E) Its kinetic energy increases as it moves in the direction of the electric field.

Answer: A, C, D

8) Suppose you have two point charges of opposite sign. As you move them farther and farther apart, the potential energy of this system relative to infinity
A) increases.
B) decreases.
C) stays the same.

Answer: A

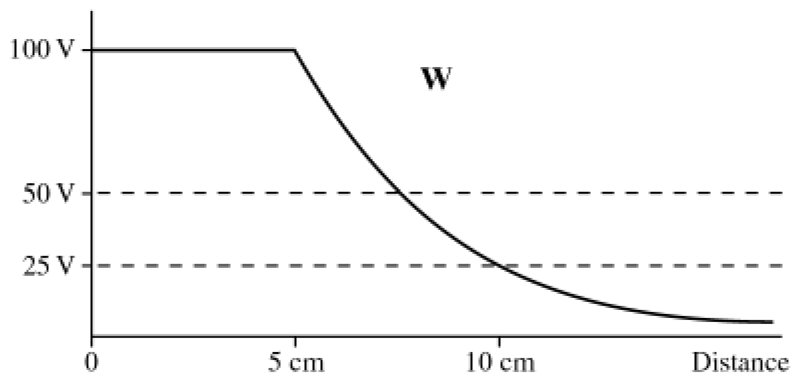
9) Suppose you have two negative point charges. As you move them farther and farther apart, the potential energy of this system relative to infinity
A) increases.
B) decreases.
C) stays the same.

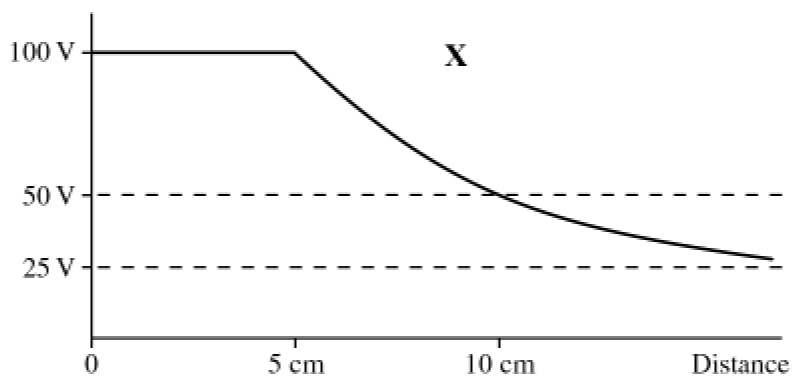
Answer: B

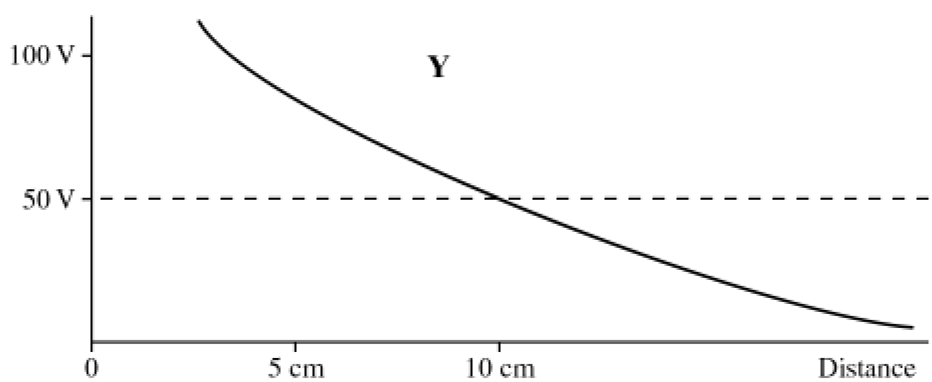
10) Two equal positive charges are held in place at a fixed distance. If you put a third positive charge midway between these two charges, its electrical potential energy of the system (relative to infinity) is zero because the electrical forces on the third charge due to the two fixed charges just balance each other.
   A) True
   B) False

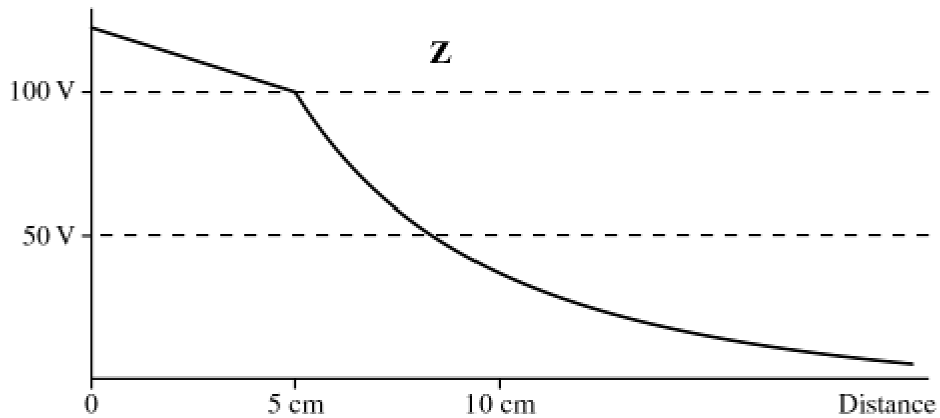
Answer: B

11) A metallic sphere of radius 5 cm is charged such that the potential of its surface is 100 V (relative to infinity). Which of the following plots correctly shows the potential as a function of distance from the center of the sphere?





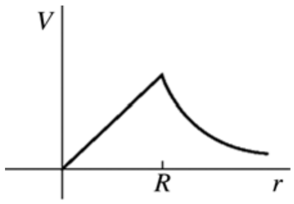


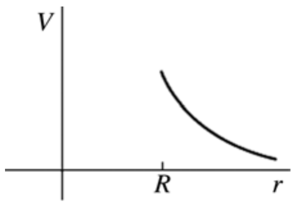


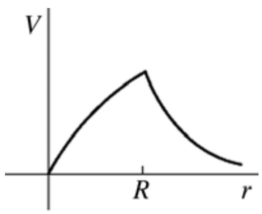
A) plot W
B) plot X
C) plot Y
D) plot Z

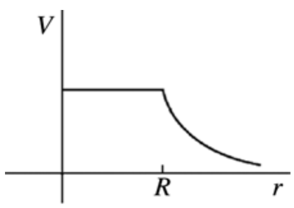
Answer: B

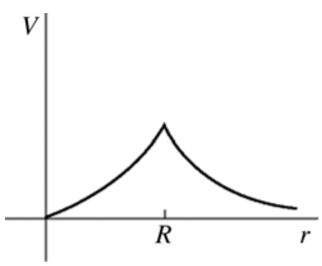
12) A conducting sphere of radius R carries an excess positive charge and is very far from any other charges. Which one of the following graphs best illustrates the potential (relative to infinity) produced by this sphere as a function of the distance r from the center of the sphere?

A)


B)


C)


D)


E)


Answer: D

13) A nonconducting sphere contains positive charge distributed uniformly throughout its volume. Which statements about the potential due to this sphere are true? All potentials are measured relative to infinity. (There may be more than one correct choice.)
A) The potential is highest at the center of the sphere.
B) The potential at the center of the sphere is zero.
C) The potential at the center of the sphere is the same as the potential at the surface.
D) The potential at the surface is higher than the potential at the center.
E) The potential at the center is the same as the potential at infinity.

Answer: A

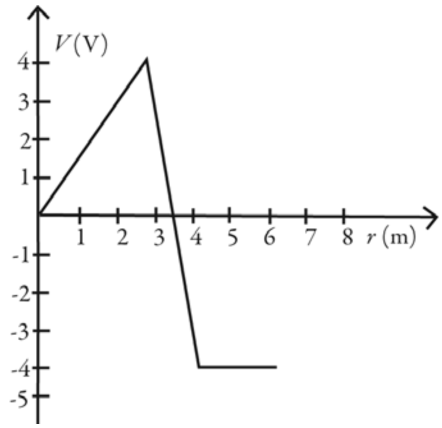
14) A conducting sphere contains positive charge distributed uniformly over its surface. Which statements about the potential due to this sphere are true? All potentials are measured relative to infinity. (There may be more than one correct choice.)
A) The potential is lowest, but not zero, at the center of the sphere.
B) The potential at the center of the sphere is zero.
C) The potential at the center of the sphere is the same as the potential at the surface.
D) The potential at the surface is higher than the potential at the center.
E) The potential at the center is the same as the potential at infinity.

Answer: C

15) A negative charge is moved from point *A* to point *B* along an equipotential surface. Which of the following statements must be true for this case?
A) The negative charge performs work in moving from point *A* to point *B*.
B) Work is required to move the negative charge from point *A* to point *B*.
C) No work is required to move the negative charge from point *A* to point *B*.
D) The work done on the charge depends on the distance between *A* and *B*.
E) Work is done in moving the negative charge from point *A* to point *B*.

Answer: C

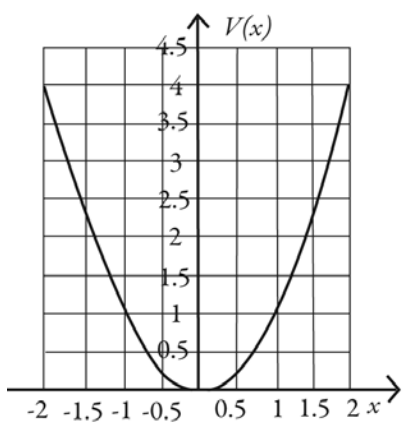
16) The graph in the figure shows the variation of the electric potential V (measured in volts) as a function of the radial direction r (measured in meters). For which range or value of r is the magnitude of the electric field the largest?



A) from r = 0 m to r = 3 m
B) from r = 3 m to r = 4 m
C) from r = 4 m to r = 6 m
D) at r = 3 m
E) at r = 4 m

Answer: B

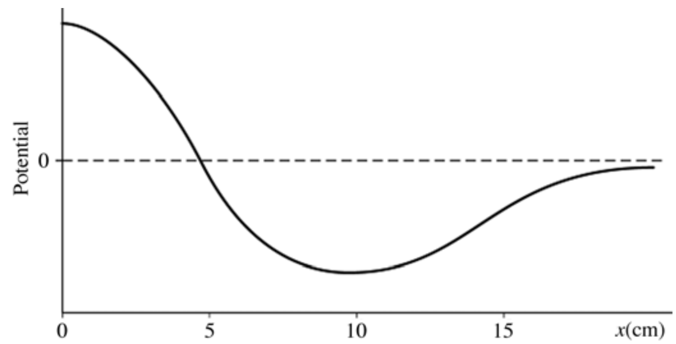
17) The graph in the figure shows the variation of the electric potential $V(x)$ (in arbitrary units) as a function of the position x (also in arbitrary units). Which of the choices below correctly describes the orientation of the x-component of the electric field along the x-axis?



A) E_x is positive from x = -2 to x = 2.
B) E_x is positive from x = -2 to x = 0, and negative from x = 0 to x = 2.
C) E_x is negative from x = -2 to x = 0, and positive from x = 0 to x = 2.
D) E_x is negative from x = -2 to x = 2.

Answer: B

18) The potential as a function of position x is shown in the graph in the figure. Which statement about the electric field is true?

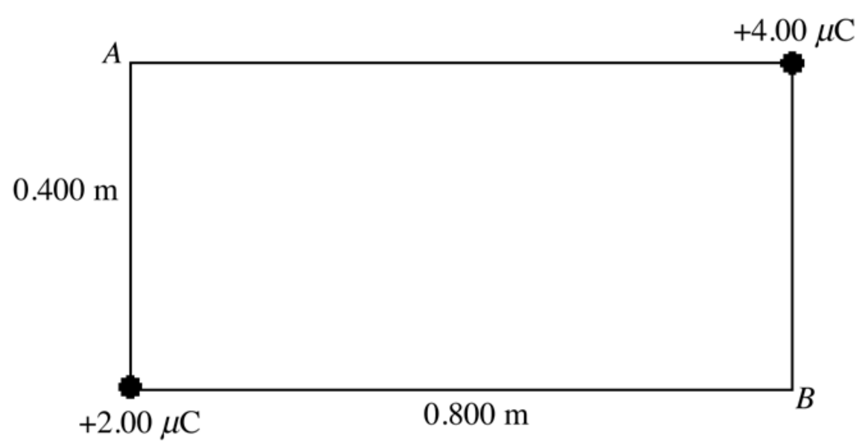


A) The electric field is zero at $x = 0$, its magnitude is at a maximum at $x = 5$ cm, and the field is directed to the right there.
B) The electric field is zero at $x = 5$ cm, its magnitude is at a maximum at $x = 0$, and the field is directed to the right there.
C) The electric field is zero at $x = 0$, its magnitude is at a maximum at $x = 15$ cm, and the field is directed to the left there.
D) The electric field is zero at $x = 10$ cm, its magnitude is at a maximum at $x = 5$ cm, and the field is directed to the left there.

Answer: A

22.2 Problems

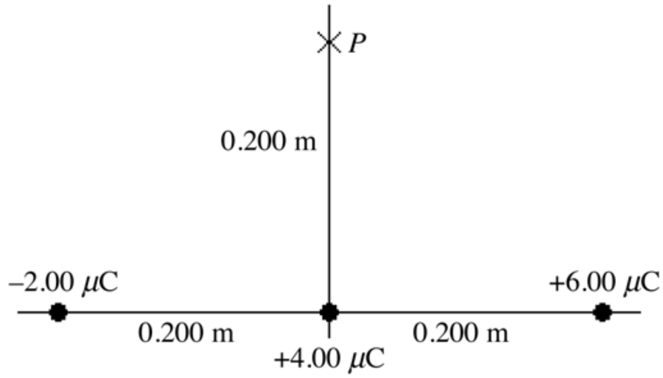
1) Two positive point charges +4.00 μC and +2.00 μC are placed at the opposite corners of a rectangle as shown in the figure. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}$)



(a) What is the potential at point A (relative to infinity) due to these charges?
(b) What is the potential at point B (relative to infinity) due to these charges?

Answer: (a) $+8.99 \times 10^4$ V (b) 1.12×10^5 V

2) Three point charges of -2.00 μC, +4.00 μC, and +6.00 μC are placed along the x–axis as shown in the figure. What is the electrical potential at point P (relative to infinity) due to these charges? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)



A) -307 kV
B) +307 kV
C) -154 kV
D) +154 kV
E) 0 kV

Answer: B

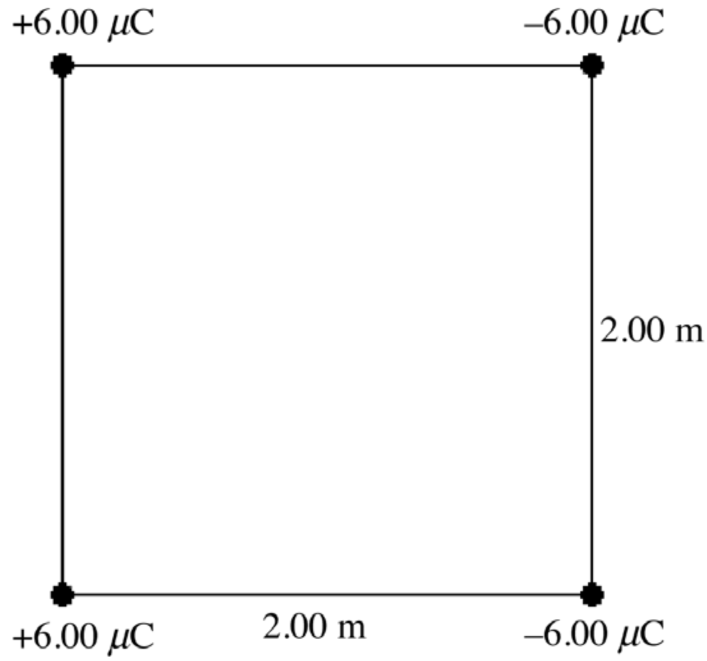
3) Four equal +6.00–μC point charges are placed at the corners of a square 2.00 m on each side. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

(a) What is the electric potential (relative to infinity) due to these charges at the center of this square?

(b) What is the magnitude of the electric field due to these charges at the center of the square?

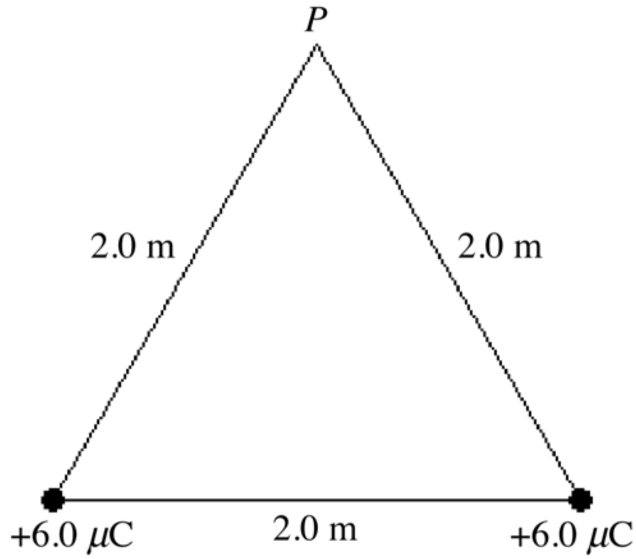
Answer: (a) 153 kV (b) zero

4) Four point charges of magnitude 6.00 μC and of varying signs are placed at the corners of a square 2.00 m on each side, as shown in the figure. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)
(a) What is the electric potential (relative to infinity) at the center of this square due to these charges?
(b) What is the magnitude of the electric field due to these charges at the center of the square?



Answer: (a) zero (b) 7.63×10^4 N/C

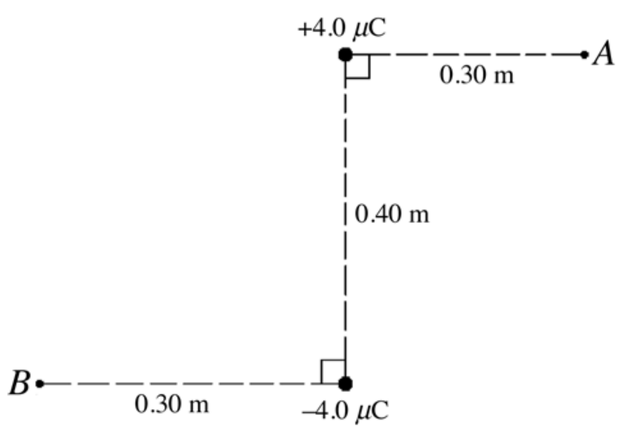
5) Two +6.0–μC point charges are placed at the corners of the base of an equilateral triangle, as shown in the figure. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}$) At the vertex, P, of the triangle



(a) what is the electric potential (relative to infinity) due to these charges?
(b) what is the magnitude of the electric field due to these charges?

Answer: (a) 54 kV (b) 2.3×10^4 N/C

6) A +4.0 μC–point charge and a -4.0–μC point charge are placed as shown in the figure. What is the potential difference, $V_A - V_B$, between points A and B? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}$)



A) 48 V
B) 96 V
C) 0.00 V
D) 96 kV
E) 48 kV

Answer: D

7) Two point charges of +2.0 μC and -6.0 μC are located on the x–axis at x = -1.0 cm and x = +2.0 cm respectively. Where should a third charge of +3.0–μC be placed on the +x–axis so that the potential at the origin is equal to zero? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

A) x = 4.0 cm
B) x = 1.0 cm
C) x = 2.0 cm
D) x = 3.0 cm
E) x = 5.0 cm

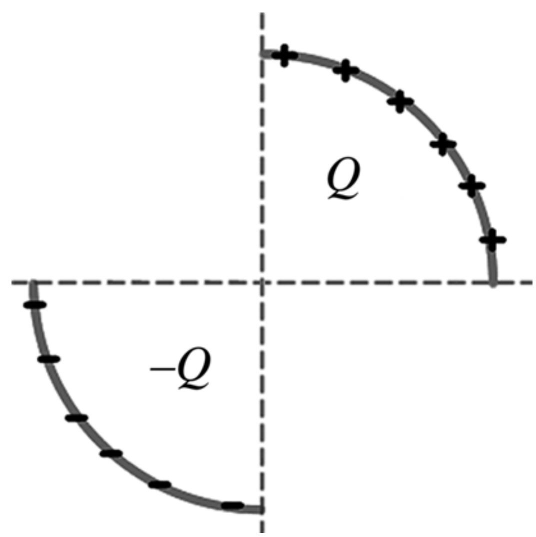
Answer: D

8) A -7.0–μC point charge has a positively charged object in an elliptical orbit around it. If the mass of the positively charged object is 1.0 kg and the distance varies from 5.0 mm to 20.0 mm between the charges, what is the maximum electric potential difference through which the positive object moves? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

A) 9.4 MV
B) 3.2 MV
C) 4.2 MV
D) 16 MV

Answer: A

9) The figure shows two arcs of a circle on which charges +Q and -Q have been spread uniformly. What is the value of the electric potential at the center of the circle?



Answer: Zero

10) A half–ring (semicircle) of uniformly distributed charge Q has radius R. What is the electric potential at its center?

Answer: $Q/4\pi\,\varepsilon_0 R$

11) A very small object carrying –6.0 μC of charge is attracted to a large, well–anchored, positively charged object. How much kinetic energy does the negatively charged object gain if the potential difference through which it moves is 3.0 mV? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

A) 18 nJ
B) 0.50 kJ
C) 0.50 J
D) 6.0 μJ

Answer: A

12) Two point charges of +1.0 μC and -2.0 μC are located 0.50 m apart. What is the minimum amount of work needed to move the charges apart to double the distance between them? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

A) -36 mJ
B) +18 mJ
C) 0 mJ
D) +36 mJ
E) -18 mJ

Answer: B

13) Two equal point charges Q are separated by a distance d. One of the charges is released and moves away from the other due only to the electrical force between them. When the moving charge is a distance $3d$ from the other charge, what is its kinetic energy?

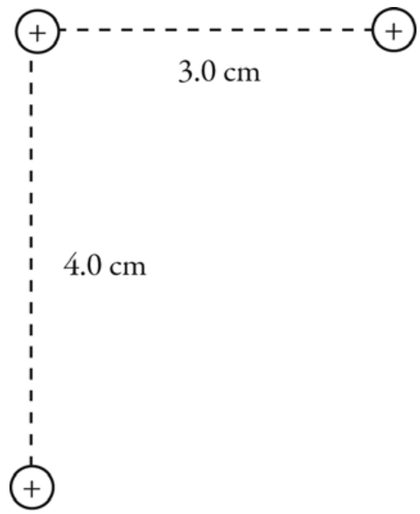
Answer: $Q^2/6\pi\varepsilon_0 d$

14) If an electron is accelerated from rest through a potential difference of 9.9 kV, what is its resulting speed? ($e = 1.60 \times 10^{-19}$ C, $k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2, $m_{el} = 9.11 \times 10^{-31}$ kg)

A) 5.9×10^7 m/s
B) 4.9×10^7 m/s
C) 3.9×10^7 m/s
D) 2.9×10^7 m/s

Answer: A

15) Consider the group of three+2.4 nC point charges shown in the figure. What is the electric potential energy of this system of charges relative to infinity? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)



A) 4.1×10^{-6} J
B) 4.6×10^{-6} J
C) 4.2×10^{-6} J
D) 4.4×10^{-6} J
Answer: A

16) An electron is released from rest at a distance of 9.00 cm from a proton. If the proton is held in place, how fast will the electron be moving when it is 3.00 cm from the proton? ($m_{el} = 9.11 \times 10^{-31}$ kg, $e = 1.60 \times 10^{-19}$ C, $k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)
A) 75.0 m/s
B) 106 m/s
C) 130 m/s
D) 1.06×10^3 m/s
E) 4.64×10^5 m/s
Answer: B

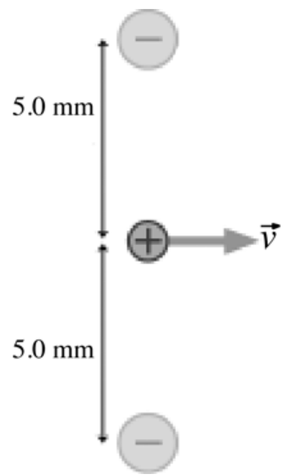
17) A -3.0-μC point charge and a -9.0-μC point charge are initially extremely far apart. How much work does it take to bring the -3.0-μC charge to $x = 3.0$ mm, $y = 0.00$ mm and the -9.0-μC charge to $x = -3.0$ mm, $y = 0.00$ mm? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)
A) 40 J
B) 81 J
C) 27 J
D) 6.8 J
Answer: A

18) A tiny object carrying a charge of +3.00 μC and a second tiny charged object are initially very far apart. If it takes 29.0 J of work to bring them to a final configuration in which the +3.00 μC object i is at x = 1.00 mm, y = 1.00 mm, and the other charged object is at x = 1.00 mm, y = 3.00 mm, find the magnitude of the charge on the second object. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

A) 2.15 μC
B) 4.30 μC
C) 10.74 μC
D) 4.30 nC

Answer: A

19) The figure shows an arrangement of two −4.5 nC charges, each separated by 5.0 mm from a proton. If the two negative charges are held fixed at their locations and the proton is given an initial velocity v as shown in the figure, what is the minimum initial speed v that the proton needs to totally escape from the negative charges? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2, $e = 1.60 \times 10^{-19}$ C, $m_{\text{proton}} = 1.67 \times 10^{-27}$ kg)



A) 1.8×10^6 m/s
B) 3.5×10^6 m/s
C) 6.8×10^6 m/s
D) 1.4×10^7 m/s

Answer: A

20) An alpha particle is a nucleus of helium. It has twice the charge and four times the mass of the proton. When they were very far away from each other, but headed toward directly each other, a proton and an alpha particle each had an initial speed of 0.0030c, where c is the speed of light. What is their distance of closest approach? *Hint:* There are *two* conserved quantities. Make use of both of them. ($c = 3.00 \times 10^8$ m/s, $k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2, $e = 1.60 \times 10^{-19}$ C, $m_{\text{proton}} = 1.67 \times 10^{-27}$ kg)

A) 2.1×10^{-13} m
B) 3.3×10^{-13} m
C) 2.6×10^{-13} m
D) 2.9×10^{-13} m

Answer: A

21) Two point charges, Q and -3Q, are located on the x–axis a distance d apart, with -3Q to the right of Q. Find the location of ALL the points on the x–axis (not counting infinity) at which the potential (relative to infinity) due to this pair of charges is equal to zero.

Answer: d/4 to the right of Q (between the charges) and d/2 to the left of Q

22) A sphere with radius 2.0 mm carries +1.0 μC of charge distributed uniformly throughout its volume. What is the potential difference, $V_B - V_A$, between point B, which is 4.0 m from the center of the sphere, and point A, which is 9.0 m from the center of the sphere? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

A) 1200 V
B) -1200 V
C) 140 V
D) -0.45 V

Answer: A

23) A conducting sphere is charged up such that the potential on its surface is 100 V (relative to infinity). If the sphere's radius were twice as large, but the charge on the sphere were the same, what would be the potential on the surface relative to infinity?

A) 50 V
B) 25 V
C) 100 V
D) 200 V

Answer: A

24) A conducting sphere of radius 20.0 cm carries an excess charge of +15.0 μC, and no other charges are present. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2) The potential (relative to infinity) due to this sphere at a point 12.0 cm from its center is closest to

A) zero.
B) 674 kV.
C) 1130 kV.
D) 3380 kV.
E) 9380 kV.

Answer: B

25) A conducting sphere 45 cm in diameter carries an excess of charge, and no other charges are present. You measure the potential of the surface of this sphere and find it to be 14 kV relative to infinity. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2) The excess charge on this sphere is closest to

A) 0.35 nC.
B) 79 nC.
C) 315 nC.
D) 350 nC.
E) 700 nC.

Answer: D

26) An extremely long thin wire carries a uniform linear charge density of 358 nC/m. Find the potential difference between points 5.0 m and 6.0 m from the wire, provided they are not near either end of the wire. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

A) 1.2 kV
B) 6.0 kV
C) 0.21 kV
D) 0.215 kV

Answer: A

27) Two long conducting cylindrical shells are coaxial and have radii of 20 mm and 80 mm. The electric potential of the inner conductor, with respect to the outer conductor, is +600 V. An electron is released from rest at the surface of the outer conductor. What is the speed of the electron as it reaches the inner conductor? ($e = 1.60 \times 10^{-19}$ C, $m_{el} = 9.11 \times 10^{-31}$ kg, $k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

A) 1.1×10^7 m/s
B) 1.3×10^7 m/s
C) 1.5×10^7 m/s
D) 1.7×10^7 m/s
E) 1.9×10^7 m/s

Answer: C

28) Two long conducting cylindrical shells are coaxial and have radii of 20 mm and 80 mm. The electric potential of the inner conductor, with respect to the outer conductor, is +600 V. What is the maximum electric field magnitude between the cylinders? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)

A) 10,000 V/m
B) 14,000 V/m
C) 18,000 V/m
D) 22,000 V/m
E) 26,000 V/m

Answer: D

29) A very long nonconducting cylinder of diameter 10.0 cm carries charge distributed uniformly over its surface. Each meter of length carries +5.50 μC of charge. A proton is released from rest just outside the surface. How far will it be from the SURFACE of the cylinder when its speed has reached 2550 km/s? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2, $e = 1.60 \times 10^{-19}$ C, $m_{proton} = 1.67 \times 10^{-27}$ kg)

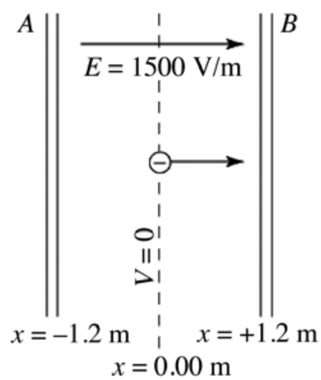
Answer: 2.05 cm

30) Two parallel conducting plates are separated by 1.0 mm and carry equal but opposite surface charge densities. If the potential difference between them is 2.0 V, what is the magnitude of the surface charge density on each plate? ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)

A) 18 nC/m^2
B) 0.13 mC/m^2
C) 35 nC/m^2
D) 0.27 mC/m^2

Answer: A

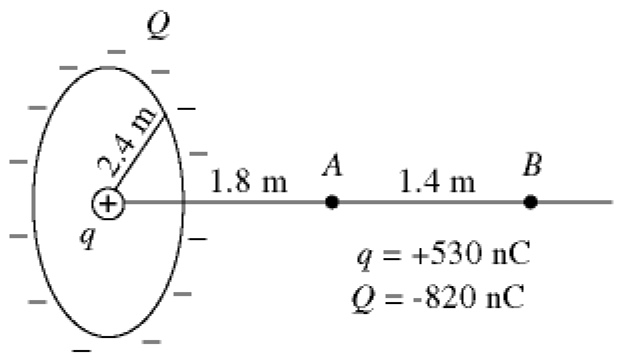
31) Two large conducting parallel plates A and B are separated by 2.4 m. A uniform field of 1500 V/m, in the positive x-direction, is produced by charges on the plates. The center plane at x = 0.00 m is an equipotential surface on which $V = 0$. An electron is projected from x = 0.00 m, with an initial velocity of 1.0×10^7 m/s perpendicular to the plates in the positive x-direction, as shown in the figure. What is the kinetic energy of the electron as it reaches plate A? ($e = 1.60 \times 10^{-19}$ C, $m_{el} = 9.11 \times 10^{-31}$ kg)



A) $+2.4 \times 10^{-16}$ J
B) $+3.3 \times 10^{-16}$ J
C) -2.4×10^{-16} J
D) -2.9×10^{-16} J
E) -3.3×10^{-16} J

Answer: B

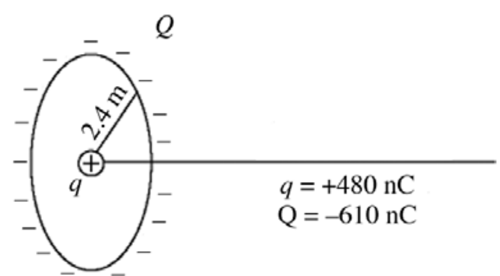
32) A charge Q = -820 nC is uniformly distributed on a ring of 2.4 m radius. A point charge q = +530 nC is fixed at the center of the ring. Points A and B are located on the axis of the ring, as shown in the figure. What is the minimum work that an external force must do to transport an electron from B to A? ($e = 1.60 \times 10^{-19}$ C, $k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N $\cdot$ m^2/C^2)



A) -8.7×10^{-17} J
B) $+7.2 \times 10^{-18}$ J
C) $+1.0 \times 10^{-16}$ J
D) $+8.7 \times 10^{-17}$ J
E) -7.2×10^{-18} J

Answer: A

33) A charge Q = -610 nC is uniformly distributed on a ring of 2.4–m radius. A point charge q = +480 nC is fixed at the center of the ring, as shown in the figure. An electron is projected from infinity toward the ring along the axis of the ring. This electron comes to a momentary halt at a point on the axis that is 5.0 m from the center of the ring. What is the initial speed of the electron at infinity? ($e = 1.60 \times 10^{-19}$ C, $k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N $\cdot$ m^2/C^2, $m_{\text{el}} = 9.11 \times 10^{-31}$ kg)



A) 6.6×10^6 m/s
B) 4.5×10^6 m/s
C) 3.4×10^6 m/s
D) 2.2×10^6 m/s
E) 1.1×10^6 m/s

Answer: A

34) If the electric potential in a region is given by $V(x) = 6/x^2$, the x component of the electric field in that region is
A) $-12x^{-3}$.
B) $-6x$.
C) $12x^{-3}$.
D) $12x$.
E) $6x$.
Answer: C

35) If the potential in a region is given by $V(x,y,z) = xy - 3z^{-2}$, then the y component of the electric field in that region is
A) $x + y - 6z^{-3}$.
B) $-y$.
C) $-x$.
D) $x + y$.
Answer: C

36) In a certain region, the electric potential due to a charge distribution is given by the equation $V(x,y,z) = 3x^2y^2 + yz^3 - 2z^3x$, where x, y, and z are measured in meters and V is in volts. Calculate the magnitude of the electric field vector at the position $(x,y,z) = (1.0, 1.0, 1.0)$.
A) 4.3 V/m
B) 2.0 V/m
C) -8.1 V/m
D) 8.6 V/m
E) 74 V/m
Answer: D

37) In a certain region, the electric potential due to a charge distribution is given by the equation $V(x,y) = 2xy - x^2 - y$, where x and y are measured in meters and V is in volts. At which point is the electric field equal to zero?
A) $x = 0.5$ m, $y = 1$ m
B) $x = 1$ m, $y = 1$ m
C) $x = 1$ m, $y = 0.5$ m
D) $x = 0.5$ m, $y = 0.5$ m
E) $x = 0$ m, $y = 0$ m
Answer: D

Chapter 23 Electrostatic Energy and Capacitors

23.1 Conceptual Questions

1) The charge on the square plates of a parallel-plate capacitor is Q. The potential across the plates is maintained with constant voltage by a battery as they are pulled apart to twice their original separation, which is small compared to the dimensions of the plates. The amount of charge on the plates is now equal to
   A) $4Q$.
   B) $2Q$.
   C) Q.
   D) $Q/2$.
   E) $Q/4$.

   Answer: D

2) The electric field between square the plates of a parallel-plate capacitor has magnitude E. The potential across the plates is maintained with constant voltage by a battery as they are pulled apart to twice their original separation, which is small compared to the dimensions of the plates. The magnitude of the electric field between the plates is now equal to
   A) $4E$.
   B) $2E$.
   C) E.
   D) $E/2$.
   E) $E/4$.

   Answer: D

3) Equal but opposite charges Q are placed on the square plates of an air-filled parallel-plate capacitor. The plates are then pulled apart to twice their original separation, which is small compared to the dimensions of the plates. Which of the following statements about this capacitor are true? (There may be more than one correct choice.)
   A) The energy stored in the capacitor has doubled.
   B) The energy density in the capacitor has increased.
   C) The electric field between the plates has increased.
   D) The potential difference across the plates has doubled.
   E) The capacitance has doubled.

   Answer: A, D

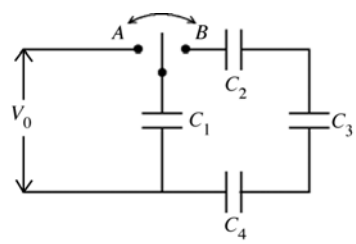
4) When two or more capacitors are connected in series across a potential difference
   A) the potential difference across the combination is the algebraic sum of the potential differences across the individual capacitors.
   B) each capacitor carries the same amount of charge.
   C) the equivalent capacitance of the combination is less than the capacitance of any of the capacitors.
   D) All of the above choices are correct.
   E) None of the above choices are correct.

   Answer: D

5) When two or more capacitors are connected in parallel across a potential difference
   A) the potential difference across each capacitor is the same.
   B) each capacitor carries the same amount of charge.
   C) the equivalent capacitance of the combination is less than the capacitance of any of the capacitors.
   D) All of the above choices are correct.
   E) None of the above choices are correct.

Answer: A

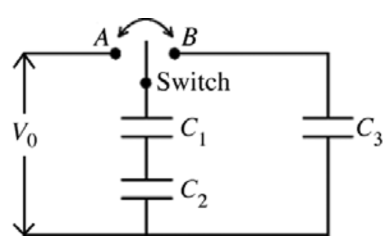
6) The four identical capacitors in the circuit shown in the figure are initially uncharged. Let the charges on the capacitors be Q_1, Q_2, Q_3, and Q_4 and the potential differences across them be V_1, V_2, V_3, and V_4. The switch is thrown first to position A and kept there for a long time. It is then thrown to position B. Which of the following conditions is true with the switch in position B?



   A) $V_1 = V_2 = V_3 = V_4$
   B) $V_1 = V_0$
   C) $V_1 + V_2 + V_3 + V_4 = V_0$
   D) $Q_1 = 3\ Q_2$
   E) $Q_1 = Q_2$

Answer: D

7) In the circuit shown in the figure, the capacitors are initially uncharged. The switch is first thrown to position A and kept there for a long time. It is then thrown to position B. Let the charges on the capacitors be Q_1, Q_2, and Q_3 and the potential differences across them be V_1, V_2, and V_3. Which of the following conditions must be true with the switch in position B?



   A) $V_1 = V_2 = V_3$
   B) $V_1 + V_2 = V_3$
   C) $V_3 = V_0$
   D) $Q_1 = Q_2 = Q_3$
   E) $Q_1 + Q_2 = Q_3$

Answer: B

8) An ideal parallel-plate capacitor consists of a set of two parallel plates of area A separated by a very small distance d. When this capacitor is connected to a battery that maintains a constant potential difference between the plates, the energy stored in the capacitor is U_0. If the separation between the plates is doubled, how much energy is stored in the capacitor?
A) $4U_0$
B) $2U_0$
C) U_0
D) $U_0/2$
E) $U_0/4$

Answer: D

9) An ideal parallel-plate capacitor consists of a set of two parallel plates of area A separated by a very small distance d. When the capacitor plates carry charges $+Q$ and $-Q$, the capacitor stores energy U_0. If the separation between the plates is doubled, how much electrical energy is stored in the capacitor?
A) $4U_0$
B) $2U_0$
C) U_0
D) $U_0/2$
E) $U_0/4$

Answer: B

10) An ideal air-filled parallel-plate capacitor has round plates and carries a fixed amount of equal but opposite charge on its plates. All the geometric parameters of the capacitor (plate diameter and plate separation) are now DOUBLED. If the original capacitance was C_0, what is the new capacitance?
A) $4C_0$
B) $2C_0$
C) C_0
D) $C_0/2$
E) $C_0/4$

Answer: B

11) An ideal air-filled parallel-plate capacitor has round plates and carries a fixed amount of equal but opposite charge on its plates. All the geometric parameters of the capacitor (plate diameter and plate separation) are now DOUBLED. If the original energy stored in the capacitor was U_0, how much energy does it now store?
A) $4U_0$
B) $2U_0$
C) U_0
D) $U_0/2$
E) $U_0/4$

Answer: D

12) An ideal air-filled parallel-plate capacitor has round plates and carries a fixed amount of equal but opposite charge on its plates. All the geometric parameters of the capacitor (plate diameter and plate separation) are now DOUBLED. If the original energy density between the plates was u_0, what is the new energy density?
A) $16u_0$
B) $4u_0$
C) u_0
D) $u_0/4$
E) $u_0/16$
Answer: E

13) A charged capacitor stores energy U. Without connecting this capacitor to anything, dielectric having dielectric constant K is now inserted between the plates of the capacitor, completely filling the space between them. How much energy does the capacitor now store?
A) $2KU$
B) KU
C) U
D) $\frac{U}{K}$
E) $\frac{U}{2K}$
Answer: D

14) Two capacitors, C_1 and C_2, are connected in series across a source of potential difference. With the potential source still connected, a dielectric is now inserted between the plates of capacitor C_1. What happens to the charge on capacitor C_2?
A) The charge on C_2 increases.
B) The charge on C_2 decreases.
C) The charge on C_2 remains the same.
Answer: A

15) An air-filled parallel-plate capacitor is connected to a battery and allowed to charge up. Now a slab of dielectric material is placed between the plates of the capacitor while the capacitor is still connected to the battery. After this is done, we find that
A) the energy stored in the capacitor had decreased.
B) the voltage across the capacitor had increased.
C) the charge on the capacitor had increased.
D) the charge on the capacitor had not changed.
E) None of these choices are true.
Answer: C

23.2 Problems

1) A parallel–plate capacitor has plates of area 0.40 m^2 and plate separation of 0.20 mm. The capacitor is connected across a 9.0–V potential source. ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)
(a) What is the magnitude of the electric field between the plates?
(b) What is the capacitance of the capacitor?
(c) What is the magnitude of the charge on each plate of the capacitor?

Answer: (a) 4.5×10^4 N/C (b) 18 nF (c) 160 nC

2) Each plate of a parallel–plate air–filled capacitor has an area of 0.0020 m^2, and the separation of the plates is 0.020 mm. An electric field of 3.9×10^6 V/m is present between the plates. What is the surface charge density on the plates? ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)

A) 35 $\mu C/m^2$
B) 73 $\mu C/m^2$
C) 17 $\mu C/m^2$
D) 52 $\mu C/m^2$
E) 87 $\mu C/m^2$

Answer: A

3) Two thin–walled concentric conducting spheres of radii 5.0 cm and 10 cm have a potential difference of 100 V between them. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9\ N \cdot m^2/C^2$)
(a) What is the capacitance of this combination?
(b) What is the charge carried by each sphere?

Answer: (a) 11 pF (b) 1.1 nC

4) A metal cylinder of radius 2.0 mm is concentric with another metal cylinder of radius 5.0 mm. If the space between the cylinders is filled with air and the length of the cylinders is 50 cm, what is the capacitance of this arrangement? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9\ N \cdot m^2/C^2$)

A) 33 pF
B) 60 pF
C) 22 pF
D) 30 pF
E) 11 pF

Answer: D

5) The capacitance per unit length of a very long coaxial cable, made of two concentric cylinders, is 50 pF/m. What is the radius of the outer cylinder if the radius of the inner one is 1.0 mm? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9\ N \cdot m^2/C^2$)

A) 3.0 mm
B) 2.0 mm
C) 4.0 mm
D) 1.0 mm
E) 0.50 mm

Answer: A

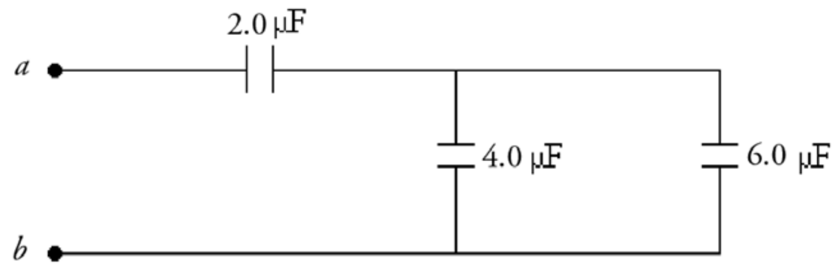
6) A cylindrical capacitor is made of two thin–walled concentric cylinders. The inner cylinder has radius r_1 = 4.0 mm, and the outer one a radius r_2= 8.0 mm. The common length of the cylinders is L = 150 m. What is the potential energy stored in this capacitor when a potential difference 4.0 V is applied between the inner and outer cylinder? ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)
   A) 9.6×10^{-8} J
   B) 1.3×10^{-8} J
   C) 6.3×10^{-8} J
   D) 0.34×10^{-8} J
   E) 4.6×10^{-8} J
   Answer: A

7) A 1.0 m long piece of coaxial cable has a wire with a radius of 1.1 mm and a concentric conductor with inner radius 1.3 mm. The area between the cable and the conductor is filled with a dielectric. If the voltage drop across the capacitor is 6000 V when the line charge density is 8.8 μC/m, find the value of the dielectric constant. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2)
   A) 4.4
   B) 4.8
   C) 5.3
   D) 5.7
   Answer: A

8) An air–filled capacitor is formed from two long conducting cylindrical shells that are coaxial and have radii of 48 mm and 84 mm. The electric potential of the inner conductor with respect to the outer conductor is –400 V. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2) The energy stored in a 1.0–m length of this capacitor is closest to
   A) 8.0 μJ.
   B) 5.7 μJ.
   C) 11 μJ.
   D) 16 μJ.
   E) 22 μJ.
   Answer: A

9) An air–filled capacitor is formed from two long conducting cylindrical shells that are coaxial and have radii of 13 mm and 85 mm. The electric potential of the inner conductor with respect to the outer conductor is –600 V. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N • m^2/C^2) The maximum energy density of the capacitor is closest to
   A) 2.7×10^{-3} J/m^3.
   B) 1.3×10^{-3} J/m^3.
   C) 6.7×10^{-4} J/m^3.
   D) 3.4×10^{-3} J/m^3.
   E) 1.7×10^{-4} J/m^3.
   Answer: A

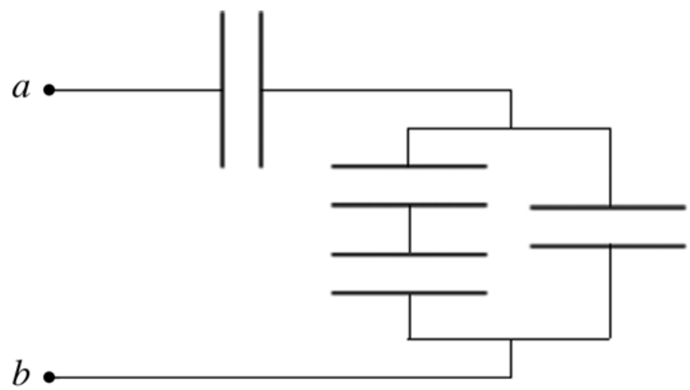
10) Three capacitors are connected as shown in the figure. What is the equivalent capacitance between points *a* and *b*?



A) 1.7 μF
B) 4.0 μF
C) 7.1 μF
D) 12 μF
E) 8.0 μF

Answer: A

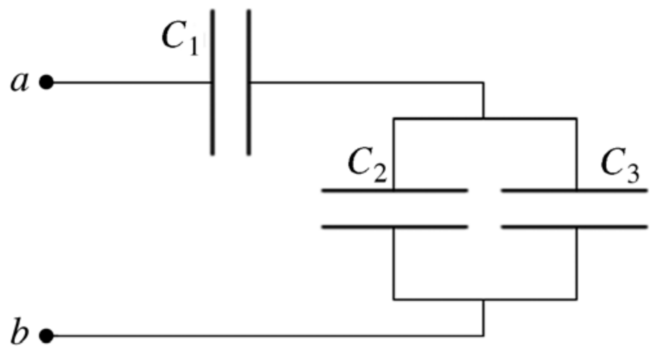
11) The capacitors in the network shown in the figure all have a capacitance of 5.0 μF. What is the equivalent capacitance, C_{ab}, of this capacitor network?



A) 20 μF
B) 3.0 μF
C) 10 μF
D) 5.0 μF
E) 1.0 μF

Answer: B

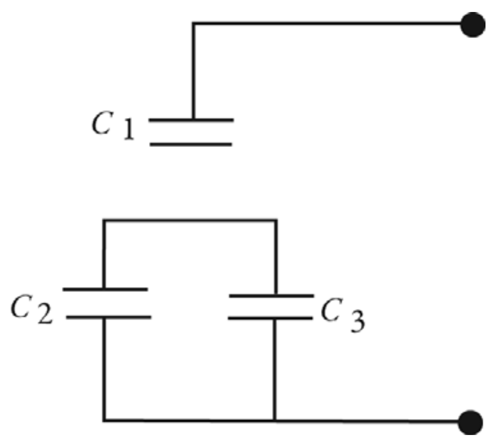
12) Three capacitors, with capacitances $C_1 = 4.0\ \mu\text{F}$, $C_2 = 3.0\ \mu\text{F}$, and $C_3 = 2.0\ \mu\text{F}$, are connected to a 12 –V voltage source, as shown in the figure. What is the charge on capacitor C_2?



A) 16 μC
B) 32 μC
C) 2.0 μC
D) 8.0 μC
E) 4.0 μC

Answer: A

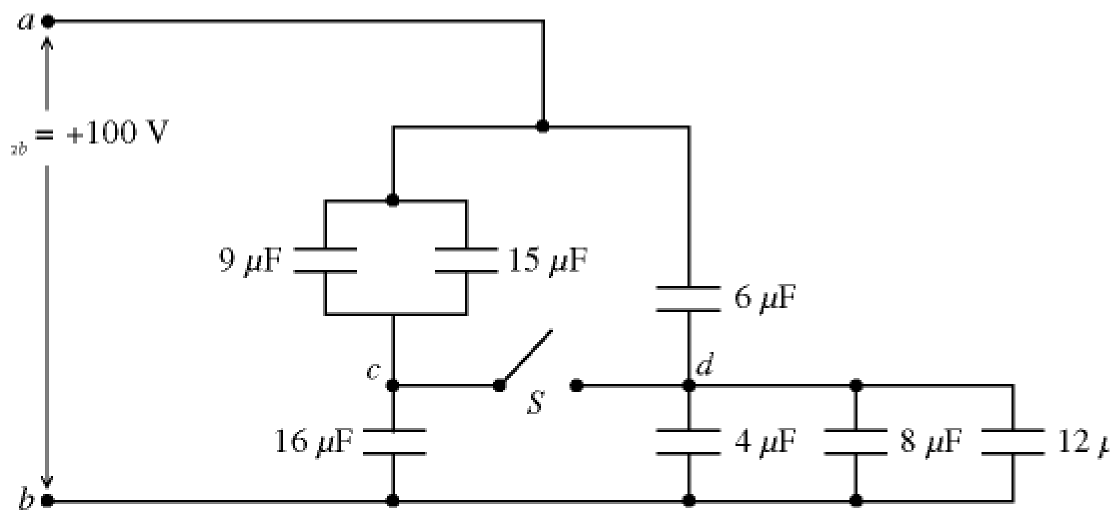
13) Three capacitors are arranged as shown in the figure. C_1 has a capacitance of 5.0 pF, C_2 has a capacitance of 10.0 pF, and C_3 has a capacitance of 15.0 pF. Find the voltage drop across the entire arrangement if the voltage drop across C_2 is 311 V.



A) 1900 V
B) 1200 V
C) 570 V
D) 520 V

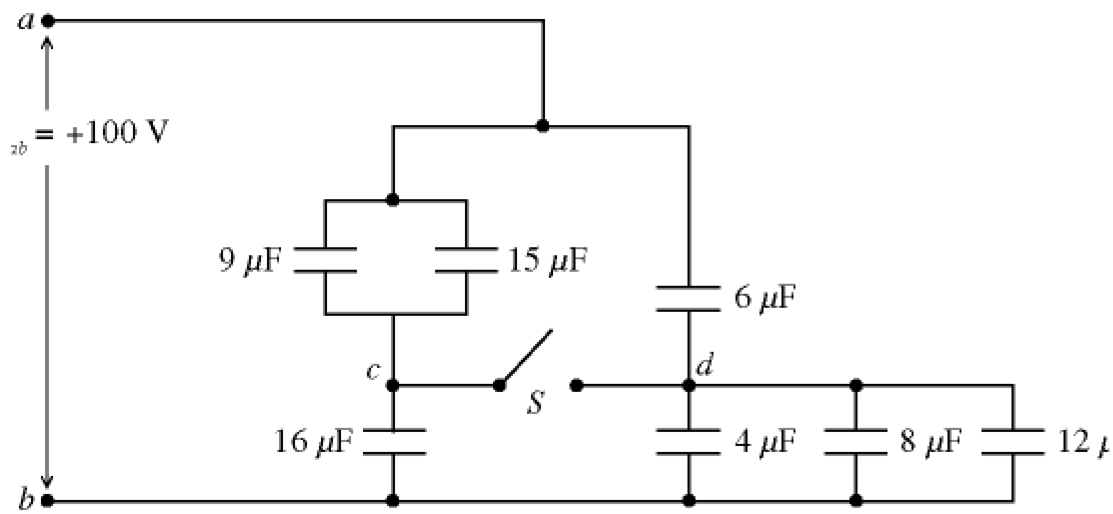
Answer: A

14) The capacitive network shown in the figure is assembled with initially uncharged capacitors. A potential difference, V_{ab} = +100V, is applied across the network. The switch S in the network is initially open but is then closed. Assume that all the capacitances shown are accurate to two significant figures. What is the equivalent capacitance between ab
(a) with the switch S open?
(b) with the switch S closed?



Answer: (a) 14 μF (b) 17 μF

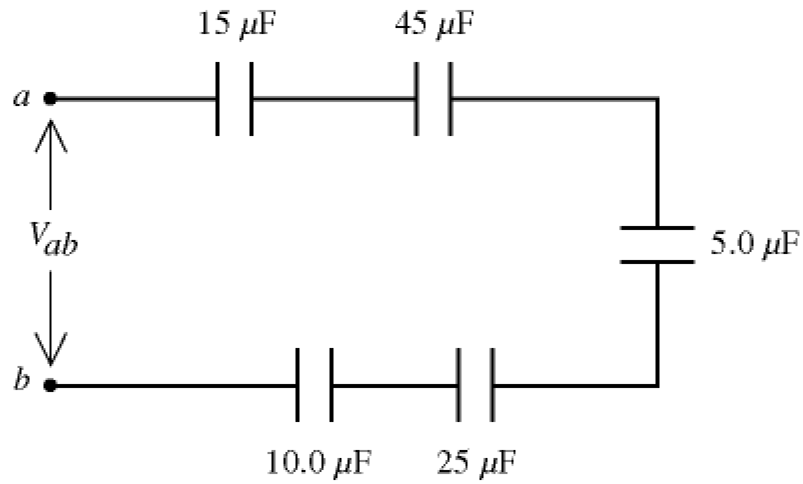
15) The capacitive network shown in the figure is assembled with initially uncharged capacitors. A potential difference, V_{ab} = +100V, is applied across the network. The switch S in the network is kept open. Assume that all the capacitances shown are accurate to two significant figures. What is potential difference V_{cd} across the open switch S?



A) 0 V
B) 40 V
C) 50 V
D) 60 V
E) 70 V

Answer: B

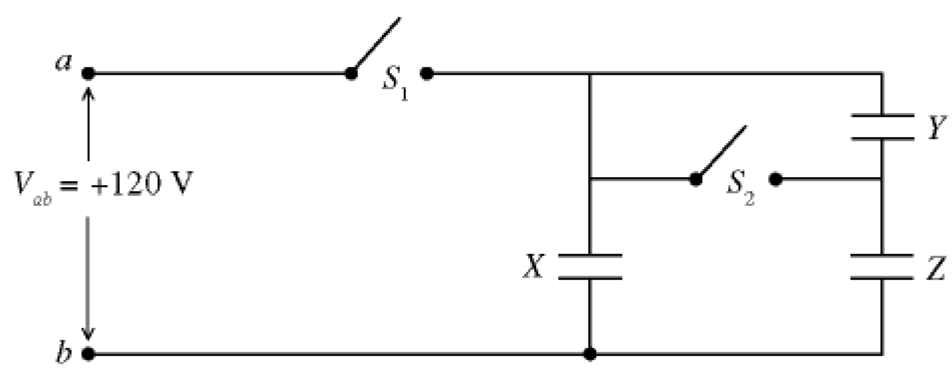
16) Five capacitors are connected across a potential difference V_{ab} as shown in the figure. Because of the dielectrics used, each capacitor will break down if the potential across it exceeds 30.0 V. The largest that V_{ab} can be without damaging any of the capacitors is closest to



A) 6.0 V.
B) 30 V.
C) 64 V.
D) 150 V.
E) 580 V.

Answer: C

17) The network shown in the figure is assembled with uncharged capacitors X, Y, and Z, with $C_X = 7.0\ \mu\text{F}$, $C_Y = 7.0\ \mu\text{F}$, and $C_Z = 6.0\ \mu\text{F}$, and open switches, S_1 and S_2. A potential difference $V_{ab} = +120$ V is applied between points a and b. After the network is assembled, switch S_1 is closed for a long time, but switch S_2 is kept open. Then switch S_1 is opened and switch S_2 is closed. What is the final voltage across capacitor X?



A) 94 V
B) 87 V
C) 79 V
D) 71 V
E) 63 V

Answer: A

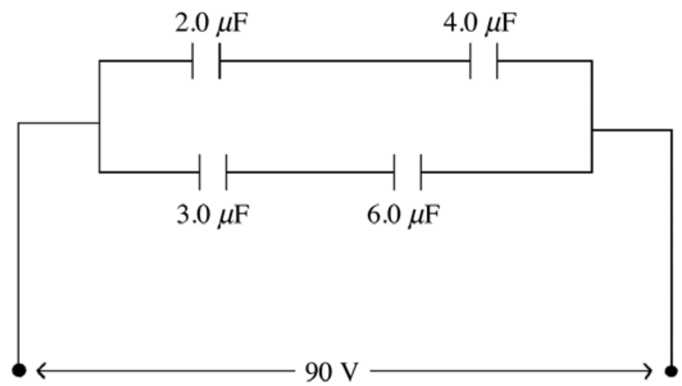
18) A 1.0–μF and a 2.0–μF capacitor are connected in series across a 3.0–V voltage source.
(a) What is the charge on the 1.0–μF capacitor?
(b) What is the voltage across the 2.0–μF capacitor?

Answer: (a) 2.0 μC (b) 1.0 V

19) Three capacitors, of capacitance 5.00 μF, 10.0 μF, and 50.0 μF, are connected in series across a 12.0–V voltage source.
(a) How much charge is stored in the 5.00–μF capacitor?
(b) What is the potential difference across the 10.0–μF capacitor?

Answer: (a) 37.5 μC (b) 3.75 V

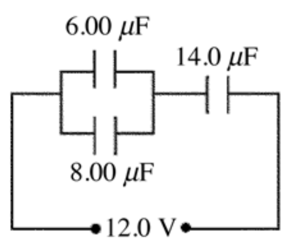
20) Four capacitors are connected across a 90–V voltage source as shown in the figure.



(a) What is the charge on the 4.0–μF capacitor?
(b) What is the charge on a 2.0–μF capacitor?
(c) What is the charge on the 3.0–μF capacitor?
(d) What is the potential difference across the 6.0–μF capacitor?

Answer: (a) 120 μC (b) 120 μC (c) 180 μC (d) 30 V

21) Two capacitors of capacitance 6.00 μF and 8.00 μF are connected in parallel. The combination is then connected in series with a 12.0–V voltage source and a 14.0–μF capacitor, as shown in the figure.



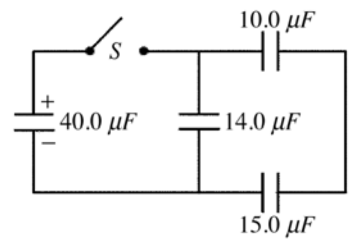
(a) What is the equivalent capacitance of this combination?
(b) What is the charge on the 6.00–μF capacitor?
(c) What is the potential difference across the 6.00–μF capacitor?

Answer: (a) 7.00 μF (b) 36.0 μC (c) 6.00 V

22) An isolated air-filled parallel-plate capacitor that is no longer connected to anything has been charged up to Q = 2.9 nC. The separation between the plates initially is 1.20 mm, and for this separation the capacitance is 31 pF. Calculate the work that must be done to pull the plates apart until their separation becomes 5.30 mm, if the charge on the plates remains constant. (ε_0 = $8.85 \times 10^{-12}\ C^2/N \cdot m^2$)

Answer: 0.46 μJ

23) In the circuit shown in the figure, all the capacitors are air-filled. With the switch S open, the 40.0-μF capacitor has an initial charge of 5.00 μC while the other three capacitors are uncharged. The switch is then closed and left closed for a long time. Calculate the initial and final values of the total electrical energy stored in these four capacitors.



Answer: U_i = 0.313 μJ, U_f = 0.208 μJ

24) A 6.00-μF parallel-plate capacitor has charges of ±40.0 μC on its plates. How much potential energy is stored in this capacitor?
A) 103 μJ
B) 113 μJ
C) 123 μJ
D) 133 μJ
E) 143 μJ

Answer: D

25) A charge of 2.00 μC flows onto the plates of a capacitor when it is connected to a 12.0-V potential source. What is the minimum amount of work that must be done in charging this capacitor?
A) 6.00 μJ
B) 24.0 μJ
C) 12.0 μJ
D) 144 μJ
E) 576 μJ

Answer: C

26) A 1.0 μF capacitor has a potential difference of 6.0 V applied across its plates. If the potential difference across its plates is increased to 8.0 V, how much ADDITIONAL energy does the capacitor store?
A) 14 μJ
B) 28 μJ
C) 2.0 μJ
D) 4.0 μJ

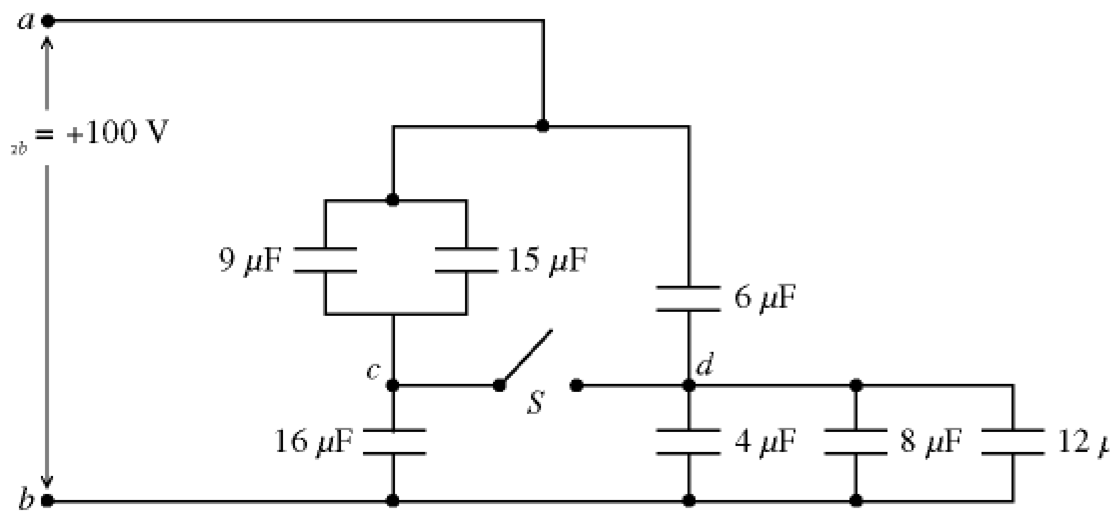
Answer: A

27) Two square air–filled parallel plates that are initially uncharged are separated by 1.2 mm, and each of them has an area of 190 mm^2. How much charge must be transferred from one plate to the other if 1.1 nJ of energy are to be stored in the plates? (ε_{00} = 8.85 × 10^{-12} C^2/N • m^2)

A) 56 pC
B) 39 pC
C) 78 pC
D) 3.5 μC

Answer: A

28) The capacitive network shown in the figure is assembled with initially uncharged capacitors. A potential difference, V_{ab} = +100V, is applied across the network. The switch S in the network is kept open. Assume that all the capacitances shown are accurate to two significant figures. What is the total energy stored in the seven capacitors?



A) 48 mJ
B) 72 mJ
C) 96 mJ
D) 120 mJ
E) 144 mJ

Answer: B

29) Each plate of an air–filled parallel–plate air capacitor has an area of 0.0040 m^2, and the separation of the plates is 0.080 mm. An electric field of 5.3 × 10^6 V/m is present between the plates. What is the energy density between the plates? (ε_0 = 8.85 × 10^{-12} C^2/N • m^2)

A) 124 J/m^3
B) 84 J/m^3
C) 170 J/m^3
D) 210 J/m^3
E) 250 J/m^3

Answer: A

30) A 15–μF air–filled capacitor is connected to a 50–V voltage source and becomes fully charged. The voltage source is then removed and a slab of dielectric that completely fills the space between the plates is inserted. The dielectric has a dielectric constant of 5.0.
(a) What is the capacitance of the capacitor after the slab has been inserted?
(b) What is the potential difference across the plates of the capacitor after the slab has been inserted?

Answer: (a) 75 μF (b) 10 V

31) A parallel–plate capacitor with plate separation of 1.0 cm has square plates, each with an area of 6.0×10^{-2} m^2. What is the capacitance of this capacitor if a dielectric material with a dielectric constant of 2.4 is placed between the plates, completely filling them? ($\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)
A) 15×10^{-12} F
B) 15×10^{-14} F
C) 64×10^{-14} F
D) 1.3×10^{-12} F
E) 1.3×10^{-10} F

Answer: E

32) A parallel–plate capacitor has a capacitance of 10 mF and is charged with a 20–V power supply. The power supply is then removed and a dielectric material of dielectric constant 4.0 is used to fill the space between the plates. What is the voltage now across the capacitor?
A) 80 V
B) 20 V
C) 10 V
D) 5.0 V
E) 2.5 V

Answer: D

33) A 6.0–μF air–filled capacitor is connected across a 100–V voltage source. After the source fully charges the capacitor, the capacitor is immersed in transformer oil (of dielectric constant 4.5). How much ADDITIONAL charge flows from the voltage source, which remained connected during the process?
A) 1.2 mC
B) 1.5 mC
C) 1.7 mC
D) 2.1 mC
E) 2.5 mC

Answer: D

34) A parallel–plate capacitor has a capacitance of 10 mF and charged with a 20 –V power supply. The power supply is then removed and a dielectric material of dielectric constant 4.0 is used to fill the space between the plates. How much energy is now stored by the capacitor?
A) 250 mJ
B) 125 mJ
C) 500 mJ
D) 62.5 mJ
E) 1200 mJ
Answer: C

35) A parallel–plate capacitor consists of two parallel, square plates that have dimensions 1.0 cm by 1.0 cm. If the plates are separated by 1.0 mm, and the space between them is filled with teflon, what is the capacitance of this capacitor? (The dielectric constant for teflon is 2.1, and $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$.)
A) 1.9 pF
B) 0.44 pF
C) 2.1 pF
D) 0.89 pF
Answer: A

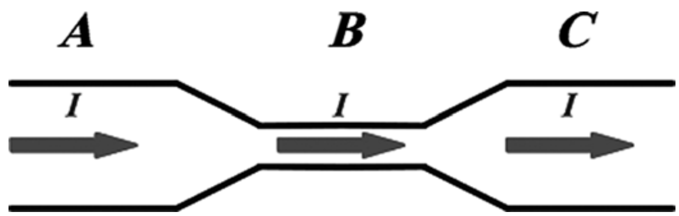
36) An air–filled capacitor stores a potential energy of 6.00 mJ due to its charge. It is accidentally filled with water in such a way as not to discharge its plates. How much energy does it continue to store after it is filled? (The dielectric constant for water is 78 and for air it is 1.0006.)
A) 0.077 mJ
B) 468 mJ
C) 0.040 mJ
D) 6.00 mJ
Answer: A

37) A parallel–plate capacitor, with air between the plates, is connected across a voltage source. This source establishes a potential difference between the plates by placing charge of magnitude 4.15×10^{-6} C on each plate. The space between the plates is then filled with a dielectric material, with a dielectric constant of 7.74. What must the magnitude of the charge on each capacitor plate now be, to produce the same potential difference between the plates as before?
Answer: 3.21×10^{-5} C

Chapter 24 Electrict Current

24.1 Conceptual Questions

1) The figure shows a steady electric current passing through a wire with a narrow region. What happens to the drift velocity of the moving charges as they go from region A to region B and then to region C?



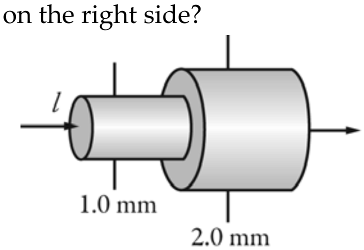
A) The drift velocity decreases from A to B and increases from B to C.
B) The drift velocity increases all the time.
C) The drift velocity remains constant.
D) The drift velocity decreases all the time.
E) The drift velocity increases from A to B and decreases from B to C.

Answer: E

2) When electric current is flowing in a metal, the electrons are moving
A) at nearly the speed of light.
B) at the speed of light.
C) at the speed of sound in the metal.
D) at the speed of sound in air.
E) at none of the above speeds.

Answer: E

3) The figure shows two connected wires that are made of the same material. The current entering the wire on the left is 2.0 A and in that wire the electron drift speed is v_d. What is the electron drift speed in the wire on the right side?



A) $4v_d$
B) $2v_d$
C) v_d
D) $v_d/2$
E) $v_d/4$

Answer: E

4) A narrow copper wire of length L and radius b is attached to a wide copper wire of length L and radius $2b$, forming one long wire of length $2L$. This long wire is attached to a battery, and a current is flowing through it. If the electric field in the narrow wire is E, the electric field in the wide wire is
   A) E.
   B) $2E$.
   C) $4E$.
   D) $E/2$.
   E) $E/4$.

   Answer: E

5) A cylindrical wire has a resistance R and resistivity ρ. If its length and diameter are BOTH cut in half,
   (a) what will be its resistance?
   A) $4R$
   B) $2R$
   C) R
   D) $R/2$
   E) $R/4$

   (b) what will be its resistivity?
   A) 4ρ
   B) 2ρ
   C) ρ
   D) $\rho/2$
   E) $\rho/4$

   Answer: (a) B (b) C

6) You are given a copper bar of dimensions 3 cm × 5 cm × 8 cm and asked to attach leads to it in order to make a resistor.
   (a) If you want to achieve the SMALLEST possible resistance, you should attach the leads to the opposite faces that measure
   A) 3 cm × 5 cm.
   B) 3 cm × 8 cm.
   C) 5 cm × 8 cm.
   D) Any pair of faces produces the same resistance.

   (b) If you want to achieve the LARGEST possible resistance, you should attach the leads to the opposite faces that measure
   A) 3 cm × 5 cm.
   B) 3 cm × 8 cm.
   C) 5 cm × 8 cm.
   D) Any pair of faces produces the same resistance.

   Answer: (a) C (b) A

7) A wire of resistivity ρ must be replaced in a circuit by a wire of the same material but 4 times as long. If, however, the resistance of the new wire is to be the same as the resistance of the original wire, the diameter of the new wire must be
   A) the same as the diameter of the original wire.
   B) 1/2 the diameter of the original wire.
   C) 1/4 the diameter of the original wire.
   D) 2 times the diameter of the original wire.
   E) 4 times the diameter of the original wire.

Answer: D

8) As current flows through a uniform wire, the wire gets hotter because the electrons stop moving and therefore transform their lost kinetic energy into thermal energy in the wire.
   A) True
   B) False

Answer: B

9) When a potential difference of 10 V is placed across a certain solid cylindrical resistor, the current through it is 2 A. If the diameter of this resistor is now tripled, the current will be
   A) 2/9 A.
   B) 2/3 A.
   C) 2 A.
   D) 3 A.
   E) 18 A.

Answer: E

10) Two cables of the same length are made of the same material, except that one cable has twice the diameter of the other cable. When the same potential difference is maintained across both cables, which of the following statements are true? (There may be more than one correct choice.)
   A) The same current flows through both cables.
   B) Both cables carry the same current density.
   C) The electrons have the same drift velocity in both cables.
   D) The current in the thin cable is twice as great as the current in the thick cable.
   E) The current in the thin cable is four times as great as the current in the thick cable.

Answer: B, C

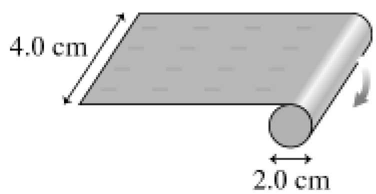
24.2 Problems

1) An electric device delivers a current of 5.0 A to a device. How many electrons flow through this device in 10 s? ($e = 1.60 \times 10^{-19}$ C)
   A) 0.20
   B) 20
   C) 2.0
   D) 3.1×10^{20}
   E) 31×10^{20}

Answer: D

2) In a certain electroplating process gold is deposited by using a current of 14.0 A for 19 minutes. A gold ion, Au^{+}, has a mass of approximately 3.3×10^{-22} g. How many grams of gold are deposited by this process?
A) 33 g
B) 16 g
C) 22 g
D) 28 g
E) 97 g
Answer: A

3) The figure shows a 2.0-cm diameter roller that turns at 90 rpm. A 4.0-cm wide plastic film is being wrapped onto the roller, and this plastic carries an excess electric charge having a uniform surface charge density of 5.0 nC/cm^2. What is the current of the moving film?



A) 190 nA
B) 23 μA
C) 30 nA
D) 11 μA
Answer: A

4) The current supplied by a battery as a function of time is $I(t) = (0.88\ \text{A})e^{-t/(6.0\ \text{hr})}$. What is the total number of electrons transported from the positive electrode to the negative electrode from the time the battery is first used until it is essentially dead? ($e = 1.60 \times 10^{-19}$ C)
A) 1.2×10^{23}
B) 4.4×10^{22}
C) 5.3×10^{23}
D) 3.3×10^{19}
Answer: A

5) A gold wire that is 1.8 mm in diameter and 15 cm long carries a current of 260 mA. How many electrons per second pass a given cross section of the wire? ($e = 1.60 \times 10^{-19}$ C)
A) 1.6×10^{18}
B) 1.6×10^{17}
C) 1.5×10^{23}
D) 3.7×10^{15}
E) 6.3×10^{15}
Answer: A

6) In an electroplating process, copper (ionic charge $+2e$, atomic weight 63.6 g/mol) is deposited using a current of 10.0 A. What mass of copper is deposited in 10.0 minutes? Avogadro's number is 6.022×10^{23} molecules/mol and $e = 1.60 \times 10^{-19}$ C.
   A) 3.96 g
   B) 2.52 g
   C) 0.99 g
   D) 2.52 g
   E) 1.98 g
   Answer: E

7) The current in a wire varies with time according to the equation $I(t) = 6.00$ A + (4.80 A/s)t, where t is in seconds. How many coulombs of charge pass a cross section of the wire in the time period between $t = 0.00$ s and $t = 3.00$ s?
   Answer: 39.6 C

8) If a current of 2.4 A is flowing in a cylindrical wire of diameter 2.0 mm, what is the average current density in this wire?
   A) 7.6×10^5 A/m^2
   B) 5.2×10^{-6} A/m^2
   C) 1.9×10^5 A/m^2
   D) 3.6×10^5 A/m^2
   E) 21×10^{-6} A/m^2
   Answer: A

9) A proton beam that carries a total current of 1.3 mA has 10.0 mm diameter. The current density in the proton beam increases linearly with distance from the center. This is expressed mathematically as $J(r) = J_0\,(r/R)$, where R is the radius of the beam and J_0 is the current density at the edge. Determine the value of J_0.
   A) 25 A/m^2
   B) 6.2 A/m^2
   C) 12 A/m^2
   D) 17 A/m^2
   Answer: A

10) A certain fuse "blows" if the current in it exceeds 1.0 A, at which instant the fuse melts with a current density of620 A/cm^2. What is the diameter of the wire in the fuse?
   A) 0.45 mm
   B) 0.63 mm
   C) 0.68 mm
   D) 0.91 mm
   Answer: A

11) If the current density in a wire or radius R is given by $J = kr$, $0 < r < R$, what is the current in the wire?
   A) $2\pi kR^3/3$
   B) $3\pi kR^3/2$
   C) $kR^3/3$
   D) kR^2
   E) $kR^2/2$
   Answer: A

12) A silver wire has a cross sectional area A = 2.0 mm^2. A total of 9.4×10^{18} electrons pass through the wire in 3.0 s. The conduction electron density in silver is 5.8×10^{28} electrons/m^3 and $e = 1.60 \times 10^{-19}$ C. What is the drift velocity of these electrons?
   A) 2.7×10^{-5} m/s
   B) 9.1×10^{-5} m/s
   C) 5.2×10^{-5} m/s
   D) 1.1×10^{-5} m/s
   E) 7.4×10^{-5} m/s
   Answer: A

13) The diameter of a 12-gauge copper wire is 0.081 in. The maximum safe current it can carry (in order to prevent fire danger in building construction) is 20 A. At this current, what is the drift velocity of the electrons? The number of electron carriers in 1.0 cm^3 of copper is 8.5×10^{22} and $e = 1.60 \times 10^{-19}$ C.
   A) 0.044 mm/s
   B) 0.44 mm/s
   C) 0.44 cm/s
   D) 0.44 m/s
   E) 4.4 cm/s
   Answer: B

14) A wire has a cross-sectional area of 0.10 mm^2. If there are 4.0×10^{28} atoms per cubic meter in this wire, and if each atom contributes 2 free electrons, what is the drift velocity of the electrons when the current in the wire is 6.0 A? ($e = 1.60 \times 10^{-19}$ C)
   A) 0.0047 m/s
   B) 0.0092 m/s
   C) 0.94 m/s
   D) 0.019 m/s
   Answer: A

15) Building codes usually limit the current carried by a No. 14 copper wire to 15 A. Many household circuits are wired with this size wire. What is the drift velocity of the electrons in this case? The diameter of this wire is 1.6 mm. Assume one conduction electron per atom in copper. The atomic weight of copper is 63.3 g/mol and its density is 8900 kg/m^3. Avogadro's number is 6.022×10^{23} molecules/mol and $e = 1.60 \times 10^{-19}$ C.

A) 5.51×10^{-4} m/s
B) 4.56×10^{-4} m/s
C) 1.65×10^{-3} m/s
D) 4.44×10^{-2} m/s
E) 4.89×10^{-5} m/s

Answer: A

16) The resistivity of gold is $2.44 \times 10^{-8}\ \Omega \cdot$ m at room temperature. A gold wire that is 0.9 mm in diameter and 14 cm long carries a current of 940 mA. What is the electric field in the wire?

A) 0.036 V/m
B) 0.0090 V/m
C) 0.028 V/m
D) 0.046 V/m
E) 0.090 V/m

Answer: A

17) A silver wire with resistivity $1.59 \times 10^{-8}\ \Omega \cdot$ m carries a current density of 4.0 A/mm^2. What is the magnitude of the electric field inside the wire?

A) 0.064 V/m
B) 2.5 V/m
C) 0.040 V/m
D) 0.10 V/m

Answer: A

18) A tube of mercury with resistivity $9.84 \times 10^{-7}\ \Omega \cdot$ m has an electric field inside the column of mercury of magnitude 23 N/C that is directed along the length of the tube. How much current is flowing through this tube if its diameter is 1.0 mm?

A) 18 A
B) 180 A
C) 29 A
D) 280 A

Answer: A

19) What length of a certain metal wire of diameter 0.15 mm is needed for the wire to have a resistance of 15 Ω? The resistivity of this metal is $1.68 \times 10^{-8}\ \Omega \cdot$ m.

A) 16 mm
B) 16 cm
C) 1.6 m
D) 16 m
E) 160 m

Answer: D

20) A 2.0 mm diameter wire of length 20 m has a resistance of 0.25 Ω. What is the resistivity of the wire?
A) 5.0×10^{-7} Ω • m
B) 3.9×10^{-8} Ω • m
C) 4.0×10^{-7} Ω • m
D) 16×10^{-8} Ω • m
E) 0.25 Ω • m
Answer: B

21) What must be the diameter of a cylindrical 120-m long metal wire if its resistance is to be 6.0 Ω? The resistivity of this metal is 1.68×10^{-8} Ω • m.
A) 0.065 mm
B) 0.65 mm
C) 0.65 cm
D) 0.325 mm
E) 0.0325 mm
Answer: B

22) Nichrome wire, often used for heating elements, has resistivity of 1.0×10^{-6} Ω • m at room temperature. What length of No. 30 wire (of diameter 0.250 mm) is needed to wind a resistor that has 50 ohms at room temperature?
A) 3.66 m
B) 2.45 m
C) 0.61 m
D) 6.54 m
E) 22.4 m
Answer: B

23) Calculate the current through a 10.0-m long 22 gauge (having radius 0.321 mm) nichrome wire if it is connected to a 12.0-V battery. The resistivity of nichrome is 100×10^{-8} Ω • m.
A) 17.5 A
B) 30.9 A
C) 61.8 A
D) 388 mA
E) 776 mA
Answer: D

24) How much current will be flowing through a 40.0 m length of cylindrical metal wire with radius 0.0 mm if it is connected to a source supplying 16.0 V? The resistivity of this metal is 1.68×10^{-8} Ω • m.
A) 1200 A
B) 9.5×10^{8} A
C) 68 nA
D) 710 A
Answer: A

25) When a voltage difference is applied to a piece of metal wire, a 5.0–mA current flows through it. If this metal wire is now replaced with a silver wire having twice the diameter of the original wire, how much current will flow through the silver wire? The lengths of both wires are the same, and the voltage difference remains unchanged. (The resistivity of the original metal is $1.68 \times 10^{-8}\ \Omega \cdot \mathrm{m}$, and the resistivity of silver is $1.59 \times 10^{-8}\ \Omega \cdot \mathrm{m}$.)
A) 21 mA
B) 19 mA
C) 11 mA
D) 5.3 mA
Answer: A

26) A cylindrical wire of radius 2.0 mm carries a current of 2.5 A. The potential difference between points on the wire that are 46 m apart is 3.7 V.
(a) What is the electric field in the wire?
(b) What is the resistivity of the material of which the wire is made?
Answer: a) 0.080 V/m
b) $4.0 \times 10^{-7}\ \Omega \cdot \mathrm{m}$

27) The power rating of a 400–Ω resistor is 0.800 W.
(a) What is the maximum voltage that can be applied across this resistor without damaging it?
(b) What is the maximum current this resistor can draw without damaging it?
Answer: (a) 17.9 V (b) 44.7 mA

28) A 110–V hair dryer is rated at 1200 W. What current will it draw when operating from a 110–V electrical outlet?
A) 90 mA
B) 1.0 A
C) 5.0 A
D) 11 A
E) 14 A
Answer: D

29) A light bulb is connected to a 110–V source. What is the resistance of this bulb if it is a 100–W bulb?
A) 100 Ω
B) 8.0 mΩ
C) 6.0 mΩ
D) 120 Ω
E) 240 Ω
Answer: D

30) A certain electric furnace consumes 24 kW when it is connected to a 240–V line. What is the resistance of the furnace?
A) 1.0 kΩ
B) 10 Ω
C) 2.4 Ω
D) 0.42 Ω
E) 100 Ω
Answer: C

31) A 1500–W heater is connected to a 120–V line. How much heat energy does it produce in 2.0 hours?
A) 1.5 kJ
B) 3.0 kJ
C) 0.18 MJ
D) 11 MJ
E) 18 MJ
Answer: D

32) The resistivity of gold is $2.44 \times 10^{-8}\ \Omega \cdot \mathrm{m}$ at room temperature. A gold wire that is 1.8 mm in diameter and 11 cm long carries a current of 170 mA. How much power is dissipated in the wire?
A) 0.030 mW
B) 0.0076 mW
C) 0.013 mW
D) 0.019 mW
E) 0.025 mW
Answer: A

33) A 400–W computer (including the monitor) is turned on for 8.0 hours per day. If electricity costs 10¢ per kWh, how much does it cost to run the computer annually for a typical 365–day year?
A) $120
B) $1200
C) $15
D) $17
E) $150
Answer: A

34) The voltage and power ratings of a particular light bulb, which are its normal operating values, are 110 V and 60 W. Assume the resistance of the filament of the bulb is constant and is independent of operating conditions. If the light bulb is operated with a current that is 50% of the current rating of the bulb, what is the actual power drawn by the bulb?
A) 10 W
B) 15 W
C) 20 W
D) 25 W
E) 30 W
Answer: B

35) The voltage and power ratings of a particular light bulb, which are its normal operating values, are 110 V and 60 W. Assume the resistance of the filament of the bulb is constant and is independent of operating conditions. If the light bulb is operated at a reduced voltage and the power drawn by the bulb is 36 W, what is the operating voltage of the bulb?
A) 66 V
B) 72 V
C) 78 V
D) 85 V
E) 90 V
Answer: D

36) The heater element of a particular 120-V toaster is a 8.9-m length of nichrome wire, whose diameter is 0.86 mm. The resistivity of nichrome at the operating temperature of the toaster is $1.3 \times 10^{-6}\ \Omega \cdot \text{m}$. If the toaster is operated at a voltage of 120 V, how much power does it draw?

A) 720 W
B) 700 W
C) 750 W
D) 770 W
E) 800 W

Answer: A

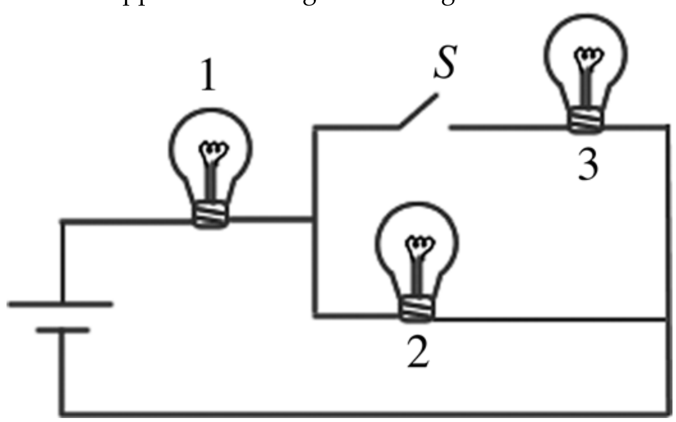
Chapter 25 Electric Circuits

25.1 Conceptual Questions

1) As more resistors are added in parallel across a constant voltage source, the power supplied by the source
   A) increases.
   B) decreases.
   C) does not change.

   Answer: A

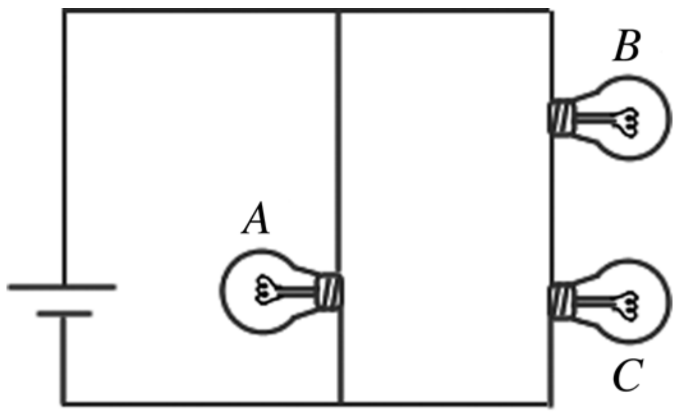
2) The figure shows three identical lightbulbs connected to a battery having a constant voltage across its terminals. What happens to the brightness of lightbulb 1 when the switch S is closed?



   A) The brightness will increase momentarily then return to its previous level.
   B) The brightness increases permanently.
   C) The brightness will decrease momentarily then return to its previous level.
   D) The brightness remains the same as before the switch is closed.
   E) The brightness decreases permanently.

   Answer: B

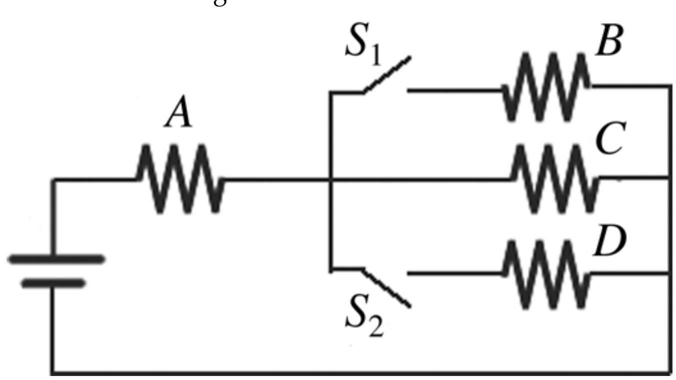
3) In the circuit shown in the figure, all the lightbulbs are identical. Which of the following is the correct ranking of the brightness of the bulbs?



A) *B* and *C* have equal brightness, and *A* is the dimmest.
B) *A* and *B* have equal brightness, and *C* is the dimmest.
C) *A* is brightest, *C* is dimmest, and *B* is in between.
D) *A* is the brightest, and *B* and *C* have equal brightness but less than *A*.
E) All three bulbs have the same brightness.

Answer: D

4) In the circuit shown in the figure, four identical resistors labeled *A* to *D* are connected to a battery as shown. S_1 and S_2 are switches. Which of the following actions would result in the GREATEST amount of current through resistor *A*?



A) closing both switches
B) closing S_1 only
C) closing S_2 only
D) leaving both switches open as shown.

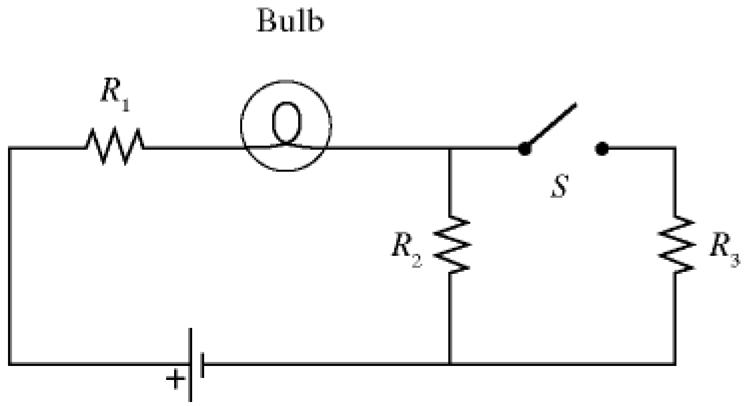
Answer: A

5) A resistor is made out of a long wire having a length L. Each end of the wire is attached to a terminal of a battery providing a constant voltage V_0. A current I flows through the wire. If the wire were cut in half, making two wires of length $L/2$, and both wires were attached to the battery (the end of both wires attached to one terminal, and the other ends attached to the other terminal), what would be the total current flowing through the two wires?

A) $4I$
B) $2I$
C) I
D) $I/2$
E) $I/4$

Answer: A

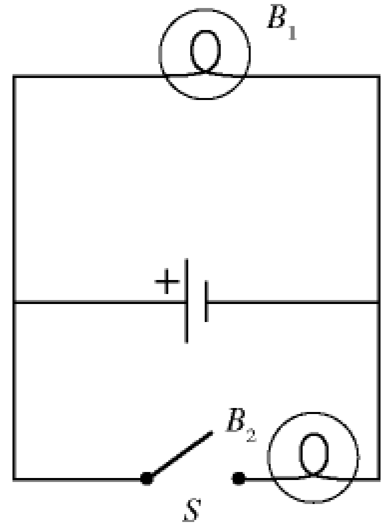
6) A light bulb is connected in the circuit shown in the figure with the switch S open. All the connecting leads have no appreciable resistance and the battery has no internal resistance. When we close the switch, which statements below accurately describe the behavior of the circuit? (There may be more than one correct choice.)



A) The brightness of the bulb will increase.
B) The brightness of the bulb will decrease.
C) The brightness of the bulb will not change.
D) The potential drop across R_2 will decrease.
E) The potential drop across R_2 will not change.

Answer: A, D

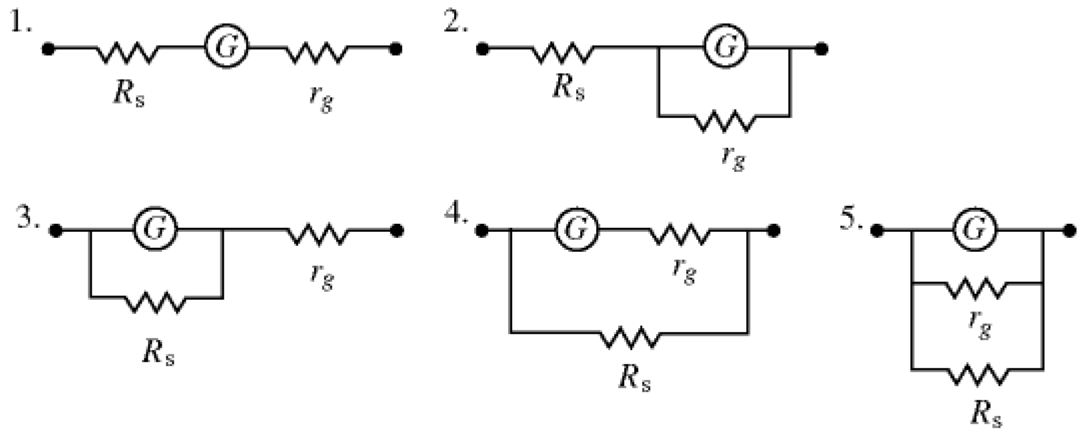
7) Two light bulbs, B_1 and B_2, are connected to a battery having appreciable internal resistance as shown in the figure. What happens to the brightness of bulb B_1 when we close the switch S?



A) The brightness of B_1 increases permanently.
B) The brightness of B_1 decreases permanently.
C) The brightness of B_1 does not change.
D) The brightness of B_1 increases temporarily but gradually decreases back to its original brightness.
E) The brightness of B_1 decreases temporarily but gradually increases back to its original brightness.

Answer: B

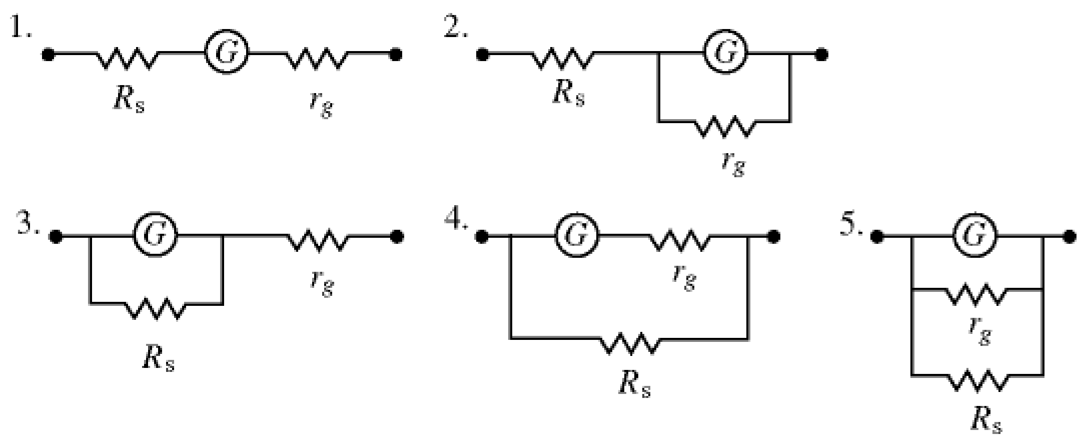
8) A galvanometer G has an internal resistance r_g. An AMMETER is constructed by incorporating the galvanometer and an additional resistance R_s. Which one of the figures below is the most appropriate circuit diagram for the ammeter?



A) 1
B) 2
C) 3
D) 4
E) 5

Answer: D

9) A galvanometer G has an internal resistance r_g. A VOLTMETER is constructed by incorporating the galvanometer and an additional resistance R_s. Which one of the figures below is the most appropriate circuit diagram for the voltmeter?



A) 1
B) 2
C) 3
D) 4
E) 5

Answer: A

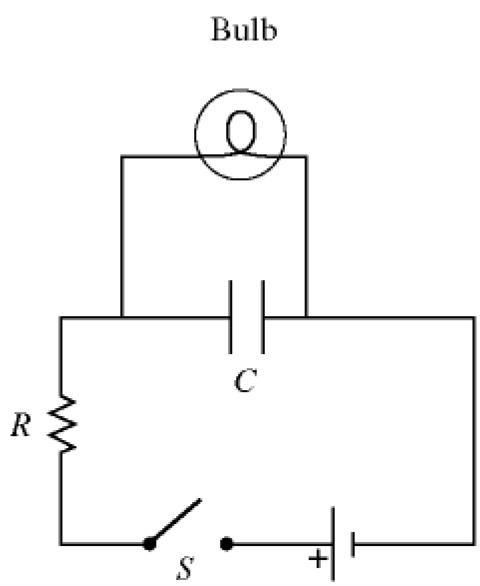
10) A resistor and a capacitor are connected in series across an ideal battery having a constant voltage across its terminals. At the moment contact is made with the battery
(a) the voltage across the capacitor is
A) equal to the battery's terminal voltage.
B) less than the battery's terminal voltage, but greater than zero.
C) equal to the battery's terminal voltage.
D) zero.
(b) the voltage across the resistor is
A) equal to the battery's terminal voltage.
B) less than the battery's terminal voltage, but greater than zero.
C) equal to the battery's terminal voltage.
D) zero.

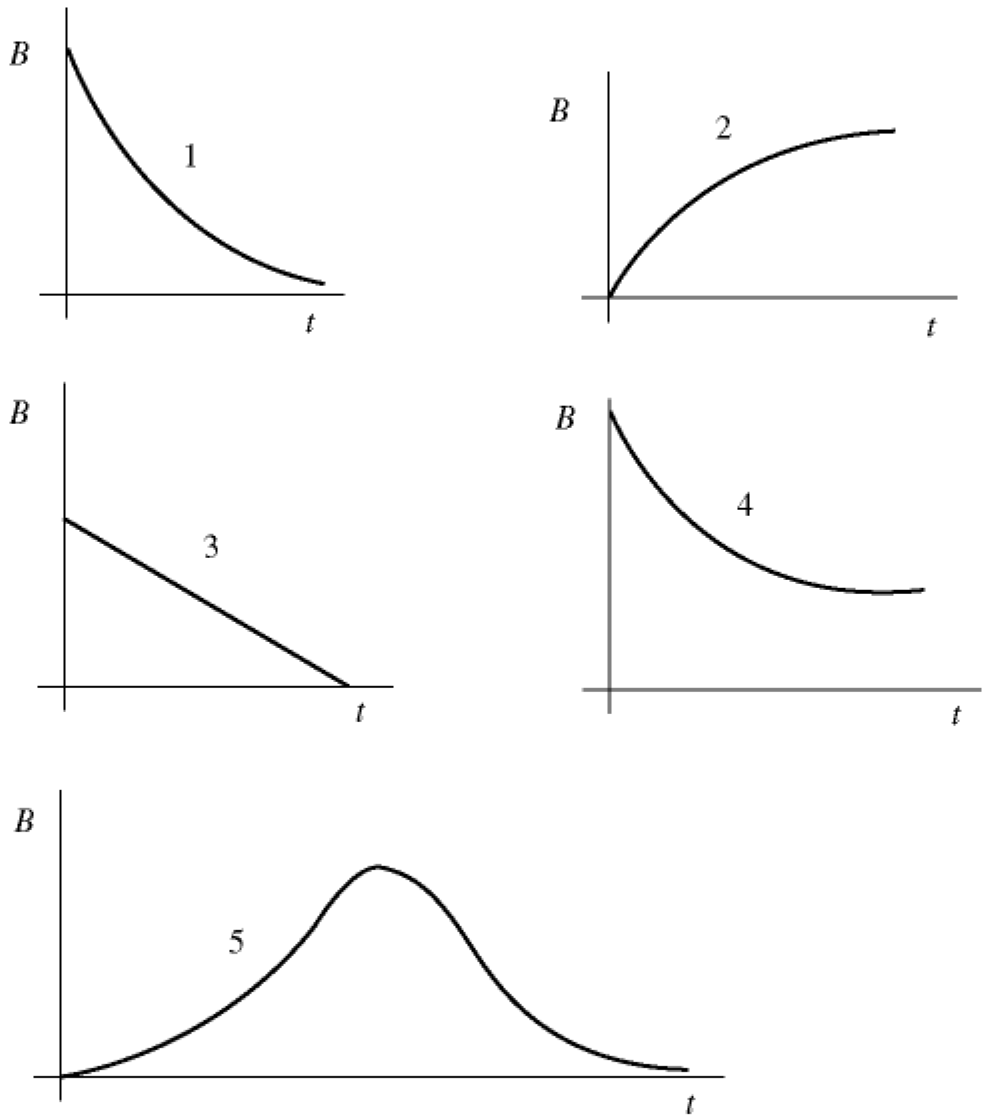
Answer: (a) D (b) C

11) An *RC* circuit is connected across an ideal DC voltage source through an open switch. The switch is closed at time $t = 0$ s. Which of the following statements regarding the circuit are correct? (There may be more than one correct choice.)
A) The capacitor charges to its maximum value in one time constant and the current is zero at that time.
B) The potential difference across the resistor and the potential difference across the capacitor are always equal.
C) The potential difference across the resistor is always greater than the potential difference across the capacitor.
D) The potential difference across the capacitor is always greater than the potential difference across the resistor
E) Once the capacitor is essentially fully charged, there is no appreciable current in the circuit.

Answer: E

12) A light bulb is connected in the circuit shown in the figure with the switch *S* open and the capacitor uncharged. The battery has no appreciable internal resistance. Which one of the following graphs best describes the brightness *B* of the bulb as a function of time *t* after closing the switch?



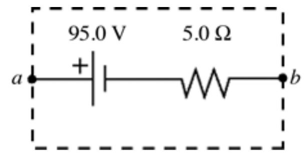


A) 1
B) 2
C) 3
D) 4
E) 5

Answer: B

25.2 Problems

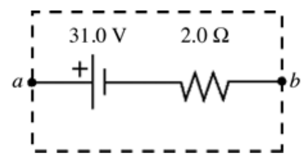
1) The emf and the internal resistance of a battery are as shown in the figure. If a current of 8.3 A is drawn from the battery when a resistor *R* is connected across the terminals *ab* of the battery, what is the power dissipated by the resistor *R*?



A) 440 W
B) 700 W
C) 620 W
D) 530 W
E) 790 W

Answer: A

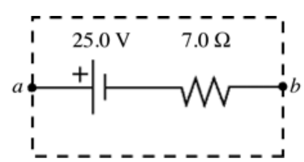
2) The emf and the internal resistance of a battery are as shown in the figure. When the terminal voltage V_{ab} is equal to 17.4 V, what is the current through the battery, including its direction?



A) 6.8 A, from *b* to *a*
B) 8.7 A, from *b* to *a*
C) 6.8 A, from *a* to *b*
D) 8.7 A, from *a* to *b*
E) 16 A, from *b* to *a*

Answer: A

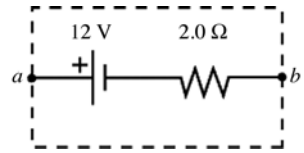
3) The emf and the internal resistance of a battery are shown in the figure. If a current of 7.8 A is established through the battery from *b* to *a*, what is the terminal voltage V_{ab} of the battery?



A) -30 V
B) 80 V
C) 30 V
D) -80 V
E) zero

Answer: A

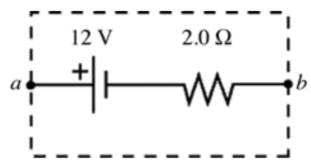
4) In the figure a current of 6.0 A is drawn from the battery. What is the terminal voltage V_{ab} of the battery?



A) 0.00 V
B) +12 V
C) +24 V
D) -12 V
E) -24 V

Answer: A

5) In the figure, when the terminal voltage V_{ab} of the battery is equal to 20 V, how much current passes through the battery, including its direction?



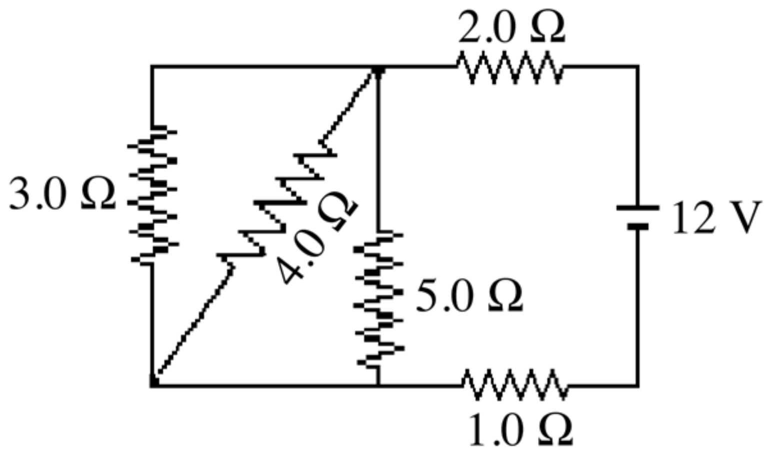
A) 4 A, from *a* to *b*
B) 5 A, from *a* to *b*
C) 6 A, from *a* to *b*
D) 4 A, from *b* to *a*
E) 5 A, from *b* to *a*

Answer: A

6) A 5.0-Ω resistor and a 9.0-Ω resistor are connected in parallel. A 4.0-Ω resistor is then connected in series with this parallel combination. An ideal 6.0-V battery is then connected across the series-parallel combination of the three resistors. What is the current through
(a) the 4.0-Ω resistor?
(b) the 5.0-Ω resistor?
(c) the 9.0-Ω resistor?

Answer: (a) 0.83 A (b) 0.53 A (c) 0.30 A

7) For the circuit shown in the figure, determine the current in
   (a) the 1.0–Ω resistor.
   (b) the 3.0–Ω resistor.
   (c) the 4.0–Ω resistor.

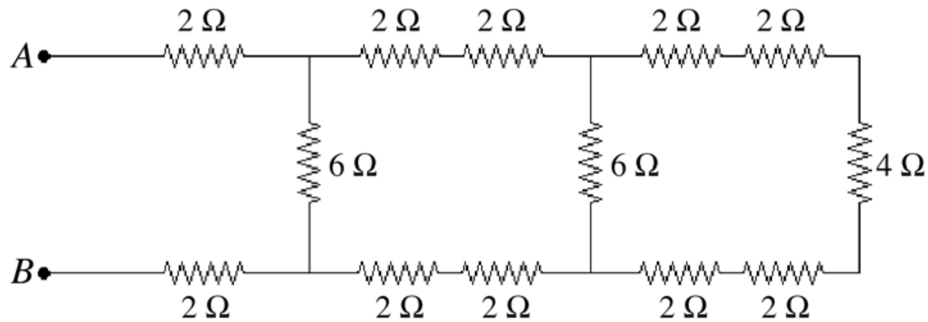


Answer: (a) 2.8 A (b) 1.2 A (c) 0.90 A

8) A 4.00–Ω resistor, an 8.00–Ω resistor, and a 24.0–Ω resistor are connected together.
   (a) What is the maximum resistance that can be produced using all three resistors?
   (b) What is the minimum resistance that can be produced using all three resistors?
   (c) How would you connect these three resistors to obtain a resistance of 10.0 Ω?
   (d) How would you connect these three resistors to obtain a resistance of 8.00 Ω?

Answer: (a) 36.0 Ω (b) 2.40 Ω
(c) Connect the 8.00–Ω and 24.0–Ω resistors in parallel and then connect this combination in series with the 4.00–Ω resistor.
(d) Connect the 4.00–Ω and 8.00–Ω resistors in series and then connect this combination in parallel with the 24.0–Ω resistor.

9) Thirteen resistors are connected across points *A* and *B* as shown in the figure. If all the resistors are accurate to 2 significant figures, what is the equivalent resistance between points *A* and *B*?



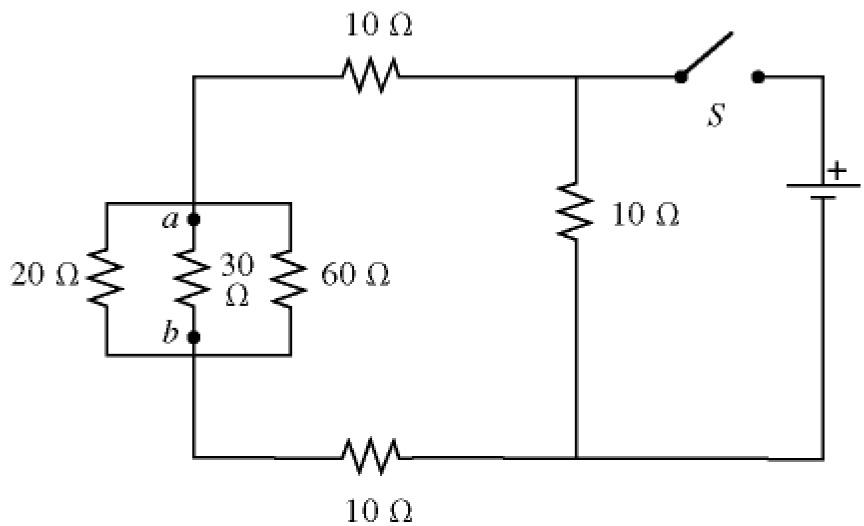
A) 4.0 Ω
B) 6.0 Ω
C) 8.0 Ω
D) 10 Ω
E) 12 Ω

Answer: C

10) Two unknown resistors are connected together. When they are connected in series their equivalent resistance is 15 Ω. When they are connected in parallel, their equivalent resistance is 3.3 Ω. What are the resistances of these resistors?

Answer: 4.9 Ω and 10 Ω

11) In the circuit shown in the figure, an ideal ohmmeter is connected across *ab* with the switch *S* open. All the connecting leads have negligible resistance. The reading of the ohmmeter will be closest to



A) 7.5 Ω.
B) 10 Ω.
C) 30 Ω.
D) 40 Ω.
E) 60 Ω.

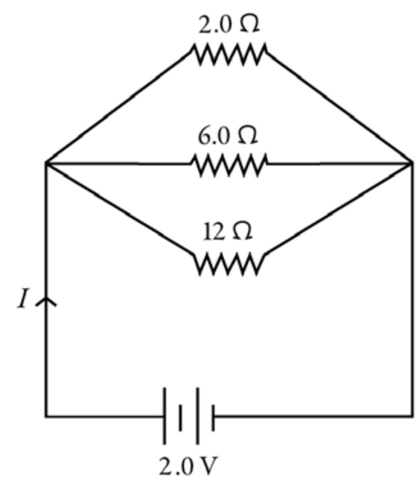
Answer: A

12) Three resistors having resistances of 4.0 Ω, 6.0 Ω, and 10.0 Ω are connected in parallel. If the combination is connected in series with an ideal 12-V battery and a 2.0-Ω resistor, what is the current through the 10.0-Ω resistor?

A) 0.59 A
B) 2.7 A
C) 6.4 A
D) 11.2 A
E) 16 A

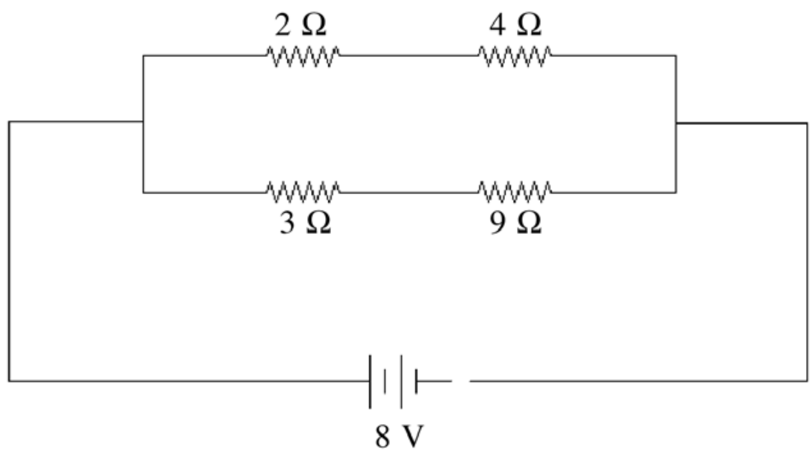
Answer: A

13) Three resistors are connected across an ideal 2.0–V DC battery as shown in the figure.
(a) At what rate does the battery supply energy to the resistors?
(b) At what rate is heat produced in the 6.0–Ω resistor?



Answer: (a) 3.0 W (b) 0.67 W

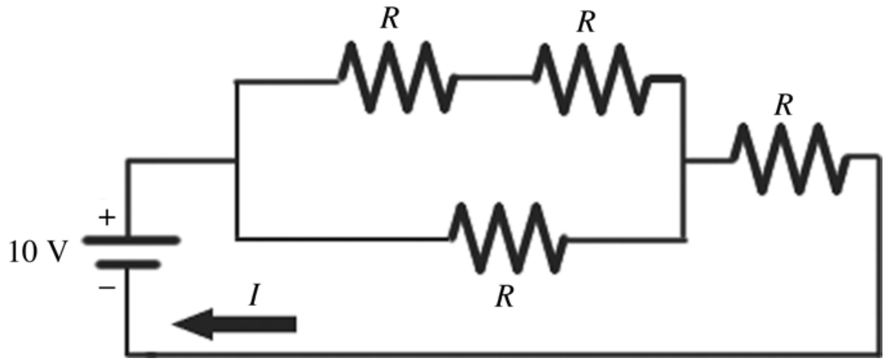
14) Four resistors are connected across an 8–V DC battery as shown in the figure. The current through the 9–Ω resistor is closest to



A) 1 A.
B) 0.7 A.
C) 0.5 A.
D) 0.9 A.
E) 2 A.

Answer: B

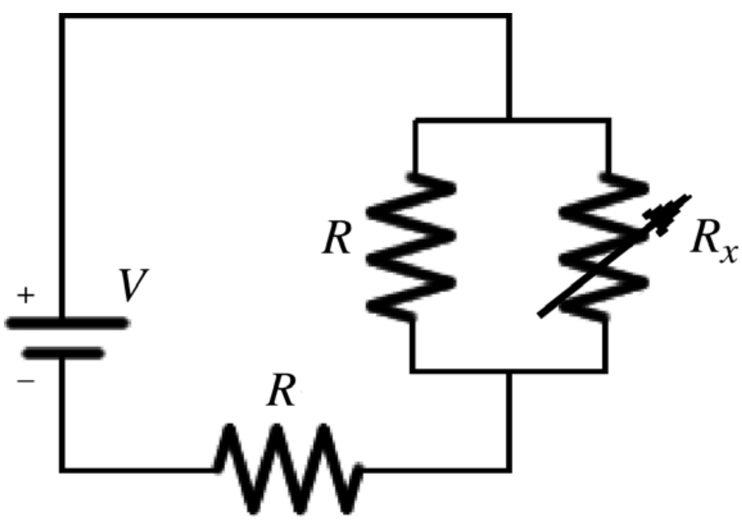
15) When four identical resistors are connected to an ideal battery of voltage $V = 10$ V as shown in the figure, the current I is equal to 0.20 A. What is the value of the resistance R of the resistors?



A) 20 Ω
B) 40 Ω
C) 30 Ω
D) 50 Ω
E) 10 Ω

Answer: C

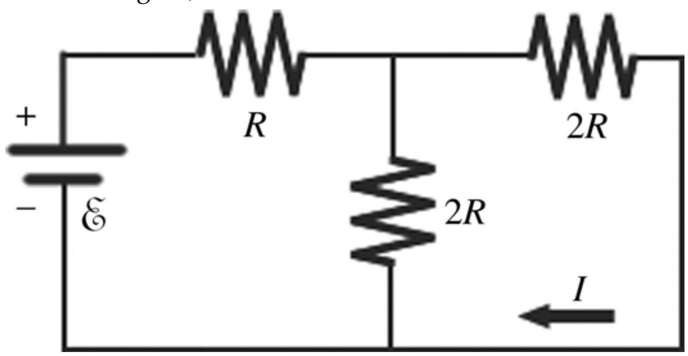
16) Two identical resistors of resistance $R = 24\ \Omega$ and a variable resistor R_x are connected to an ideal battery of voltage V as shown in the figure. What should be the value of the variable resistance R_x to make the voltage across the two parallel resistors equal to $\frac{V}{5}$.



A) 4.0 Ω
B) 24 Ω
C) 8.0 Ω
D) 16 Ω
E) 40 Ω

Answer: C

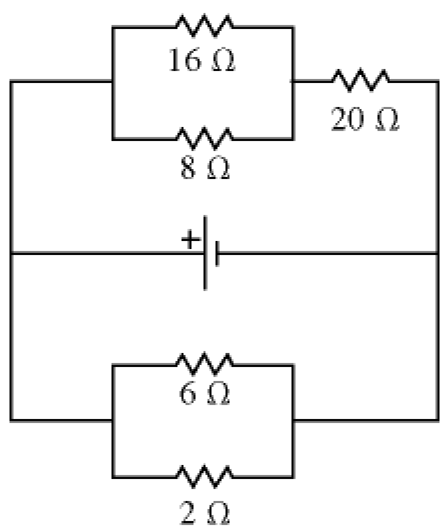
17) For the circuit shown in the figure, $I = 0.50$ A and $R = 12\ \Omega$. What is the value of the emf $\mathcal{E}$?



A) 18 V
B) 24 V
C) 6.0 V
D) 12 V
E) 48 V

Answer: B

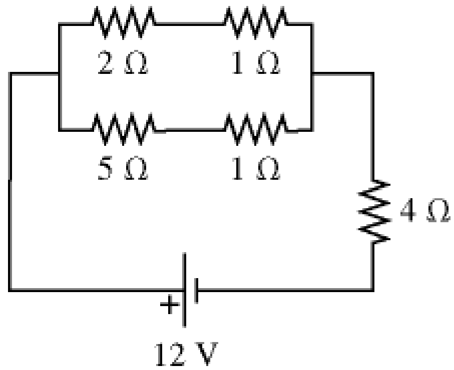
18) For the circuit shown in the figure, the current in the 8-Ω resistor is 0.50 A, and all quantities are accurate to 2 significant figures. What is the current in the 2-Ω resistor?



A) 2.25 A
B) 0.75 A
C) 4.5 A
D) 9.5 A
E) 6.4 A

Answer: D

19) For the circuit shown in the figure, all quantities are accurate to 3 significant figures. What is the power dissipated in the 2-Ω resistor?



A) 5.33 W
B) 8.0 W
C) 6.67 W
D) 2.67 W
E) 3.56 W

Answer: E

20) When a 20.0-ohm resistor is connected across the terminals of a 12.0-V battery, the voltage across the terminals of the battery falls by 0.300 V. What is the internal resistance of this battery?

A) 3.60 Ω
B) 1.56 Ω
C) 0.98 Ω
D) 0.30 Ω
E) 0.51 Ω

Answer: E

21) What is the maximum current that can be drawn from a 1.50-V battery with an internal resistance of 0.30 ohm?

A) 2.5 A
B) 5.0 A
C) 0.45 A
D) 0.20 A
E) 4.5 A

Answer: B

22) When a 100–Ω resistor is connected across the terminals of a battery of emf $\mathcal{E}$ and internal resistance r, the battery delivers 0.794 W of power to the 100–Ω resistor. When the 100–Ω resistor is replaced by a 200–Ω resistor, the battery delivers 0.401 W of power to the 200–Ω resistor. What are the emf and internal resistance of the battery?

A) $\mathcal{E}$ = 10.0 V, r = 5.02 Ω

B) $\mathcal{E}$ = 4.50 V, r = 4.00 Ω

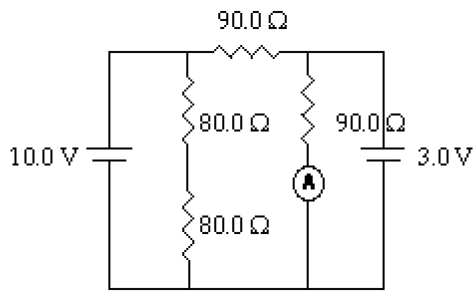
C) $\mathcal{E}$ = 9.00 V, r = 2.04 Ω

D) $\mathcal{E}$ = 9.00 V, r = 1.01 Ω

E) $\mathcal{E}$ = 12.0 V, r = 6.00 Ω

Answer: D

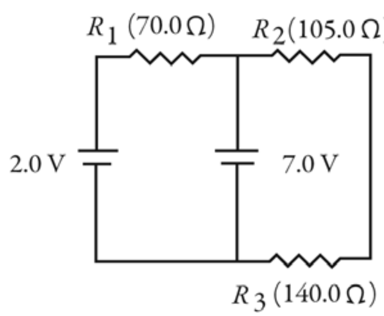
23) For the circuit shown in the figure, what current does the ideal ammeter read?



A) 0.033 A
B) 0.078 A
C) 0.23 A
D) 0.12 A

Answer: A

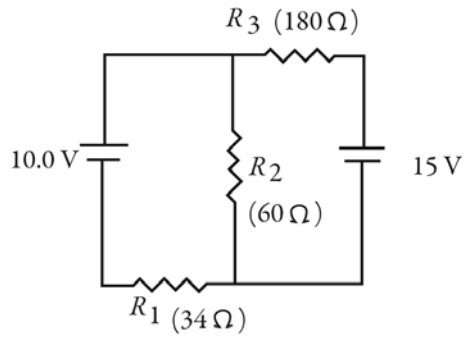
24) For the circuit shown in the figure, what is the current through resistor R_1?



A) 0.071 A
B) 0.13 A
C) 0.029 A
D) 0.016 A

Answer: A

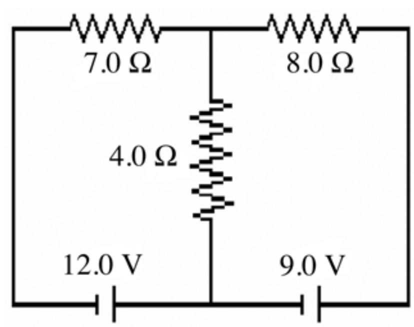
25) For the circuit shown in the figure, what is the current through resistor R_3?



A) 0.043 A
B) 1.5 A
C) 0.028 A
D) 0.086 A

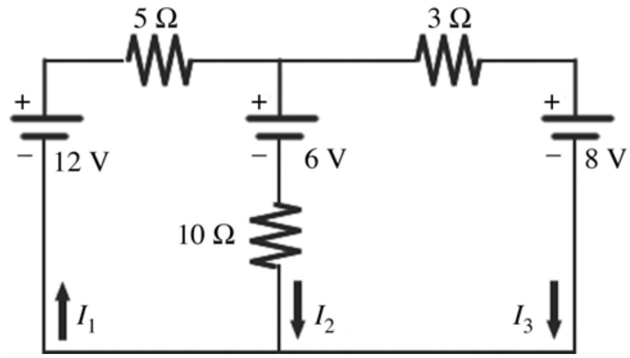
Answer: A

26) For the circuit shown in the figure, determine the current in
(a) the 7.0–Ω resistor.
(b) the 8.0–Ω resistor.
(c) the 4.0–Ω resistor.



Answer: (a) 1.6 A (b) 1.3 A (c) 0.28 A

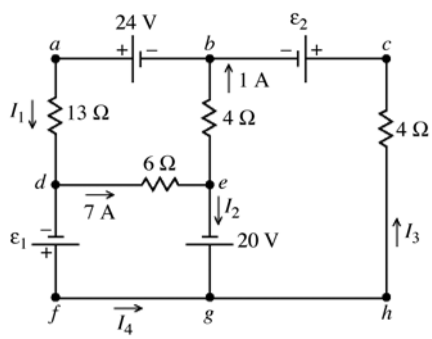
27) For the circuit shown in the figure, all quantities are accurate to 2 significant figures. What is the value of the current I_1?



A) 0.32 A
B) 0.11 A
C) 0.29 A
D) 0.61 A
E) 0.89 A

Answer: D

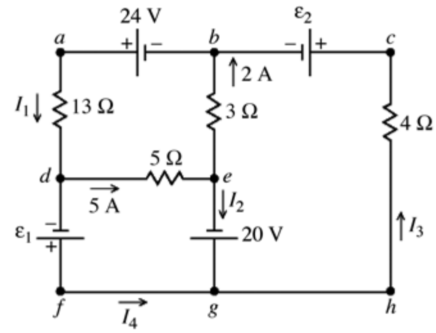
28) A multiloop circuit is shown in the figure. It is not necessary to solve the entire circuit. The current I_2 is closest to



A) −6 A.
B) 6 A.
C) 8 A.
D) −8 A.
E) zero.

Answer: A

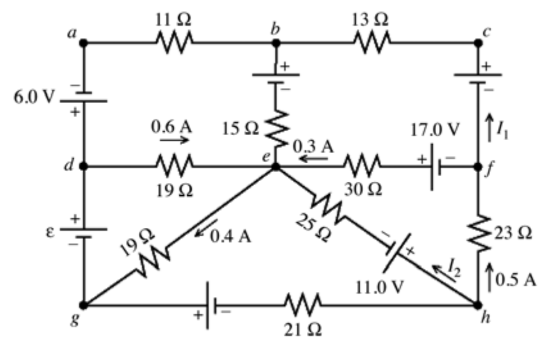
29) A multiloop circuit is shown in the figure. It is not necessary to solve the entire circuit. Compared to the polarity shown in the figure, the emf ε_1 is closest to



A) −5 V.
B) 5 V.
C) 45 V.
D) 51 V.
E) −51 V.

Answer: A

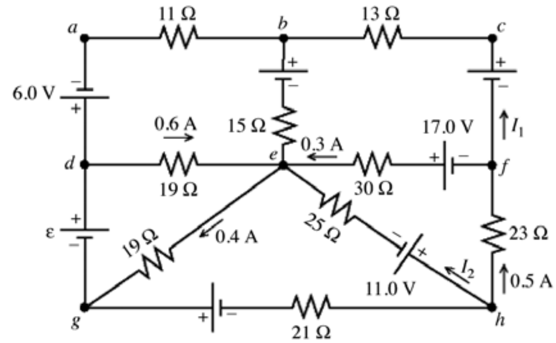
30) A multiloop circuit is shown in the figure. Some circuit quantities are not labeled. It is not necessary to solve the entire circuit. The current I_1 is closest to



A) zero.
B) +0.2 A.
C) +0.4 A.
D) −0.2 A.
E) −0.4 A.

Answer: B

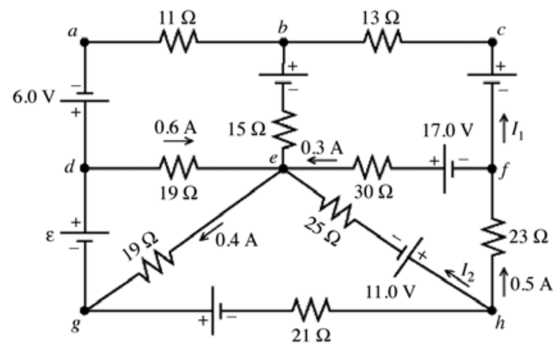
31) A multiloop circuit is shown in the figure. Some circuit quantities are not labeled. It is not necessary to solve the entire circuit. The emf ε is closest to



A) +3 V.
B) +19 V.
C) −3 V.
D) −10 V.
E) −1 V.

Answer: B

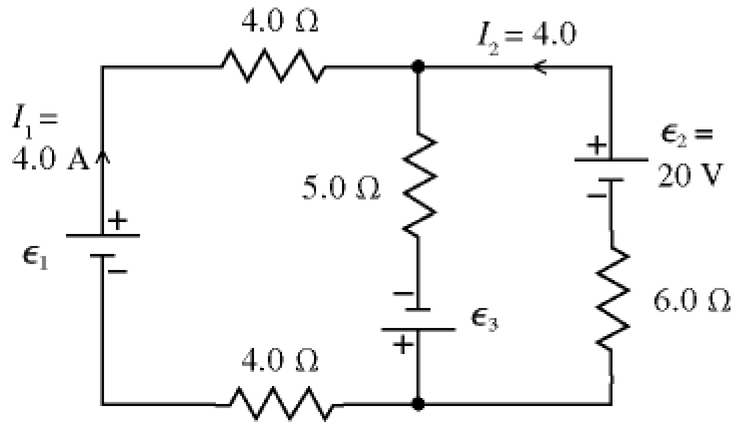
32) A multiloop circuit is shown in the figure. Some circuit quantities are not labeled. It is not necessary to solve the entire circuit. The current I_2 is closest to



A) +0.1 A.
B) +0.3 A.
C) +0.5 A.
D) −0.1 A.
E) −0.3 A.

Answer: E

33) Consider the circuit shown in the figure. Note that two currents are shown. Calculate the emfs ε_1 and ε_3.



Answer: ε_1 = 28 V, ε_3 = 44 V

34) A galvanometer coil having a resistance of 20 Ω and a full-scale deflection at 1.0 mA is connected in series with a 4980 Ω resistance to build a voltmeter. What is the maximum voltage that this voltmeter can read?
A) 3.0 V
B) 1.0 V
C) 50 V
D) 5.0 V
E) 10 V

Answer: D

35) A galvanometer has an internal resistance of 100 Ω and deflects full-scale at 2.00 mA. What size resistor should be added to the galvanometer to convert it to a milliammeter capable of reading up to 4.00 mA, and how should this resistor be connected to the galvanometer?
A) 50.0 Ω in series with the galvanometer
B) 50.0 Ω in parallel with the galvanometer
C) 75.0 Ω in parallel with the galvanometer
D) 100 Ω in series with the galvanometer
E) 100 Ω in parallel with the galvanometer

Answer: E

36) A galvanometer has a coil with a resistance of 24.0 Ω, and a current of 180 μA causes it to deflect full scale. If this galvanometer is to be used to construct an ammeter that can read up to 10.0 A, what shunt resistor is required?
A) 123 μΩ
B) 234 μΩ
C) 342 μΩ
D) 432 μΩ
E) 423 μΩ

Answer: D

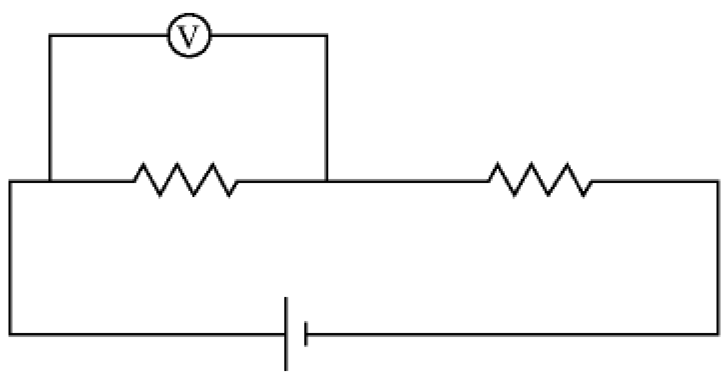
37) A galvanometer has an internal resistance of 100 Ω and deflects full–scale at a current of 2.00 mA. What size resistor should be added to it to convert it to a millivoltmeter capable of reading up to 400 mV, and how should this resistor be connected to the galvanometer?
A) 50.0 Ω in series with the galvanometer
B) 50.0 Ω in parallel with the galvanometer
C) 75.0 Ω in parallel with the galvanometer
D) 100 Ω in series with the galvanometer
E) 100 Ω in parallel with the galvanometer

Answer: D

38) A galvanometer with a resistance of 40.0 Ω deflects full scale at a current of 2.0 mA. What resistance should be used with this galvanometer in order to construct a voltmeter that can read a maximum of 50 V?
A) 25 kΩ
B) 27 kΩ
C) 29 kΩ
D) 31 kΩ
E) 35 kΩ

Answer: A

39) In the circuit shown in the figure, two 360.0–Ω resistors are connected in series with an ideal source of emf. A voltmeter with internal resistance of 6350 Ω is connected across one of the resistors and reads 3.23 V. Find the emf of the source.



Answer: 6.64 V

40) A 6.0–μF capacitor is connected in series with= 5.0 MΩ resistor, and this combination is connected across an ideal 15–V DC battery. What is the current in the circuit when the capacitor has reached 20% of its maximum charge?
A) 6.5 μA
B) 2.4 μA
C) 1.3 μA
D) 4.7 μA
E) 9.1 μA

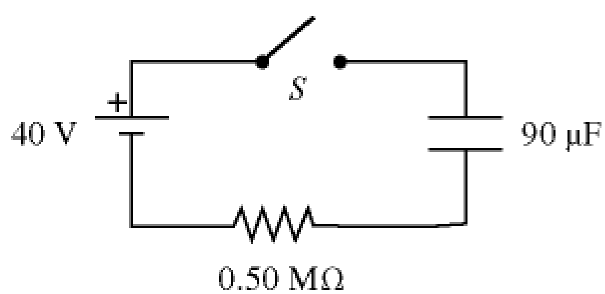
Answer: B

41) A 4.0–mF capacitor is discharged through a 4.0–kΩ resistor. How long will it take for the capacitor to lose half its initial stored energy?
A) 9.2 s
B) 2.7 s
C) 10.2 s
D) 5.5 s
E) 1.6 s
Answer: D

42) An uncharged 1.0–μF capacitor is connected in series with a 23–kΩ resistor, an ideal 7.0–V battery, and an open switch. What is the voltage across the capacitor 11 ms after closing the switch?
A) 2.7 V
B) 1.6 V
C) 2.6 V
D) 0.62 V
Answer: A

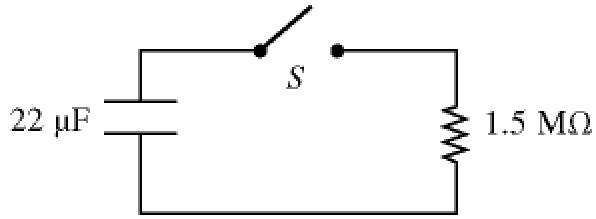
43) A 4.0–μF capacitor that is initially uncharged is connected in series with a 4.0–kΩ resistor and an ideal 17.0–V battery. How much energy is stored in the capacitor 17 ms after the battery has been connected?
A) 250,000 nJ
B) 15,000 kJ
C) 25 μJ
D) 890 nJ
Answer: A

44) For the circuit shown in the figure, the switch S is initially open and the capacitor is uncharged. The switch is then closed at time $t = 0$. How many seconds after closing the switch will the energy stored in the capacitor be equal to 50.2 mJ?



A) 81 s
B) 65 s
C) 97 s
D) 110 s
E) 130 s
Answer: A

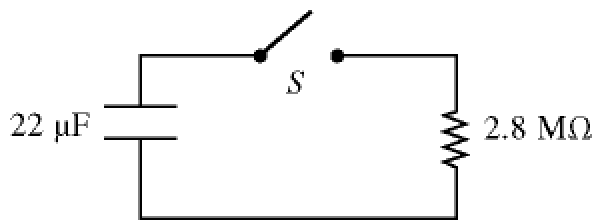
45) For the circuit shown in the figure, the switch S is initially open and the capacitor voltage is 80 V. The switch is then closed at time $t = 0$. What is the charge on the capacitor when the current in the circuit is 33 μA?



A) 1100 μC
B) 1000 μC
C) 960 μC
D) 890 μC
E) 830 μC

Answer: A

46) For the circuit shown in the figure, the switch S is initially open and the capacitor voltage is 80 V. The switch is then closed at time $t = 0$. How long after closing the switch will the current in the resistor be 7.0 μA?



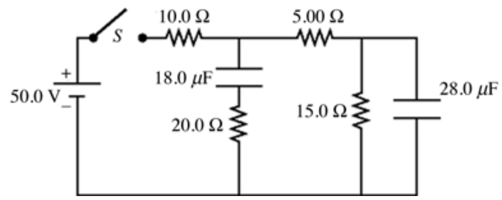
A) 87 s
B) 95 s
C) 78 s
D) 69 s
E) 61 s

Answer: A

47) An uncharged 30.0-μF capacitor is connected in series with a 25.0-Ω resistor, a DC battery, and an open switch. The battery has an internal resistance of 10.0 Ω and the open-circuit voltage across its terminals is 50.0 V. The leads have no appreciable resistance. At time $t = 0$, the switch is suddenly closed.
(a) What is the maximum current through the 25.0-Ω resistor and when does it occur (immediately after closing the switch or after the switch has been closed for a long time)?
(b) What is the maximum charge that the capacitor receives?
(c) When the current in the circuit is 0.850 A, how much charge is on the plates of the capacitor?

Answer: (a) 1.43 A, immediately after closing the switch
(b) 1500 μC (c) 608 μC

48) For the circuit shown in the figure, the capacitors are all initially uncharged, the connecting leads have no resistance, the battery has no appreciable internal resistance, and the switch *S* is originally open.



(a) Just after closing the switch *S*, what is the current in the 15.0–Ω resistor?

A) 0.00 A
B) 1.67 A
C) 2.50 A
D) 3.33 A
E) 5.00 A

(b) After the switch *S* has been closed for a very long time, what is the potential difference across the 28.0–μF capacitor?

A) 0.00 V
B) 25.0 V
C) 3.33 V
D) 37.5 V
E) 50.0 V

Answer: (a) A (b) B

Chapter 26 Magnetism: Force and Field

26.1 Conceptual Questions

1) A vertical wire carries a current straight down. To the east of this wire, the magnetic field points
   A) toward the north.
   B) toward the east.
   C) toward the west.
   D) toward the south.
   E) downward.

   Answer: D

2) A current carrying loop of wire lies flat on a table top. When viewed from above, the current moves around the loop in a counterclockwise sense.
   (a) For points OUTSIDE the loop, the magnetic field caused by this current
   A) circles the loop in a clockwise direction.
   B) circles the loop in a counterclockwise direction.
   C) points straight up.
   D) points straight down.
   E) is zero.
   (b) For points INSIDE the loop, the magnetic field caused by this current\
   A) circles the loop in a clockwise direction.
   B) circles the loop in a counterclockwise direction.
   C) points straight up.
   D) points straight down.
   E) is zero.

   Answer: (a) D (b) C

3) A horizontal wire carries a current straight toward you. From your point of view, the magnetic field at a point directly below the wire points
   A) directly away from you.
   B) to the left.
   C) to the right.
   D) directly toward you.
   E) vertically upward.

   Answer: C

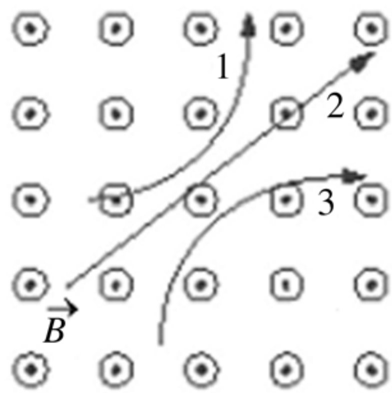
4) An electron moving in the direction of the $+x$-axis enters a magnetic field. If the electron experiences a magnetic deflection in the $-y$ direction, the direction of the magnetic field in this region points in the direction of the
   A) $+z$-axis.
   B) $-z$-axis.
   C) $-x$-axis.
   D) $+y$-axis.
   E) $-y$-axis.

   Answer: B

5) An electron, moving toward the west, enters a uniform magnetic field. Because of this field the electron curves upward. The direction of the magnetic field is
A) towards the north.
B) towards the south.
C) towards the west.
D) upward.
E) downward.

Answer: A

6) Three particles travel through a region of space where the magnetic field is out of the page, as shown in the figure. The electric charge of each of the three particles is, respectively,



A) 1 is neutral, 2 is negative, and 3 is positive.
B) 1 is neutral, 2 is positive, and 3 is negative.
C) 1 is positive, 2 is neutral, and 3 is negative.
D) 1 is positive, 2 is negative, and 3 is neutral.
E) 1 is negative, 2 is neutral, and 3 is positive.

Answer: E

7) A charge is accelerated from rest through a potential difference V and then enters a uniform magnetic field oriented perpendicular to its path. The field deflects the particle into a circular arc of radius R. If the accelerating potential is tripled to $3V$, what will be the radius of the circular arc?
A) $9R$
B) $3R$
C) $\sqrt{3}R$
D) $R/\sqrt{3}$
E) $R/9$

Answer: C

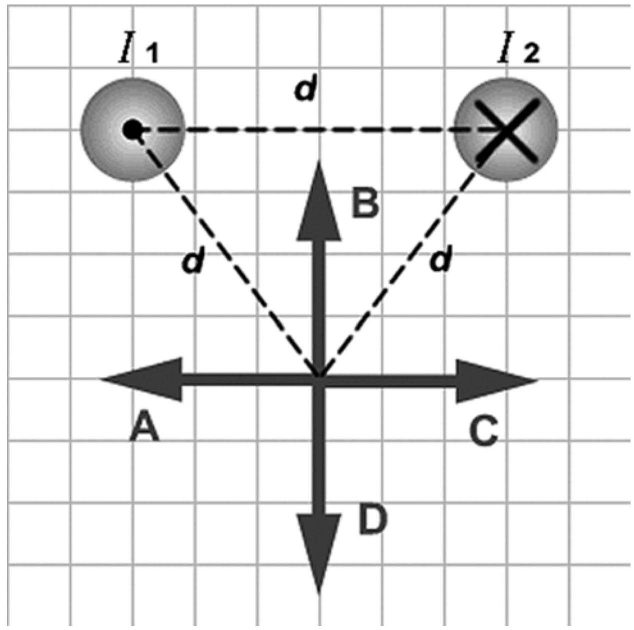
8) Ions having equal charges but masses of M and $2M$ are accelerated through the same potential difference and then enter a uniform magnetic field perpendicular to their path. If the heavier ions follow a circular arc of radius R, what is the radius of the arc followed by the lighter?
A) $4R$
B) $3R$
C) $\sqrt{2}R$
D) $R/\sqrt{2}$
E) $R/2$
Answer: D

9) A charged particle is moving with speed v perpendicular to a uniform magnetic field. A second identical charged particle is moving with speed $2v$ perpendicular to the same magnetic field. If the frequency of revolution of the first particle is f, the frequency of revolution of the second particle is
A) f.
B) $2f$.
C) $4f$.
D) $f/2$.
E) $f/4$.
Answer: A

10) A vertical wire carries a current vertically upward in a region where the magnetic field vector points toward the north. What is the direction of the magnetic force on this current due to the field?
A) downward
B) toward the north
C) toward the south
D) toward the east
E) toward the west
Answer: E

11) Two long parallel wires placed side-by-side on a horizontal table carry identical size currents in opposite directions. The wire on your right carries current toward you, and the wire on your left carries current away from you. From your point of view, the magnetic field at the point exactly midway between the two wires
A) points upward.
B) points downward.
C) points toward you.
D) points away from you.
E) is zero.
Answer: B

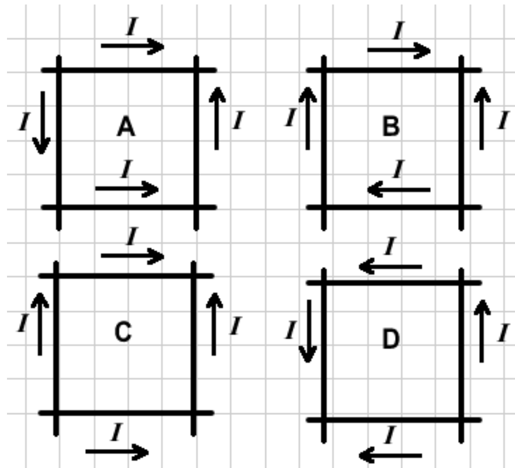
12) The figure shows two long wires carrying equal currents I_1 and I_2 flowing in opposite directions. Which of the arrows labeled A through D correctly represents the direction of the magnetic field due to the wires at a point located at an equal distance d from each wire?



A) A
B) B
C) C
D) D
E) The magnetic field is zero at that point.

Answer: B

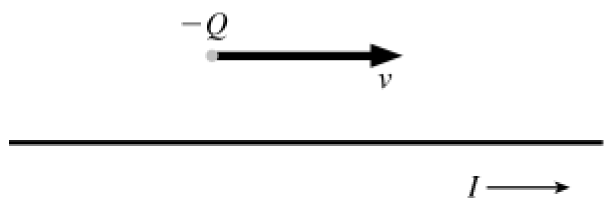
13) The figure shows four different sets of insulated wires that cross each other at right angles without actually making electrical contact. The magnitude of the current is the same in all the wires, and the directions of current flow are as indicated. For which (if any) configuration will the magnetic field at the center of the square formed by the wires be equal to zero?



A) A
B) B
C) C
D) D
E) The field is not equal to zero in any of these cases.

Answer: C

14) A negatively charged particle is moving to the right, directly above a wire having a current flowing to the right, as shown in the figure. In which direction is the magnetic force exerted on the particle?



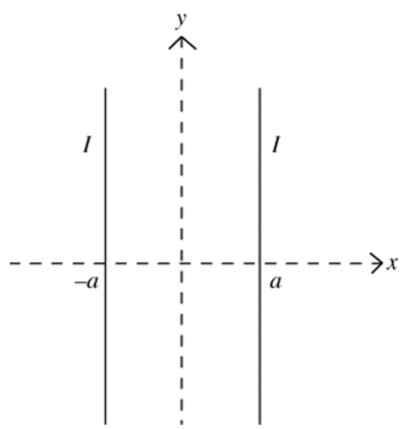
A) into the page
B) out of the page
C) downward
D) upward
E) The magnetic force is zero since the velocity is parallel to the current.

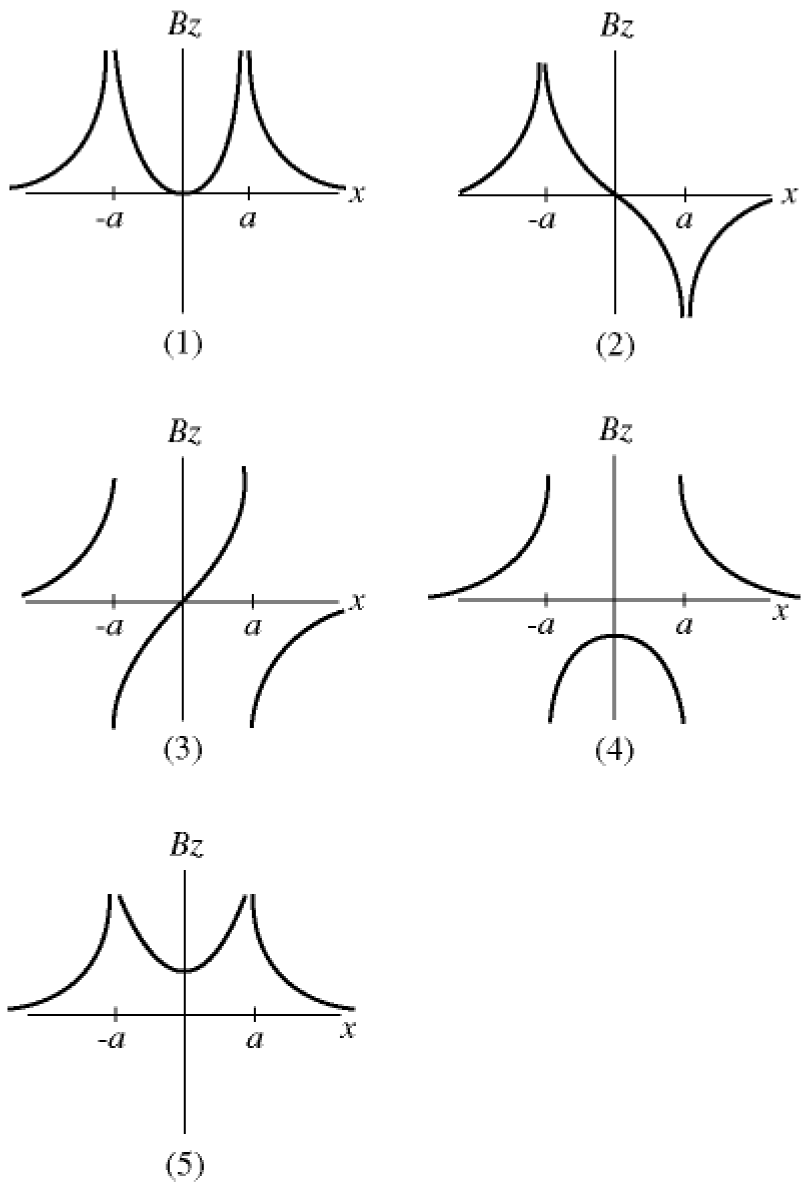
Answer: D

15) Two very long parallel wires are a distance d apart and carry equal currents in opposite directions. The locations where the net magnetic field due to these currents is equal to zero are
A) midway between the wires.
B) a distance $d/2$ to the left of the left wire and also a distance $d/2$ to the right of the right wire.
C) a distance d to the left of the left wire and also a distance d to the right of the right wire.
D) a distance $d/\sqrt{2}$ to the left of the left wire and also a distance $d/\sqrt{2}$ to the right of the right wire.
E) The net field is not zero anywhere.

Answer: E

16) Two very long parallel wires in the xy-plane, a distance $2a$ apart, are parallel to the y-axis and carry equal currents I as shown in the figure. The $+z$ direction points perpendicular to the xy-plane in a right-handed coordinate system. If both currents flow in the $+y$ direction, which one of the graphs shown in the figure below best represents the z component of the net magnetic field, in the xy-plane, as a function of x? (*Caution:* These graphs are *not* magnetic field lines.)

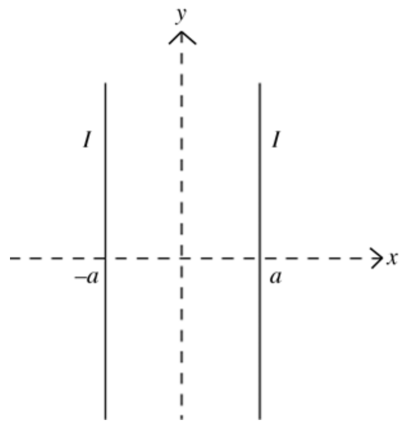


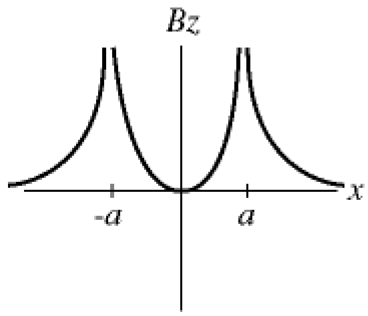


A) 1
B) 2
C) 3
D) 4
E) 5

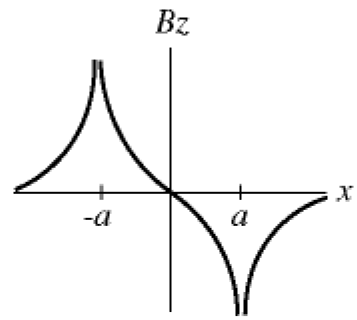
Answer: C

17) Two very long parallel wires in the *xy*-plane, a distance 2*a* apart, are parallel to the *y*-axis and carry equal currents *I* as shown in the figure. The +*z* direction points perpendicular to the *xy*-plane in a right-handed coordinate system. If the left current flows in the +*y* direction and the right current flows in the −*y* direction, which one of the graphs shown in the figure below best represents the *z* component of the net magnetic field, in the *xy*-plane, as a function of *x*? (*Caution:* These graphs are *not* magnetic field lines.)

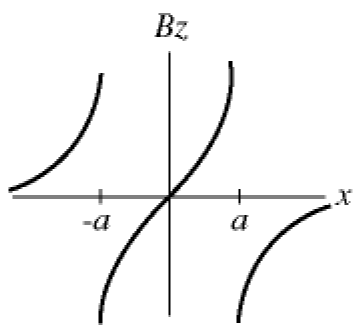




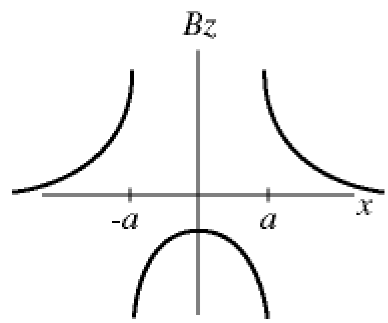
(1)



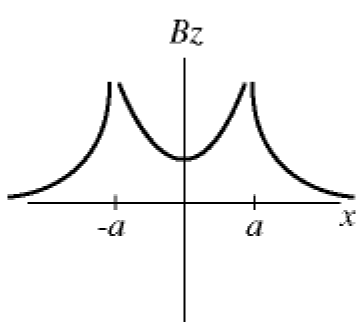
(2)



(3)



(4)



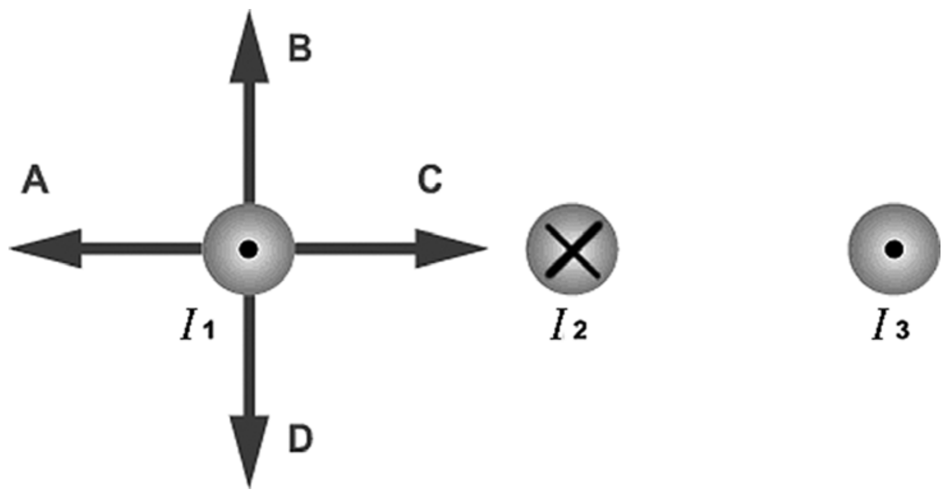
(5)

A) 1
B) 2

C) 3
D) 4
E) 5

Answer: D

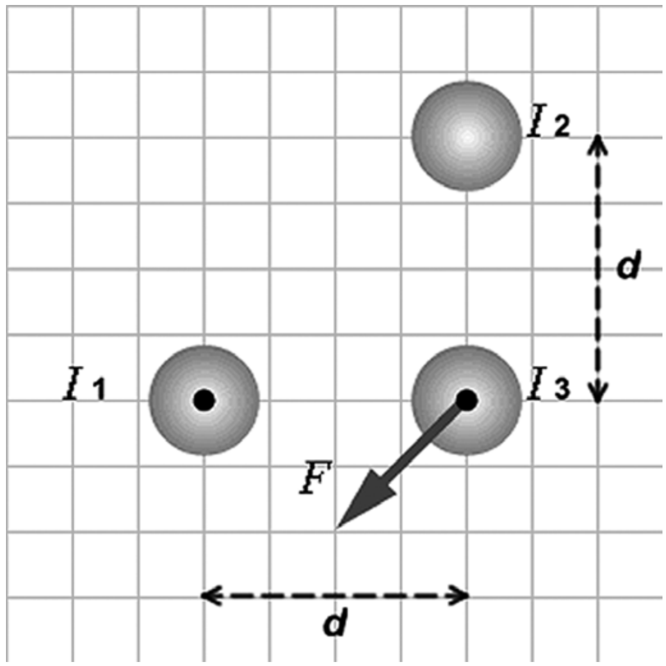
18) The figure shows three long, parallel current-carrying wires. The magnitudes of the currents are equal and their directions are indicated in the figure. Which of the arrows drawn near the wire carrying current 1 correctly indicates the direction of the magnetic force acting on that wire?



A) A
B) B
C) C
D) D
E) The magnetic force on current 1 is equal to zero.

Answer: A

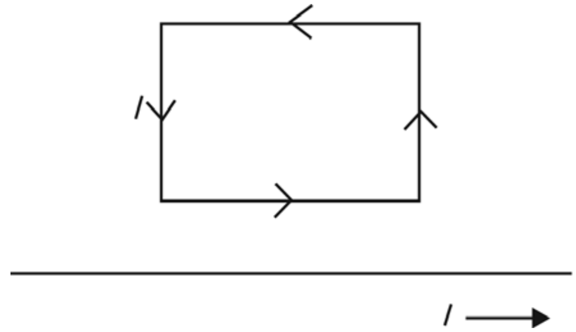
19) The figure shows three long, parallel, current-carrying wires. The current directions are indicated for currents I_1 and I_3. The arrow labeled F represents the net magnetic force acting on current I_3. The three currents have equal magnitudes. What is the direction of the current I_2?



A) into the picture (in the direction opposite to that of I_1 and I_3)
B) horizontal to the right
C) vertically upward
D) vertically downward
E) out of the picture (in the same direction as I_1 and I_3)

Answer: A

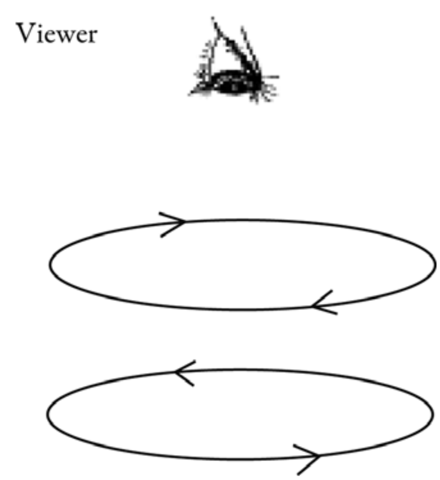
20) A long straight conductor has a constant current flowing to the right. A wire rectangle is situated above the wire, and also has a constant current flowing through it (as shown in the figure). Which of the following statements is true?



A) The net magnetic force on the wire rectangle is upward, and there is also a net torque on the it.
B) The net magnetic force on the wire rectangle is zero, and the net torque on it is zero.
C) The net magnetic force on the wire rectangle is downward, and there is also a net torque on the it.
D) The net magnetic force on the wire rectangle is zero, but there is a net torque on it.
E) The net magnetic force on the wire rectangle is downward, and the net torque on it is zero.

Answer: E

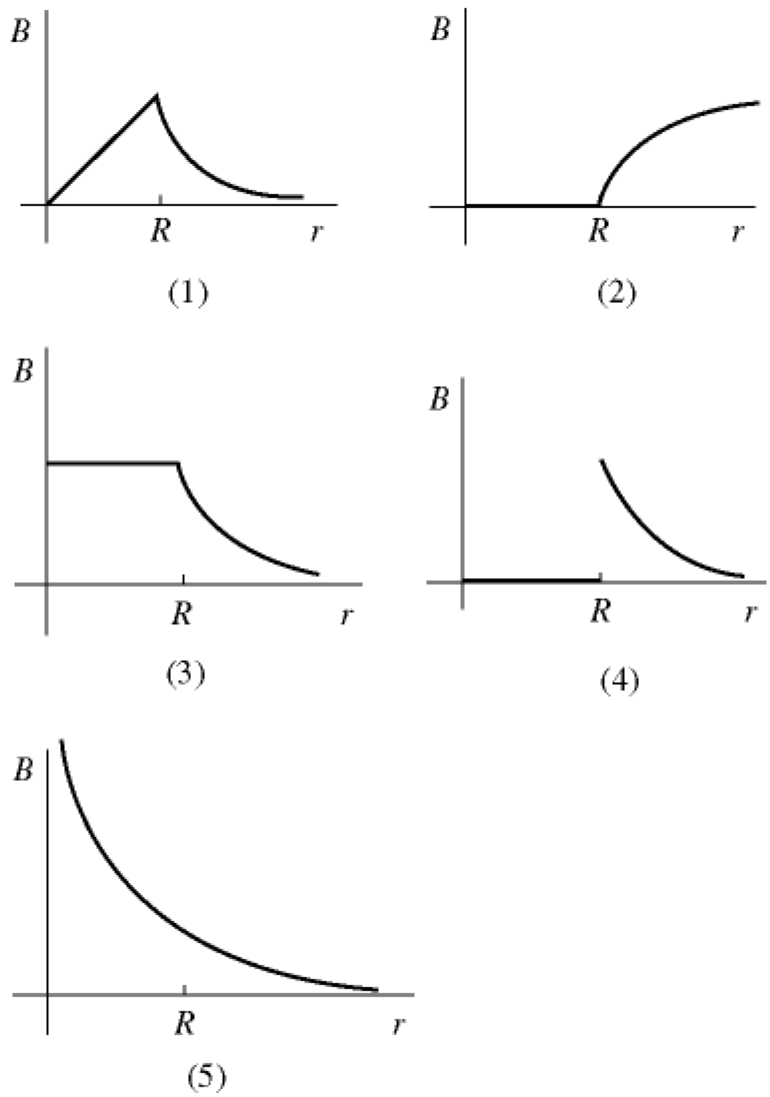
21) A ring with a clockwise current (as seen from above the ring) is situated with its center directly above another ring, which has a counter-clockwise current, as shown in the figure. In what direction is the net magnetic force exerted on the top ring?



A) upward
B) downward
C) to the right
D) to the left
E) The net force is zero.

Answer: A

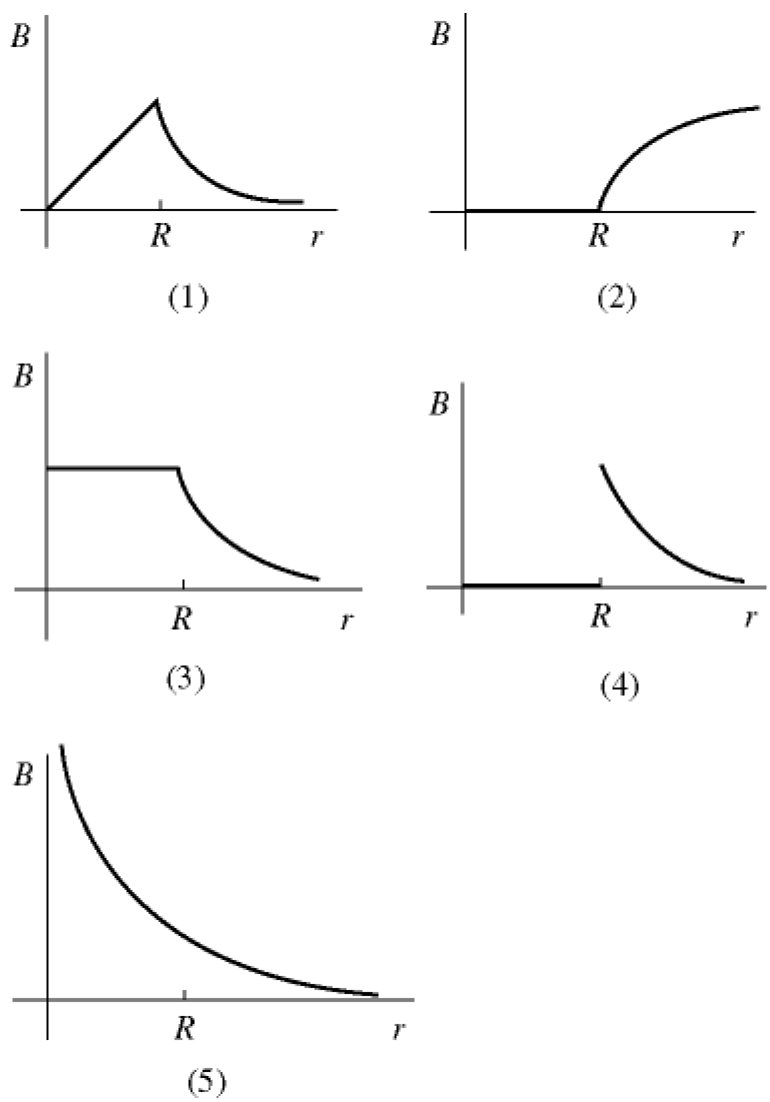
22) A very long, hollow, thin-walled conducting cylindrical shell (like a pipe) of radius R carries a current along its length uniformly distributed throughout the thin shell. Which one of the graphs shown in the figure most accurately describes the magnitude B of the magnetic field produced by this current as a function of the distance r from the central axis?



A) 1
B) 2
C) 3
D) 4
E) 5

Answer: D

23) A very long, solid, conducting cylinder of radius R carries a current along its length uniformly distributed throughout the cylinder. Which one of the graphs shown in the figure most accurately describes the magnitude B of the magnetic field produced by this current as a function of the distance r from the central axis?



A) 1
B) 2
C) 3
D) 4
E) 5

Answer: A

24) Consider a solenoid of length L, N windings, and radius b (L is much longer than b). A current I is flowing through the wire. If the radius of the solenoid were doubled (becoming $2b$), and all other quantities remained the same, the magnetic field inside the solenoid would
A) remain the same.
B) become twice as strong.
C) become one half as strong.

Answer: A

25) Consider a solenoid of length L, N windings, and radius b (L is much longer than b). A current I is flowing through the wire. If the length of the solenoid became twice as long ($2L$), and all other quantities remained the same, the magnetic field inside the solenoid would
A) remain the same.
B) become twice as strong.
C) become one half as strong.

Answer: C

26.2 Problems

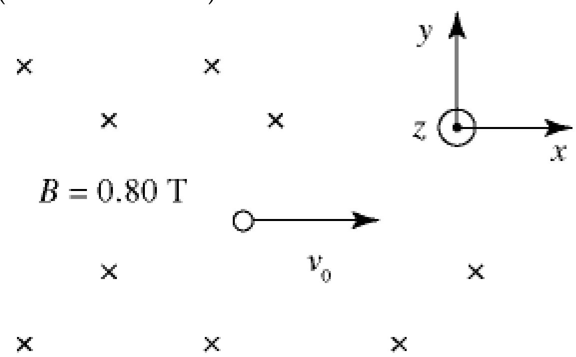
1) An electron moves with a speed of 8.0×10^6 m/s along the $+x$–axis. It enters a region where there is a magnetic field of 2.5 T, directed at an angle of 60° to the $+x$–axis and lying in the xy–plane. (1 eV = 1.60×10^{-19} C, $m_{\text{el}} = 9.11 \times 10^{-31}$ kg) Calculate the magnitude of
(a) the magnetic force on the electron.
(b) the acceleration of the electron.

Answer: (a) 2.8×10^{-12} N (b) 3.0×10^{18} m/s^2

2) An electron traveling toward the north with speed 4.0×10^5 m/s enters a region where the Earth's magnetic field has the magnitude 5.0×10^{-5} T and is directed downward at 45° below horizontal. What is the magnitude of the force that the Earth's magnetic field exerts on the electron? ($e = 1.60 \times 10^{-19}$ C)
A) 2.3×10^{-18} N
B) 3.2×10^{-18} N
C) 2.3×10^{-19} N
D) 3.2×10^{-19} N
E) 2.3×10^{-20} N

Answer: A

3) A uniform magnetic field of magnitude 0.80 T in the negative z direction is present in a region of space, as shown in the figure. A uniform electric field is also present and is set at 76,000 V/m in the $+y$ direction. An electron is projected with an initial velocity $v_0 = 9.5 \times 10^4$ m/s in the $+x$ direction. The y component of the initial force on the electron is closest to which of the following quantities? ($e = 1.60 \times 10^{-19}$ C)



A) -2.4×10^{-14} N
B) $+2.4 \times 10^{-14}$ N
C) -1.0×10^{-14} N
D) $+1.0 \times 10^{-14}$ N
E) zero

Answer: A

4) A particle with charge -5.00 C initially moves at $\vec{v} = (1.00\,\hat{i} + 7.00\,\hat{j})$ m/s. If it encounters a magnetic field $\vec{B} = 10.00$ T $\hat{k}$, find the magnetic force vector on the particle.

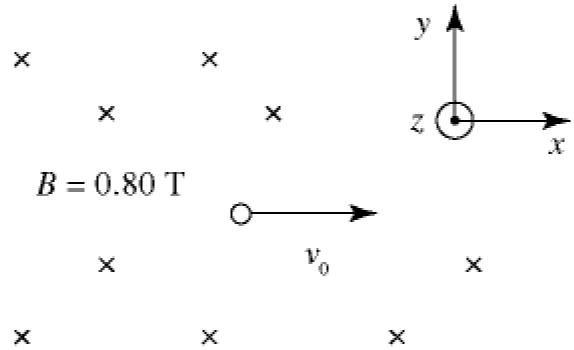
A) $(-350\,\hat{i} + 50.0\,\hat{j})$ N
B) $(-350\,\hat{i} - 50.0\,\hat{j})$ N
C) $(350\,\hat{i} + 50.0\,\hat{j})$ N
D) $(350\,\hat{i} - 50.0\,\hat{j})$ N

Answer: A

5) A proton, with mass 1.67×10^{-27} kg and charge $+1.6 \times 10^{-19}$ C, is sent with velocity 7.1×10^4 m/s in the $+x$ direction into a region where there is a uniform electric field of magnitude 730 V/m in the $+y$ direction. What are the magnitude and direction of the uniform magnetic field in the region, if the proton is to pass through undeflected? Assume that the magnetic field has no x-component and neglect gravitational effects.

Answer: 0.010 T, $+z$ direction

6) A uniform magnetic field of magnitude 0.80 T in the negative z-direction is present in a region of space, as shown in the figure. A uniform electric field is also present. An electron that is projected with an initial velocity $v_0 = 9.1 \times 10^4$ m/s in the positive x-direction passes through the region without deflection. What is the electric field vector in the region?

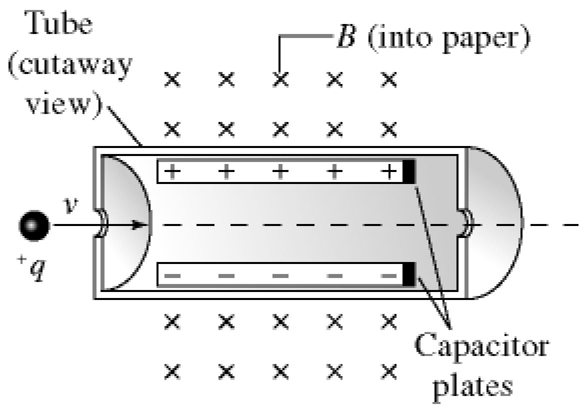


A) −73 kV/m $\hat{j}$
B) +73 kV/m $\hat{i}$
C) +110 kV/m $\hat{i}$
D) +110 kV/m $\hat{j}$
E) −110 kV/m $\hat{j}$
Answer: A

7) A beam of electrons is accelerated through a potential difference of 10 kV before entering a region having uniform electric and magnetic fields that are perpendicular to each other and perpendicular to the direction in which the electron is moving. If the magnetic field in this region has a value of 0.010 T, what magnitude of the electric field is required if the particles are to be undeflected as they pass through the region?
A) 2.3×10^3 V/m
B) 7.9×10^3 V/m
C) 5.9×10^5 V/m
D) 6.0×10^5 V/m
E) 7.2×10^6 V/m
Answer: C

8) An electron moving with a velocity $\vec{v} = 5.0 \times 10^7$ m/s $\hat{i}$ enters a region of space where perpendicular electric and a magnetic fields are present. The electric field is $\vec{E} = \hat{j}$. What magnetic field will allow the electron to go through the region without being deflected?
A) $\vec{B} = +2.0 \times 10^{-4}$ T $\hat{j}$
B) $\vec{B} = -2.0 \times 10^{-4}$ T $\hat{j}$
C) $\vec{B} = +2.0 \times 10^{-4}$ T $\hat{k}$
D) $\vec{B} = -2.0 \times 10^{-4}$ T $\hat{k}$
E) $\vec{B} = +5.0 \times 10^{-4}$ T $\hat{k}$
Answer: C

9) The figure shows a velocity selector that can be used to measure the speed of a charged particle. A beam of particles is directed along the axis of the instrument. A parallel plate capacitor sets up an electric field E, which is oriented perpendicular to a uniform magnetic field B. If the plates are separated by 2.0 mm and the value of the magnetic field is 0.60 T, what voltage between the plates will allow particles of speed 5.0×10^5 m/s to pass straight through without deflection?



A) 600 V
B) 1900 V
C) 3800 V
D) 190 V
E) 94 V

Answer: A

10) An alpha particle is moving at a speed of 5.0×10^5 m/s in a direction perpendicular to a uniform magnetic field of strength 0.040 T. The charge on an alpha particle is 3.2×10^{-19} C and its mass is 6.6×10^{-27} kg.
(a) What is the radius of the path of the alpha particle?
(b) How long does it take the alpha particle to make one complete revolution around its path?

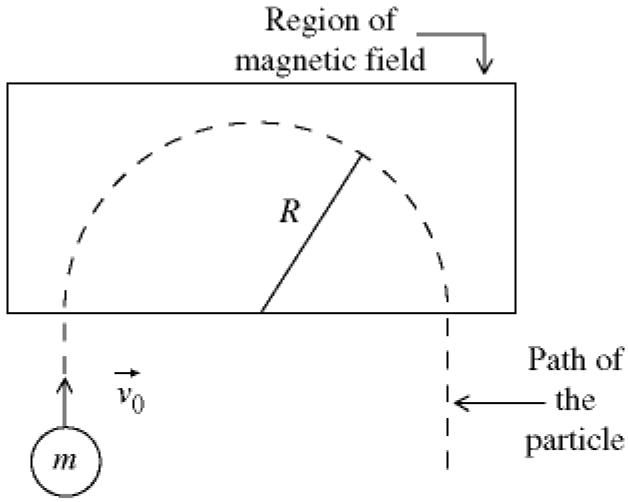
Answer: (a) 0.26 m (b) 3.2 μs

11) An electron moving perpendicular to a uniform magnetic field of 3.2×10^{-2} T moves in a circle of radius 0.40 cm. How fast is this electron moving? ($m_{el} = 9.11 \times 10^{-31}$ kg. $e = 1.60 \times 10^{-19}$ C)

A) 2.2×10^7 m/s
B) 1.9×10^{-2} m/s
C) 1.9×10^{-30} m/s
D) 3.0×10^6 m/s
E) 8.0×10^6 m/s

Answer: A

12) As shown in the figure, a small particle of charge $q = -7.0 \times 10^{-6}$ C and mass $m = 3.1 \times 10^{-12}$ kg has velocity $v_0 = 9.4 \times 10^3$ m/s as it enters a region of uniform magnetic field. The particle is observed to travel in the semicircular path shown, with radius $R = 5.0$ cm. Calculate the magnitude and direction of the magnetic field in the region.



Answer: 0.083 T, directed into the paper

13) A proton starting from rest travels through a potential of 1.0 kV and then moves into a uniform 0.040-T magnetic field. What is the radius of the proton's resulting orbit? ($m_{\text{proton}} = 1.67 \times 10^{-27}$ kg, $e = 1.60 \times 10^{-19}$ C)
A) 0.080 m
B) 0.11 m
C) 0.14 m
D) 0.17 m
E) 0.19 m

Answer: B

14) A proton is first accelerated from rest through a potential difference V and then enters a uniform 0.750-T magnetic field oriented perpendicular to its path. In this field, the proton follows a circular arc having a radius of curvature of 1.84 cm. What was the potential difference V? ($m_{\text{proton}} = 1.67 \times 10^{-27}$ kg, $e = 1.60 \times 10^{-19}$ C)

Answer: 9.12 kV

15) A charged particle of mass 0.0020 kg is subjected to a 6.0 T magnetic field which acts at a right angle to its motion. If the particle moves in a circle of radius 0.20 m at a speed of 5.0 m/s, what is the magnitude of the charge on the particle?
A) 0.0083 C
B) 120 C
C) 0.00040 C
D) 2500 C

Answer: A

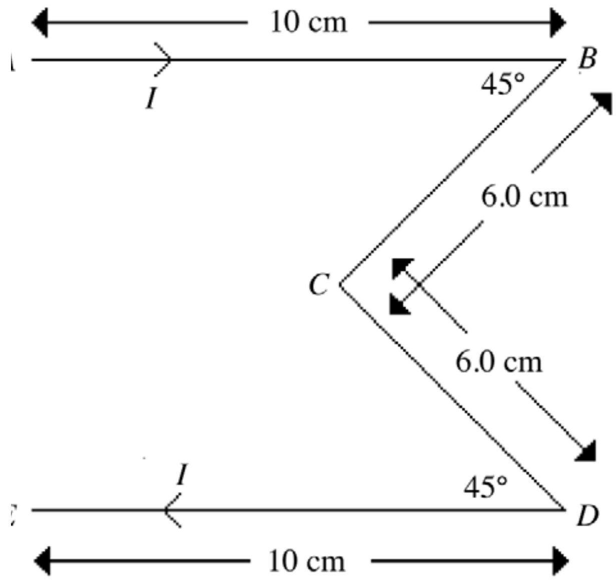
16) In a mass spectrometer, a singly-charged particle (charge e) has a speed of 1.0×10^6 m/s and enters a uniform magnetic field of 0.20 T. The radius of the circular orbit of the particle is 0.020 m. What is the mass of this particle? ($e = 1.60 \times 10^{-19}$ C)
A) 3.2×10^{-28} kg
B) 6.4×10^{-28} kg
C) 1.7×10^{-27} kg
D) 4.5×10^{-27} kg
E) 3.1×10^{-31} kg
Answer: B

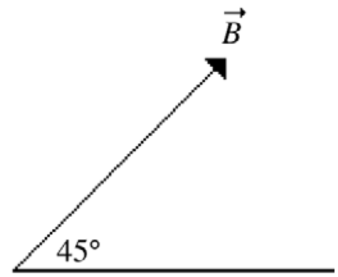
17) A doubly charged ion (charge $2e$) with velocity 6.9×10^6 m/s moves in a circular path of diameter 60.0 cm in a magnetic field of 0.80 T in a mass spectrometer. What is the mass of this ion? ($e = 1.60 \times 10^{-19}$ C)
A) 11×10^{-27} kg
B) 6.7×10^{-27} kg
C) 4.5×10^{-27} kg
D) 3.3×10^{-27} kg
E) 8.2×10^{-27} kg
Answer: A

18) An electron enters a magnetic field of 0.75 T with a velocity perpendicular to the direction of the field. At what frequency does the electron traverse a circular path? ($m_{el} = 9.11 \times 10^{-31}$ kg, $e = 1.60 \times 10^{-19}$ C)
A) 2.1×10^{10} Hz
B) 4.8×10^{-7} Hz
C) 2.1×10^{14} Hz
D) 4.8×10^{-11} Hz
Answer: A

19) Alpha particles (charge = $+2e$, mass = 6.68×10^{-27} kg, $e = 1.60 \times 10^{-19}$ C) are accelerated in a cyclotron to a final orbit radius of 0.90 m. The magnetic field in the cyclotron is 0.30 T. The period of the circular motion of the alpha particles is closest to
A) 0.44 μs.
B) 0.67 μs.
C) 0.87 μs.
D) 1.1 μs.
E) 1.3 μs.
Answer: A

20) A wire in the shape of an "M" lies in the plane of the paper. It carries a current of 2.0 A, flowing from points *A* to *E*, as shown in the figure. It is placed in a uniform magnetic field of 0.75 T in the same plane, directed as shown on the right side of the figure. The figure indicates the dimensions of the wire. What are the magnitude and direction of the force acting on





(a) section *AB* of this wire?
(b) section *BC* of this wire?
(c) section *CD* of this wire?
(d) section *DE* of this wire?
(e) the entire wire?

Answer: (a) 0.11 N perpendicular out of the page
(b) 0.00 N
(c) 0.090 N perpendicular out of the page
(d) 0.11 N perpendicular into the page
(e) 0.090 N perpendicular out of the page

21) A straight wire that is 0.60 m long is carrying a current of 2.0 A. It is placed in a uniform magnetic field of strength 0.30 T. If the wire experiences a force of 0.18 N, what angle does the wire make with respect to the magnetic field?
A) 25°
B) 30°
C) 35°
D) 60°
E) 90°

Answer: B

22) A thin copper rod that is 1.0 m long and has a mass of 0.050 kg is in a magnetic field of 0.10 T. What minimum current in the rod is needed in order for the magnetic force to cancel the weight of the rod?
A) 1.2 A
B) 2.5 A
C) 4.9 A
D) 7.6 A
E) 9.8 A

Answer: C

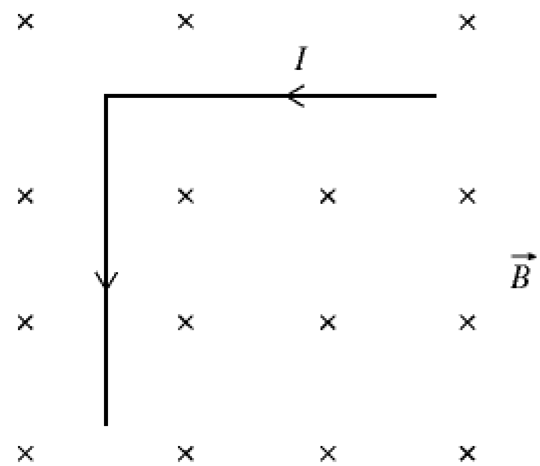
23) A wire carries a 4.0-A current along the $+x$-axis through a magnetic field $\vec{B} = (5.0\,\hat{i} + 7.0\,\hat{j})$ T. If the wire experiences a force of 30 N $\hat{k}$ as a result, how long is the wire?
A) 1.1 m
B) 0.87 m
C) 1.5 m
D) 0.63 m

Answer: A

24) A straight 15.0-g wire that is 2.00 m long carries a current of 8.00 A. This wire is aligned horizontally along the west-east direction with the current going from west to east. You want to support the wire against gravity using the *weakest possible* uniform external magnetic field.
(a) Which way should the magnetic field point?
(b) What is the magnitude of the weakest possible magnetic field you could use?

Answer: (a) from south to north (b) 9.19×10^{-3} T

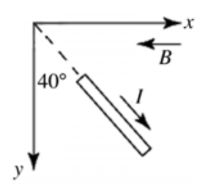
25) An L–shaped metal machine part is made of two equal–length segments that are perpendicular to each other and carry a 4.50–A current as shown in the figure. This part has a total mass of 3.80 kg and a total length of 3.00 m, and it is in an external 1.20 –T magnetic field that is oriented perpendicular to the plane of the part, as shown. What is the magnitude of the NET magnetic force that the field exerts on the part?



A) 8.10 N
B) 11.5 N
C) 16.2 N
D) 22.9 N
E) 32.4 N

Answer: B

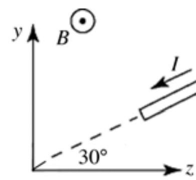
26) A wire segment 1.2 m long carries a current $I = 3.5$ A and is oriented as shown in the figure. A uniform magnetic field of magnitude 0.50 T pointing toward the $-x$ direction is present as shown. The $+z$–axis points directly into the page. What is the magnetic force vector on the wire segment?



A) +1.6 N $\hat{j}$
B) -1.6 N $\hat{k}$
C) +1.6 N $\hat{k}$
D) (+1.3 $\hat{j}$ - 1.6 $\hat{k}$) N
E) (-1.3 $\hat{j}$ + 1.6 $\hat{k}$ N

Answer: C

27) A wire segment 1.2 m long carries a current $I = 3.5$ A, and is oriented as shown in the figure. The +x–axis points directly into the page. A uniform magnetic field of magnitude 0.50 T pointing toward the -x direction is present as shown. What is the magnetic force vector on the wire segment?



A) $(+1.1\,\hat{j} - 1.8\,\hat{k})$ N
B) $(-1.1\,\hat{j} + 1.8\,\hat{k})$ N
C) $(-1.1\,\hat{j} - 1.8\,\hat{k})$ N
D) $(+1.8\,\hat{j} - 1.1\,\hat{k})$ N
E) $(-1.8\,\hat{j} + 1.1\,\hat{k})$ N

Answer: D

28) A wire along the z–axis carries a current of 6.8 A in the +z direction. Find the magnitude and direction of the force exerted on a 6.1–cm long length of the wire by a uniform magnetic field with magnitude 0.36 T in the $-x$ direction.

Answer: 0.15 N, $-y$ direction

29) A 15–turn rectangular loop of wire of width 10 cm and length 20 cm has a current of 2.5 A flowing through it. Two sides of the loop are oriented parallel to a uniform magnetic field of strength 0.037 T, and the other two sides are perpendicular to the magnetic field.
(a) What is the magnitude of the magnetic moment of the loop?
(b) What torque does the magnetic field exert on the loop?

Answer: (a) 0.75 A • m^2 (b) 0.028 N • m

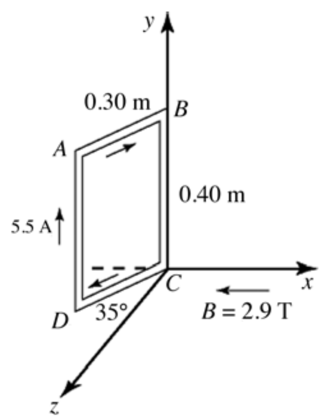
30) A rectangular loop of wire carrying a 4.0–A current is placed in a magnetic field of 0.60 T. The magnitude of the torque acting on this wire when the plane of the loop makes a 30° angle with the field is measured to be 1.1 N • m. What is the area of this loop?

A) 0.20 m^2
B) 0.40 m^2
C) 0.26 m^2
D) 0.80 m^2
E) 0.53 m^2

Answer: E

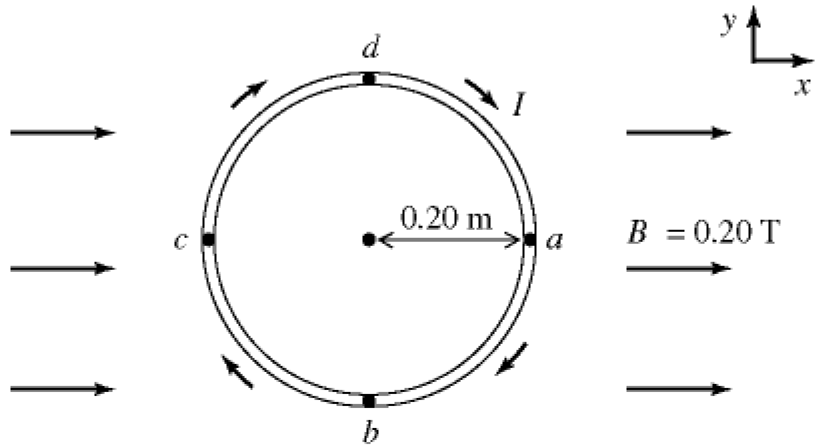
31) A circular loop of diameter 10 cm, carrying a current of 0.20 A, is placed inside a magnetic field $\vec{B} = 0.30\ \text{T}\ \hat{k}$. The normal to the loop is parallel to a unit vector $\hat{n} = -0.60\ \hat{i} - 0.80\ \hat{j}$. Calculate the magnitude of the torque on the loop due to the magnetic field.
A) 4.7×10^{-4} N • m
B) 2.8×10^{-4} N • m
C) 0.60×10^{-4} N • m
D) 1.2×10^{-4} N • m
E) zero
Answer: A

32) A rigid rectangular loop, which measures 0.30 m by 0.40 m, carries a current of 5.5 A, as shown in the figure. A uniform external magnetic field of magnitude 2.9 T in the negative x direction is present. Segment CD is in the xz–plane and forms a 35° angle with the z–axis, as shown. Find the magnitude of the external torque needed to keep the loop in static equilibrium.



A) 1.1 N • m
B) 0.73 N • m
C) 1.3 N • m
D) 1.4 N • m
E) 1.6 N • m
Answer: A

33) A rigid circular loop has a radius of 0.20 m and is in the xy–plane. A clockwise current I is carried by the loop, as shown. The magnitude of the magnetic moment of the loop is 0.75 A • m^2. A uniform external magnetic field, B = 0.20 T in the positive x–direction, is present.



(a) What is the current in the loop?
(b) Find the magnitude of the magnetic torque exerted on the loop.
(c) If the loop is released from rest, in what direction will points a and c initially move?

Answer: (a) 6.0 A (b) 0.15 N • m
(c) a moves out of the plane and c moves into the plane

34) A circular coil of wire of 200 turns and diameter 2.0 cm carries a current of 4.0 A. It is placed in a magnetic field of 0.70 T with the plane of the coil making an angle of 30° with the magnetic field. What is the magnetic torque on the coil?

A) 0.15 N • m
B) 0.088 N • m
C) 0.29 N • m
D) 0.40 N • m
E) 0.076 N • m

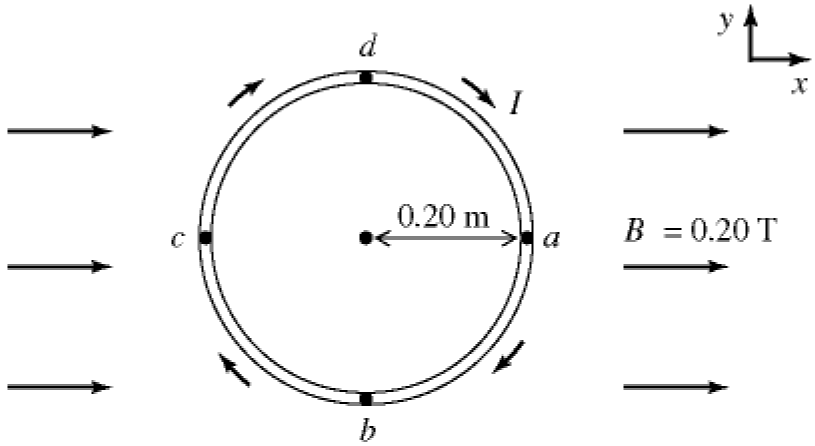
Answer: A

35) A round loop of diameter 12 cm, carrying a current of 0.40 A, is placed inside a magnetic field $\vec{B}$ = 0.20 T $\hat{i}$ + 0.40 T $\hat{j}$. The normal to the loop is parallel to the unit vector $\hat{n}$ = –0.60 $\hat{i}$ – 0.80 $\hat{j}$. What is the potential energy of the loop?

A) -4.5 × 10^{-3} J
B) +2.0 × 10^{-3} J
C) -2.0 × 10^{-3} J
D) -2.3 × 10^{-3} J
E) +4.5 × 10^{-3} J

Answer: B

36) A rigid circular loop has a radius of 0.20 m and is in the xy-plane. A clockwise current I is carried by the loop, as shown. The magnitude of the magnetic moment of the loop is 0.75 A • m^2. A uniform external magnetic field, $B = 0.20$ T in the positive x-direction, is present. An external torque changes the orientation of the loop from one of lowest potential energy to one of highest potential energy. The work done by this external torque is closest to



A) 0.20 J
B) 0.30 J
C) 0.40 J
D) 0.50 J
E) 0.60 J

Answer: B

37) At what distance from the central axis of a long straight thin wire carrying a current of 5.0 A is the magnitude of the magnetic field due to the wire equal to the strength of the Earth's magnetic field of about 5.0×10^{-5} T? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 1.0 cm
B) 2.0 cm
C) 3.0 cm
D) 4.0 cm
E) 5.0 cm

Answer: B

38) A very long thin wire produces a magnetic field of 0.0050×10^{-4} T at a distance of 3.0 mm. from the central axis of the wire. What is the magnitude of the current in the wire? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 7.5 mA
B) 1.7 mA
C) 3300 mA
D) 24,000 mA

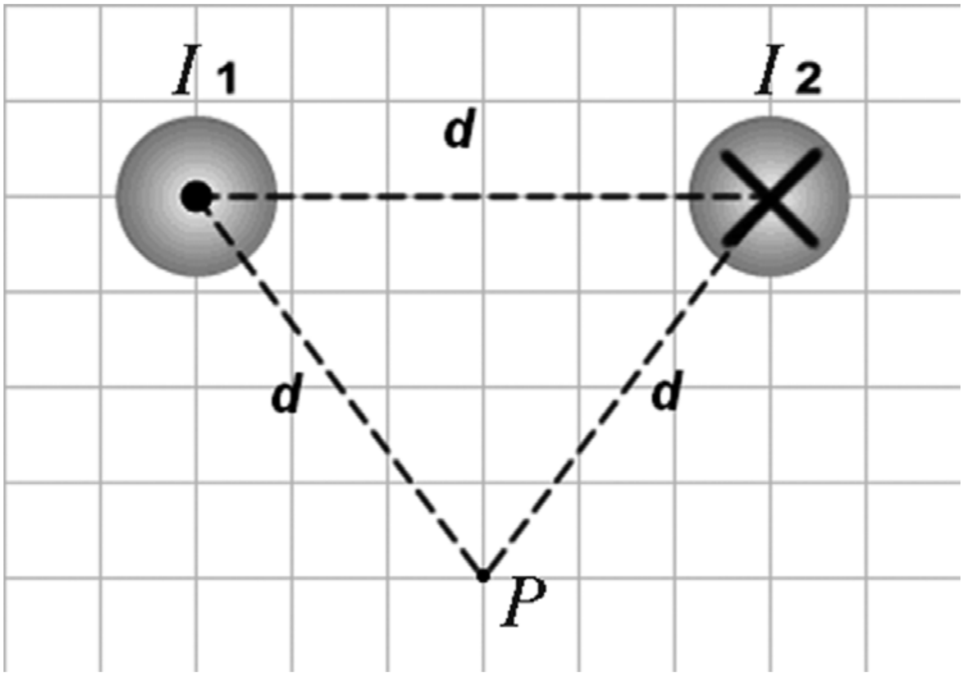
Answer: A

39) The magnetic field at a distance of 2 cm from a current carrying wire is 4 μT. What is the magnetic field at a distance of 4 cm from the wire?
A) 1/2 μT
B) 1 μT
C) 2 μT
D) 4 μT
E) 8 μT
Answer: C

40) Two long parallel wires carry currents of 20 A and 5.0 A in opposite directions. The wires are separated by 0.20 m. What is the magnitude of the magnetic field midway between the two wires? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)
A) 1.0×10^{-5} T
B) 2.0×10^{-5} T
C) 3.0×10^{-5} T
D) 4.0×10^{-5} T
E) 5.0×10^{-5} T
Answer: E

41) Two long parallel wires carry currents of 10 A in opposite directions. They are separated by 40 cm. What is the magnitude of the magnetic field in the plane of the wires at a point that is 20 cm from one wire and 60 cm from the other? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)
A) 1.5 μT
B) 3.3 μT
C) 6.7 μT
D) 33 μT
E) 67 μT
Answer: C

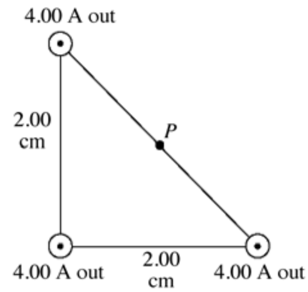
42) The figure shows two long, parallel current-carrying wires. The wires carry equal currents $I_1 = I_2 = 20$ A in the directions indicated and are located a distance $d = 0.5$ m apart. Calculate the magnitude and direction of the magnetic field at the point P that is located an equal distance d from each wire. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)



A) 8 μT downward
B) 8 μT upward
C) 4 μT downward
D) 4 μT upward
E) 4 μT to the right

Answer: B

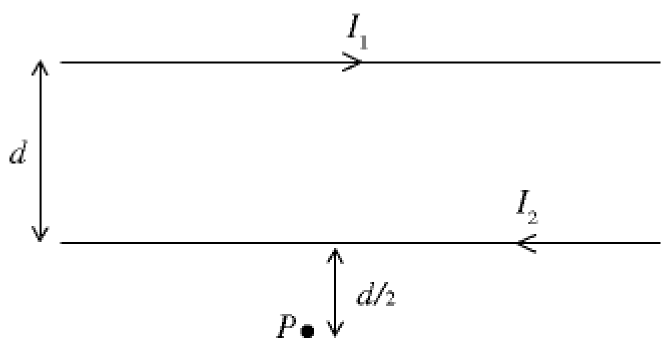
43) Three very long, straight, parallel wires each carry currents of 4.00 A, directed out of the page as shown in the figure. The wires pass through the vertices of a right isosceles triangle of side 2.00 cm. What is the magnitude of the magnetic field at point P at the midpoint of the hypotenuse of the triangle?



A) 4.42×10^{-6} T
B) 1.77×10^{-5} T
C) 5.66×10^{-5} T
D) 1.26×10^{-4} T
E) 1.77×10^{-6} T

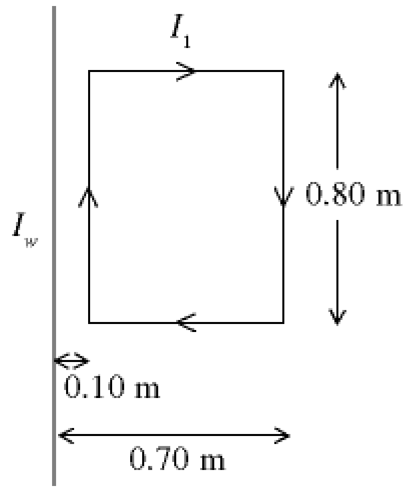
Answer: C

44) As shown in the figure, two long straight wires are separated by a distance of $d = 0.80$ m. The currents are $I_1 = 2.0$ A to the right in the upper wire and $I_2 = 7.0$ A to the left in the lower wire. What are the magnitude and direction of the magnetic field at point P, which is a distance $d/2 = 0.40$ m below the lower wire? ($\mu_0 = 4\pi \times 10^{-7} \text{T} \cdot \text{m/A}$)



Answer: $B = 3.2 \times 10^{-6}$ T, directed out of the plane of the paper.

45) As shown in the figure, a rectangular current loop is carrying current $I_1 = 3.0$ A, in the direction shown, and is located near a long wire carrying a current I_w. The long wire is parallel to the sides of the rectangle. The rectangle loop has length 0.80 m and its sides are 0.10 m and 0.70 m from the wire, as shown. We measure that the net force on the rectangular loop is 4.9×10^{-6} N and is directed towards the wire.($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)



(a) What is the magnitude of the current I_w?

(b) In which direction does I_w flow: from top to bottom or from bottom to top in the sketch?

Answer: (a) 1.2 A (b) from bottom to top

46) A very long straight wire carries a 12-A current eastward and a second very long straight wire carries a 14-A current westward. The wires are parallel to each other and are 42 cm apart. Calculate the force on a 6.4 m length of one of the wires. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 8.0×10^{-7} N
B) 5.1×10^{-4} N
C) 8.0×10^{-5} N
D) 5.1×10^{-6} N
E) 2.2×10^{-4} N

Answer: B

47) A rectangular loop of wire measures 1.0 m by 1.0 cm. If a 7.0-A current flows through the wire, what is the magnitude of the magnetic force on the centermost 1.0-cm segment of the 1.0-m side of the loop? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 9.8×10^{-6} N
B) 7.8×10^{-7} N
C) 9.8×10^{-8} N
D) 4.9×10^{-6} N

Answer: A

48) A circular loop of wire of radius 10 cm carries a current of 6.0 A. What is the magnitude of the magnetic field at the center of the loop? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 3.8×10^{-5} T
B) 3.8×10^{-7} T
C) 1.2×10^{-5} T
D) 1.2×10^{-7} T
E) 3.8×10^{-8} T

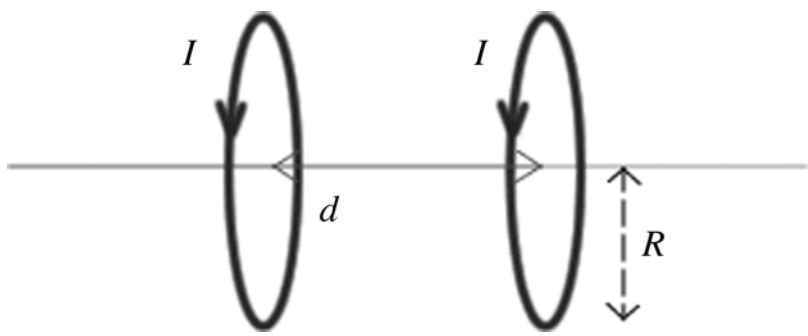
Answer: A

49) A wire carrying a current is shaped in the form of a circular loop of radius 3.0 mm. If the magnetic field strength that this current produces at the center of the loop is 1.1 mT, what is the magnitude of the current that flows through the wire? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 5.3 A
B) 16 A
C) 9.1 A
D) 23 A

Answer: A

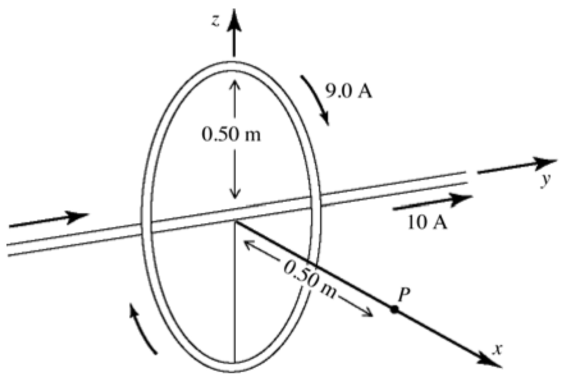
50) Two coaxial circular coils of radius R = 15 cm, each carrying 4.0 A in the same direction, are positioned a distance d = 20 cm apart, as shown in the figure. Calculate the magnitude of the magnetic field halfway between the coils along the line connecting their centers. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)



A) 0.90×10^{-5} T
B) 3.9×10^{-5} T
C) 1.9×10^{-5} T
D) 6.3×10^{-5} T
E) 9.2×10^{-5} T

Answer: C

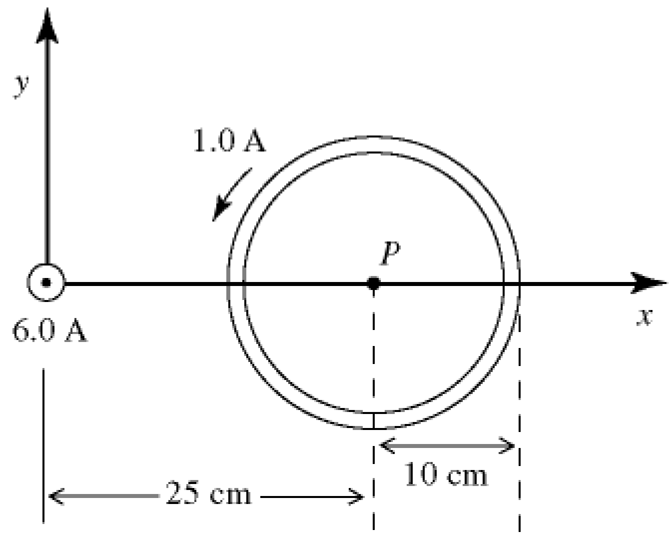
51) A long straight very thin wire on the y–axis carries a 10–A current in the positive y–direction. A circular loop 0.50 m in radius, also of very thin wire and lying in the yz–plane, carries a 9.0–A current, as shown. Point P is on the positive x–axis, at a distance of 0.50 m from the center of the loop. What is the magnetic field vector at point P due to these two currents? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)



A) zero
B) -8.0×10^{-6} T $\hat{k}$
C) $(+4.0 \times 10^{-6}$ T$)\hat{i} - (4.0 \times 10^{-6}$ T$)\hat{k}$
D) $(-4.0 \times 10^{-6}$ T$)\hat{i} - (4.0 \times 10^{-6}$ T$)\hat{k}$
E) $(-4.0 \times 10^{-6}$ T$)\hat{i} - (8.0 \times 10^{-6}$ T$)\hat{k}$

Answer: D

52) A long straight wire on the z–axis carries a current of 6.0 A in the positive direction. A circular loop in the xy–plane, of radius 10 cm, carries a 1.0–A current, as shown in the figure. Point P, at the center of the loop, is 25 cm from the z–axis. An electron is projected from P with a velocity of 1.0×10^6 m/s in the negative x–direction. What is the y component of the force on the electron? ($e = 1.60 \times 10^{-19}$ C, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A)



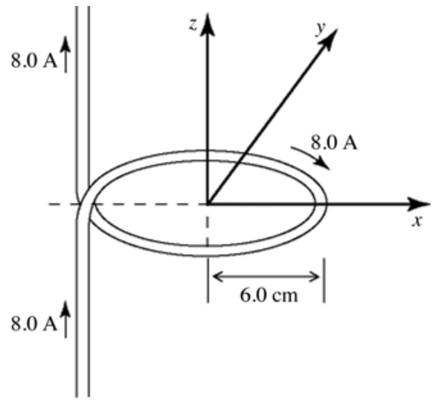
A) -1.0×10^{-18} N
B) $+1.0 \times 10^{-18}$ N
C) -2.0×10^{-18} N
D) $+2.0 \times 10^{-18}$ N
E) zero

Answer: A

53) Two circular coils of diameter 30.0 cm are parallel to each other and have their centers along the same line L but separated by 22.0 cm. When an experimenter views the coils along L, the coil closer to her carries a clockwise current of 2.50 A. Find the magnitude and sense (clockwise or counterclockwise) of the current needed in the other coil so that the net magnetic field on L midway between the two coils will have a magnitude of 4.10 μT and point away from the experimenter who is viewing the coils along L. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

Answer: 0.633 A, counterclockwise

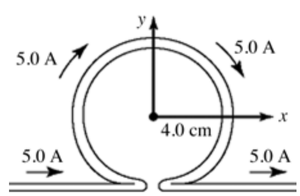
54) As shown in the figure, an insulated wire is bent into a circular loop of radius 6.0 cm and has two long straight sections. The loop is in the xy–plane, with the center at the origin. The straight sections are parallel to the z–axis. The wire carries a current of 8.0 A. What is the magnitude of the magnetic field at the origin? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)



A) 75 μT
B) 81 μT
C) 88 μT
D) 110 μT
E) 120 μT

Answer: C

55) As shown in the figure, a wire is bent into the shape of a tightly closed omega (Ω), with a circular loop of radius 4.0 cm and two long straight sections. The loop is in the xy–plane, with the center at the origin. The straight sections are parallel to the x–axis. The wire carries a 5.0–A current, as shown. What is the magnitude of the magnetic field at the center of the loop? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)



A) 25 μT
B) 40 μT
C) 54 μT
D) 80 μT
E) 104 μT

Answer: C

56) A type of transmission line for electromagnetic waves consists of two parallel conducting plates (assumed infinite in width) separated by a distance a. Each plate carries the same uniform surface current density of 16.0 A/m, but the currents run in opposite directions. What is the magnitude of the magnetic field between the plates at a point 1.00 mm from one of the plates if a = 0.800 cm? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

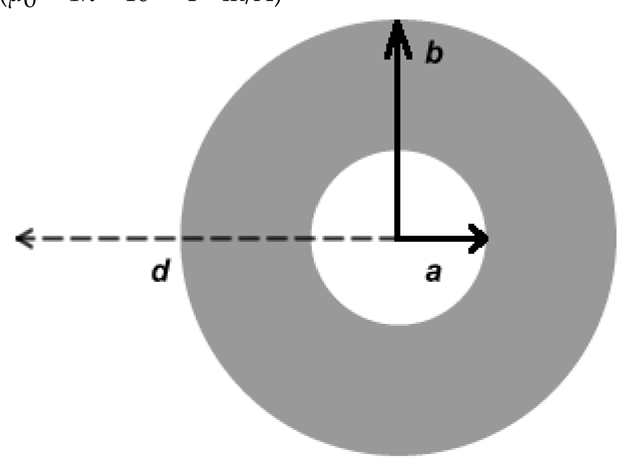
A) 3.20×10^{-3} T
B) 1.00×10^{-5} T
C) 4.63×10^{-5} T
D) 2.01×10^{-5} T
E) 7.07×10^{-4} T

Answer: D

57) A coaxial cable consists of an inner cylindrical conductor of radius R_1 = 0.040 m on the axis of an outer hollow cylindrical conductor of inner radius R_2 = 0.080 m and outer radius R_3 = 0.090 m. The inner conductor carries current I_1 = 4.40 A in one direction, and the outer conductor carries current I_2 = 7.70 A in the opposite direction. What is the magnitude of the magnetic field at the following distances from the central axis of the cable? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)
(a) At r = 0.060 m (in the gap midway between the two conductors)
(b) At r = 0.150 m (outside the cable)

Answer: (a) $B = 1.47 \times 10^{-5}$ T (b) $B = 4.40 \times 10^{-6}$ T

58) The figure shows the cross–section of a hollow cylinder of inner radius a = 5.0 cm and outer radius b = 7.0 cm. A uniform current density of 1.0 A/ cm^2 flows through the cylinder parallel to its axis. Calculate the magnitude of the magnetic field at a distance of d = 10 cm from the axis of the cylinder. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)



A) 0.00 T
B) 1.5×10^{-4} T
C) 2.5×10^{-4} T
D) 4.5×10^{-4} T
E) 0.50×10^{-4} T

Answer: B

59) A tube with a 3.0–mm radius has ions flowing through it along its length. To determine the rate at which the charge is being moved through the tube, the magnetic field just outside the tube is measured and found to be 44.0×10^{-4} T. If the only contributor to the magnetic field is the moving ions, and if the walls of the container are very thin and do not screen magnetism, what is the magnitude of the current flowing through the tube? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 66 A
B) 132 A
C) 829 A
D) 415 A

Answer: A

60) A long, straight wire with 3.0 A current flowing through it produces magnetic field strength 1.0 T at its surface. If the wire has a radius R, where within the wire is the field strength equal to 36.0% of the field strength at the surface of the wire? Assume that the current density is uniform throughout the wire. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 0.36 R
B) 0.060 R
C) 0.64 R
D) 0.030 R

Answer: A

61) A hollow cylinder with an inner radius of 4.0 mm and an outer radius of 30 mm conducts a 3.0–A current flowing parallel to the axis of the cylinder. If the current density is uniform throughout the wire, what is the magnitude of the magnetic field at a point 12 mm from its center? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 7.2×10^{-6} T
B) 8.0×10^{-6} T
C) 8.9×10^{-7} T
D) 7.1×10^{-8} T

Answer: A

62) A solenoid with 400 turns has a radius of 0.040 m and is 40 cm long. If this solenoid carries a current of 12 A, what is the magnitude of the magnetic field near the center of the solenoid? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 16 mT
B) 4.9 mT
C) 15 mT
D) 6.0 mT
E) 9.0 mT

Answer: C

63) A solenoid having N turns and carrying a current of 2.000 A has a length of 34.00 cm. If the magnitude of the magnetic field generated at the center of the solenoid is 9.000 mT, what is the value of N? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 860.0
B) 1591
C) 2318
D) 3183
E) 1218

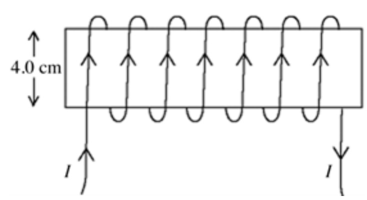
Answer: E

64) A cylindrical insulated wire of diameter 5.0 mm is tightly wound 200 times around a cylindrical core to form a solenoid with adjacent coils touching each other. When a 0.10 A current is sent through the wire, what is the magnitude of the magnetic field on the axis of the solenoid near its center? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 6.6×10^{-5} T
B) 2.5×10^{-5} T
C) 1.3×10^{-5} T
D) 3.6×10^{-5} T
E) 9.8×10^{-5} T

Answer: B

65) A solenoid is wound with 970 turns on a form 4.0 cm in diameter and 50 cm long. The windings carry a current I in the sense that is shown in the figure. The current produces a magnetic field, of magnitude 4.3 mT, near the center of the solenoid. Find the current in the solenoid windings. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)



A) 1.8 A
B) 1.5 A
C) 1.3 A
D) 2.2 A
E) 2.0 A

Answer: A

66) A solenoid of length 18 cm consists of closely spaced coils of wire wrapped tightly around a wooden core. The magnetic field strength is 2.0 mT inside the solenoid near its center when a certain current flows through the coils. If the coils of the solenoid are now pulled apart slightly, stretching it to 21 cm without appreciably changing the size of the coils, what does the magnetic field become near the center of the solenoid when the same current flows through the coils? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 1.7 mT
B) 3.4 mT
C) 0.85 mT
D) 2.0 mT

Answer: A

67) A toroidal solenoid has a central radius of 0.50 m and a cross-sectional diameter of 10 cm. When a current passes through the coil of the solenoid, the magnetic field inside the solenoid at its CENTER has a magnitude of 2.0 μT. What is the largest value of the magnetic field inside the solenoid when this current is flowing? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 3.5 μT
B) 1.8 μT
C) 2.2 μT
D) 0.50 μT
E) 2.8 μT

Answer: C

68) A 1000-turn toroidal solenoid has a central radius of 4.2 cm and is carrying a current of 1.7 A. What is the magnitude of the magnetic field inside the solenoid at the central radius? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

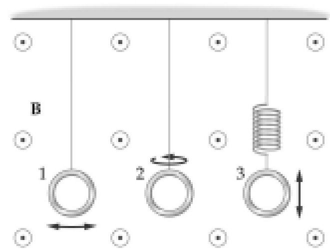
A) 8.1 mT
B) 51 mT
C) 16 mT
D) 81 mT
E) zero

Answer: A

Chapter 27 Electromagnetic Induction

27.1 Conceptual Questions

1) The three loops of wire shown in the figure are all subject to the same uniform magnetic field $\vec{B}$ that does not vary with time. Loop 1 oscillates back and forth as the bob in a pendulum, loop 2 rotates about a vertical axis, and loop 3 oscillates up and down at the end of a spring. Which loop, or loops, will have an emf induced in them?



A) loop 1 only
B) loop 2 only
C) loop 3 only
D) loops 1 and 2
E) loops 2 and 3

Answer: B

2) A large magnetic flux change through a coil must induce a greater emf in the coil than a small flux change.
A) True
B) False

Answer: B

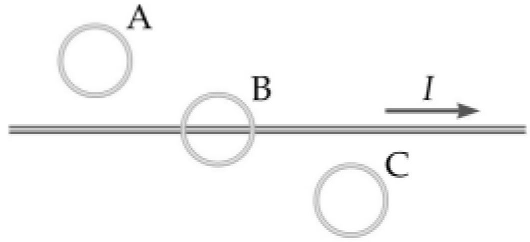
3) A circular loop of wire lies in the plane of the paper. An increasing magnetic field points out of the paper. What is the direction of the induced current in the loop?
A) counter-clockwise then clockwise
B) clockwise then counter-clockwise
C) clockwise
D) counter-clockwise
E) There is no current induced in the loop.

Answer: C

4) A coil lies flat on a tabletop in a region where the magnetic field vector points straight up. The magnetic field vanishes suddenly. When viewed from above, what is the direction of the induced current in this coil as the field fades?
A) counter-clockwise then clockwise
B) clockwise then counter-clockwise
C) clockwise
D) counter-clockwise
E) There is no current induced in the coil.

Answer: D

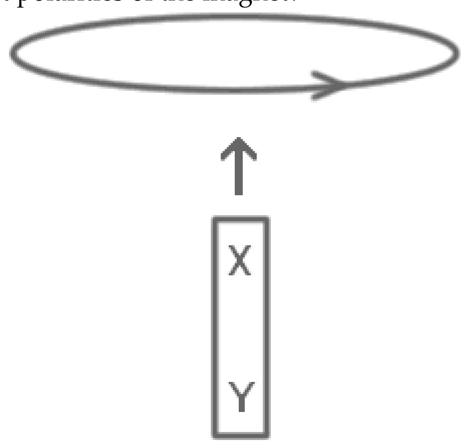
5) The long straight wire in the figure carries a current *I* that is decreasing with time at a constant rate. The circular loops A, B, and C all lie in a plane containing the wire. The induced emf in each of the loops A, B, and C is such that



A) no emf is induced in any of the loops.
B) a counterclockwise emf is induced in all the loops.
C) loop A has a clockwise emf, loop B has no induced emf, and loop C has a counterclockwise emf.
D) loop A has a counter-clockwise emf, loop B has no induced emf, and loop C has a clockwise emf.
E) loop A has a counter-clockwise emf, loops B and C have clockwise emfs.

Answer: D

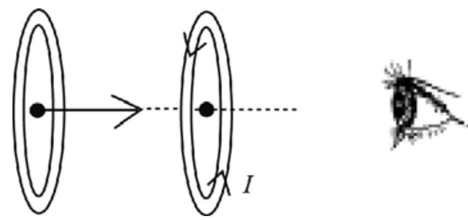
6) The figure shows a bar magnet moving vertically upward toward a horizontal coil. The poles of the bar magnets are labeled X and Y. As the bar magnet approaches the coil it induces an electric current in the direction indicated on the figure (counter-clockwise as viewed from above). What are the correct polarities of the magnet?



A) X is a south pole, Y is a north pole.
B) X is a north pole, Y is a south pole.
C) Both X and Y are north poles.
D) Both X and Y are south poles.
E) The polarities of the magnet cannot be determined from the information given.

Answer: A

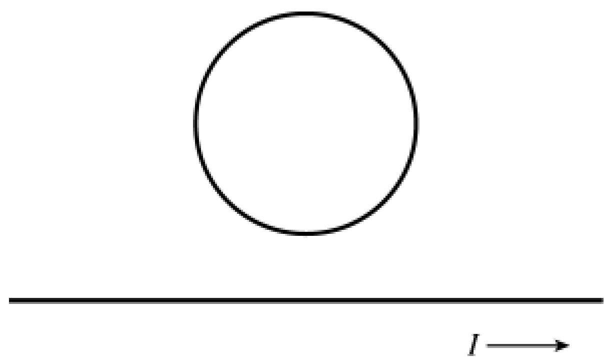
7) A closed, circular loop has a counter-clockwise current flowing through it as viewed by a person on the right, as shown in the figure. If a second closed circular loop with the same radius approaches this loop with constant velocity along a common axis as shown, in what direction will a current flow in the approaching loop as viewed by the person on the right?



A) clockwise
B) counter-clockwise
C) No current will be induced because the velocity of approach is constant.

Answer: A

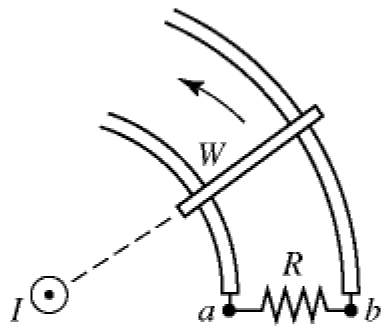
8) A circular metal ring is situated above a long straight wire, as shown in the figure. The straight wire has a current flowing to the right, and the current is increasing in time at a constant rate. Which statement is true?



A) There is an induced current in the metal ring, flowing in a clockwise direction.
B) There is an induced current in the metal ring, flowing in a counter-clockwise direction.
C) There is no induced current in the metal ring because the current in the wire is changing at a constant rate.

Answer: A

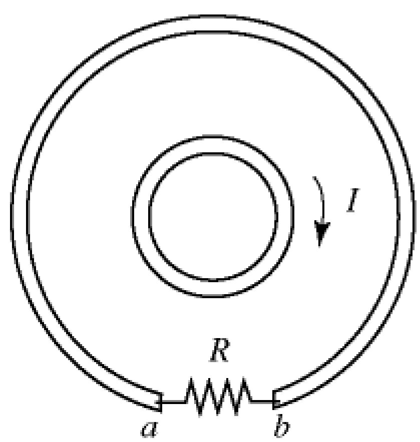
9) In the figure, a straight wire carries a steady current *I* perpendicular to the plane of the page. A bar is in contact with a pair of circular rails, and rotates about the straight wire. The direction of the induced current through the resistor *R* is



A) from *a* to *b*.
B) from *b* to *a*.
C) There is no induced current through the resistor.

Answer: C

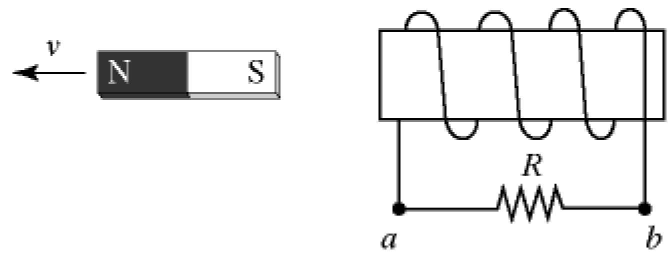
10) In the figure, the inner loop carries a clockwise current *I* that is increasing. The resistor *R* is in the outer loop and both loops are in the same plane. The induced current through the resistor *R* is



A) from *a* to *b*.
B) from *b* to *a*.
C) There is no induced current through the resistor.

Answer: A

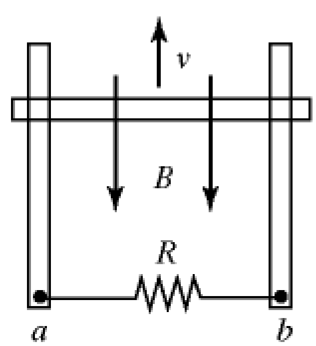
11) In the figure, a bar magnet moves away from the solenoid. The induced current through the resistor R is



A) from a to b.
B) from b to a.
C) There is no induced current through the resistor.

Answer: A

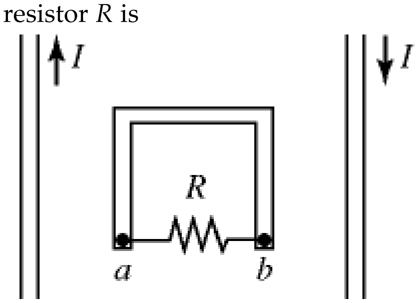
12) In the figure, a copper bar is in contact with a pair of parallel metal rails and is in motion with velocity v. A uniform magnetic field is present pointing downward, as shown. The bar, the rails, and the resistor R are all in the same plane. The induced current through the resistor R is



A) from a to b.
B) from b to a.
C) There is no induced current through the resistor.

Answer: C

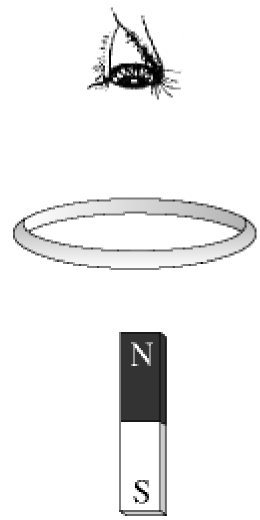
13) In the figure, two parallel wires carry currents of magnitude I in opposite directions. A rectangular loop is midway between the wires. The current I is decreasing with time. The induced current through the resistor R is



A) from a to b.
B) from b to a.
C) There is no induced current through the resistor.

Answer: A

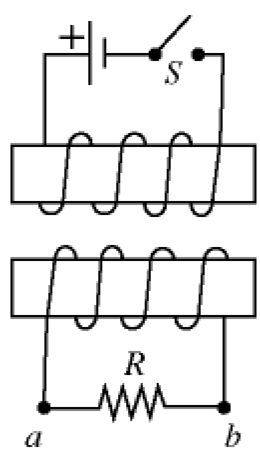
14) A bar magnet is held vertically with its upper end a little bit below the center of a horizontal metal ring. The upper end of the magnet is its north pole, as shown in the figure. The bar magnet is now dropped. An observer views the ring from above its center. To this observer, how will the induced current in the ring behave as the magnet falls?



A) The current will flow clockwise and be increasing.
B) The current will flow clockwise and be decreasing.
C) The current will flow counter-clockwise and be increasing.
D) The current will flow counter-clockwise and be decreasing.
E) The induced current will be zero.

Answer: D

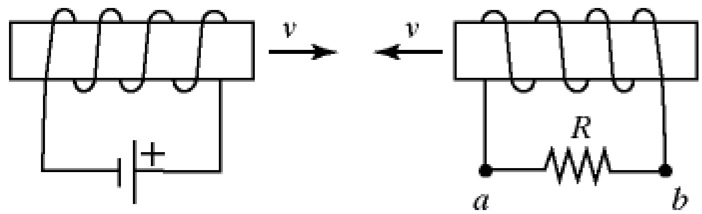
15) In the figure, two solenoids are side by side. The switch *S*, initially open, is closed. The induced current through the resistor *R* is



A) from *a* to *b*.
B) from *b* to *a*.
C) There is no induced current through the resistor.

Answer: B

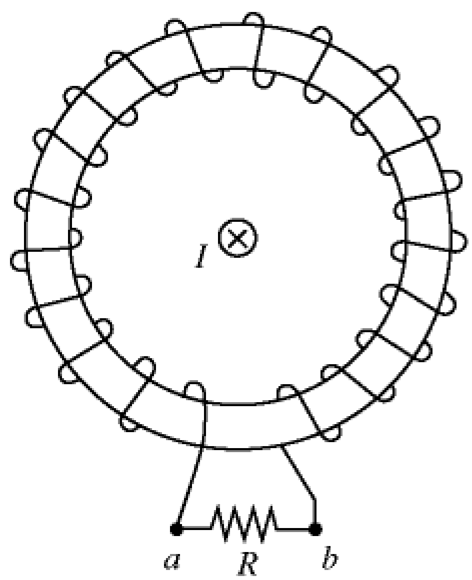
16) In the figure, two solenoids are approaching each other with speed v as shown. The induced current through the resistor R is



A) from a to b.
B) from b to a.
C) There is no induced current through the resistor.

Answer: A

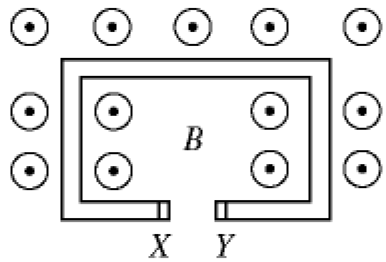
17) In the figure, a straight wire carries a current I. The wire passes through the center of a toroidal coil. If the current in the wire is quickly reduced to zero, the induced current through the resistor R is



A) from a to b.
B) from b to a.
C) There is no induced current through the resistor.

Answer: B

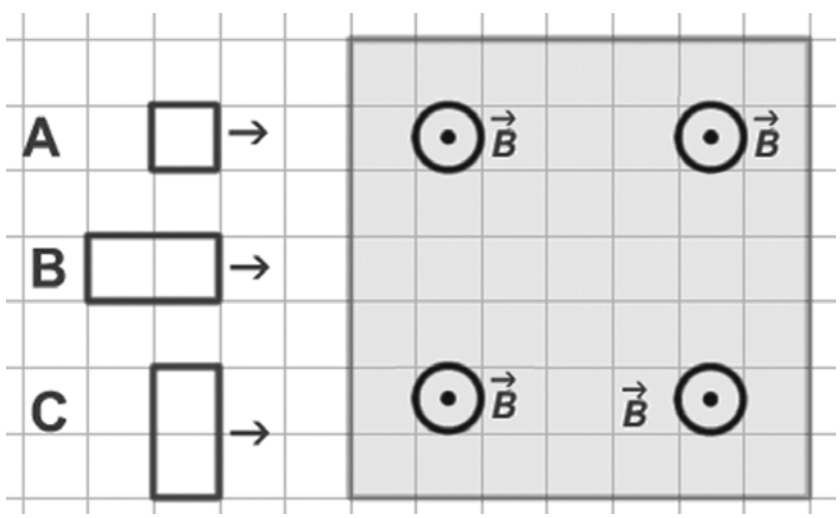
18) In the figure, a C-shaped conductor is in a uniform magnetic field B, which is increasing. The polarity of the induced emf in terminals X and Y is



A) X and Y are at the same potential.
B) X is positive and Y is negative.
C) X is negative and Y is positive.

Answer: C

19) The figure shows three metal coils labeled A, B, and C heading towards a region where a uniform static magnetic field exists. The coils move with the same constant velocity and all have the same resistance. Their relative sizes are indicated by the background grid. As they enter the magnetic field the coils will have an induced electric current in them. For which coil will the current be the greatest?



A) A
B) B
C) C
D) The current is the same in all three cases since all the coils move with the same velocity.
E) There is no induced current in any of the coils since they move at constant velocity.

Answer: C

20) A capacitor is charging in a simple *RC* circuit with a dc battery. Which one of the following statements about this capacitor is accurate?
   A) There is a magnetic field between the capacitor plates because charge travels between the plates by jumping from one plate to the other.
   B) There is no magnetic field between the capacitor plates because no charge travels between the plates.
   C) There is a magnetic field between the capacitor plates, even though no charge travels between them, because the magnetic flux between the plates is changing.
   D) There is a magnetic field between the capacitor plates, even though no charge travels between them, because the electric flux between the plates is changing.
   E) The magnetic field between the capacitor plates is increasing with time because the charge on the plates is increasing.

Answer: D

21) A resistor and an ideal inductor are connected in series to an ideal battery having a constant terminal voltage V_0. At the moment contact is made with the battery,

(a) the voltage across the resistor is
   A) V_0.
   B) V_0/e.
   C) $V_0/2$.
   D) zero.

(b) the voltage across the inductor is
   A) V_0.
   B) V_0/e.
   C) $V_0/2$.
   D) zero.

Answer: (a) D (b) A

22) Which of the following statements about inductors are correct? There may be more than one correct choice.
   A) When it is connected in a circuit, an inductor always resists having current flow through it.
   B) Inductors store energy by building up charge.
   C) When an inductor and a resistor are connected in series with a DC battery, the current in the circuit is reduced to zero in one time constant.
   D) An inductor always resists any change in the current through it.
   E) When an inductor and a resistor are connected in series with a DC battery, the current in the circuit is zero after a very long time.

Answer: D

27.2 Problems

1) A circular loop of radius 0.10 m is rotating in a uniform external magnetic field of 0.20 T. Find the magnetic flux through the loop due to the external field when the plane of the loop and the magnetic field vector are
(a) parallel.
(b) perpendicular.
(c) at an angle of 30° with each other.

Answer: (a) zero (b) 6.3×10^{-3} T • m^2 (c) 3.1×10^{-3} T • m^2

2) A 2.0–m long conducting wire is formed into a square and placed in the horizontal xy–plane. A uniform magnetic field is oriented 30.0° above the horizontal with a strength of 9.0 T. What is the magnetic flux through the square?

A) 1.1 T • m^2
B) 1.9 T • m^2
C) 2.3 T • m^2
D) 18 T • m^2

Answer: A

3) A 200–loop coil of cross sectional area 8.5 cm^2 lies in the plane of the page. An external magnetic field of 0.060 T is directed out of the plane of the page. The external field decreases to 0.020 T in 12 milliseconds.
(a) What is the magnitude of the change in the external magnetic flux enclosed by the coil?
(b) What is the magnitude of the average voltage induced in the coil as the external flux is changing?
(c) If the coil has a resistance of 4.0 ohms, what is the magnitude of the average current in the coil?

Answer: (a) 4.0×10^{-3} T • m^2 (b) 0.57 V (c) 0.14 A

4) A ten–loop coil having an area of 0.23 m^2 and a very large resistance is in a 0.047–T uniform magnetic field oriented so that the maximum flux goes through the coil. The coil is then rotated so that the flux through it goes to zero in 0.34 s. What is the magnitude of the average emf induced in the coil during the 0.34 s?

A) 0.0032 V
B) 0.00 V
C) 0.032 V
D) 0.32 V
E) 1.0 V

Answer: D

5) A uniform magnetic field is applied perpendicular to the plane of a 60–turn circular coil with a radius of 6.0 cm and a resistance of 0.60 Ω. If the magnetic field increases uniformly from 0.20 T to 1.8 T in 0.20 s, what is the magnitude of the emf induced in the coil?

A) 7.2 V
B) 5.4 V
C) 9.2 V
D) 12 V
E) 16 V

Answer: B

6) A loop of radius $r = 3.0$ cm is placed parallel to the xy–plane in a uniform magnetic field $\vec{B}$ = 0.75 T $\hat{k}$. The resistance of the loop is 18 Ω. Starting at $t = 0$, the magnitude of the field decreases uniformly to zero in 0.15 seconds. What is the magnitude of the electric current produced in the loop during that time?
A) 0.79 mA
B) 3.9 mA
C) 1.7 mA
D) 2.1 mA
E) 0.20 mA

Answer: A

7) A circular coil of radius 5.0 cm and resistance 0.20 Ω is placed in a uniform magnetic field perpendicular to the plane of the coil. The magnitude of the field changes with time according to $B = 0.50e^{-20t}$ T. What is the magnitude of the current induced in the coil at the time $t = 2.0$ s?
A) 1.3 mA
B) 9.2 mA
C) 7.5 mA
D) 4.2 mA
E) 2.6 mA

Answer: E

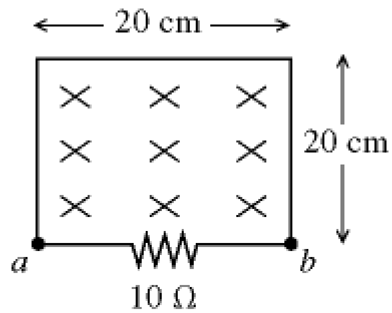
8) A coil of 160 turns and area 0.20 m^2 is placed with its axis parallel to a magnetic field of initial magnitude 0.40 T. The magnetic field changes uniformly from 0.40 T in the $+x$ direction to 0.40 T in the $-x$ direction in 2.0 s. If the resistance of the coil is 16 Ω, at what rate is power generated in the coil?
A) 5.0 W
B) 10 W
C) 15 W
D) 20 W
E) 25 W

Answer: B

9) A closed loop conductor that forms a circle with a radius of 2.0 m is located in a uniform but changing magnetic field. If the maximum emf induced in the loop is 5.0 V, what is the maximum rate at which the magnetic field strength is changing if the magnetic field is oriented perpendicular to the plane in which the loop lies?
A) 0.40 T/s
B) 2.5 T/s
C) 0.080 T/s
D) 5.0 T/s

Answer: A

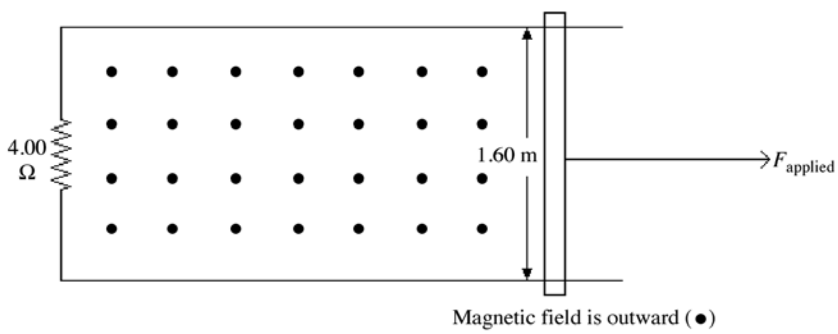
10) As shown in the figure, a wire and a 10-Ω resistor are used to form a circuit in the shape of a square, 20 cm by 20 cm. A uniform but nonsteady magnetic field is directed into the plane of the circuit. The magnitude of the magnetic field is decreased from 1.50 T to 0.50 T in a time interval of 63 ms. The average induced current and its direction through the resistor, in this time interval, are closest to



A) 63 mA, from *b* to *a*.
B) 38 mA, from *b* to *a*.
C) 63 mA, from *a* to *b*.
D) 38 mA, from *a* to *b*.
E) 95 mA, from *a* to *b*.

Answer: A

11) A conducting bar moves along frictionless conducting rails connected to a 4.00-Ω resistor as shown in the figure. The length of the bar is 1.60 m and a uniform magnetic field of 2.20 T is applied perpendicular to the paper pointing outward, as shown.
(a) What is the applied force required to move the bar to the right with a constant speed of 6.00 m/s?
(b) At what rate is energy dissipated in the 4.00 Ω resistor?



Answer: (a) 18.6 N (b) 112 W

12) A conducting bar slides without friction on two parallel horizontal rails that are 50 cm apart and connected by a wire at one end. The resistance of the bar and the rails is constant and equal to 0.10 Ω. A uniform magnetic field is perpendicular to the plane of the rails. A 0.080-N force parallel to the rails is required to keep the bar moving at a constant speed of 0.50 m/s. What is the magnitude of the magnetic field?
A) 0.10 T
B) 0.25 T
C) 0.36 T
D) 0.54 T
E) 0.93 T

Answer: B

13) A 50-cm wire placed in an east-west direction is moved horizontally to the north with a speed of 2.0 m/s. The horizontal component of the earth's magnetic field at that location is 25 μT toward the north and the vertical component is 50μT downward. What is the emf induced between the ends of the wire?
A) 10 μV
B) 20 μV
C) 30 μV
D) 40 μV
E) 50 μV

Answer: E

14) For a long ideal solenoid having a circular cross-section, the magnetic field strength within the solenoid is given by the equation $B(t) = 5.0t$ T, where t is time in seconds. If the induced electric field outside the solenoid is 1.1 V/m at a distance of 2.0 m from the axis of the solenoid, find the radius of the solenoid.
A) 0.30 m
B) 77 m
C) 0.94 m
D) 9.0 m

Answer: C

15) The coil in a 60-Hz ac generator has 125 turns, each having an area of 3.0×10^{-2} m^2 and is rotated in a uniform 0.12-T magnetic field. What is the peak output voltage of this generator?
A) 170 V
B) 120 V
C) 200 V
D) 110 V
E) 220 V

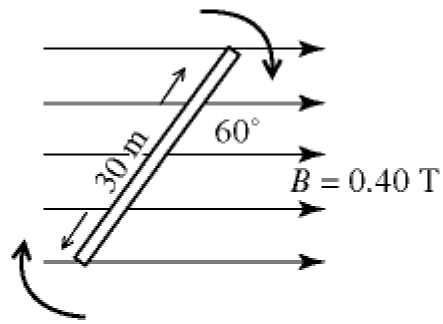
Answer: A

16) Suppose that you wish to construct a simple ac generator having an output of 12 V maximum when rotated at 60 Hz. A uniform magnetic field of 0.050 T is available. If the area of the rotating coil is 100 cm^2, how many turns do you need?
A) 8
B) 16
C) 32
D) 64
E) 128
Answer: D

17) You are designing a generator to have a maximum emf of 8.0 V. If the generator coil has 200 turns and a cross-sectional area of 0.030 m^2, what should be the frequency of the generator in a uniform magnetic field of 0.030 T?
A) 7.1 Hz
B) 7.5 Hz
C) 8.0 Hz
D) 22 Hz
E) 44 Hz
Answer: A

18) A rectangular coil having *N* turns and measuring 15 cm by 25 cm is rotating in a uniform 1.6-T magnetic field with a frequency of 75 Hz. The rotation axis is perpendicular to the direction of the field. If the coil develops a sinusoidal emf of maximum value 56.9 V, what is the value of *N*?
A) 2
B) 4
C) 6
D) 8
E) 10
Answer: A

19) Wire is wound on a square frame, 30 cm by 30 cm, to form a coil of 7 turns. The frame is mounted on a horizontal shaft through its center (perpendicular to the plane of the diagram), as shown in the figure. The coil is in clockwise rotation, with a period of 0.060 s. A uniform, horizontal, magnetic field of magnitude 0.40 T is present. At a given instant, the plane of the coil forms a 60° angle with the horizontal, as shown. At that instant, what is the magnitude of the emf induced in the coil?



A) 13 V
B) 23 V
C) 2.1 V
D) 3.6 V
E) 26 V

Answer: A

20) What is the self-inductance of a solenoid 30.0 cm long having 100 turns of wire and a cross-sectional area of 1.00×10^{-4} m^2? ($\mu_0 = 4\pi \times 10^{-7}$ T · m/A)

A) 4.19 nH
B) 4.19 pH
C) 4.19 μH
D) 4.19 mH
E) 4.19 H

Answer: C

21) At what rate would the current in a 100-mH inductor have to change to induce an emf of 1000 V in the inductor?

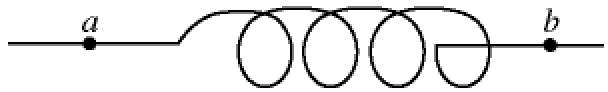
A) 100 A/s
B) 1 A/s
C) 1000 A/s
D) 10,000 A/s
E) 10 A/s

Answer: D

22) An inductor has a current $I(t) = (0.500\text{ A})\cos[(275\text{ s}^{-1})t]$ flowing through it. If the maximum emf across the inductor is equal to 0.500 V, what is the self-inductance of the inductor?
A) 4.37 mH
B) 3.64 mH
C) 2.75 mH
D) 0.73 mH
E) 1.43 mH

Answer: B

23) In the figure, the current in a solenoid having no appreciable resistance is flowing from *b* to *a* and is decreasing at a rate of 9.6 A/s. The self-induced emf in the solenoid is found to be 8.4 V.



(a) What is the self-inductance of the solenoid?
(b) Which point, *a* or *b* is at higher potential?

Answer: (a) 0.88 H (b) point *a*

24) An insulated wire of diameter 1.0 mm and negligible resistance is wrapped tightly around a cylindrical core of radius 5.0 cm and length 30 cm to build a solenoid. What is the energy stored in this solenoid when a current $I = 0.20$ A flows through it? ($\mu_0 = 4\pi \times 10^{-7}\text{ T} \cdot \text{m/A}$)
A) 1.2×10^{-4} J
B) 9.6×10^{-4} J
C) 4.8×10^{-4} J
D) 2.4×10^{-4} J
E) 5.9×10^{-5} J

Answer: E

25) A solenoid of length 0.700 m having a circular cross-section of radius 5.00 cm stores 6.00 μJ of energy when a 0.400-A current runs through it. What is the winding density of the solenoid? ($\mu_0 = 4\pi \times 10^{-7}\text{ T} \cdot \text{m/A}$)
A) 865 turns/m
B) 472 turns/m
C) 1080 turns/m
D) 104 turns/m
E) 327 turns/m

Answer: D

26) At a certain instant the current flowing through a 5.0-H inductor is 3.0 A. If the energy in the inductor at this instant is increasing at a rate of 3.0 J/s, how fast is the current changing?
A) 0.20 A/s
B) 0.40 A/s
C) 0.10 A/s
D) 0.80 A/s

Answer: A

27) How much energy is stored in a room 3.0 m by 4.0 m by 2.4 m due to the earth's magnetic field with a strength of 5.0×10^{-5} T? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 570 mJ.
B) 29 mJ.
C) 10 mJ.
D) 100 mJ.
E) 570 mJ.

Answer: B

28) What is the energy density in the magnetic field 25 cm from a long straight wire carrying a current of 12 A? ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)

A) 7.3×10^{-5} J/m^3
B) 3.7×10^{-5} J/m^3
C) 3.6×10^{-4} J/m^3
D) 1.2×10^{-4} J/m^3
E) The density cannot be determined without knowing the volume.

Answer: B

29) A series circuit consists of a 0.55-H inductor with internal resistance of 8.0 Ω connected in series with a 4.0-Ω resistor, an open switch, and an ideal 12-V battery.
(a) When the switch is closed, what is the initial current through the 4.0-Ω resistor?
(b) What is the current through the 4.0-Ω resistor a very long time after the switch is closed?

Answer: (a) 0.00 A (b) 1.0 A

30) A 45-mH ideal inductor is connected in series with a 60-Ω resistor through an ideal 15-V DC power supply and an open switch. If the switch is closed at time $t = 0$ s, what is the current 7.0 ms later?

A) 250 mA
B) 650 mA
C) 550 mA
D) 280 mA
E) 850 mA

Answer: A

31) A series *LR* circuit consists of a 2.0-H inductor with negligible internal resistance, a 100-ohm resistor, an open switch, and a 9.0-V ideal power source. After the switch is closed, what is the maximum power delivered by the power supply?

A) 0.40 W
B) 81 W
C) 0.090 W
D) 8.1 W
E) 0.81 W

Answer: E

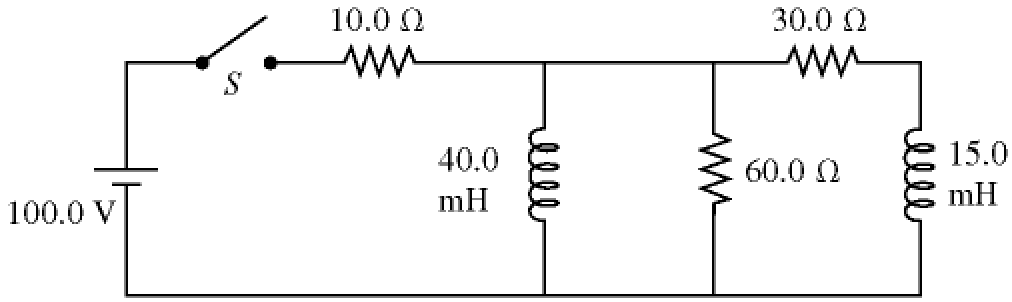
32) What resistance should be added in series with a 3.0–H inductor to complete an *LR* circuit with a time constant of 4.0 ms?
A) 0.75 k Ω
B) 12 Ω
C) 0.75 Ω
D) 2.5 Ω
Answer: A

33) A series *LR* circuit contains an emf source of 14 V having no internal resistance, a resistor, a 34 H inductor having no appreciable resistance, and a switch. If the emf across the inductor is 80% of its maximum value 4.0 s after the switch is closed, what is the resistance of the resistor?
A) 14 Ω
B) 1.9 Ω
C) 1.5 Ω
D) 5.0 Ω
Answer: B

34) An *LR* circuit contains an ideal 60–V battery, a 42–H inductor having no resistance, a 24–Ω resistor, and a switch *S*, all in series. Initially, the switch is open and has been open for a very long time. At time $t = 0$ s, the switch is suddenly closed. How long after closing the switch will the potential difference across the inductor be 24 V?
A) 1.6 s
B) 1.4 s
C) 1.8 s
D) 1.9 s
E) 2.1 s
Answer: A

35) An *LR* circuit contains an ideal 60–V battery, a 51–H inductor having no resistance, a 21–Ω resistor, and a switch *S*, all in series. Initially, the switch is open and has been open for a very long time. At time $t = 0$ s, the switch is suddenly closed. When the voltage across the resistor is equal to the voltage across the inductor, what is the current in the circuit?
A) 1.4 A
B) 0.57 A
C) 1.1 A
D) 0.86 A
E) 1.7 A
Answer: A

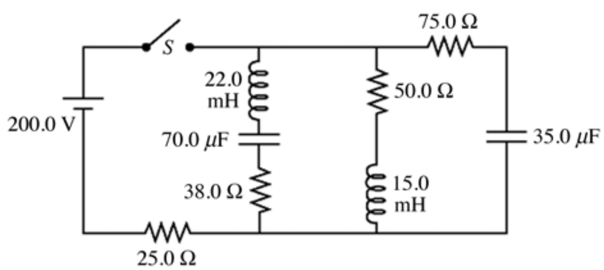
36) For the circuit shown in the figure, the inductors have no appreciable resistance and the switch has been open for a very long time.



(a) The instant after closing the switch, what is the current through the 60.0-Ω resistor?
(b) The instant after closing the switch, what is the potential difference across the 15.0-mH inductor?
(c) After the switch has been closed and left closed for a very long time, what is the potential drop across the 60.0-Ω resistor?

Answer: (a) 1.43 A (b) 85.7 V (c) 0.00 V

37) For the circuit shown in the figure, the switch has been open for a very long time.



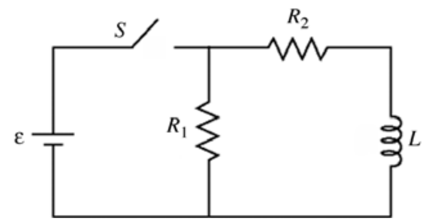
(a) What is the potential drop across the 15.0-mH inductor just after closing the switch?
(b) What is the potential drop across the 70.0-μF capacitor after the switch has been closed for a very long time?

Answer: (a) 150.0 V (b) 133 V

38) An ideal solenoid is 18.5 cm long, has a circular cross-section 2.20 cm in diameter, and contains 545 equally spaced thin windings. This solenoid is connected in a series circuit with an open switch, a 15.0-Ω resistor, and a battery of internal resistance 5.00 Ω and open-circuit terminal voltage of 25.0 V. ($\mu_0 = 4\pi \times 10^{-7}$ T • m/A)
(a) What is the maximum amount of energy that the solenoid will store after closing the switch?
(b) How long after closing the switch will it take for the stored energy in the solenoid to reach one-half of its maximum value?

Answer: (a) 0.599 mJ (b) 47.1 μs

39) Consider the circuit shown in the figure. The battery has emf $\varepsilon = 25$ volts and negligible internal resistance. The inductance is $L = 0.80$ H and the resistances are $R_1 = 12\ \Omega$ and $R_2 = 9.0\ \Omega$. Initially the switch S is open and no currents flow. Then the switch is closed.



(a) What is the current in the resistor R_1 just after the switch is closed?

(b) After leaving the switch closed for a very long time, it is opened again. Just after it is opened, what is the current in R_1?

Answer: (a) 2.1 A (b) 2.8 A

Chapter 28 Alternating–Current Circuits

28.1 Conceptual Questions

1) An ac source of period T and maximum voltage V is connected to a single unknown ideal element that is either a resistor, and inductor, or a capacitor. At time $t = 0$ the voltage is zero. At time $t = T/4$ the current in the unknown element is equal to zero, and at time $t = T/2$ the current is $I = -I_{max}$, where I_{max} is the current amplitude. What is the unknown element?
   A) a resistor
   B) an inductor
   C) a capacitor
   D) an inductor or a capacitor

   Answer: C

2) A resistor is connected to an ideal ac power supply.
   (a) The phase angle between the current and voltage is
   A) 0
   B) $\pi/2$ radians.
   C) $-\pi/2$ radians.
   D) π radians.
   E) $3\pi/4$ radians.
   (b) The current in the resistor
   A) leads the voltage across the resistor by 90°.
   B) lags the voltage across the resistor by 90°.
   C) is in phase with the voltage across the resistor.
   D) the voltage across the resistor by 45°.
   E) lags the voltage across the resistor by 45°.
   (c) How does the average power dissipated in the resistor change as the frequency in the ac power supply decreases?
   A) It decreases.
   B) It increases.
   C) It does not change.
   D) It increases or decreases depending on the sign of the phase angle.

   Answer: (a) A (b) C (c) C

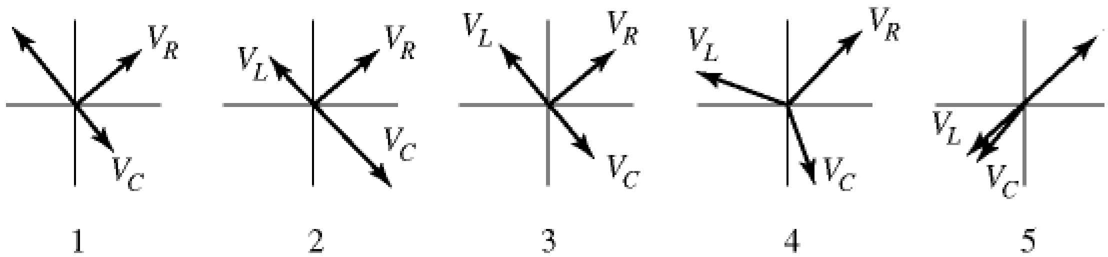
3) When an LRC series circuit is at resonance, which one of the following statements about that circuit is accurate? (There may be more than one correct choice.)
   A) The impedance has its maximum value.
   B) The reactance of the inductor is zero.
   C) The reactance of the capacitor is zero.
   D) The reactance due to the inductor and capacitor has its maximum value.
   E) The current amplitude is a maximum.

   Answer: E

4) In a series *LRC* circuit, the frequency at which the circuit is at resonance is f_0. If you double the resistance, the inductance, the capacitance, and the voltage amplitude of the ac source, what is the new resonance frequency?
   A) 4 f_0
   B) 2 f_0
   C) f_0
   D) $f_0/2$
   E) $f_0/4$

   Answer: D

5) Which one of the phasor diagrams shown below best represents a series *LRC* circuit driven at resonance?



   A) 1
   B) 2
   C) 3
   D) 4
   E) 5

   Answer: C

6) When an *LRC* series circuit is driven at resonance, which of the following statements about the circuit are correct? (There may be more than one correct choice.)
   A) The impedance of the circuit is zero.
   B) The impedance of the circuit has its maximum value.
   C) The impedance of the circuit has its minimum value.
   D) The inductive reactance and the capacitive reactance are both zero.
   E) The inductive reactance and the capacitive reactance are exactly equal to each other.

   Answer: C, E

28.2 Problems

1) (a) In an ac circuit, if the peak value of the voltage is 100 V, what is the rms value of the voltage?
   A) 141 V
   B) 100 V
   C) 210 V
   D) 71 V
   E) 120 V

   (b) In an ac circuit, if the rms value of the current is 100 mA, what is the peak value of the current?
   A) 141 mA
   B) 100 mA
   C) 210 mA
   D) 71 mA
   E) 120 mA

   Answer: (a) D (b) A

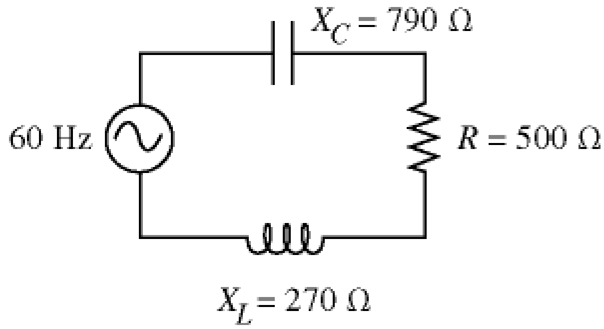
2) An alternating current is supplied to an electronic component with a warning that the voltage across it should never exceed 12 V. What is the highest rms voltage that can be supplied to this component while staying below the voltage limit in the warning?
   A) $6\sqrt{2}$ V
   B) $12\sqrt{2}$ V
   C) 144 V
   D) 6 V

   Answer: A

3) The inductor in a radio receiver carries a current of amplitude 200 mA when a voltage of amplitude 2.40 V is across it at a frequency of 1400 kHz. What is the value of the inductance?
   A) 1.43 μH
   B) 1.36 μH
   C) 9.20 μH
   D) 4.42 μH
   E) 1.97 μH

   Answer: B

4) The 60–Hz ac source of the series circuit shown in the figure has a voltage amplitude of 120 V. The capacitive reactance is 790 Ω, the inductive reactance is 270 Ω, and the resistance is 500Ω.



(a) What is the capacitance of the capacitor?
(b) What is the inductance of the inductor?

Answer: (a) 3.4 μF (b) 720 mH

5) If the voltage amplitude across an 8.50–nF capacitor is equal to 12.0 V when the current amplitude through it is 3.33 mA, the frequency is closest to:

A) 32.6 MHz
B) 5.20 MHz
C) 32.6 kHz
D) 5.20 kHz
E) 32.6 Hz

Answer: B

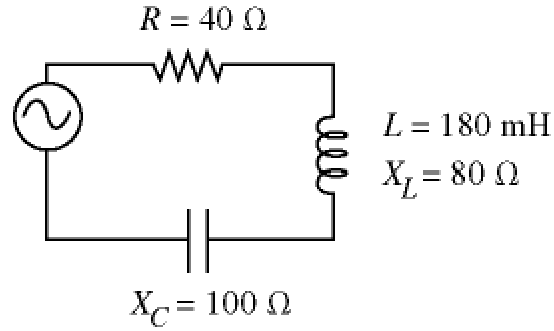
6) An ac series circuit consists of a voltage source, an 880–Ω resistor, and an inductance L. (There is no capacitance in the circuit.) The current amplitude is 0.60 A, and the phase angle between the source voltage and the current has a magnitude of 41°
(a) Does the source voltage lag or lead the current?
(b) What is the voltage amplitude of the source?

Answer: (a) The source voltage leads the current.
(b) 700 volts

7) An LRC series circuit has $R = 15.0\ \Omega$, $L = 25.0$ mH, and $C = 30.0\ \mu$F. The circuit is connected to a 120–V (rms) ac source with frequency 200 Hz.
(a) What is the impedance of the circuit?
(b) What is the rms current in the circuit?
(c) What is the rms voltage across the resistor?
(d) What is the rms voltage across the inductor?
(e) What is the rms voltage across the capacitor?

Answer: (a) 15.8 Ω (b) 7.61 A (c) 114 V (d) 239 V (e) 202 V

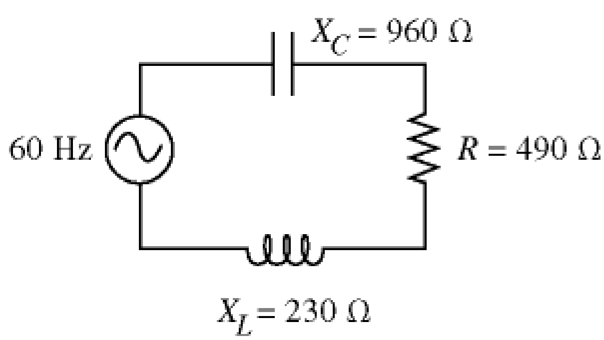
8) An ac circuit is shown in the figure. The rms current in the circuit is measured to be 1.8 A. What is the capacitance of the capacitor?



A) 23 μF
B) 24 μF
C) 21 μF
D) 19 μF
E) 18 μF

Answer: A

9) The 60–Hz ac source of a series circuit has a voltage amplitude of 120 V. The resistance, capacitive reactance, and inductive reactance are as shown in the figure. What is the rms current in the circuit?



A) 0.097 A
B) 0.11 A
C) 0.12 A
D) 0.14 A
E) 0.17 A

Answer: A

10) A series ac circuit consists of an inductor having a reactance of 80 Ω and an inductance of 190 mH, a 40–Ω resistor, a capacitor whose reactance is 100 Ω, and an ac source. The rms current in the circuit is measured to be 2.2 A. What is the rms voltage of the source?

A) 98 V
B) 96 V
C) 93 V
D) 91 V
E) 88 V

Answer: A

11) A 120–V rms voltage at 1000 Hz is applied to an inductor, a 2.00–μF capacitor and a 100–Ω resistor, all in series. If the rms value of the current in this circuit is 0.680 A, what is the inductance of the inductor?
A) 34.2 mH
B) 35.8 mH
C) 11.4 mH
D) 17.9 mH
E) 22.8 mH

Answer: B

12) A series *LRC* circuit has a sinusoidal voltage supplied to it at 197 kHz with a peak voltage of 270 V, a 41–kΩ resistance, a 14–μF capacitor, and a 63–H inductance. What is the peak current for this circuit?
A) 3.5 μA
B) 2.3 μA
C) 4.2 μA
D) 6.6 μA

Answer: A

13) A series circuit consists of a 50–Hz ac source, a 50–Ω resistor, a 0.50–H inductor, and a 60–μF capacitor. The rms current in the circuit is measured to be 3.1 A. What is the voltage amplitude of the source?
A) 510 V
B) 270 V
C) 220 V
D) 180 V
E) 160 V

Answer: A

14) A series circuit consists of ac source, a 90–Ω resistor, a 0.80–H inductor, and an 80–μF capacitor. The frequency of the source is adjusted so that the capacitive reactance is equal to twice the inductive reactance. What is the frequency of the source?
A) 14 Hz
B) 13 Hz
C) 16 Hz
D) 17 Hz
E) 19 Hz

Answer: A

15) An *LRC* series circuit consists of an 85.0–Ω resistor, a 14.0–μF capacitor, a 1.50–mH inductor, and a variable frequency ac source of voltage amplitude 13.25 V. At what angular frequency will the inductive reactance be 4.00 times as large as the capacitive reactance?
A) 1.38×10^4 rad/s
B) 6.90×10^3 rad/s
C) 3.45×10^4 rad/s
D) 2.20×10^4 rad/s
E) 1.10×10^4 rad/s

Answer: A

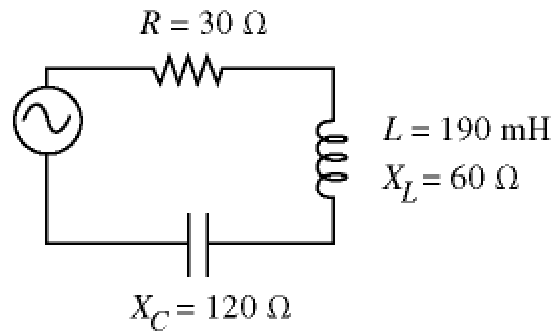
16) A series ac circuit consists of a voltage source of frequency 60 Hz and source voltage amplitude 345 volts, a 701–Ω resistor, a 1.6 –μF capacitor, and an inductor of inductance L.
(a) What must be the value of L for the phase angle to be zero?
(b) When L has the value calculated in part (a), what is the current amplitude in the circuit?

Answer: (a) 4.4 H (b) 0.492 A

17) A series *LRC* circuit consists of an ac voltage source of amplitude 75.0 V and variable frequency, a 12.5–μF capacitor, a 5.00–mH inductor, and a 35.0–Ω resistor.
(a) To what angular frequency should the ac source be set so that the current amplitude has its largest value?
(b) Under the conditions of part (a), what is the maximum current amplitude?
(c) Suppose that the voltage source is set to twice the angular frequency needed in part (a). What will be the current amplitude in this case?

Answer: (a) 4.00×10^3 rad/s (b) 2.14 A (c) 1.63 A

18) An ac circuit is shown in the figure. The rms current in the circuit is 1.3 A. What is the peak magnetic energy in the inductance?



A) 0.32 J
B) 0.16 J
C) 0.48 J
D) 0.64 J
E) 0.80 J

Answer: A

19) A 120–V rms voltage at 60.0 Hz is applied across an inductor, a capacitor, and a resistor in series. If the peak current in this circuit is 0.8484 A, what is the impedance of this circuit?
A) 200 Ω
B) 141 Ω
C) 20.4 Ω
D) 120 Ω
E) 100 Ω

Answer: A

20) A 25.0–mH inductor, a 2.00–μF capacitor, and a certain resistor are connected in series across an ac voltage source at 1000 Hz. If the impedance of this circuit is 200 Ω, what is the resistance of the resistor?
A) 100 Ω
B) 184 Ω
C) 200 Ω
D) 552 Ω
E) 579 Ω

Answer: B

21) A series circuit has a resistance of 4.0 Ω, a reactance (due to the capacitance) of 21.0 Ω, and a reactance (due to the inductance) of 17.0 Ω. Find the impedance of the circuit.
A) 5.7 Ω
B) 27 Ω
C) 8.0 Ω
D) 42 Ω

Answer: A

22) The phase angle of an *LRC* series circuit with an inductive reactance of 200 Ω and a capacitive reactance of 100 Ω is 40.0°. What is the value of the resistor in this circuit?
A) 100 Ω
B) 119 Ω
C) 156 Ω
D) 200 Ω
E) 265 Ω

Answer: B

23) The phase angle of an *LRC* series circuit with an inductive reactance of 200 Ω, a resistor of 200 Ω and a certain capacitor at 1000 Hz is 40.0°. What is the value of the capacitance in this circuit?
A) 1.95 μF
B) 2.95 μF
C) 3.95 μF
D) 4.95 μF
E) 5.95 μF

Answer: D

24) The phase angle of an *LRC* series circuit with a capacitive reactance of 40 Ω, a resistor of 100 Ω and a certain inductor at 1000 Hz is 40.0°. What is the value of the inductance in this circuit?
A) 11.8 mH
B) 124 mH
C) 212 mH
D) 61.9 mH
E) 19.7 mH

Answer: E

25) An *LRC* series circuit has voltage supplied to it at a frequency of 13.0 kHz with a phase difference between the current and the voltage of magnitude 0.20 rad. If the circuit has a capacitance of 5.0 μF and an inductance of 0.050 H find the resistance of the circuit.
A) 20 kΩ
B) 0.99 kΩ
C) 9.0 kΩ
D) 0.32 kΩ
Answer: A

26) A series *LRC* ac circuit has a resistance of 4.0 kΩ, a capacitance of 33.0 μF, and an inductance of 23.0 H. If the frequency of the alternating current is 2.0/π kHz, what is the phase angle between the voltage and the current?
A) 1.5 rad
B) -1.6 rad
C) 23 rad
D) 3.1 rad
Answer: A

27) An *LRC* ac series circuit has $R = 15\ \Omega$, $L = 25$ mH, and $C = 30\ \mu$F. The circuit is connected to a 120-V (rms) ac source with frequency 200 Hz.
(a) What is the average power dissipated by the circuit?
(b) What is the power factor for the circuit?
Answer: (a) 870 W (b) 0.95

28) An *LRC* ac series circuit with $R = 15\ \Omega$, $L = 25$ mH, and $C = 30\ \mu$F, is attached to a 100-V (rms) ac power supply. The frequency of the power supply is adjusted so that the circuit is in resonance.
(a) What is the rms current in the circuit?
(b) What is the power dissipated by the circuit?
Answer: (a) 6.7 A (b) 670 W

29) What is the average power dissipated by a 25-Ω resistor in an *LRC* series ac circuit for which the power factor is equal to 0.25 and the maximum voltage of the ac source is 8.0 V?
A) 0.040 W
B) 0.32 W
C) 0.16 W
D) 0.62 W
E) 0.080 W
Answer: E

30) A series *LRC* ac circuit has a peak voltage of 111 V and a peak current of 2.00 A. If the current lags the voltage by 35.0°, what is the average power of the circuit?
A) 91 W
B) 182 W
C) 78 W
D) 156 W
Answer: A

31) An *LRC* ac circuit has a reactance (due to its capacitance) of 17 kΩ, a reactance (due to its inductance) of 9.0 kΩ, and a resistance of 28 kΩ. What is the power factor of the circuit?
A) 0.96
B) 0.28
C) 1.04
D) 0.48

Answer: A

32) For an *RLC* ac circuit, the rms current is 10 A. If the impedance is 12 kΩ when the voltage leads the current by 39°, find the average power of the circuit.
A) 930 kW
B) 47 kW
C) 93 kW
D) 190 kW

Answer: A

33) A series *LRC* ac circuit has a peak current of 1.0 A with a frequency of 54 kHz. If the resistance of the circuit is 51 kΩ, the capacitance of the circuit is 19 μF, and the inductance of the circuit is 25 μH, determine the average power of the circuit.
A) 26 kW
B) 77 kW
C) 7.7 kW
D) 4.1 kW

Answer: A

34) A series circuit consists of a 50–Hz ac source, a 40–Ω resistor, a 0.30–H inductor, and a 60–μF capacitor. The rms current in the circuit is measured to be 1.6 A. What is the power factor of the circuit?
A) 0.70
B) 0.66
C) 0.63
D) 0.59
E) 0.56

Answer: A

35) An ac series circuit consists of a voltage source of frequency 60 Hz and voltage amplitude *V*, a 533–Ω resistor, and a capacitor of capacitance 6.4 μF. What must be the source voltage amplitude *V* for the average electrical power consumed in the resistor to be 989 W? There is no inductance in the circuit.

Answer: 1300 V

36) For an *LRC* series circuit containing a resistance of 11.0 kΩ, a capacitance of 2.0 μF, and an inductance of 24.0 H, what frequency is needed to minimize the impedance?
A) 0.023 kHz
B) 0.14 kHz
C) 10 kHz
D) 1.7 kHz

Answer: A

37) A series *LRC* circuit consists of a 100-Ω resistor, a 0.100-μF capacitor and a 2.00-mH inductor connected across a 120-V rms ac voltage source operating at $\frac{1000}{\pi}$. At what frequency will this circuit be in resonance?
A) 70.7 kHz
B) 17.9 kHz
C) 22.5 kHz
D) 35.3 kHz
E) 11.3 kHz
Answer: E

38) An ac source having a maximum voltage output of 30 V is connected in series with a 50-Ω resistor, a 0.60-H inductor, and a 20-μF capacitor. What is the maximum charge on the capacitor when the frequency of the source is adjusted so that the circuit is in resonance?
A) 1.0 mC
B) 0.00 mC
C) 2.1 mC
D) 4.2 mC
E) 8.4 mC
Answer: C

39) A series *LRC* circuit consists of a 5.00-pF capacitor, a 7.25-mH inductor, a 75.0-Ω resistor, and a 50.0-V ac power source of variable frequency. At what frequency will the impedance of this circuit be equal to 75.0 Ω?
Answer: 836 kHz

40) A series *LRC* circuit consists of a 12.0-mH inductor, a 15.0-μF capacitor, a resistor, and a 110-V (rms) ac voltage source. If the impedance of this circuit is 45.0 Ω at resonance, what is its impedance at a frequency twice the resonance frequency?
Answer: 61.8 Ω

41) The primary coil of a transformer has 100 turns and its secondary coil has 400 turns. If the ac voltage applied to the primary coil is 120 V, what voltage is present in its secondary coil?
A) 100 V
B) 30 V
C) 70 V
D) 480 V
E) 400 V
Answer: D

42) A transformer changes the 10,000 V power line to 120 V. If the primary coil contains 750 turns, how many turns are on the secondary?
A) 3
B) 6
C) 9
D) 63,000
E) 21,000
Answer: C

43) In a transformer, how many turns are necessary in a 110–V primary if the 24–V secondary has 100 turns?
A) 458
B) 240
C) 110
D) 22
E) 4

Answer: A

44) When a current of 2.0 A flows in the 100–turn primary of an ideal transformer, this causes 14 A to flow in the secondary. How many turns are in the secondary?
A) 700
B) 356
C) 114
D) 14
E) 4

Answer: D

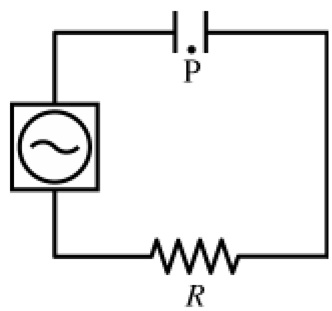
45) An ideal transformer consists of a 500–turn primary coil and a 2000–turn secondary coil. If the current in the secondary is 3.0 A, what is the current in the primary?
A) 0.75 A
B) 1.3 A
C) 12 A
D) 24 A
E) 48 A

Answer: C

Chapter 29 Maxwell's Equations and Electromagnetic Waves

29.1 Conceptual Questions

1) A capacitor is hooked up to a resistor and an AC voltage source as shown in the figure. The output of the source is given by $V(t) = V_0 \sin \omega t$. The plates of the capacitor are disks of radius R. Point P is directly between the two plates, equidistant from them and a distance $R/2$ from the center axis. At point P



A) there is no magnetic field because there is no charge moving between the plates.
B) there is a constant magnetic field.
C) there is a time-varying magnetic field.

Answer: C

2) Which one of the following lists is a correct representation of electromagnetic waves from longer wavelength to shorter wavelength?
A) radio waves, infrared, microwaves, UV, visible, X-rays, gamma rays
B) radio waves, UV, X-rays, microwaves, infrared, visible, gamma rays
C) radio waves, microwaves, visible, X-rays, infrared, UV, gamma rays
D) radio waves, microwaves, infrared, visible, UV, X-rays, gamma rays
E) radio waves, infrared, X-rays, microwaves, UV, visible, gamma rays

Answer: D

3) In an electromagnetic wave, the electric and magnetic fields are oriented such that they are
A) parallel to one another and perpendicular to the direction of wave propagation.
B) parallel to one another and parallel to the direction of wave propagation.
C) perpendicular to one another and perpendicular to the direction of wave propagation.
D) perpendicular to one another and parallel to the direction of wave propagation.

Answer: C

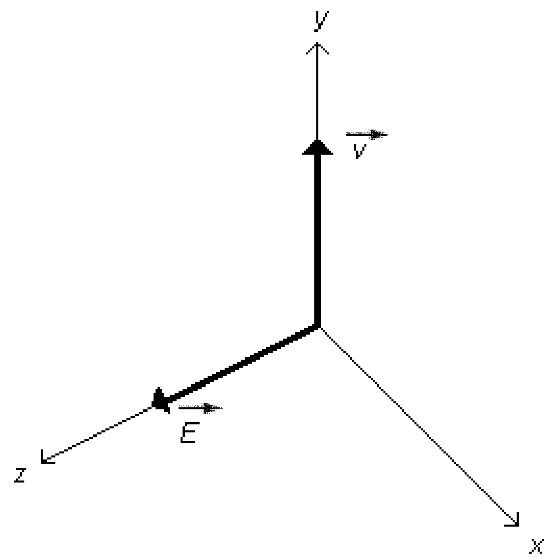
4) If the magnetic field of an electromagnetic wave is in the $+x$-direction and the electric field of the wave is in the $+y$-direction, the wave is traveling in the
A) xy-plane.
B) $+z$-direction.
C) $-z$-direction.
D) $-x$-direction.
E) $-y$-direction.

Answer: C

5) An electromagnetic wave is propagating towards the west. At a certain moment the direction of the magnetic field vector associated with this wave points vertically up. The direction of the electric field vector of this wave is
   A) horizontal and pointing south.
   B) vertical and pointing down.
   C) horizontal and pointing north.
   D) vertical and pointing up.
   E) horizontal and pointing east.

   Answer: A

6) An electromagnetic wave propagates along the $+y$ direction as shown in the figure. If the electric field at the origin is along the $+z$ direction, what is the direction of the magnetic field?



   A) $+z$
   B) $-z$
   C) $+y$
   D) $+x$
   E) $-x$

   Answer: D

7) The energy per unit volume in an electromagnetic wave is
   A) equally divided between the electric and magnetic fields.
   B) mostly in the electric field.
   C) mostly in the magnetic field.
   D) all in the electric field.
   E) all in the magnetic field.

   Answer: A

8) If an electromagnetic wave has components $E_y = E_0 \sin(kx - \omega t)$ and $B_z = B_0 \sin(kx - \omega t)$, in what direction is it traveling?
   A) $-x$
   B) $+x$
   C) $+y$
   D) $-y$
   E) $+z$
   Answer: B

9) When an electromagnetic wave falls on a white, perfectly reflecting surface, it exerts a force F on that surface. If the surface is now painted a perfectly absorbing black, what will be the force that the same wave will exert on the surface?
   A) $4F$
   B) $2F$
   C) F
   D) $F/2$
   E) $F/4$
   Answer: D

29.2 Problems

1) Given that the wavelengths of visible light range from 400 nm to 700 nm, what is the highest frequency of visible light? ($c = 3.0 \times 10^8$ m/s)
   A) 3.1×10^8 Hz
   B) 7.5×10^{14} Hz
   C) 2.3×10^{20} Hz
   D) 4.3×10^{14} Hz
   E) 5.0×10^8 Hz
   Answer: B

2) The magnitude of the electric field at a point P for a certain electromagnetic wave is 570 N/C. What is the magnitude of the magnetic field for that wave at P? ($c = 3.0 \times 10^8$ m/s)
   A) 2.91 μT
   B) 1.90 μT
   C) 1.10 μT
   D) 1.41 μT
   E) 2.41 μT
   Answer: B

3) The magnitude of the magnetic field at point P for a certain electromagnetic wave is 2.12 μT. What is the magnitude of the electric field for that wave at P? ($c = 3.0 \times 10^8$ m/s)
   A) 636 N/C
   B) 745 N/C
   C) 5.23 μN/C
   D) 6.36 μN/C
   E) 7.45 μN/C
   Answer: A

4) If the electric field and magnetic field of an electromagnetic wave are given by $E = E_0 \sin(kx - \omega t)$ and $B = B_0 \sin(kx - \omega t)$, and if the value of E_0 is 51 μV/m, what is the value of B_0? ($c = 3.0 \times 10^8$ m/s)
A) 1.7×10^{14} T
B) 1.7×10^{3} T
C) 1.7×10^{-14} T
D) 1.7×10^{4} T
E) 1.7×10^{-13} T
Answer: E

5) A planar electromagnetic wave is propagating in the $+x$ direction. At a certain point P and at a given instant, the electric field of the wave is given by $\vec{E} = (0.082 \text{ V/m}) \hat{j}$. What is the magnetic vector of the wave at the point P at that instant? ($c = 3.0 \times 10^8$ m/s)
A) 0.27 nT $\hat{k}$
B) -0.27 nT $\hat{k}$
C) 0.27 nT $\hat{j}$
D) 6.8 nT $\hat{k}$
E) -6.8 nT $\hat{j}$
Answer: A

6) If the z–component of the magnetic field of an electromagnetic wave traveling in the $+x$ direction through vacuum obeys the equation $B_z(x, t) = (1.25\ \mu\text{T}) \cos[(3800 \text{ m}^{-1})x - (1.14 \times 10^{-12} \text{ rad/s})t]$, what is the largest that the y component of the electric field can be? ($c = 3.0 \times 10^8$ m/s)
A) 375 N/C
B) 4.17×10^{-15} N/C
C) 3.75×10^{8} N/C
D) 4.17×10^{-9} N/C
E) 1.25×10^{6} N/C
Answer: A

7) The y component of the electric field of an electromagnetic wave traveling in the $+x$ direction through vacuum obeys the equation $E_y = (375 \text{ N/C}) \cos[kx - (2.20 \times 10^{14} \text{ rad/s})t]$. What is the wavelength of this electromagnetic wave? ($c = 3.0 \times 10^8$ m/s)
A) 0.272 μm
B) 1.36 μm
C) 2.72 μm
D) 8.57 μm
E) 17.1 μm
Answer: D

8) The y–component of the electric field of an electromagnetic wave traveling in the $+x$ direction through vacuum obeys the equation $E_y = (375 \text{ N/C}) \cos[kx - (2.20 \times 10^{14} \text{ rad/s})t]$. ($c = 3.0 \times 10^8$ m/s)
(a) What is the largest that the x–component of the wave can be?
(b) What is the largest that the z–component of the wave can be?
Answer: (a) zero (b) 1.25 μT

9) A planar electromagnetic wave is propagating in the $+x$ direction. At a certain point P and at a given instant, the electric field of the wave is given by $\vec{E} = (0.082 \text{ V/m})\,\hat{\boldsymbol{j}}$. What is the Poynting vector at the point P at that instant? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)
A) 18 μW/m^2 $\hat{\boldsymbol{i}}$
B) -18 μW/m^2 $\hat{\boldsymbol{i}}$
C) 9.0 μW/m^2 $\hat{\boldsymbol{i}}$
D) -9.0 μW/m^2 $\hat{\boldsymbol{i}}$
E) -18 μW/m^2 $\hat{\boldsymbol{k}}$
Answer: A

10) The magnitude of the Poynting vector of a planar electromagnetic wave has an average value of 0.724 W/m^2. What is the maximum value of the magnetic field in the wave? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)
A) 77.9 nT
B) 55.1 nT
C) 38.9 nT
D) 108 nT
E) 156 nT
Answer: A

11) The magnitude of the Poynting vector of a planar electromagnetic wave has an average value of 0.939 W/m^2. The wave is incident upon a rectangular area, 1.5 m by 2.0 m, at right angles. How much total electromagnetic energy falls on the area during 1.0 minute? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)
A) 170 J
B) 210 J
C) 250 J
D) 300 J
E) 340 J
Answer: A

12) The magnetic field of an electromagnetic wave has a peak value of 5.0×10^{-10} T. What is the intensity of the wave? ($c = 3.0 \times 10^8$ m/s, $c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 1.0×10^{-13} W/m^2
B) 1.5×10^{-5} W/m^2
C) 3.0×10^{-5} W/m^2
D) 2.0×10^{-13} W/m^2
E) 7.5×10^{5} W/m^2

Answer: C

13) A sinusoidal electromagnetic wave in vacuum delivers energy at an average rate of 5.00 μW/m^2. What are the amplitudes of the electric and magnetic fields of this wave? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

Answer: $E_{max} = 0.0614$ V/m, $B_{max} = 0.205$ nT

14) If the intensity of an electromagnetic wave is 80 MW/m^2, what is the amplitude of the magnetic field of this wave? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 0.82 mT
B) 0.33 μT
C) 10 T
D) 14 T
E) 0.58 mT

Answer: A

15) A laser with a power of 1.0 mW has a beam radius of 1.0 mm. What is the peak value of the electric field in that beam? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 490 V/m
B) 840 V/m
C) 65 V/m
D) 120 V/m
E) 22 V/m

Answer: A

16) If a beam of electromagnetic radiation has an intensity of 120 W/m^2, what is the maximum value of the electric field? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 1.5 kV/m
B) 1.0 μT
C) 1.0 μV/m
D) 0.30 kV/m
E) 0.0032 V/m

Answer: D

17) Near the earth the intensity of radiation from the sun is 1.35 kW/m^2. What volume of space in this region contains 1.0 J of electromagnetic energy? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 4.5×10^{-6} m^3
B) 3300 m^3
C) 7.4×10^{-4} m^3
D) 1400 m^3
E) 220,000 m^3

Answer: E

18) An electromagnetic wave has a peak electric field of 3.0 kV/m. What is the intensity of the wave? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 24 kW/m^2
B) 12 kW/m^2
C) 8.0 kW/m^2
D) 4.0 kW/m^2

Answer: B

19) An 800-kHz radio signal is detected at a point 4.5 km distant from a transmitter tower. The electric field amplitude of the signal at that point is 0.63 V/m. Assume that the signal power is radiated uniformly in all directions and that radio waves incident upon the ground are completely absorbed. What is the magnetic field amplitude of the signal at that point? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 2.1 nT
B) 1.7 nT
C) 1.3 nT
D) 2.5 nT
E) 2.9 nT

Answer: A

20) An 800-kHz radio signal is detected at a point 8.5 km distant from a transmitter tower. The electric field amplitude of the signal at that point is 0.90 V/m. Assume that the signal power is radiated uniformly in all directions and that radio waves incident upon the ground are completely absorbed. What is the average electromagnetic energy density at that point? ($c = 3.0 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 3.6 pJ/m^3
B) 5.1 pJ/m^3
C) 7.2 pJ/m^3
D) 10 pJ/m^3
E) 14 pJ/m^3

Answer: A

21) An 800-kHz radio signal is detected at a point 2.7 km distant from a transmitter tower. The electric field amplitude of the signal at that point is 0.36 V/m. Assume that the signal power is radiated uniformly in all directions and that radio waves incident upon the ground are completely absorbed. What is the intensity of the radio signal at that point? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 170 μW/m^2
B) 240 μW/m^2
C) 340 μW/m^2
D) 120 μW/m^2
E) 86 μW/m^2

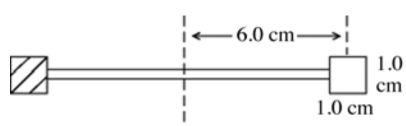
Answer: A

22) An 800-kHz radio signal is detected at a point 9.1 km distant from a transmitter tower. The electric field amplitude of the signal at that point is 0.440 V/m. Assume that the signal power is radiated uniformly in all directions and that radio waves incident upon the ground are completely absorbed. What is the average total power radiated by the transmitter? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 0.27 MW
B) 0.32 MW
C) 0.38 MW
D) 0.45 MW
E) 0.50 MW

Answer: A

23) A radiometer has two square vanes (each measuring 1.0 cm by 1.0 cm), attached to a light horizontal cross arm, and pivoted about a vertical axis through the center, as shown in the figure. The center of each vane is 6.0 cm from the axis. One vane is silvered and it reflects all radiant energy incident upon it. The other vane is blackened and it absorbs all incident radiant energy. An electromagnetic wave with an intensity of 0.30 kW/m^2 is incident normally upon the vanes. What is the electromagnetic power absorbed by the blackened vane? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)



A) 0.030 W
B) 0.040 W
C) 0.050 W
D) 0.060 W
E) 0.090 W

Answer: A

24) A microwave oven operates with sinusoidal microwaves at a frequency of 2400 MHz. The height of the oven cavity is 25 cm and the base measures 30 cm by 30 cm. Assume that microwave energy is generated uniformly on the upper surface of the cavity and propagates directly downward toward the base. The base is lined with a material that completely absorbs microwave energy. The total microwave energy content of the cavity is 0.50 μJ. What is the amplitude of the electric field? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 1600 V/m
B) 1900 V/m
C) 2200 V/m
D) 2500 V/m
E) 2800 V/m

Answer: C

25) A microwave oven operates with sinusoidal microwaves at a frequency of 2400 MHz. The height of the oven cavity is 25 cm and the base measures 30 cm by 30 cm. Assume that microwave energy is generated uniformly on the upper surface of the cavity and propagates directly downward toward the base. The base is lined with a material that completely absorbs microwave energy. The total microwave energy content of the cavity is 0.50 μJ. What is the power output of the oven? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 0.50 kW
B) 0.55 kW
C) 0.60 kW
D) 0.65 kW
E) 0.70 kW

Answer: C

26) A microwave oven operates with sinusoidal microwaves at a frequency of 2400 MHz. The height of the oven cavity is 25 cm and the base measures 30 cm by 30 cm. Assume that microwave energy is generated uniformly on the upper surface of the cavity and propagates directly downward toward the base. The base is lined with a material that completely absorbs microwave energy. The total microwave energy content of the cavity is 0.50 μJ. What is the intensity of the microwave beam? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 5.2 kW/m^2
B) 5.7 kW/m^2
C) 6.2 kW/m^2
D) 6.7 kW/m^2
E) 7.2 kW/m^2

Answer: D

27) A 7.5×10^{14} Hz laser emits a 7.7-μs pulse, 5.0 mm in diameter, with a beam energy density of 0.51 J/m^3. What is the amplitude of the electric field of the emitted waves? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)
A) 340 kV/m
B) 480 kV/m
C) 240 kV/m
D) 150 kV/m
E) 120 kV/m
Answer: A

28) 28) A sinusoidal electromagnetic wave is propagating in vacuum. At a given point P and at a particular time, the electric field is in the $+x$ direction and the magnetic field is in the $-y$ direction.
(a) What is the direction of propagation of the wave?
(b) If the intensity of the wave at point P is 0.36 W/m^2, what is the electric field amplitude at that point? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)
Answer: (a) $-z$ direction (b) 16 V/m

29) A very small source of light that radiates uniformly in all directions produces an electric field amplitude of 2.96 V/m at a point 33.0 m from the source. What is the power output from the source? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)
Answer: 159 W

30) The average intensity of the sunlight in Miami, Florida, is 1.04 kW/m^2. For surfaces on which the light is all absorbed, what is the average value of the radiation pressure due to this sunlight in Miami? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)
A) 2.28 μPa
B) 1.73 μPa
C) 6.93 μPa
D) 3.47 μPa
E) 9.78 μPa
Answer: D

31) The intensity of solar radiation near the earth is 1.4 kW/m^2. What force is exerted by solar radiation impinging normally on a 5.0 m^2 perfectly reflecting panel of an artificial satellite orbiting the earth? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)
A) 14 kN
B) 94 μN
C) 140 μN
D) 23 μN
E) 47 μN
Answer: E

32) The total electromagnetic power emitted by the sun is 3.8×10^{26} W. What is the radiation pressure on a totally absorbing satellite at the orbit of Mercury, which has an orbital radius of 5.8×10^{10} m? ($c = 3.00 \times 10^{8}$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)

A) 30 μPa
B) 0.30 μPa
C) 0.030 μPa
D) 300 μPa
E) 3.0 μPa

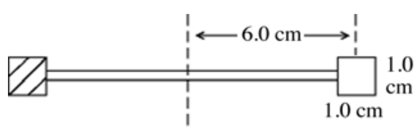
Answer: A

33) A 22.0-kg mirror with a surface area of 1.0 m^2 and a 98% reflectivity is bombarded by light of average intensity 770.0 W/m^2 at an angle of 30.0° to the normal of its surface. If the light has a duration of 0.60 s, how much does the velocity of the mirror change during that time? ($c = 3.00 \times 10^{8}$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)

A) 120 nm/s
B) 4.2 nm/s
C) 3.6 nm/s
D) 2.1 nm/s

Answer: A

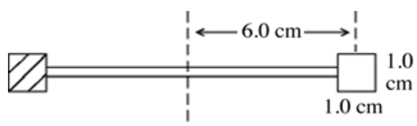
34) A radiometer has two square vanes (1.0 cm by 1.0 cm), attached to a light horizontal cross arm, and pivoted about a vertical axis through the center, as shown in the figure. The center of each vane is 6.0 cm from the axis. One vane is silvered and it reflects all radiant energy incident upon it. The other vane is blackened and it absorbs all incident radiant energy. An electromagnetic wave with an intensity of 0.30 kW/m^2 is incident normally upon the vanes. What is the radiation pressure on the blackened vane? ($c = 3.00 \times 10^{8}$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N • m^2)



A) 1.0×10^{-10} Pa
B) 1.0×10^{-9} Pa
C) 1.0×10^{-8} Pa
D) 1.0×10^{-7} Pa
E) 1.0×10^{-6} Pa

Answer: E

35) A radiometer has two square vanes (1.0 cm by 1.0 cm), attached to a light horizontal cross arm, and pivoted about a vertical axis through the center, as shown in the figure. The center of each vane is 6.0 cm from the axis. One vane is silvered and it reflects all radiant energy incident upon it. The other vane is blackened and it absorbs all incident radiant energy. An electromagnetic wave with an intensity of 0.30 kW/m^2 is incident normally upon the vanes. What is the torque due to radiation pressure on the vane assembly about the vertical axis? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)



A) 2.4×10^{-12} N • m
B) 6.0×10^{-12} N • m
C) 1.2×10^{-11} N • m
D) 1.8×10^{-11} N • m
E) 2.4×10^{-11} N • m

Answer: B

36) A microwave oven operates with sinusoidal microwaves at a frequency of 2400 MHz. The height of the oven cavity is 25 cm and the base measures 30 cm by 30 cm. Assume that microwave energy is generated uniformly on the upper surface of the cavity and propagates directly downward toward the base. The base is lined with a material that completely absorbs microwave energy. The total microwave energy content of the cavity is 0.50 μJ. What magnitude force does the microwave beam exert on the base of the oven? ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

A) 1.6 μN
B) 2.0 μN
C) 2.5 μN
D) 3.0 μN
E) 3.5 μN

Answer: B

37) A totally absorbing surface having an area of 7.7 cm^2 faces a small source of sinusoidal electromagnetic radiation that is 2.4 m away. At the surface, the electric field amplitude of the radiation is 84 V/m. ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)

(a) What is the radiation pressure exerted on the surface?
(b) What is the total power output of the source, if it is assumed to radiate uniformly in all directions?

Answer: (a) 0.031 μPa (b) 680 W

38) A laser beam has a wavelength of 633 nm and a power of 0.500 mW spread uniformly over a circle 1.20 mm in diameter. This beam falls perpendicularly on a perfectly reflecting piece of paper having twice the diameter of the laser beam and a mass of 1.50 mg. ($c = 3.00 \times 10^8$ m/s, $\mu_0 = 4\pi \times 10^{-7}$ T • m/A, $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$)
(a) What are the amplitudes of the electric and magnetic fields in this laser beam?
(b) What acceleration does the laser beam give to the paper?

Answer: (a) 577 N/C, 1.92 μT (b) 2.22 $\mu m/s^2$

39) Light of intensity I_0 and polarized horizontally passes through three polarizes. The first and third polarizing axes are horizontal, but the second one is oriented 20.0° to the horizontal. In terms of I_0, what is the intensity of the light that passes through the set of polarizers?
A) $0.780I_0$
B) $0.180I_0$
C) $0.442I_0$
D) $0.883I_0$

Answer: A

40) Polarized light passes through a polarizer. If the electric vector of the polarized light is horizontal what, in terms of the initial intensity I_0, is the intensity of the light that passes through a polarizer if the polarizer is tilted 22.5° from the horizontal?
A) $0.854I_0$
B) $0.147I_0$
C) $0.191I_0$
D) $0.011I_0$

Answer: A

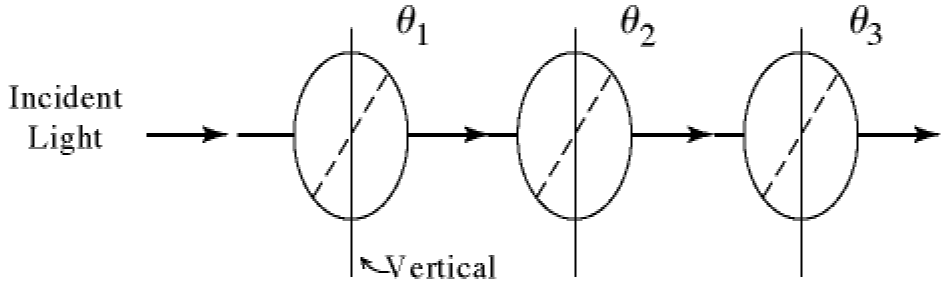
41) Unpolarized light is incident upon two polarization filters that do not have their transmission axes aligned. If 18% of the light passes through this combination of filters, what is the angle between the transmission axes of the filters?
A) 53°
B) 73°
C) 85°
D) 80°

Answer: A

42) Unpolarized light passes through three polarizing filters. The first one is oriented with a horizontal transmission axis, the second filter has its transmission axis 25.7° from the horizontal, and the third one has a vertical transmission axis. What percent of the light gets through this combination of filters?
A) 7.6%
B) 92.4%
C) 50.0%
D) 0.00%

Answer: A

43) In the figure, the orientation of the transmission axis for each of three polarizing sheets is labeled relative to the vertical direction. A beam of light, polarized in the vertical direction, is incident on the first polarized with an intensity of 1000 W/m^2. What is the intensity of the beam after it has passed through the three polarizing sheets when θ_1 = 30°, θ_2 = 30° and θ_3 =60°?



A) 141 W/m^2
B) 316 W/m^2
C) 433 W/m^2
D) 563 W/m^2
E) 188 W/m^2

Answer: D

44) The following are positioned in sequence: A source of a beam of natural light of intensity I_0; three ideal polarizers *A*, *B*, and *C*; and an observer. Polarizer axis angles are measured clockwise from the vertical, from the perspective of the observer. The axis angle of polarizer *A* is set at 0° (vertical), and the axis angle of polarizer *C* is set at 50°. Polarizer *B* is set so that the beam intensity is zero at the observer. Which of the following pairs of angles are possible axis angle settings of polarizer *B*?

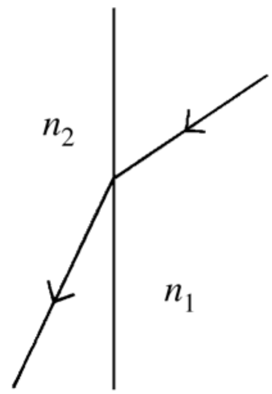
A) 40° and 90°
B) 40° and 130°
C) 40° and 140°
D) 90° and 130°
E) 90° and 140°

Answer: E

Chapter 30 Reflection and Refraction

30.1 Conceptual Questions

1) A ray of light goes from one transparent material into another, as shown in the figure. What can you conclude about the indices of refraction of these two materials?



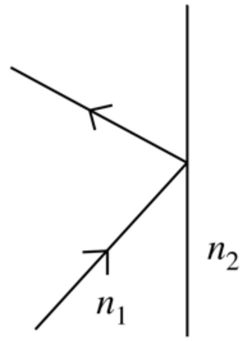
A) $n_1 \geq n_2$
B) $n_1 > n_2$
C) $n_1 = n_2$
D) $n_2 \geq n_1$
E) $n_2 > n_1$

Answer: B

2) When light goes from one material into another material having a HIGHER index of refraction
A) its speed, wavelength, and frequency all decrease.
B) its speed and wavelength decrease, but its frequency stays the same.
C) its speed decreases but its wavelength and frequency both increase.
D) its speed decreases but its frequency and wavelength stay the same.
E) its speed increases, its wavelength decreases, and its frequency stays the same.

Answer: B

3) A ray of light strikes a boundary between two transparent materials, and there is no transmitted ray, as shown in the figure. What can you conclude about the indices of refraction of these two materials?



A) $n_1 \geq n_2$
B) $n_1 > n_2$
C) $n_1 = n_2$
D) $n_2 \geq n_1$
E) $n_2 > n_1$

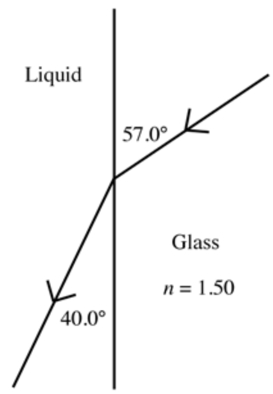
Answer: B

4) Which one of the following is an accurate statement about light?
A) When light strikes a surface at Brewster's angle, the reflected and transmitted light are both 100% polarized.
B) When light strikes a surface at Brewster's angle, it is completely reflected at the surface.
C) When light strikes a surface at Brewster's angle, only the reflected light is 100% polarized.
D) When light strikes a surface at the critical angle, only the reflected light is 100% polarized.
E) When light strikes a surface at the critical angle, all the light passes through the surface.

Answer: C

30.2 Problems

1) A ray of light passes from glass into a liquid, as shown in the figure. What is the speed of the light in the liquid? ($c = 3.00 \times 10^8$ m/s)

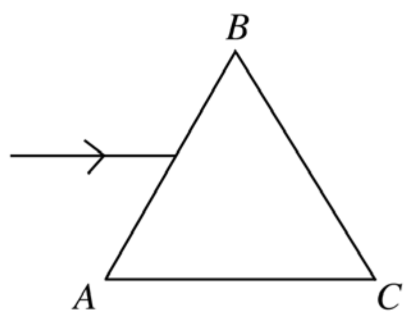


Answer: 2.81×10^8 m/s

2) Light strikes a 5.0–cm thick sheet of glass at an angle of incidence in air of 50°. The sheet has parallel faces and the glass has an index of refraction 1.50.
(a) What is the angle of refraction in the glass?
(b) After traveling through the glass the light re–emerges into the air. What is the final angle of refraction in air?
(c) As it leaves the glass, by what distance is the path of the ray is displaced from what it was before entering the glass?

Answer: (a) 31° (b) 50° (c) 1.9 cm

3) Light in air is initially traveling parallel to the face *AC* of an equilateral triangular prism, as shown in the figure. The prism is made of glass with an index of refraction of 1.52. If the light does not strike the face *AC*, what is the angle between the ray as it leaves the prism at face *BC* and the normal in air at that face?



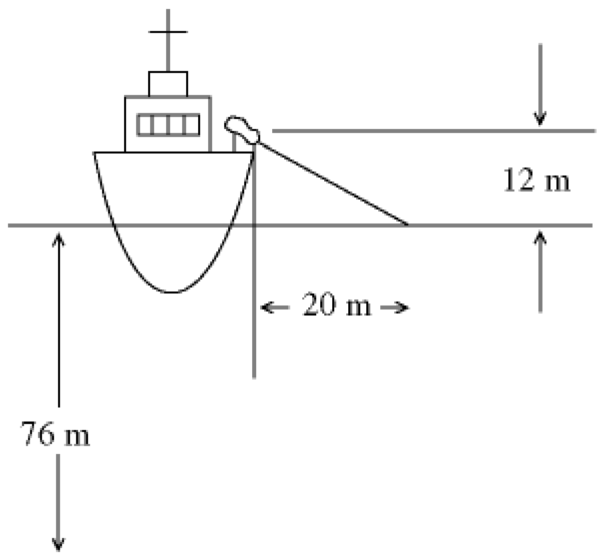
A) 83°
B) 19°
C) 59°
D) 27°
E) 55°

Answer: A

4) An oil layer that is 5.0 cm thick is spread smoothly and evenly over the surface of water on a windless day. What is the angle of refraction in the water for a ray of light that has an angle of incidence of 45° as it enters the oil from the air above? (The index of refraction for the oil is 1.15, and for water it is 1.33.)
   A) 27°
   B) 32°
   C) 36°
   D) 39°
   E) 52°

   Answer: B

5) In the figure, a laser positioned on a ship is used to communicate with a small two–man research submarine resting on the bottom of a lake. The laser is positioned 12 m above the surface of the water, and it strikes the water 20 m from the side of the ship. The water is 76 m deep and has an index of refraction of 1.33. How far horizontally is the submarine from the side of the ship?



   A) 84.1 m
   B) 64.1 m
   C) 104 m
   D) 74.1 m
   E) 94.1 m

   Answer: A

6) A tank holds a 1.44–m thick layer of oil that floats on a 0.96–m thick layer of brine. Both liquids are clear and do not intermix. Point *O* is at the bottom of the tank, on a vertical axis. The indices of refraction of the oil and the brine are 1.40 and 1.52, respectively. A ray originating at *O* crosses the brine–oil interface at a point 0.60 m from the axis. The ray continues and emerges into the air above the oil. What is the angle that the ray in the air makes with the vertical?
A) 48°
B) 51°
C) 54°
D) 57°
E) 60°

Answer: C

7) The speed of light in a material is 0.50*c*. What is the critical angle of a light ray at the interface between the material and a vacuum?
A) 30°
B) 21°
C) 24°
D) 27°

Answer: A

8) The critical angle in air for a particular type of glass is 39.0°. What is the speed of light in this class glass? ($c = 3.00 \times 10^8$ m/s)
A) 1.97×10^8 m/s
B) 1.94×10^8 m/s
C) 1.91×10^8 m/s
D) 1.89×10^8 m/s
E) 2.00×10^8 m/s

Answer: D

9) What is the critical angle for light traveling from crown glass ($n = 1.52$) into water ($n = 1.33$)?
A) 42°
B) 48°
C) 53°
D) 57°
E) 61°

Answer: E

10) An optic fiber is made of clear plastic with index of refraction of 1.50, surrounded by air. For what angles of incidence θ will light remain within the plastic fiber?
A) $\theta \geq 21.1°$
B) $\theta < 38.3°$
C) $\theta > 38.3°$
D) $\theta < 41.8°$
E) $\theta > 41.8°$

Answer: E

11) An optical fiber made of glass with an index of refraction 1.50 is coated with a plastic with index of refraction 1.30. What is the critical angle of this fiber at the glass–plastic interface?
A) 90.0°
B) 41.8°
C) 60.1°
D) 50.2°
E) 61.1°

Answer: C

12) A glass plate whose index of refraction is 1.56 is immersed in a liquid. The surface of the glass is inclined at an angle of 42.0° with the vertical. A horizontal ray in the glass is incident on the interface. When the liquid is a certain alcohol, the incident ray arrives at the interface at the critical angle. What is the index of refraction of the alcohol?
A) 1.04
B) 1.02
C) 1.00
D) 0.984
E) 1.06

Answer: A

13) A tank holds a 1.44–m thick layer of oil that floats on a 0.96–m thick layer of brine. Both liquids are clear and do not intermix. Point *O* is at the bottom of the tank, on a vertical axis. The indices of refraction of the oil and the brine are 1.40 and 1.52, respectively. A ray originating at *O* reaches the brine–oil interface at the critical angle. What is the distance of this point from the axis?
A) 1.5 m
B) 1.7 m
C) 1.9 m
D) 2.1 m
E) 2.3 m

Answer: E

14) A ray of light traveling in air strikes the surface of a certain plastic slab at 63.0° with respect to the normal in air. It travels in the plastic slab at a 30.6° angle with respect to the normal. Find the critical angle for the plastic in air.

Answer: 34.8°

15) A ray of light consisting of blue light (wavelength 480 nm) and red light (wavelength 670 nm) is incident on a thick piece of glass at 80°. What is the angular separation between the refracted red and refracted blue beams while they are in the glass? (The respective indices of refraction for the blue light and the red light are 1.4636 and 1.4561.)
A) 0.27°
B) 0.33°
C) 0.36°
D) 0.46°
E) 0.54°

Answer: A

16) A beam of light of two different wavelengths enters a pane of glass 3.00 mm thick at an angle of incidence of 56°. The indices of refraction for the two different colors are 1.514 and 1.528. Because of dispersion, the colored beams, although parallel, are separated by a small distance. How far apart are they?
   A) 0.057 mm
   B) 0.0083 mm
   C) 0.025 mm
   D) 0.014 mm
   E) 0.0062 mm

   Answer: D

17) Light consisting of a mixture of red and blue light enters a 40°, 70°, 70° prism along a line parallel to the side opposite the 40° vertex. The index of refraction of the prism material for blue light is 1.530, and for red light it is 1.525. What is the angle between the two emerging beams of light?
   A) 0.5°
   B) 0.9°
   C) 0.1°
   D) 0.3°
   E) 0.7°

   Answer: D

18) The critical angle for an air–glass interface is 29.6°. When a light ray in air is incident on the interface, the reflected ray is 100% polarized. What is the angle of refraction of that ray?
   A) 26.3°
   B) 25.7°
   C) 25.1°
   D) 24.5°
   E) 23.9°

   Answer: A

Chapter 31 Images and Optical Instruments

31.1 Conceptual Questions

1) As you walk away from a vertical plane mirror, your image in the mirror
   A) is always the same height.
   B) may or may not decrease in height, depending on where the observer is positioned.
   C) is always a real image, no matter how far you are from the mirror.
   D) changes from being a virtual image to a real image as you pass the focal point.
   E) decreases in height.

   Answer: A

2) Suppose you place your face in front of a concave mirror. Which one of the following statements is correct?
   A) If you position yourself between the center of curvature and the focal point of the mirror, you will not be able to see a sharp image of your face.
   B) No matter where you place yourself, a real image will be formed.
   C) Your image will always be inverted.
   D) Your image will be diminished in size.
   E) None of these statements are true.

   Answer: A

3) Which statements are true about a VIRTUAL image? (There may be more than one correct choice.)
   A) Its location can be calculated, but it cannot be viewed directly by your eye without using auxiliary lenses.
   B) It cannot be photographed.
   C) It cannot be viewed on a screen.
   D) A plane mirror always forms a virtual image.
   E) A concave lens always forms a virtual image.

   Answer: C, D, E

4) A convex lens has focal length f. If an object is located extremely far from the lens (at infinity), the image formed is located what distance from the lens?
   A) infinity
   B) $2f$
   C) between f and $2f$
   D) f
   E) between the lens and f

   Answer: D

5) A convex lens has a focal length *f*. An object is placed at a distance between *f* and 2*f* on a line perpendicular to the center of the lens. The image formed is located at what distance from the lens?
   A) 2*f*
   B) between *f* and 2*f*
   C) *f*
   D) between the lens and *f*
   E) farther than 2*f*

   Answer: E

6) A convex lens has a focal length *f*. An object is placed between infinity and 2*f* from the lens along a line perpendicular to the center of the lens. The image is located at what distance from the lens?
   A) farther than 2*f*
   B) 2*f*
   C) between *f* and 2*f*
   D) *f*
   E) between the lens and *f*

   Answer: C

7) An object is placed in front of a lens which forms an image of the object.
   A) If the lens is convex, the image cannot be virtual.
   B) If the image is real, then it is also inverted.
   C) If the image is real, then it is also upright.
   D) If the image is virtual, then it is also inverted.
   E) If the image is virtual, the lens must be a diverging lens.

   Answer: B

8) Which one of the following is a characteristic of a compound microscope?
   A) The objective is a diverging lens.
   B) The eyepiece is a diverging lens.
   C) The final image is real.
   D) The image formed by the objective is virtual.
   E) The image formed by the objective is real.

   Answer: E

9) A simple refracting telescope provides large magnification by employing
   A) a short focal length objective and a short focal length eyepiece.
   B) a short focal length objective and a long focal length eyepiece.
   C) a long focal length objective and a short focal length eyepiece.
   D) a long focal length objective and a long focal length eyepiece.

   Answer: C

31.2 Problems

1) How far are you from your image when you stand 0.750 m in front of a vertical plane mirror?
   A) 0.375 m
   B) 0.750 m
   C) 1.50 m
   D) 3.00 m

   Answer: C

2) A object is 12 cm in front of a concave spherical mirror, and the image is 3.0 cm in front of the mirror. What is the focal length of the mirror?
   A) 0.25 cm
   B) 15 cm
   C) 4.0 cm
   D) 2.4 cm
   E) 1.3 cm

   Answer: D

3) A concave spherical mirror with a radius of 20 cm creates a real image 30 cm from the mirror. How far is the object from the mirror?
   A) 50 cm
   B) 20 cm
   C) 15 cm
   D) 7.5 cm
   E) 5.0 cm

   Answer: C

4) The spherical side mirror on a car is convex and has a radius of curvature of 25 cm. Another car is following, 20 m behind the mirror. If the height of the car is 1.6 m, how tall is its image?
   A) 5.0 cm
   B) 2.0 cm
   C) 4.0 cm
   D) 3.0 cm
   E) 0.99 cm

   Answer: E

5) A man's face is 30 cm in front of a concave spherical shaving mirror. If the image is erect and 1.5 times as large as his face, what is the radius of curvature of the mirror?
   A) 40 cm
   B) 60 cm
   C) 100 cm
   D) 140 cm
   E) 180 cm

   Answer: E

6) A convex spherical mirror with a focal length of magnitude 25 cm has a 4.0 –cm tall flower placed 100 cm in front of it. What is the height of the image of the flower?
   A) 0.80 cm
   B) 20 cm
   C) 4.0 cm
   D) 1.6 cm
   E) 8.0 cm

   Answer: A

7) An object 4.0 cm in height is placed 8.0 cm in front of a concave spherical mirror with a focal length of 10.0 cm. What is the position of its image in relation to the mirror, and what are the characteristics of the image?
   A) 40.0 cm on the other side of mirror, real, 6.0 times bigger
   B) 10.0 cm on the other side of mirror, virtual, 10.0 times bigger
   C) 18.0 cm on the same side of mirror, virtual, 2.25 times bigger
   D) 10.0 cm on the same side of mirror, real, 6.0 times bigger
   E) 40.0 cm on the other side of mirror, virtual, 5.0 times bigger

   Answer: E

8) The image of a plant is 4.0 cm from a concave spherical mirror having a radius of curvature of 10 cm. Where is the plant relative to the mirror?
   A) 2.2 cm in front of the mirror
   B) 4.4 cm in front of the mirror
   C) 9.0 cm in front of the mirror
   D) 1.0 cm in front of the mirror
   E) 20 cm in front of the mirror

   Answer: A

9) A convex spherical mirror with a radius of 50 cm has a 4.0 cm tall object placed 100 cm in front of it. What is the position of the image relative to the mirror?
   A) 20 cm behind the mirror
   B) 25 cm behind the mirror
   C) 100 cm in front of the mirror
   D) 25 cm in front of the mirror
   E) 20 cm in front of the mirror

   Answer: A

10) An object 3.4 mm tall is placed 25 cm from the vertex of a convex spherical mirror. The radius of curvature of the mirror has a magnitude of 52 cm.
   (a) How far is the image from the vertex of the mirror?
   (b) What is the height of the image?

   Answer: (a) 13 cm (b) 1.7 mm

11) A swimming pool is filled to a depth of 2.0 m. How deep does the pool appear to be from above the water, which has an index of refraction of 1.33?
A) 1.5 m
B) 1.33 m
C) 2.5 m
D) 3.0 m
E) 4.0 cm

Answer: A

12) A goldfish bowl is spherical, 8.0 cm in radius. A goldfish is swimming 3.0 cm from the wall of the bowl. Where does the fish appear to be to an observer outside? The index of refraction of water is 1.33. Neglect the effect of the glass wall of the bowl.
A) 3.3 cm inside the bowl
B) 3.9 cm inside the bowl
C) 2.5 cm inside the bowl
D) 3.0 cm inside the bowl
E) 1.7 cm inside the bowl

Answer: C

13) A fish appears to be 2.00 m below the surface of a pond when viewed almost directly above by a fisherman. What is the actual depth of the fish? (n_{water} = 1.33)
A) 2.66 m
B) 0.67 m
C) 1.5 m
D) 0.38 m

Answer: A

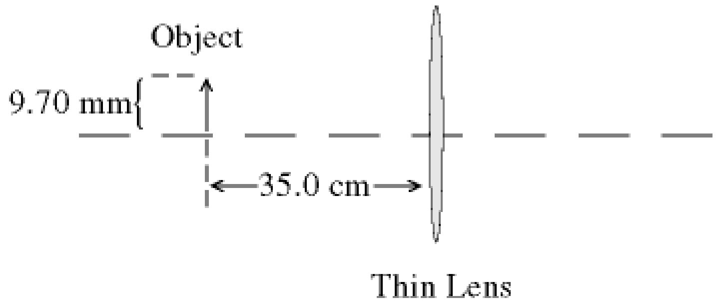
14) A fisherman in a stream 39 cm deep looks downward into the water and sees a rock on the stream bed. How deep does the stream appear to the fisherman? The index of refraction of the water is 1.33.
A) 29 cm
B) 52 cm
C) 33 cm
D) 45 cm

Answer: A

15) The left-hand end of a glass rod is ground to a spherical surface. The glass has index of refraction 1.50. A small object 4.00 mm tall is placed on the axis of the rod, 37.0 cm to the left of the vertex of the spherical surface. The image is formed in the rod, 50.0 cm to the right of the vertex.
(a) What is the magnitude of the radius of curvature of the spherical surface at the end of the rod?
(b) What is the height of the image?

Answer: (a) 8.8 cm (b) 3.60 mm

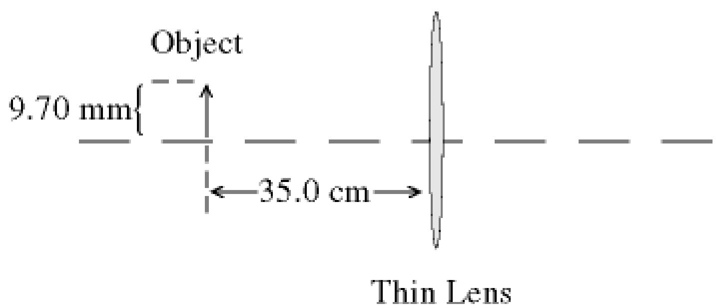
16) In the figure, the thin lens forms a real image of the object 94.0 cm from the object. What is the focal length of the lens?



A) 22.0 cm
B) 25.5 cm
C) 27.5 cm
D) 55.8 cm
E) 86.0 cm

Answer: A

17) In the figure, the image is viewed on a screen and is 13.5 mm tall. What is the focal length of the lens?



A) +14.6 cm
B) -14.6 cm
C) +20.4 cm
D) -89.3 cm
E) +124 cm

Answer: C

18) A thin converging lens is found to form an image of a distant building 24 cm from the lens. If an insect is now placed 16 cm from this lens, how far FROM THE INSECT will its image be formed?

A) 64 cm
B) 72 cm
C) 32 cm
D) 96 cm
E) 48 cm

Answer: C

19) An object is placed 10 cm from a convex lens of focal length 20 cm. What is the lateral magnification of the object?
A) 0.50
B) 1.0
C) 1.5
D) 2.0
E) 2.5

Answer: D

20) It is desired to project the image of an object four times its actual size using a lens of focal length 20 cm. How far from the lens should the object be placed?
A) 100 cm
B) 80 cm
C) 4.0 cm
D) 25 cm
E) 5.0 cm

Answer: D

21) When an object 1.15 cm tall is placed 12 cm from a lens, the lens produces an upright image of the object that is 5.75 cm tall. What is the focal length of the lens?
A) 24 cm
B) 18 cm
C) 60 cm
D) 15 cm
E) 9.0 cm

Answer: D

22) A 4.0-cm tall object is placed 60 cm away from a converging lens of focal length 30 cm. What are the nature and location of the image? The image is
A) real, 2.5 cm tall, and 30 cm from the lens on the same side as the object.
B) virtual, 2.5 cm tall, and 30 cm from the lens on the side opposite the object.
C) virtual, 2.0 cm tall, and 15 cm from the lens on the side opposite the object.
D) virtual, 4.0 cm tall, and 60 cm from the lens on the same side as the object.
E) real, 4.0 cm tall, and 60 cm from the lens on the side opposite the object.

Answer: E

23) A 4.0-cm tall object is placed 50.0 cm from a diverging lens having a focal length of magnitude 25.0 cm. What are the nature and location of the image? The image is
A) real, 4.0 cm tall, and 20 cm from the lens on the side opposite the object.
B) virtual, 4.0 cm tall, and 20 cm from the lens on the side opposite the object.
C) virtual, 2.0 cm tall, and 10 cm from the lens on the side opposite the object.
D) virtual, 1.3 cm tall, and 16.7 cm from the lens on the same side of the object.
E) real, 1.3 cm tall, and 16.7 cm from the lens on the same side of the object.

Answer: D

24) An object is placed 100 cm in front of a lens of focal length 20 cm. A second lens is placed 35 cm beyond the first, this second lens having a focal length of 8.0 cm. If the height of the object is 6.0 cm, what is the height of the final image?
A) 1.5 cm
B) 12 cm
C) 9.0 cm
D) 3.0 cm
E) 6.0 cm

Answer: E

25) An object 1.80 cm tall is placed 100 cm in front of a diverging lens having a focal length of magnitude 25 cm. A converging lens with a focal length of magnitude 33.33 cm is placed 30 cm past the first lens. What is the lateral magnification of this system of lenses?
A) 2.5
B) –2.5
C) –0.40
D) 1.0
E) 0.40

Answer: C

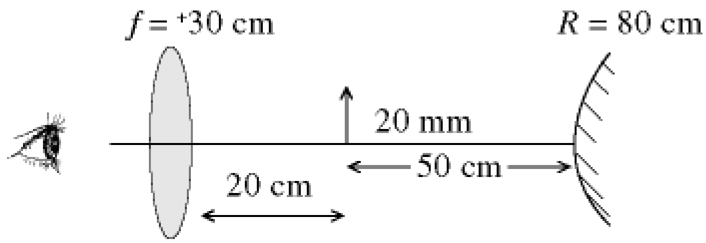
26) An object 1.25 cm tall is placed 100 cm in front of a convex lens with a focal length of magnitude 50 cm. A concave lens with a focal length of magnitude 20 cm is placed 90 cm beyond the first lens. Where is the final image located?
A) 10 cm in front of the second lens
B) 20 cm past the second lens
C) 17 cm past the second lens
D) 10 cm past the second lens
E) 20 cm in front of the second lens

Answer: B

27) An object is placed 100 cm in front of a diverging lens with a focal length of magnitude 25 cm. A converging lens having a focal length of magnitude 33.33 cm is placed 30 cm past the first lens. Where is the final image formed?
A) 30 cm after the second lens
B) 20 cm in front of the first lens
C) 3.0 meters before the second lens
D) 100 cm after the second lens
E) 3.0 cm before the second lens

Answer: D

28) An optical system comprises in turn, from left to right: an observer, a lens of focal length +30 cm, an erect object 20 mm high, and a convex mirror of radius 80 cm. The object is between the lens and the mirror, 20 cm from the lens and 50 cm from the mirror. The observer views the image that is formed first by reflection and then by refraction. What is the position of the final image, measured from the mirror?



A) 90 cm
B) 102 cm
C) 114 cm
D) 126 cm
E) 138 cm

Answer: C

29) In the figure, the radius of curvature of the curved part of the lens is 24.0 cm, and the refractive index of the lens material is 1.750. What is the focal length of the lens?

A) +32.0 cm
B) -32.0 cm
C) -16.0 cm
D) +13.8 cm
E) -13.8 cm

Answer: A

30) In the figure, the radius of curvature of the curved part of the lens is 35.0 cm, and the refractive index of the lens material is 1.620. What is the focal length of the lens?

A) +56.5 cm
B) -56.5 cm
C) +28.2 cm
D) +21.6 cm
E) -21.6 cm

Answer: B

31) A convex-concave thin lens is made with the radius of curvature of the convex surface being 25.0 cm and the concave surface 45.0 cm. If the glass used has index of refraction 1.500, what is the focal length of this lens?
A) -32.0 cm
B) 32.0 cm
C) 113 cm
D) 67.5 cm
E) -113 cm

Answer: C

32) A double-convex thin lens is made of glass with an index of refraction of 1.52. The radii of curvature of the faces of the lens are 60 cm and 72 cm. What is the focal length of the lens?
A) 70 cm
B) 63 cm
C) 75 cm
D) 66 cm
E) 58 cm

Answer: B

33) A lens is made with a focal length of -40 cm using a material with index of refraction 1.50. A second lens is made with the SAME GEOMETRY as the first lens, but using a material having refractive index of 2.00. What is the focal length of the second lens?
A) -40 cm
B) -80 cm
C) -53 cm
D) -20 cm
E) -30 cm

Answer: D

34) A double-concave lens has equal radii of curvature of 15.1 cm. An object placed 14.2 cm from the lens forms a virtual image 5.29 cm from the lens. What is the index of refraction of the lens material?
A) 1.90
B) 1.98
C) 1.82
D) 1.77

Answer: A

35) A thin double convex lens is to focus the image of an object onto a screen so that the image is life-sized. The lens surfaces have equal radii of curvature of 112 cm, and the refractive index of the lens material is 1.500.
(a) How far from the lens should the screen be placed?
(b) How far is the screen from the object?

Answer: (a) 224 cm (b) 448 cm

36) A compound lens is made by joining the plane surfaces of two thin plano–convex lenses of different glasses. The radius of curvature of each convex surface is 80 cm. The indices of refraction of the two glasses are 1.50 and 1.60. What is the focal length of the compound lens?
A) 67
B) 69
C) 71
D) 73
E) 75

Answer: D

37) A 35–mm camera equipped with a 95 mm focal length lens is used to photograph a tree that is 8.0 m tall. A 32 mm high image of the tree on the film is needed. The required distance, between the tree and the camera lens, to take the photograph is closest to
A) 24 m.
B) 25 m.
C) 26 m.
D) 27 m.
E) 29 m.

Answer: A

38) In a 35.0–mm single lens reflex camera (SLR), the distance from the lens to the film is varied in order to focus on objects at varying distances. Over what distance range must a lens of 55–mm focal length vary if the camera is to be able to focus on objects ranging in distance from infinity down to 0.60 m from the camera?
A) 5.55 mm
B) 4.44 mm
C) 16.7 mm
D) 22.2 mm
E) 7.77 mm

Answer: A

39) A person's eye lens is 2.7 cm away from the retina. This lens has a near point of 25 cm and a far point at infinity.
(a) What must the focal length of this lens be in order for an object placed at the near point of the eye to focus on the retina?
(b) What must the focal length of this lens be in order for an object placed at the far point of the eye to focus on the retina?

Answer: (a) 2.4 cm (b) 2.7 cm

40) What is the focal length of the corrective contact lens needed by a nearsighted person whose far point is 60 cm?
A) -60 cm
B) -30 cm
C) +30 cm
D) +60 cm
E) +130 cm

Answer: A

41) A nearsighted person has her distant vision corrected using a –2.0–diopter contact lens. Her uncorrected near point is 15 cm. What is her near point using this lens if the lens is 2.0 cm from the eye?
   A) 17 cm
   B) 20 cm
   C) 13 cm
   D) 18 cm
   E) 15 cm

   Answer: B

42) The near point of a person's uncorrected eyes is 125.0 cm and the far point is at infinity. What is the focal length of a contact lens that will move the near point to 25.0 cm from this person's eyes?
   A) –100 cm
   B) –31.3 cm
   C) 10.2 cm
   D) 20.8 cm
   E) 31.3 cm

   Answer: E

43) The near point of a farsighted person's uncorrected eyes is 80 cm. What power contact lens should be used to move the near point to 25 cm from this person's eyes?
   A) 2.8 diopters
   B) –2.8 diopters
   C) –4.0 diopters
   D) –4.2 diopters
   E) 4.2 diopters

   Answer: A

44) What power contact lens must be used to correct the vision of a nearsighted person whose far point is 40 cm?
   A) 2.5 diopters
   B) -2.5 diopters
   C) -3.6 diopters
   D) -4.0 diopters
   E) 4.0 diopters

   Answer: B

45) What is the uncorrected near point of a person who has a near point that is 25 cm from his eyes when he is wearing 3.33–diopter contact lenses?
   A) 1.5 m
   B) 0.50 m
   C) 1.9 m
   D) 0.75 m
   E) 0.60 m

   Answer: A

46) A person can read the newspaper when it is held at 60 cm from his eyes. What should the focal length of his contact lenses be to allow him to read the newspaper comfortably at a distance of 30 cm?
A) -30 cm
B) 30 cm
C) -60 cm
D) 60 cm
E) 90 cm

Answer: D

47) A man is nearsighted and cannot see things clearly beyond 110from his eyes. What is the focal length of the contact lenses that will enable him to see very distant objects clearly?
A) 50 cm
B) −50 cm
C) −110 cm
D) 110 cm
E) −30 cm

Answer: C

48) A nearsighted physicist cannot see things clearly beyond 90 cm from her eyes. What is the power of the contact lenses that will enable her to see very distant objects clearly?
A) 1.1 diopters
B) -1.1 diopters
C) -1.7 diopters
D) -2.2 diopters
E) 2.2 diopters

Answer: B

49) A singer is farsighted and cannot see objects clearly that are closer than 80.0 cm from his unaided eye. What is the refractive power of the contact lenses that will move his near point to a distance of 25.0 cm from his eye?
A) 2.75 diopters
B) −2.75 diopters
C) −4.72 diopters
D) 4.72 diopters
E) 7.00 diopters

Answer: A

50) A myopic (nearsighted) dancer wears eyeglasses that allow him to have clear distant vision. The power of the lenses of his eyeglasses is −3.00 diopters. Without eyeglasses, what is the far point of the dancer?
A) 0.33 m
B) 0.25 m
C) 0.17 m
D) 0.42 m
E) 0.50 m

Answer: A

51) A machinist with normal vision has a near point at 25 cm. The machinist wears eyeglasses in order to do close work. The power of the lenses is +1.75 diopters. With these eyeglasses, what is the near point of the machinist?
A) 17 cm
B) 14 cm
C) 10 cm
D) 21 cm
E) 24 cm

Answer: A

52) A person having a near point of 25 cm and a far point at infinity uses a converging lens of focal length 5.0 cm as a magnifying glass. What is the magnification if the person's eye is relaxed (with the image at his far point)?

Answer: 5.0 x

53) A magnifying lens has a focal length of 10 cm. A person has a near point of 25 cm and a far point at infinity. What is the angular magnification of the lens for that person when their eyes are focused at infinity?

Answer: 2.5 x

54) What is the focal length of a magnifying glass that produces an angular magnification of 7.0 x when used by a person with a near point at 28 cm?
A) 2.0 cm
B) 3.0 cm
C) 4.0 cm
D) 5.0 cm
E) 6.0 cm

Answer: C

55) What is the angular magnification of a magnifying glass of focal length 4.0 cm if the image is to be viewed by a relaxed eye (image at the far point) having a near point of 25 cm and a far point at infinity?
A) 2.0 x
B) 3.0 x
C) 3.6 x
D) 4.0 x
E) 6.3 x

Answer: E

56) A magnifying glass uses a converging lens with a refractive power of 20 diopters. What is the magnification if the image is to be viewed by a relaxed eye (image at the far point) having a near point of 25 cm and a far point at infinity?
A) 5.0 x
B) 3.0 x
C) 4.0 x
D) 1.0 x
E) 2.0 x

Answer: A

57) The focal lengths of the objective and the eyepiece of a microscope are 0.50 cm and 2.0 cm, respectively, and their separation adjusted for minimum eyestrain (with the final image at the viewer's far point) is 6.0 cm. The near point of the person using the microscope is 25 cm and the far point is infinity.
(a) If the microscope is focused on a small object, what is the distance between the object and the objective lens?
(b) If the microscope is focused on a small object, what is its final magnification?

Answer: (a) 0.57 cm (b) −100 x

58) The distance between the object and the eyepiece of a compound microscope is 25.0 cm. The focal length of its objective lens is 0.200 cm and the eyepiece has a focal length of 2.60 cm. A person with a near point of 25.0 cm and a far point at infinity is using the microscope.
(a) What is the angular magnification obtainable using the eyepiece alone as a magnifying lens if the final image is at the person's far point?
(b) What is the total magnification of the microscope when used by the person of normal eyesight?

Answer: (a) 9.62 x (b) −1070 x

59) The focal lengths of the objective and eyepiece in a compound microscope are 0.80 cm and 2.5 cm, respectively. The image formed by the objective is 16 cm from it and the final image is 25 cm from the eye. What is the total overall magnification of the microscope?
A) -19 x
B) -11 x
C) -2.0 x
D) -100 x
E) -200 x

Answer: E

60) The focal lengths of the objective and the eyepiece in a microscope are 0.29 cm and 2.50 cm, respectively. An object is placed at 0.30 cm from the objective lens and the image of this object is viewed with the eyepiece adjusted for minimum eyestrain (with the eye focused at the far point). The near point of the person using the microscope is 25 cm and the far point is at infinity. What is the final overall magnification of the microscope?
A) -190 x
B) -240 x
C) -300 x
D) -320 x
E) -470 x

Answer: C

61) The distance between the object and the eyepiece of a compound microscope is 18.0 cm. The focal length of its objective lens is 0.80 cm and the eyepiece has a focal length of 2.3 cm. The near−point distance of the person using the microscope is 25.0 cm. What is the total overall magnification of the microscope?
A) -120 x
B) -184 x
C) -200 x
D) -360 x
E) -480 x

Answer: C

62) The focal lengths of the objective and the eyepiece in a microscope are 0.290 cm and 2.50 cm, respectively. An object is placed 0.300 cm from the objective. The image of this object is viewed with the eyepiece adjusted for minimum eyestrain (image at the far point of the eye) for a person with normal vision. What is the distance between the objective and the eyepiece?

A) 9.85 cm
B) 10.1 cm
C) 10.4 cm
D) 11.2 cm
E) 11.5 cm

Answer: D

63) The objective and the eyepiece of a microscope have focal lengths of 4.00 mm and 25.0 mm, respectively. The objective produces a real image 30 times the size of the object. The final image is viewed at infinity, and the near point of the microscope user is at 25.0 cm. What is the distance between the object and the focal point of the objective?

A) 0.13 mm
B) 0.18 mm
C) 0.23 mm
D) 0.28 mm
E) 0.33 mm

Answer: A

64) The eyepiece of a compound microscope has a focal length of 2.50 cm and the objective has a focal length of 1.60 cm. The two lenses are separated by 15.0 cm. The microscope is used by a person with normal eyes (near point at 25 cm). What is the angular magnification of the microscope?

A) 78 x
B) 94 x
C) 195 x
D) 234 x
E) 125 x

Answer: A

65) You have available lenses of focal lengths 2.0 cm, 4.0 cm, 8.0 cm, and 16.0 cm.
(a) If you were to use any two of these lenses to build a telescope, what is the maximum magnification you could achieve?
(b) If you were to use any two of these lenses to build a telescope, what is the lens separation for the maximum magnification telescope?

Answer: (a) 8.0 x (b) 18 cm

66) The objective lens of a refracting telescope has a focal length of 60 cm and the eyepiece a focal length of 8.0 cm. What is the angular magnification of the telescope?

A) 34 x
B) 480 x
C) 68 x
D) 0.13 x
E) 7.5 x

Answer: E

67) An astronomical telescope has an objective of diameter 20 cm with a focal length of 180 cm. The telescope is used with an eyepiece of focal length 30 mm. What is the angular magnification of this telescope?
A) 360 x
B) 60 x
C) 540 x
D) 6 x
E) 180 x
Answer: B

68) The angular magnification of a refracting telescope is 40 x. When the object and final image are both at infinity, the distance between the eyepiece and the objective is 143.5 cm. The telescope is used to view a distant radio tower. The real image of the tower, formed by the objective, is 6.0 mm in height. The focal point of the eyepiece is positioned at the real image. What is the focal length of the objective lens?
A) 137 cm
B) 138 cm
C) 139 cm
D) 140 cm
E) 141 cm
Answer: D

69) The angular magnification of a refracting telescope is 40 x. When the object and final image are both at infinity, the distance between the eyepiece and the objective is 143.5 cm. The telescope is used to view a distant radio tower. The real image of the tower, formed by the objective, is 6.0 mm in height. The focal point of the eyepiece is positioned at the real image. What is the angle subtended by the final image of the tower.
A) 0.15 rad
B) 0.17 rad
C) 0.19 rad
D) 0.21 rad
E) 0.23 rad
Answer: B

70) The objective and the eyepiece of a refracting astronomical telescope have focal lengths of 320 cm and 4.0 cm, respectively. The telescope is used to view Neptune and the final image is set at infinity. The diameter of Neptune is 4.96×10^7 m and the distance from the earth at the time of observation is 4.4×10^{12} m. What is the angle (in mrad) subtended by the final telescopic image of Neptune?
A) 0.90 mrad
B) 1.1 mrad
C) 1.3 mrad
D) 1.5 mrad
E) 1.7 mrad
Answer: A

Chapter 32 Interference and Diffraction

32.1 Conceptual Questions

1) In a double-slit experiment, if the slit separation is increased, which of the following happens to the interference pattern shown on the screen?
   A) The minima get closer together.
   B) The maxima stay at the same position.
   C) The minima and maxima stay at the same position.
   D) The minima stay at the same position.
   E) The maxima get further apart.

   Answer: A

2) In a single-slit diffraction experiment, the width of the slit through which light passes is reduced. What happens to the width of the central bright fringe?
   A) It stays the same.
   B) It becomes narrower.
   C) It becomes wider.
   D) Its behavior depends on the wavelength of the light.

   Answer: C

3) A single-slit diffraction pattern is formed on a distant screen. Assuming the angles involved are small, by what factor will the width of the central bright spot on the screen change if the slit width is doubled?
   A) It will be cut to one-quarter its original size.
   B) It will be cut in half.
   C) It will double.
   D) It will become four times as large.
   E) It will become eight times as large.

   Answer: B

4) A light beam shines through a thin slit and illuminates a distant screen. The central bright fringe on the screen is 1.00 cm wide, as measured between the dark fringes that border it on either side. Which of the following actions would *decrease* the width of the central bright fringe? (There may be more than one correct choice.)
   A) increase the wavelength of the light
   B) decrease the wavelength of the light
   C) increase the width of the slit
   D) decrease the width of the slit
   E) put the apparatus all under water

   Answer: B, C, E

5) A lens is designed to work in the visible, near-infrared, and near-ultraviolet. The best resolution of this lens from a diffraction standpoint is
A) the same for all wavelengths.
B) in the near-ultraviolet.
C) in the visible.
D) in the near-infrared.
E) indeterminate.

Answer: B

6) If the diameter of a radar dish is doubled, what happens to its resolving power assuming that all other factors remain unchanged?
A) The resolving power quadruples.
B) The resolving power doubles.
C) The resolving power is reduced to 1/2 of its original value.
D) The resolving power is reduced to 1/4 of its original value.
E) The resolving power does not change unless the focal length changes.

Answer: B

32.2 Problems

1) In the two–slit experiment, monochromatic light of frequency 5.00×10^{14} Hz passes through a pair of slits separated by 2.20×10^{-5} m. ($c = 3.00 \times 10^{8}$ m/s)
(a) At what angle away from the central bright spot does the third bright fringe past the central bright spot occur?
(b) At what angle does the second dark fringe occur?

Answer: (a) 4.69° (b) 2.34°

2) Light from a monochromatic source shines through a double slit onto a screen 5.00 m away. The slits are 0.180 mm apart. The dark bands on the screen are measured to be 1.70 cm apart. What is the wavelength of the incident light?
A) 457 nm
B) 306 nm
C) 392 nm
D) 612 nm
E) 784 nm

Answer: D

3) In a two–slit experiment, the slit separation is 3.00×10^{-5} m. The interference pattern is recorded on a flat screen–like detector that is 2.00 m away from the slits. If the seventh bright fringe on the detector is 10.0 cm away from the central fringe, what is the wavelength of the light passing through the slits?
A) 100 nm
B) 204 nm
C) 214 nm
D) 224 nm
E) 234 nm

Answer: C

4) Light of wavelength 575 nm passes through a double–slit and the third order bright fringe is seen at an angle of 6.5° away from the central fringe. What is the separation between the double slits?
   A) 5.0 μm
   B) 10 μm
   C) 15 μm
   D) 20 μm
   E) 25 μm

   Answer: C

5) In a double slit experiment, if the separation between the two slits is 0.050 mm and the distance from the slits to a screen is 2.5 m, find the spacing between the first–order and second–order bright fringes when coherent light of wavelength 600 nm illuminates the slits.
   A) 1.5 cm
   B) 3.0 cm
   C) 4.5 cm
   D) 6.0 cm
   E) 9.0 cm

   Answer: B

6) In a double–slit experiment, the slit separation is 2.0 mm, and two wavelengths, 750 nm and 900 nm, illuminate the slits simultaneously. A screen is placed 2.0 m from the slits. At what distance from the central maximum on the screen will a bright fringe from one pattern first coincide with a bright fringe from the other?
   A) 1.5 mm
   B) 3.0 mm
   C) 4.5 mm
   D) 6.0 mm
   E) 9.0 mm

   Answer: C

7) Light from a 600 nm source goes through two slits 0.080 mm apart. What is the angular separation of the two first order maxima occurring on a screen 2.0 m from the slits?
   A) 0.15°
   B) 0.86°
   C) 0.015°
   D) 0.0075°
   E) 1.75°

   Answer: B

8) In a double slit experiment, the slit separation is constructed to be exactly 4 times the wavelength of the light passing through the slits. At what angles from the center of the pattern will the third bright fringes on both sides of the central fringe occur?
   A) ±48.6°
   B) ±75.0°
   C) ±67.5°
   D) ±36.9°
   E) ±43.0°

   Answer: A

9) A double slit illuminated with light of wavelength 588 nm forms a diffraction pattern on a screen 11.0 cm away. The slit separation is 2464 nm. What is the distance between the third and fourth bright fringes away from the central fringe?
A) 23.9 cm
B) 5.96 cm
C) 5.59 cm
D) 2.63 cm

Answer: A

10) Two sources of light illuminate a double slit simultaneously. One has wavelength 570 nm and the second has an unknown wavelength. The $m = 5$ bright fringe of the unknown wavelength overlaps the $m = 4$ bright fringe of the light of 570 nm wavelength. What is the unknown wavelength?
A) 456 nm
B) 326 nm
C) 380 nm
D) 713 nm

Answer: A

11) A pair of narrow slits, separated by 1.8 mm, is illuminated by a monochromatic light source. Light waves arrive at the two slits in phase, and a fringe pattern is observed on a screen 4.8 m from the slits. If there are 5.0 complete bright fringes per centimeter on the screen near the center of the pattern, what is the wavelength of the monochromatic light?
A) 550 nm
B) 600 nm
C) 650 nm
D) 700 nm
E) 750 nm

Answer: E

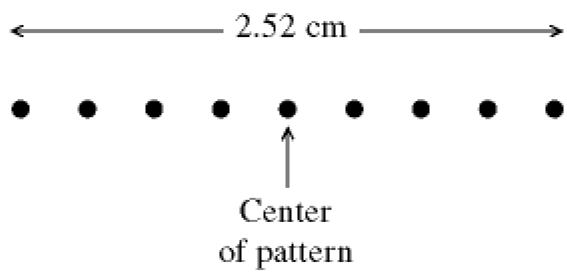
12) At most, how many bright fringes can be formed on each side of the central bright fringe (not counting the central bright fringe) when light of 625 nm falls on a double slit whose spacing is 1.97×10^{-6} m?
A) 1
B) 2
C) 3
D) 4
E) 5

Answer: C

13) Two radio antennas are 120 m apart on a north–south line, and they radiate in phase at a frequency of 3.4 MHz. All radio measurements are made far from the antennas. If the east–west reference line passes midway between the two antennas, what is the smallest angle from the antennas, measured north of east, at which constructive interference of two radio waves occurs? ($c = 3.00 \times 10^8$ m/s)
A) 43°
B) 22°
C) 68°
D) 47°
E) 30°
Answer: D

14) Two small forward–facing speakers are 2.50 m apart. They are both emitting, in phase with each other, a sound of frequency 1100 Hz in a room where the speed of sound is 344 m/s. A woman is standing opposite the midpoint between the speakers and is initially 35.0 m from the midpoint. As she slowly walks parallel to the line connecting the speakers, at what angle θ (relative to the centerline coming outward from the midpoint between the speakers) will she first hear no sound?
A) 0.063°
B) 3.6°
C) 7.2°
D) 1.8°
E) 11°
Answer: B

15) Coherent monochromatic light of wavelength 632.8 nm passes through a pair of thin parallel slits. The figure shows the central portion of the pattern of bright fringes viewed on a screen 1.40 m beyond the slits. What is the distance between the two slits?



A) 0.0703 mm
B) 0.141 mm
C) 0.281 mm
D) 0.562 mm
E) 0.633 mm
Answer: C

16) Light of wavelength 519 nm passes through two slits. In the interference pattern on a screen 4.6 m away, adjacent bright fringes are separated by 5.2 mm in the general vicinity of the center of the pattern. What is the separation of the two slits?
Answer: 0.46 mm

17) Monochromatic laser light of frequency 5.20×10^{14} Hz is shown on a pair of thin parallel slits, and the pattern is viewed on a screen 1.20 m away. The fifth bright fringes (not counting the central fringe) occur at ±2.12 cm on either side of the central bright fringe. The entire apparatus is now immersed in a transparent liquid. When the experiment is repeated, the fifth bright fringes now occur at ±1.43 cm from the central bright fringe. ($c = 3.00 \times 10^8$ m/s)
(a) How far apart are the slits?
(b) What is the index of refraction of the liquid?

Answer: (a) 0.163 mm (b) 1.48

18) In a double slit experiment, the intensity of light at the center of the central bright fringe is measured to be 6.2 $\mu W/m^2$. What is the intensity halfway between the center of this fringe and the first dark band, assuming that the small-angle approximation is valid?
A) 6.2 $\mu W/m^2$
B) 3.1 $\mu W/m^2$
C) 4.7 $\mu W/m^2$
D) 1.6 $\mu W/m^2$
E) 0.12 $\mu W/m^2$

Answer: B

19) Light passes through a pair of very thin parallel slits. The resulting interference pattern is viewed far from the slits at various angles θ relative to the centerline coming outward from the midpoint between the slits. The central bright fringe is at $\theta = 0°$. If the central bright fringe has intensity I_0, what is the intensity of the next bright fringe on either side of it?
A) I_0
B) $I_0/\sqrt{2}$
C) $I_0/2$
D) $I_0 \cos 15°$
E) $I_0 \cos^2 15°$

Answer: A

20) Light of wavelength 525 nm passes through two slits separated by 0.500 mm and produces an interference pattern on a screen 7.80 m away. The intensity at the central maximum is I_0. What is the distance on the screen from the center of this central maximum to the point where the intensity due to double-slit interference has fallen to 1/2 I_0?

Answer: 2.05 mm

21) Light of frequency 6.00×10^{14} Hz illuminates a soap film ($n = 1.33$) having air on both sides of it. When viewing the film by reflected light, what is the minimum thickness of the film that will give an interference maximum when the light is incident normally on it? ($c = 3.00 \times 10^8$ m/s)
A) 24.0 nm
B) 94.0 nm
C) 188 nm
D) 279 nm
E) 376 nm

Answer: B

22) A thin layer of oil (n = 1.25) is on top of a puddle of water (n = 1.33). If normally incident 500-nm light is strongly reflected, what is the minimum nonzero thickness of the oil layer?
A) 200 nm
B) 250 nm
C) 100 nm
D) 400 nm
E) 150 nm
Answer: A

23) White light is incident normally on a thin soap film having an index of refraction of 1.34. It reflects with an interference maximum at 684 nm and an interference minimum at 570 nm with no minima between those two values. The film has air on both sides of it. What is the thickness of the soap film?
A) 766 nm
B) 627 nm
C) 638 nm
D) 894 nm
E) 510 nm
Answer: C

24) A coating is being applied to reduce the reflectivity of a pane of glass to light with a frequency of 5.75×10^{14} Hz that is incident normally on the pane. If the material has an index of refraction of 1.375 and the glass has an index of refraction of 1.537, what is the minimum thickness the coating should have? ($c = 3.00 \times 10^8$ m/s)
A) 60.0 nm
B) 94.9 nm
C) 145 nm
D) 65.2 nm
E) 80.1 nm
Answer: B

25) Two extremely flat glass plates, 10.0 cm wide, touch at one end but are separated by a thin wire at the other end, forming a wedge. Light with a wavelength of 450 nm shines almost perpendicularly on the glass and forms fringes which are 1.80 mm apart. What is the diameter of the wire?
A) 25.0 μm
B) 17.5 μm
C) 20.0 μm
D) 12.5 μm
E) 10.0 μm
Answer: D

26) A puddle of water has a thin film of gasoline floating on it. A beam of light is shining perpendicular on the film. If the wavelength of light incident on the film is 560 nm and the indices of refraction of gasoline and water are 1.40 and 1.33, respectively, what is the minimum thickness of the film to see a bright reflection?
A) 100 nm
B) 200 nm
C) 300 nm
D) 400 nm
E) 500 nm

Answer: A

27) A piece of glass has a thin film of gasoline floating on it. A beam of light is shining perpendicular on the film. If the wavelength of light incident on the film is 560 nm and the indices of refraction of gasoline and glass are 1.40 and 1.50, respectively, what is the minimum nonzero thickness of the film to see a bright reflection?
A) 500 nm
B) 400 nm
C) 300 nm
D) 200 nm
E) 100 nm

Answer: D

28) A 360-nm thick oil film floats on the surface of the water. The indices of refraction of the oil and the water are 1.5 and 1.33, respectively. The surface of the oil is illuminated from above at normal incidence with white light. What TWO wavelengths of light in the 400-nm to 800-nm wavelength band are most strongly reflected?
A) 410 nm and 700 nm
B) 430 nm and 720 nm
C) 450 nm and 740 nm
D) 470 nm and 760 nm
E) 490 nm and 780 nm

Answer: B

29) Light of wavelength 425.0 nm in air falls at normal incidence on an oil film that is 850.0 nm thick. The oil is floating on a water layer 15 cm thick. The refractive index of water is 1.33, and that of the oil is 1.40. You want to add oil so that light reflected off of the top of the oil film will be canceled. What is the minimum distance that you should INCREASE the oil film?
A) 60.7 nm
B) 75.9 nm
C) 106 nm
D) 121 nm
E) 152 nm

Answer: A

30) Two optically flat glass plates, 16.0 cm long, are in contact at one end and separated by 0.0200 mm at the other end. The space between the plates is occupied by oil with index of refraction 1.45. The index of refraction of the glass plates is 1.55. The plates are illuminated at normal incidence with monochromatic light, and fringes are observed. If the dark fringes are spaced 2.00 mm apart, what is the wavelength of the monochromatic light?
A) 425 nm
B) 475 nm
C) 525 nm
D) 675 nm
E) 725 nm

Answer: E

31) Light is incident normally from air onto a liquid film that is on a glass plate. The liquid film is 164 nm thick, and the liquid has index of refraction 1.60. The glass has index of refraction n = 1.50. Calculate the longest visible wavelength (as measured in air) of the light for which there will be totally destructive interference between the rays reflected from the top and bottom surfaces of the film. (Assume that the visible spectrum lies between 400 and 700 nm.)

Answer: 525 nm

32) A soap bubble, when illuminated with light of frequency 5.11×10^{14} Hz, appears to be especially reflective. If it is surrounded by air and if its index of refraction is 1.35, what is the thinnest thickness the soap film can be? ($c = 3.00 \times 10^{8}$ m/s)

Answer: 109 nm

33) A single slit forms a diffraction pattern, with the first minimum at an angle of 40.0° from central maximum, when monochromatic light of 630-nm wavelength is used. The same slit, illuminated by a new monochromatic light source, produces a diffraction pattern with the second minimum at a 60.0° angle from the central maximum. What is the wavelength of this new light?
A) 425 nm
B) 450 nm
C) 475 nm
D) 500 nm
E) 525 nm

Answer: A

34) A single slit forms a diffraction pattern, with the first minimum at an angle of 40.0° from central maximum, using monochromatic light of 490-nm wavelength. What is the width of the slit?
A) 762 nm
B) 731 nm
C) 700 nm
D) 668 nm
E) 637 nm

Answer: A

35) A slit of width 0.010 mm has light of frequency 5.0×10^{14} Hz passing through it onto a screen 60 cm away. How wide is the central maximum? ($c = 3.00 \times 10^8$ m/s)
A) 0.12 cm
B) 7.2 cm
C) 1.8 cm
D) 3.6 cm
E) 0.90 cm
Answer: B

36) A single slit, which is 0.050 mm wide, is illuminated by light of 550 nm wavelength. What is the angular separation between the first two minima on either side of the central maximum?
A) 0.36°
B) 0.47°
C) 0.54°
D) 0.63°
E) 0.73°
Answer: D

37) Light of wavelength 687 nm is incident on a single slit 0.75 mm wide. At what distance from the slit should a screen be placed if the second dark fringe in the diffraction pattern is to be 1.7 mm from the center of the diffraction pattern?
A) 0.39 m
B) 0.47 m
C) 0.93 m
D) 1.1 m
E) 1.9 m
Answer: C

38) If the fifth order minimum in the diffraction pattern due to a thin slit is at 40° from the central maximum, at what angle does the first order minimum occur?
A) 8.0°
B) 3.4°
C) 4.0°
D) 7.4°
E) 1.7°
Answer: D

39) If the fifth order minimum in the diffraction pattern of a thin slit is at 40° from the central maximum, what is the highest order minimum in the pattern?
A) 6
B) 11
C) 8
D) 7
E) 9
Answer: D

40) A single slit illuminated with a 500 nm light gives a diffraction pattern on a far screen. The 5th minimum occurs at 7.00° away from the central maximum. At what angle does the 18th minimum occur?
A) 26.0°
B) 1.94°
C) 5.05°
D) 0.44°

Answer: A

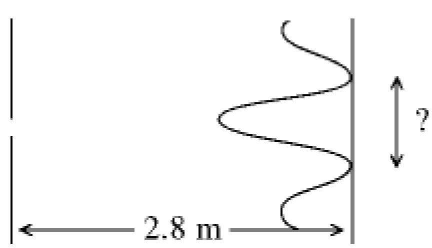
41) A single slit forms a diffraction pattern with monochromatic light. The 4th minimum of the pattern occurs at an angle of 35° from the central maximum. How many bright bands are on each side of the central maximum?
A) 5
B) 4
C) 6
D) 7
E) 8

Answer: A

42) A laser beam passes through a thin slit. When the pattern is viewed on a screen 1.25 m past the slit, you observe that the fifth–order dark fringes occur at ±2.41 cm from the central bright fringe. The entire experiment is now performed within a liquid, and you observe that each of the fifth–order dark fringes is 0.790 cm closer to the central fringe than it was in air. What is the index of refraction of this liquid?
A) 1.33
B) 1.40
C) 1.49
D) 1.62
E) 3.05

Answer: C

43) In the figure, a slit 0.30 mm wide is illuminated by light of wavelength 426 nm. A diffraction pattern is seen on a screen 2.8 m from the slit. What is the linear distance on the screen between the first diffraction minima on either side of the central diffraction maximum?



Answer: 8.0 mm

44) If the central maximum in a single slit diffraction pattern has intensity I_0, the intensity of the secondary maximum that is nearest to it is closest to
A) $0.045 I_0$.
B) $I_0/4$.
C) $I_0/2$.
D) I_0.
E) $2I_0$.

Answer: A

45) A slit of width 2.0 μm is used in a single slit experiment with light of wavelength 650 nm. If the intensity at the central maximum is I_0, what is the intensity 10° from the center?
A) $0.53 I_0$
B) $0.030 I_0$
C) $0.43 I_0$
D) $0.50 I_0$
E) $0.35 I_0$

Answer: E

46) A single slit that is 2100 nm wide forms a diffraction pattern when illuminated by monochromatic light of 680-nm wavelength. At an angle of 10° from the central maximum, what is the ratio of the intensity to the intensity of the central maximum?
A) $I/I_0 = 0.35$
B) $I/I_0 = 0.39$
C) $I/I_0 = 0.43$
D) $I/I_0 = 0.47$
E) $I/I_0 = 0.51$

Answer: A

47) A thin beam of light of wavelength 625 nm goes through a thin slit and falls on a screen 3.00 m past the slit. You observe that the first completely dark fringes occur on the screen at distances of ±8.24 mm from the central bright fringe, and that the central bright fringe has an intensity of 2.00 W/m^2 at its center.
(a) How wide is the slit?
(b) What is the intensity of light at a point on the screen that is one-quarter of the way from the central bright fringe to the first dark fringe?

Answer: (a) 0.228 mm (b) 1.62 W/m^2

48) When monochromatic light illuminates a grating with 7000 lines per centimeter, its second order maximum is at 62.4°. What is the wavelength of the light?
A) 336 nm
B) 363 nm
C) 452 nm
D) 633 nm
E) 752 nm

Answer: D

49) Monochromatic light is incident on a grating that is 75 mm wide and ruled with 50,000 lines. The second–order maximum is seen at 32.5°. What is the wavelength of the incident light?
A) 202 nm
B) 403 nm
C) 452 nm
D) 605 nm
E) 806 nm
Answer: B

50) In a diffraction grating experiment, light of 600 nm wavelength produces a first–order maximum 0.350 mm from the central maximum on a distant screen. A second monochromatic source produces a third–order maximum 0.870 mm from the central maximum when it passes through the same diffraction grating. What is the wavelength of the light from the second source?
A) 479 nm
B) 497 nm
C) 567 nm
D) 749 nm
E) 794 nm
Answer: B

51) A diffraction grating has 300 lines per mm. If light of frequency 4.76×10^{14} Hz is sent through this grating, at what angle does the first order maximum occur? ($c = 3.00 \times 10^8$ m/s)
A) 56°
B) 44°
C) 22°
D) 11°
E) 28°
Answer: D

52) A diffraction grating has 300 lines per mm. If light of wavelength 630 nm is sent through this grating, what is the highest order maximum that will appear?
A) 8
B) 2
C) 6
D) 5
E) 5.3
Answer: D

53) A He–Ne laser, which produces light of wavelength 632.8 nm, is used to calibrate a diffraction grating. If the first–order maximum occurs at 20.5° from the central spot, what is the distance between the slits of the grating?
A) 0.905 μm
B) 1.81 μm
C) 2.20 μm
D) 3.62 μm
E) 4.52 μm
Answer: B

54) Monochromatic light of wavelength 500 nm is incident normally on a diffraction grating. If the third–order maximum of the diffraction pattern is observed at 32.0° from the central spot, how many TOTAL number of maxima can be seen?
A) 5
B) 7
C) 10
D) 11
E) 13

Answer: D

55) What is the angular separation of the two second–order spectral lines having wavelengths 417 nm and 388 nm using a diffraction grating having 456 lines/mm?
A) 1.63°
B) 1.52°
C) 0.815°
D) 3.26°

Answer: A

56) An 18–mm wide diffraction grating has rulings of 880 lines per mm. Monochromatic light of 590 nm wavelength is incident normally on the grating. What is the largest angle, measured from the central bright spot, at which an intensity maximum is formed?
A) 31°
B) 29°
C) 27°
D) 25°
E) 23°

Answer: A

57) A diffraction grating has rulings of 890 lines/mm. When white light is incident normally on the grating, what is the longest wavelength that forms an intensity maximum in the fifth order?
A) 225 nm
B) 200 nm
C) 250 nm
D) 275 nm
E) 300 nm

Answer: A

58) A metallic sheet has a large number of slits, 5.0 mm wide and 20 cm apart, and is used as a diffraction grating for microwaves. A wide parallel beam of microwaves is incident normally on the sheet. If the microwave wavelength is 6.0 cm, what is the largest angle away from the central maximum at which an intensity maximum occurs.
A) 64°
B) 69°
C) 74°
D) 79°
E) 84°

Answer: A

59) A metallic sheet has a large number of slits, 5.0 mm wide and 20 cm apart, and is used as a diffraction grating for microwaves. A wide parallel beam of microwaves is incident normally on the sheet. What is the smallest microwave frequency for which only the central maximum occurs? ($c = 3.00 \times 10^8$ m/s)
A) 0.50 GHz
B) 0.70 GHz
C) 1.0 GHz
D) 1.5 GHz
E) 2.0 GHz
Answer: D

60) A diffraction grating has 450 lines per mm. What is the highest order m that contains the entire visible spectrum from 400 nm to 700 nm?
A) $m = 2$
B) $m = 3$
C) $m = 4$
D) $m = 5$
E) $m = 6$
Answer: B

61) A thin beam of laser light of wavelength 514 nm passes through a diffraction grating having 3952 lines/cm. The resulting pattern is viewed on a distant curved screen that can show all bright fringes up to and including ±90.0° from the central spot. What is the TOTAL number of bright fringes that will show up on the screen?
A) 4
B) 5
C) 8
D) 9
E) 10
Answer: D

62) A thin beam of laser light of wavelength 514 nm passes through a diffraction grating having 3952 lines/cm. The resulting pattern is viewed on a distant curved screen that can show all bright fringes up to and including ±90.0° from the central spot. If the experiment were performed with all of the apparatus under water (which has an index of refraction of 1.33), what would be the TOTAL number of bright spots that would show up on the screen?
A) 6
B) 7
C) 12
D) 13
E) 14
Answer: D

63) A diffraction grating is to be used to find the wavelength of the light in the emission spectrum of a gas. The grating spacing is not known, but a light having a known wavelength of 632.8 nm is deflected by 43.2° away from the central maximum in the second order by this grating. Light of the wavelength to be measured is deflected by 48.2° away from the central maximum in the second order. What is the wavelength of this light?
Answer: 689 nm

64) If an x-ray beam of wavelength 1.4×10^{-10} m makes an angle of 30° with a set of planes in a crystal causing first order constructive interference, what is the plane spacing?
A) 0.28 nm
B) 0.070 nm
C) 0.32 nm
D) 0.16 nm
E) 0.14 nm

Answer: E

65) If an x-ray beam of wavelength 1.4×10^{-10} m makes an angle of 20° with a set of planes in a crystal causing first order constructive interference, at what angle will the second order line appear?
A) 40°
B) 20°
C) 43°
D) 4.0°
E) 11°

Answer: C

66) Certain planes of a crystal of halite have a spacing of 0.399 nm. The crystal is irradiated by a beam of x-rays. First order constructive interference occurs when the beam makes an angle of 20° with the planes. What is the wavelength of the x-rays?
A) 0.14 nm
B) 0.17 nm
C) 0.21 nm
D) 0.24 nm
E) 0.27 nm

Answer: E

67) A researcher is investigating a cubic crystal with x-rays. He is looking at Bragg reflection from the planes parallel to the cube faces. He finds that when using x-rays of 0.165 nm a strong first maximum occurs when the beam makes an angle of 23.5° with the planes. What is the spacing of adjacent atoms in the crystal?

Answer: 0.207 nm

68) Light of wavelength 500 nm illuminates a round 0.50-mm diameter hole. A screen is placed 6.3 m behind the slit. What is the diameter of the central bright area on the screen?
A) 15 mm
B) 270 μm
C) 7.7 mm
D) 3800 μm

Answer: A

69) Light of wavelength 633 nm from a He–Ne laser passes through a circular aperture and is observed on a screen 4.0 m behind the aperture. The diameter of the central bright area is 5.4 cm. What is the diameter of the aperture?
A) 110 μm
B) 2.0 μm
C) 6600 μm
D) 960 μm
Answer: A

70) A radio telescope 200 m in diameter is used to investigate sources emitting a 21–cm wavelength wave. What is the minimum angular separation of the sources that can be resolved by this system?
A) 0.073°
B) 0.030°
C) 0.0013°
D) 0.154°
E) 0.0026°
Answer: A

71) A certain astronomical telescope has a diameter of 5.60 m. Considering only the limitation due to diffraction, what is the minimum angle of resolution for this telescope at a wavelength of 620 nm?
A) 0.111 μrad
B) 0.311 μrad
C) 0.270 μrad
D) 0.135 μrad
E) 0.405 μrad
Answer: D

72) A 10–inch telescope (25.4 cm in diameter) is used to determine if what appears to be one star is actually two stars. Stars are so far away that they are essentially point sources. How close (in angle) can the two stars be and still be resolved by this telescope if it is focusing light of wavelength of 550 nm? (Consider only the limitation due to diffraction.)
A) 4.2×10^{-8} degree
B) 2.6×10^{-6} degree
C) 3.0×10^{-4} degree
D) 1.5×10^{-4} degree
E) 6.6×10^{-8} degree
Answer: D

73) If the headlights on a car are separated by 1.3 m, how far down the road can they be resolved if the angular resolution of the eye is 5.0×10^{-4} rad and the person has excellent vision?
A) 1.3 km
B) 5.0 km
C) 4.8 km
D) 0.65 km
E) 2.6 km
Answer: E

74) What is the limiting angle of resolution for the eye if the pupil diameter of the eye is 4.0 mm, the wavelength of the light is 600 nm, and index of refraction of the liquid in the eye is 1.34?
A) 0.42 mrad
B) 0.21 mrad
C) 0.14 mrad
D) 0.11 mrad
E) 0.26 mrad

Answer: C

75) A camera used for aerial surveillance has a lens with a 30–cm maximum aperture and a 42–cm focal length. Assume light of 550–nm wavelength is used and that the resolution of the camera is limited solely by diffraction. What is the angular resolution of the camera at maximum aperture?
A) 1.6 μrad
B) 2.2 μrad
C) 3.2 μrad
D) 4.5 μrad
E) 6.3 μrad

Answer: B

76) Treat each of your eyes as a circular aperture of diameter 3.5 mm. Light of wavelength 500 nm is used to view two point sources that are 894 m distant from you. How far apart must these two point sources be if they are to be just resolved by your eye? Assume that the resolution is diffraction limited and use Rayleigh's criterion.

Answer: 16 cm

Chapter 33 Relativity

33.1 Conceptual Questions

1) A rocket is moving at 1/4 the speed of light relative to Earth. At the center of this rocket, a light suddenly flashes. To an observer at rest on Earth
   A) the light will reach the front of the rocket at the same instant that it reaches the back of the rocket.
   B) the light will reach the front of the rocket before it reaches the back of the rocket.
   C) the light will reach the front of the rocket after it reaches the back of the rocket.

   Answer: C

2) A rocket is moving at 1/4 the speed of light relative to Earth. At the center of this rocket, a light suddenly flashes. To an observer at rest in the rocket
   A) the light will reach the front of the rocket at the same instant that it reaches the back of the rocket.
   B) the light will reach the front of the rocket before it reaches the back of the rocket.
   C) the light will reach the front of the rocket after it reaches the back of the rocket.

   Answer: A

3) An astronaut in an inertial reference frame measures a time interval Δt between her heartbeats. What will observers in all other inertial reference frames measure for the time interval between her heartbeats?
   A) Δt
   B) more than Δt
   C) less than Δt
   D) The answer depends on whether they are moving toward her or away from her.

   Answer: B

4) You are a passenger on a spaceship. As the speed of the spaceship increases, you would observe that
   A) the length of your spaceship is getting shorter.
   B) the length of your spaceship is getting longer.
   C) the length of your spaceship is not changing.

   Answer: C

5) A star is moving towards the earth with a speed at 90% the speed of light. It emits light, which moves away from the star at the speed of light. Relative to us on earth, what is the speed of the light moving toward us from the star?
   A) $0.90c$
   B) c
   C) $1.1c$
   D) $1.20c$
   E) $1.9c$

   Answer: B

6) The special theory of relativity predicts that there is an upper limit to the speed of a particle. It therefore follows that there is also an upper limit on the following properties of a particle.
A) the kinetic energy
B) the total energy
C) the linear momentum
D) more than one of these
E) none of these
Answer: E

33.2 Problems

1) Astronaut Spud Nick is space-traveling from planet X to planet Y at a speed of $0.60c$ relative to the planets, which are at rest relative to each other. When he is precisely halfway between the planets, a distance of 1.0 light-hour from each one as measured in the planet frame, nuclear devices are detonated on each planet. The explosions are simultaneous in the frame of the planets. What is the difference in the time of arrival of the flashes from the explosions as observed by Spud?
A) 300 min
B) 150 min
C) 75 min
D) 0 min
E) 113 min
Answer: E

2) Astronaut Mark Uri is space-traveling from planet X to planet Y at a speed of $0.65c$ relative to the planets, which are at rest relative to each other. When he is precisely halfway between the planets, a distance of 1.0 light-hour from each one as measured in the planet frame, nuclear devices are detonated on both planets. The explosions are simultaneous in Mark's frame. What is the difference in the time of arrival of the flashes from the explosions as observed by Mark?
A) 0 min
B) 180 min
C) 90 min
D) 360 min
E) 113 min
Answer: A

3) As measured in Earth's rest frame, a spaceship traveling at $0.964c$ takes 11.2 y to travel between planets. How long does the trip take as measured by someone on the spaceship?
A) 2.98 y
B) 7.28 y
C) 42.1 y
D) 30.7 y
Answer: A

4) An astronaut on a spaceship moving at $0.927c$ says that the trip between two stationary stars took 7.49 y. How long does this journey take as measured by someone at rest relative to the two stars?
   A) 20.0 y
   B) 2.81 y
   C) 4.05 y
   D) 22.1 y

   Answer: A

5) Someone in Earth's rest frame says that a spaceship's trip between two planets took 10.0 y, while an astronaut on the space ship says that the trip took 6.27 y. Find the speed of the spaceship in terms of the speed of light.
   A) $0.779c$
   B) $0.687c$
   C) $0.975c$
   D) $0.384c$

   Answer: A

6) An unstable particle is moving at a speed of 2.6×10^8 m/s relative to a laboratory. Its lifetime is measured by a stationary observer in the laboratory to be 4.7×10^{-6} seconds. What is the lifetime of the particle, measured in the rest frame of the particle? ($c = 3.00 \times 10^8$ m/s)

   Answer: 2.3 μs

7) The closest known star to our solar system is Alpha Centauri, which is approximately 4.30 light years away. A spaceship with a constant speed of $0.800c$ relative to the earth travels from Earth to this star.
   (a) How much time would elapse during the trip on a clock on board the spaceship?
   (b) How much time would elapse during the trip on a clock on Earth?

   Answer: (a) 3.23 y (b) 5.38 y

8) A spaceship approaches the earth with a speed $0.50c$. A passenger in the spaceship measures his heartbeat as 70 beats per minute. What is his heartbeat rate according to an observer that is at rest relative to the earth?
   A) 69 beats per minute
   B) 73 beats per minute
   C) 65 beats per minute
   D) 61 beats per minute
   E) 80 beats per minute

   Answer: D

9) A set of twins, Andrea and Courtney, are initially 10 years old. While Courtney remains on Earth, Andrea rides on a spaceship which travels away from Earth at a speed of 0.60 c for five years (as measured by Courtney), then immediately turns around and comes back at 0.60 c. When Andrea returns, Courtney is 20 years old. How old is Andrea upon her return?
A) 10 y
B) 12 y
C) 15 y
D) 18 y
E) 20 y

Answer: D

10) Relative to the frame of the observer making the measurement, at what speed parallel to its length is the length of a meterstick 60 cm?
A) 0.80c
B) 0.60c
C) 0.50c
D) 0.70c
E) 0.90c

Answer: A

11) An astronaut leaves Earth in a spaceship at a speed of 0.960 c relative to an observer on Earth. The astronaut's destination is a star system 14.4 light-years away (one light-year is the distance light travels in one year.) According to the astronaut, how long does the trip take?
A) 14.4 y
B) 22.7 y
C) 9.34 y
D) 15.0 y
E) 4.20 y

Answer: E

12) In their common rest frame, two stars are 90.0 light-years (ly) apart. If they are 12.0 ly apart as measured by the navigator in a spaceship traveling between them, how fast is the spaceship moving? Express your answer in terms of c.
A) 0.991c
B) 0.986c
C) 0.980c
D) 0.972c

Answer: A

13) A particle in a 453 m-long linear particle accelerator is moving at 0.875c. How long does the particle accelerator appear to the particle?
A) 219 m
B) 589 m
C) 104 m
D) 936 m

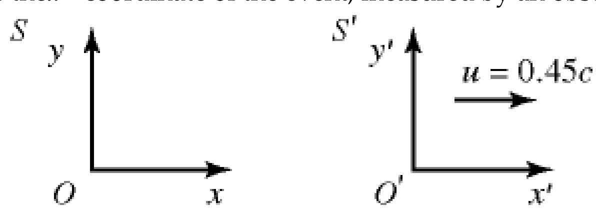
Answer: A

14) A spaceship is moving between two distant stars at $0.932c$. To someone in the ship, the distance between the two stars appears to be 26.9 light–years (ly). What is the distance between the stars in the rest frame of the stars?
A) 74.2 ly
B) 9.75 ly
C) 21.5 ly
D) 56.5 ly
Answer: A

15) Two space stations are at rest relative to each other and are 6.0×10^7 m apart, as measured by observers on the stations. A spaceship traveling from one station to the other at $0.90c$ relative to the stations passes both of them, one after the other. As measured by an observer in the spaceship, how long does it take to travel from one station to the other? ($c = 3.00 \times 10^8$ m/s)
A) 97 ms
B) 220 ms
C) 510 ms
D) 58 ms
E) 39 ms
Answer: A

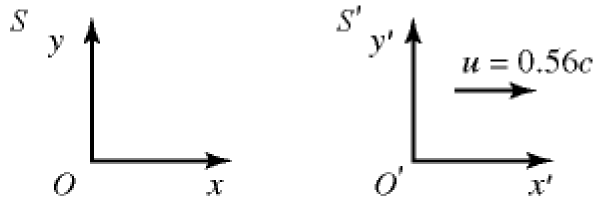
16) A spacecraft is measured by an observer on the ground to have a length of 53 m as it flies toward the earth with a speed 1.7×10^8 m/s. The spacecraft then lands and its length is again measured by the observer on the ground, this time while the spacecraft is at rest on the launchpad. What result does he now get for the length? ($c = 3.00 \times 10^8$ m/s)
Answer: 64 m

17) System S' has a velocity $u = +0.45c$ relative to system S, as shown in the figure. The clocks of S and S' are synchronized at $t = t' = 0$ when the origins O and O' coincide. An event is observed in both systems. The event takes place at $x = 600$ m and at time $t = 1.9$ μs, as measured by an observer in S. What is the x'–coordinate of the event, measured by an observer in S'?



A) 380 m
B) 340 m
C) 360 m
D) 350 m
E) 310 m
Answer: A

18) System S' has a velocity $u = +0.56c$ relative to system S, as shown in the figure. The clocks of S and S' are synchronized at $t = t' = 0$ when the origins O and O' coincide. An event is observed in both systems. The event takes place at $x = 800$ m and at time $t = 3.0$ μs as measured by an observer in S. What is the time t' of the event, measured by an observer in S'?



A) 1.8 μs
B) –4.9 μs
C) 1.7 μs
D) 1.3 μs
E) 1.5 μs

Answer: A

19) In an "atom smasher," two particles collide head on at relativistic speeds. If the velocity of the first particle is $0.741c$ to the left, and the velocity of the second particle is $0.350c$ to the right (both of these speeds are measured in Earth's rest frame), how fast are the particles moving with respect to each other?

A) $0.866c$
B) $1.091c$
C) $0.883c$
D) $0.788c$

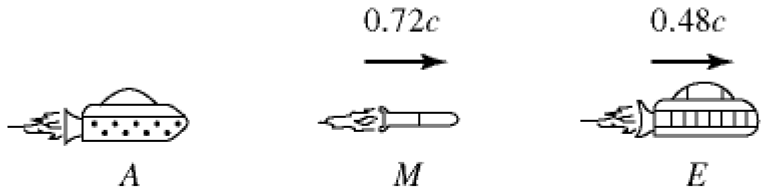
Answer: A

20) A spaceship approaching an asteroid at a speed of $0.60c$ launches a rocket forward with a speed of $0.40c$ relative to the spaceship. At what speed is the rocket approaching the asteroid as measured by an astronaut on the asteroid?

A) $0.81c$
B) $1.0c$
C) $0.76c$
D) $0.64c$
E) $0.96c$

Answer: A

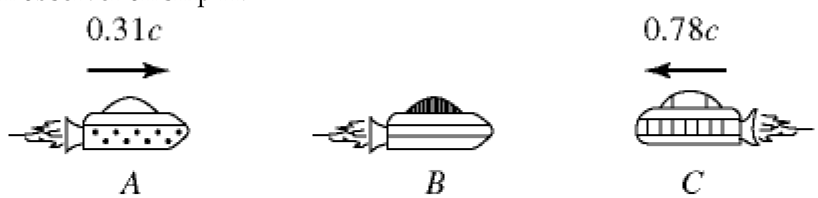
21) The captain of spaceship A observes enemy spaceship E escaping with a relative velocity of $0.48c$, as shown in the figure. A missile M is fired from ship A, with a velocity of $0.72c$ relative to ship A. What is the relative velocity of approach of missile M, observed by the crew on ship E?



A) $0.37c$
B) $0.24c$
C) $0.34c$
D) $0.30c$
E) $0.27c$

Answer: A

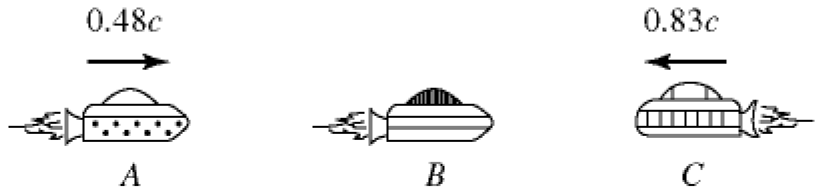
22) Three spaceships A, B, and C are in motion, as shown in the figure. The commander on ship B observes ship C approaching with a relative velocity of $0.78c$. The commander also observes ship A, advancing in the rear, with a relative velocity of $0.31c$. What is the velocity of ship C, relative to an observer on ship A?



A) $0.88c$
B) $0.38c$
C) $1.4c$
D) $0.62c$
E) $1.1c$

Answer: A

23) Three spaceships *A*, *B*, and *C* are in motion as shown in the figure. The commander on ship *B* observes ship *C* approaching with a relative velocity of 0.83*c*. The commander also observes ship *A*, advancing in the rear, with a relative velocity of 0.48*c*. As measured by commander on ship *B*, at what speed is ship *A* approaching ship *C*?



A) 1.3*c*
B) 0.94*c*
C) 0.25*c*
D) 0.58*c*
E) 2.2*c*

Answer: A

24) Consider three galaxies, Alpha, Beta and Gamma. An observer in Beta sees the other two galaxies each moving away from him in opposite directions at speed 0.70*c*. At what speed would an observer in Alpha see the galaxy Beta moving?
A) 0.82*c*
B) 0.70*c*
C) 0.94*c*
D) 0.35*c*
E) 0.57*c*

Answer: B

25) Two spaceships are approaching one another, each at a speed of 0.28*c* relative to a stationary observer on Earth. What speed does an observer on one spaceship record for the other approaching spaceship?

Answer: 0.52*c*

26) A spaceship is moving away from the earth with a constant speed of 0.80*c*. The spaceship fires a 28-kg missile with a speed of 0.50*c* relative to the spaceship. What is the speed of the missile measured by observers on the earth if the missile is fired
(a) away from the earth?
(b) toward the earth?

Answer: (a) 0.93*c* (b) 0.50*c*

27) At what speed relative to the lab will a 0.272-kg object have the same momentum as a 1.30-kg object that is moving at 0.515*c* relative to the lab?
A) 0.944*c*
B) 0.922*c*
C) 0.981*c*
D) 0.592*c*

Answer: A

28) A particle is moving at $0.75c$ relative to a lab on Earth. By what percentage is the Newtonian expression for its momentum in error? (The percentage error is the difference between the erroneous and correct values, divided by the *correct* one).
A) 34%
B) 28%
C) 38%
D) 43%
Answer: A

29) In the lab, a relativistic proton has a momentum of 1.00×10^{-19} kg • m/s and a rest energy of 0.150 nJ. What is the speed of the proton in the lab? ($c = 3.00 \times 10^8$ m/s, $m_{proton} = 1.67 \times 10^{-27}$ kg)
A) $0.170c$
B) $0.196c$
C) $0.911c$
D) $0.930c$
E) $0.951c$
Answer: B

30) An electron has a speed of $0.643c$. Through what potential difference would the electron need to be accelerated (starting from rest) in order to reach this speed? ($c = 3.00 \times 10^8$ m/s, $e = 1.60 \times 10^{-19}$ C, $m_{el} = 9.11 \times 10^{-31}$ kg)
A) 160 kV
B) 130 kV
C) 180 kV
D) 200 kV
Answer: A

31) An electron is accelerated from rest through a potential difference of 50.0 kV. What is the speed of the electron? ($c = 3.00 \times 10^8$ m/s, $e = 1.60 \times 10^{-19}$ C, $m_{el} = 9.11 \times 10^{-31}$ kg)
A) 1.24×10^8 m/s
B) 1.33×10^8 m/s
C) 3.24×10^8 m/s
D) 3.33×10^8 m/s
E) 4.12×10^8 m/s
Answer: A

32) In a certain particle accelerator, a proton has a kinetic energy that is equal to its rest energy. What is the speed of the proton relative to the accelerator?
A) $0.25c$
B) $0.50c$
C) $0.71c$
D) $0.75c$
E) $0.87c$
Answer: E

33) How many joules of energy are required to accelerate a 1.0 – kg mass from rest to a speed of 86.6% the speed of light? (c = 3.00 × 10^8 m/s)

A) 1.8 × 10^{17} J
B) 9.0 × 10^{16} J
C) 2.7 × 10^{12} J
D) 4.5 × 10^9 J
E) 3.0 × 10^3 J

Answer: B

34) How much work must be done to accelerate a particle of mass 2.1 × 10^{-14} kg from a speed of 1.5 × 10^8 m/s to a speed of 2.5 × 10^8 m/s? (c = 3.00 × 10^8 m/s)

Answer: 1200 J

35) Assume that a certain city consumes electrical energy at an average rate of 2.0 × 10^9 W. What would be the mass change in producing enough energy to keep this city running for 21 weeks? (c = 3.00 × 10^8 m/s)

A) 0.28 kg
B) 0.32 kg
C) 0.40 kg
D) 0.48 kg

Answer: A

36) During a nuclear reaction, the particles involved lose 4.8 × 10^{-28} kg of mass. How many joules of energy are released by this reaction? (c = 3.00 × 10^8 m/s)

A) 4.3 × 10^{-11} J
B) 1.4 × 10^{-19} J
C) 1.6 × 10^{-36} J
D) 2.1 × 10^{-40} J
E) 5.3 × 10^{-45} J

Answer: A

37) During a nuclear reaction, 1.7 × 10^{-4} J of energy is released. What is the resulting change in mass of the particles involved? (c = 3.00 × 10^8 m/s)

A) 5.1 × 10^{-4} kg
B) 4.3 × 10^{-11} kg
C) 1.5 × 10^{-13} kg
D) 4.8 × 10^{-18} kg
E) 1.9 × 10^{-21} kg

Answer: E

38) An electron is accelerated from rest through a potential difference of 50.0 kV. What is the TOTAL energy of the electron? ($c = 3.00 \times 10^8$ m/s, $e = 1.60 \times 10^{-19}$ C, $m_{el} = 9.11 \times 10^{-31}$ kg)

A) 8.00×10^{-15} J
B) 16.2×10^{-15} J
C) 8.20×10^{-14} J
D) 9.00×10^{-14} J
E) 16.2×10^{-14} J

Answer: D

39) A relativistic proton has a momentum of 1.0×10^{-17} kg • m/s and a rest energy of 0.15 nJ. What is the kinetic energy of this proton? ($c = 3.00 \times 10^8$ m/s, $m_{proton} = 1.67 \times 10^{-27}$ kg)

A) 1.3 pJ
B) 1.6 pJ
C) 3.0 pJ
D) 2.2 pJ
E) 2.5 pJ

Answer: C

40) A proton in a certain particle accelerator has a kinetic energy that is equal to its rest energy. What is the TOTAL energy of the proton as measured by a physicist working with the accelerator? ($c = 3.00 \times 10^8$ m/s, $m_{proton} = 1.67 \times 10^{-27}$ kg)

A) 5.69×10^{-11} J
B) 1.50×10^{-10} J
C) 2.07×10^{-10} J
D) 3.01×10^{-10} J
E) 8.77×10^{-10} J

Answer: D

41) A proton in a certain particle accelerator has a kinetic energy that is equal to its rest energy. What is the momentum of the proton as measured by a physicist working with the accelerator? ($c = 3.00 \times 10^8$ m/s, $m_{proton} = 1.67 \times 10^{-27}$ kg)

A) 2.51×10^{-19} kg • m/s
B) 2.89×10^{-19} kg • m/s
C) 4.34×10^{-19} kg • m/s
D) 5.01×10^{-19} kg • m/s
E) 8.68×10^{-19} kg • m/s

Answer: E

42) How fast must a proton move so that its kinetic energy is 80% of its total energy?

A) $0.020c$
B) $0.87c$
C) $0.92c$
D) $0.98c$
E) $0.80c$

Answer: D

43) As a spaceship is moving toward Earth, an Earthling measures its length to be 325 m, while the captain on board radios that her spaceship's length is 1150 m. (c = 3.00 × 10^8 m/s)
(a) How fast is the rocket moving relative to Earth?
(b) What is the TOTAL energy of a 75.0–kg crewman as measured by (i) the captain in the rocket and (ii) the Earthling?

Answer: (a) 0.959c = 2.88 × 10^8 m/s
(b) (i) 6.75 × 10^{18} J (ii) 2.39 × 10^{19} J

Chapter 34 Particles and Waves

34.1 Conceptual Questions

1) Monochromatic light strikes a metal surface and electrons are ejected from the metal. If the intensity of the light is increased, what will happen to the ejection rate and maximum energy of the electrons?
   A) greater ejection rate; same maximum energy
   B) same ejection rate; greater maximum energy
   C) greater ejection rate; greater maximum energy
   D) same ejection rate; same maximum energy

   Answer: A

2) A beam of red light and a beam of violet light each deliver the same power on a surface. For which beam is the number of photons hitting the surface per second the greatest?
   A) the red beam
   B) the violet beam
   C) It is the same for both beams.

   Answer: A

3) At absolute temperature T, a black body radiates its peak intensity at wavelength λ. At absolute temperature $2T$, what would be the wavelength of the peak intensity?
   A) 16λ
   B) 2λ
   C) λ
   D) $\lambda/2$
   E) $\lambda/16$

   Answer: D

4) A nonrelativistic electron and a nonrelativistic proton have the same de Broglie wavelength. Which of the following statements about these particles are accurate? (There may be more than one correct choice.)
   A) Both particles have the same speed.
   B) Both particles have the same kinetic energy.
   C) Both particles have the same momentum.
   D) The electron has more kinetic energy than the proton.
   E) The electron has more momentum than the proton.

   Answer: C, D

5) If the accuracy in measuring the position of a particle increases, the accuracy in measuring its velocity will
   A) increase.
   B) decrease.
   C) remain the same.
   D) It is impossible to say since the two measurements are independent and do not affect each other.

   Answer: B

6) If the accuracy in measuring the velocity of a particle increases, the accuracy in measuring its position will
   A) increase.
   B) decrease.
   C) remain the same.
   D) It is impossible to say since the two measurements are independent and do not affect each other.

   Answer: B

34.2 Problems

1) Light of wavelength 400 nm falls on a metal surface having a work function 1.70 eV. What is the maximum kinetic energy of the photoelectrons emitted from the metal? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J • s = 4.141×10^{-15} ev • s, 1 eV = 1.60×10^{-19} J)
   A) 4.52 eV
   B) 3.11 eV
   C) 1.41 eV
   D) 2.82 eV
   E) 1.70 eV

   Answer: C

2) When a certain metal is illuminated by light, photoelectrons are observed provided that the wavelength of the light is less than 669 nm. Which one of the following values is closest to the work function of this metal? ($h = 6.626 \times 10^{-34}$ J • s, $c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J)
   A) 1.9 eV
   B) 2.0 eV
   C) 2.2 eV
   D) 2.3 eV

   Answer: A

3) Upon being struck by 240-nm photons, a metal ejects electrons with a maximum kinetic energy of 1.45 eV. What is the work function of this metal? ($h = 6.626 \times 10^{-34}$ J • s, $c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J)
   A) 3.73 eV
   B) 3.13 eV
   C) 4.33 eV
   D) 4.92 eV

   Answer: A

4) In a photoelectric effect experiment, electrons emerge from a copper surface with a maximum kinetic energy of 1.10 eV when light shines on the surface. The work function of copper is 4.65 eV. Which one of the following values is closest to the wavelength of the light? ($h = 6.626 \times 10^{-34}$ J • s, $c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J)
   A) 220 nm
   B) 150 nm
   C) 360 nm
   D) 1100 nm

   Answer: A

5) A metal having a work function of 2.5 eV is illuminated with white light that has a continuous wavelength band from 400 nm to 700 nm. For which one of the following ranges of the wavelength band in this white light are photoelectrons NOT produced? (h = 6.626 × 10^{-34} J • s, c = 3.00 × 10^{8} m/s, 1 eV = 1.60 × 10^{-19} J)
A) 500 nm to 700 nm
B) 400 nm to 560 nm
C) 500 nm to 560 nm
D) 400 nm to 500 nm
E) 560 nm to 700 nm
Answer: A

6) A metal having a work function of 2.4 eV is illuminated with monochromatic light whose photon energy is 4.0 eV. What is the maximum kinetic energy of the photoelectrons produced by this light? (h = 6.626 × 10^{-34} J • s, 1 eV = 1.60 × 10^{-19} J)
A) 2.6 × 10^{-19} J
B) 3.8 × 10^{-19} J
C) 4.7 × 10^{-19} J
D) 5.5 × 10^{-19} J
E) 6.4 × 10^{-19} J
Answer: A

7) A metal having a work function of 2.8 eV is illuminated with monochromatic light whose photon energy is 3.9 eV. What is the threshold frequency for photoelectron production? (h = 6.626 × 10^{-34} J • s, 1 eV = 1.60 × 10^{-19} J)
A) 6.8 × 10^{14} Hz
B) 2.7 × 10^{14} Hz
C) 7.6 × 10^{14} Hz
D) 8.5 × 10^{14} Hz
E) 9.4 × 10^{14} Hz
Answer: A

8) A stopping potential of 0.50 V is required when a phototube is illuminated with monochromatic light of wavelength 590 nm. Monochromatic light of a different wavelength is now shown on the tube, and the stopping potential is measured to be 2.30 V. What is the wavelength of this new light? (c = 3.00 × 10^{8} m/s, e = – 1.60 × 10^{-19} C, h = 6.626 × 10^{-34} J • s, 1 eV = 1.60 × 10^{-19} J)
A) 320 nm
B) 300 nm
C) 340 nm
D) 360 nm
E) 410 nm
Answer: A

9) A metal surface has a work function of 1.50 eV. Calculate the maximum kinetic energy, in eV, of electrons ejected from this surface by electromagnetic radiation of wavelength 311 nm. (c = 3.00 × 10^{8} m/s, h = 6.626 × 10^{-34} J • s, e = – 1.60 × 10^{-19} C, 1 eV = 1.60 × 10^{-19} J)
Answer: 2.50 eV

10) When a metal surface is illuminated with light of wavelength 437 nm, the stopping potential for photoelectrons is 1.67 V. (c = 3.00 × 10^8 m/s, h = 6.626 × 10^{-34} J • s, e = – 1.60 × 10^{-19} C, 1 eV = 1.60 × 10^{-19} J, m_{el} = 9.11 × 10^{-31} kg)

(a) What is the work function of the metal, in eV?
(b) What is the maximum speed of the ejected electrons?

Answer: (a) 1.17 eV (b) 7.66 × 10^5 m/s

11) *Gamma rays* are photons with very high energy. How many visible–light photons with a wavelength of 500 nm would you need to match the energy of a gamma–ray photon with energy 4.1 × 10^{-13} J? (h = 6.626 × 10^{-34} J • s, c = 3.00 × 10^8 m/s)

A) 1.0 × 10^6
B) 1.4 × 10^8
C) 6.2 × 10^9
D) 3.9 × 10^3

Answer: A

12) An 84–kW AM radio station broadcasts at 1000 kHz . How many photons are emitted each second by the transmitting antenna? (h = 6.626 × 10^{-34} J • s)

A) 1.3 × 10^{32}
B) 2.9 × 10^{24}
C) 6.3 × 10^{12}
D) 1.4 × 10^{15}

Answer: A

13) A light beam from a 2.1–mW He–Ne laser has a wavelength of 633 nm. How many photons does the laser emit in one second? (h = 6.626 × 10^{-34} J • s, c = 3.00 × 10^8 m/s)

A) 6.7 × 10^{15}
B) 8.8 × 10^{15}
C) 1.1 × 10^{16}
D) 1.3 × 10^{16}

Answer: A

14) A laser emits light of wavelength 463 nm during a brief pulse that lasts for 25 ms and has a total energy of 1.2 J. How many photons are emitted in that single pulse? (c = 3.00 × 10^8 m/s, h = 6.626 × 10^{-34} J • s)

A) 2.8 × 10^{18}
B) 6.9 × 10^{19}
C) 3.4 × 10^{19}
D) 1.1 × 10^{17}
E) 2.2 × 10^{17}

Answer: A

15) A photon of initial wavelength 0.651 nm, after being scattered from a free electron at rest, moves off at an angle of 120° with respect to its incident direction. (m_{el} = 9.11 × 10^{-31} kg, h = 6.626 × 10^{-34} J • s•, c = 3.00 × 10^8 m/s)
(a) What is the wavelength of the scattered photon?
(b) What is the energy of the scattered photon?
Answer: (a) 0.655 nm (b) 3.04 × 10^{-16} J

16) In a particular case of Compton scattering, a photon collides with a free electron and scatters backwards. The wavelength after the collision is exactly double the wavelength before the collision. What is the wavelength of the incident photon? (m_{el} = 9.11 × 10^{-31} kg, h = 6.626 × 10^{-34} J • s, c = 3.00 × 10^8 m/s)
A) 3.6 pm
B) 4.8 pm
C) 2.4 pm
D) 1.2 pm
E) 6.0 pm
Answer: B

17) A beam of x-rays at a certain wavelength are scattered from a free electron at rest and the scattered beam is observed at 45.0° to the incident beam. What is the change in the wavelength of the x-rays? (m_{el} = 9.11 × 10^{-31} kg, h = 6.626 × 10^{-34} J • s, c = 3.00 × 10^8 m/s)
A) 0.175 pm
B) 0.276 pm
C) 0.000 pm
D) 0.356 pm
E) 0.710 pm
Answer: E

18) A photon of wavelength 29 pm is scattered by a stationary electron. What is the maximum possible energy loss of the photon? (m_{el} = 9.11 × 10^{-31} kg, h = 6.626 × 10^{-34} J • s, c = 3.00 × 10^8 m/s)
A) 4.0 keV
B) 7.0 keV
C) 10 keV
D) 6.1 keV
E) 12 keV
Answer: D

19) A photon of wavelength 18.0 pm is scattered through an angle of 120° by a stationary electron. What is the wavelength of the scattered photon? (m_{el} = 9.11 × 10^{-31} kg, h = 6.626 × 10^{-34} J • s, c = 3.00 × 10^8 m/s)
A) 19.2 pm
B) 20.4 pm
C) 21.6 pm
D) 22.9 pm
E) 24.1 pm
Answer: C

20) X–rays of energy 2.9×10^4 eV are scattered by a free stationary electron through an angle of 135°. What is the energy of the scattered x–rays, in electron volts? ($m_{el} = 9.11 \times 10^{-31}$ kg, $e = -1.60 \times 10^{-19}$ C, $h = 6.626 \times 10^{-34}$ J • s, $c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J)

Answer: 2.6×10^4 eV

21) The Bohr radius of the hydrogen atom is 0.529×10^{-10} m. What is the radius of the $n = 2$ state?

A) 1.06×10^{-10} m
B) 2.12×10^{-10} m
C) 0.265×10^{-10} m
D) 0.529×10^{-10} m
E) 4.23×10^{-10} m

Answer: B

22) The energy of the ground state in the Bohr model of the hydrogen atom is −13.6 eV. The energy of the $n = 2$ state of hydrogen in this model is closest to

A) −3.4 eV.
B) −6.8 eV.
C) −1.7 eV.
D) −13.6 eV.
E) −4.5 eV.

Answer: A

23) The energy of the ground state in the Bohr model of the hydrogen atom is −13.6 eV. In a transition from the $n = 2$ state to the $n = 4$ state, a photon of energy

A) 3.40 eV is emitted.
B) 3.40 eV is absorbed.
C) 2.55 eV is emitted.
D) 2.55 eV is absorbed.
E) 0.85 eV is absorbed.

Answer: D

24) What is the frequency of the light emitted by atomic hydrogen with $m = 8$ and $n = 12$? (The Rydberg constant is $R = 1.097 \times 10^7$ m^{-1}, $c = 3.00 \times 10^8$ m/s)

A) 2.86×10^{13} Hz
B) 1.43×10^{13} Hz
C) 7.46×10^{13} Hz
D) 8.82×10^{13} Hz
E) 1.05×10^{13} Hz

Answer: A

25) What is the orbital radius of the $n = 3$ excited state in the Bohr model of the hydrogen atom? The ground–state radius of the hydrogen atom is 0.529×10^{-10} m.

A) 0.476 nm
B) 0.159 nm
C) 0.381 nm
D) 0.548 nm

Answer: A

26) Light excites atomic hydrogen from its lowest level to the $n = 4$ level. What is the energy of the light? The energy of the lowest level is −13.6 eV.
A) 12.8 eV
B) 3.40 eV
C) 0.850 eV
D) 26.4 eV
Answer: A

27) Light shines through atomic hydrogen gas. It is seen that the gas absorbs light readily at a wavelength of 91.63 nm. What is the value of n of the level to which the hydrogen is being excited by the absorption of light of this wavelength? Assume that the most of the atoms in the gas are in the lowest level. ($h = 6.626 \times 10^{-34}$ J • s, $c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J, the Rydberg constant is $R = 1.097 \times 10^7$ m^{-1})
A) 14
B) 16
C) 11
D) 21
Answer: A

28) A hydrogen atom is in its $n = 2$ excited state when its electron absorbs a photon of energy 8.5 eV. What is the energy of the resulting free electron? The lowest level energy state of hydrogen is −13.6 eV. ($h = 6.626 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J)
A) 5.1 eV
B) 6.6 eV
C) 6.9 eV
D) 7.6 eV
Answer: A

29) A hydrogen atom initially in the $n = 6$ state decays to the $n = 2$ state. The emitted photon is detected in a photographic plate. What is the wavelength of the detected photon? The lowest level energy state of hydrogen is −13.6 eV. ($h = 6.626 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^8$ m/s)
A) 410 nm
B) 93.8 nm
C) 1090 nm
D) 93.1 nm
Answer: A

30) A hydrogen atom is excited to the $n = 10$ stated. It then decays to the $n = 4$ state by emitting a photon which is detected in a photographic plate. What is the frequency of the detected photon? The lowest level energy state of hydrogen is −13.6 eV. ($h = 6.626 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J)
A) 3.46×10^{14} Hz
B) 0.865×10^{14} Hz
C) 1.27×10^{14} Hz
D) 4.05×10^{14} Hz
E) 1.73×10^{14} Hz
Answer: E

31) A hydrogen atom makes a downward transition from the $n = 20$ state to the $n = 5$ state. Find the wavelength of the emitted photon. The lowest level energy state of hydrogen is -13.6 eV. ($h = 6.626 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^{8}$ m/s)
A) 2.43 μm
B) 1.46 μm
C) 1.94 μm
D) 2.92 μm
Answer: A

32) Suppose that in a parallel universe, the proton and electron were identical to their counterparts in our own universe EXCEPT that the electron had twice as much charge as our electron. In our present universe, the radius of the first Bohr orbit for hydrogen is a_0 and the speed of an electron in that orbit is v_0. In the parallel universe
(a) what would be the radius (in terms of a_0) of the first Bohr orbit for hydrogen?
(b) what would be the speed (in terms of v_0) of an electron in the first Bohr orbit for hydrogen?
Answer: (a) $a_0/2$ (b) $2v_0$

33) In the vicinity of what frequency does an object with a temperature of 1000 K radiate the largest amount of power? ($c = 3.00 \times 10^{8}$ m/s, Wien displacement law constant equals 2.90×10^{-3} m • K, $\sigma = 5.670 \times 10^{-8}$ W/m^2 • K^4)
A) 1.0×10^{14} Hz
B) 8.0×10^{14} Hz
C) 2.3×10^{14} Hz
D) 6.7×10^{14} Hz
E) 4.1×10^{14} Hz
Answer: A

34) What is the wavelength of peak emission for a black body at 37°C? ($c = 3.0 \times 10^{8}$ m/s, Wien displacement law constant is 2.9×10^{-3} m • K, $\sigma = 5.67 \times 10^{-8}$ W/m^2 • K^4)
A) 94 μm
B) 9.4 μm
C) 29 μm
D) 7.8 μm
E) 78 μm
Answer: B

35) A perfectly black body at 100°C emits light of intensity I that has the strongest intensity near wavelength λ. The temperature of this body is now increased to 200°C.
(a) In terms of I, what is the intensity at which this hotter body radiates?
(b) In terms of λ, near what wavelength does light radiated from this hotter body have the strongest intensity?
Answer: (a) $2.6I$ (b) $0.80\ \lambda$

36) An electric current through a tungsten filament maintains its temperature at 2800 K. Assume the tungsten filament behaves as an ideal radiator at that temperature. Near what wavelength does the filament emit the greatest power? ($\sigma = 5.67 \times 10^{-8}$ W/m$^2 \cdot$ K^4, Wien displacement law constant is 2.9×10^{-3} m $\cdot$ K)
A) 1000 nm
B) 1200 nm
C) 1400 nm
D) 1600 nm
E) 1800 nm

Answer: A

37) An electric current through a tungsten filament maintains its temperature at 2800 K. Assume the tungsten filament behaves as an ideal radiator at that temperature. If the radiating area of the filament is 2.0×10^{-6} m^2, at what rate does it radiate energy? ($\sigma = 5.670 \times 10^{-8}$ W/m$^2 \cdot$ K^4, Wien displacement law constant is 2.90×10^{-3} m $\cdot$ K)
A) 5.5 W
B) 7.0 W
C) 8.5 W
D) 10 W
E) 11.5 W

Answer: B

38) A perfectly black sphere 18.0 cm in diameter is held at a temperature of 215°C. ($\sigma = 5.670 \times 10^{-8}$ W/m$^2 \cdot$ K^4, Wien displacement law constant is 2.90×10^{-3} m $\cdot$ K, $h = 6.626 \times 10^{-34}$ J $\cdot$ s, $c = 3.00 \times 10^8$ m/s)
(a) Near what wavelength does this sphere radiate most strongly?
(b) If all the radiated energy were at the wavelength found in part (a), how many photons would the sphere emit each second?

Answer: (a) 5.94 μm (b) 9.79×10^{21} photons

39) Calculate the kinetic energy (in eV) of a nonrelativistic neutron that has a de Broglie wavelength of9.9×10^{-12} m. ($h = 6.626 \times 10^{-34}$ J $\cdot$ s, $m_{\text{neutron}} = 1.675 \times 10^{-27}$ kg, 1 eV = 1.60×10^{-19} J)

Answer: 8.4 eV

40) In a double slit experiment, a beam of electrons strikes a pair of slits. The slits are 15 μm apart, and the first interference maximum lies at an angle of 0.50 μrad from the center of the interference pattern. What is the momentum of the incoming electrons? ($h = 6.626 \times 10^{-34}$ J $\cdot$ s, $m_{\text{el}} = 9.11 \times 10^{-31}$ kg)
A) 4.4×10^{-23} kg $\cdot$ m/s
B) 2.2×10^{-23} kg $\cdot$ m/s
C) 1.1×10^{-23} kg $\cdot$ m/s
D) 6.6×10^{-23} kg $\cdot$ m/s
E) 8.8×10^{-23} kg $\cdot$ m/s

Answer: E

41) Electrons emerge from an electron gun with a speed of 2.0×10^6 m/s and then pass through a pair of thin parallel slits. Interference fringes with a spacing of 2.7 mm are detected on a screen far from the double slit and fairly close to the center of the pattern. What would the fringe spacing be if the electrons were replaced by neutrons with the same speed? ($m_{el} = 9.11 \times 10^{-31}$ kg, $m_{neutron} = 1.67 \times 10^{-27}$ kg)
A) 1.5 μm
B) 4.9 μm
C) 0.93 nm
D) 1.1 μm
E) 1.5 nm
Answer: A

42) What is the energy of a photon that has a wavelength equal to the de Broglie wavelength of a proton having a speed of 7.1×10^4 m/s? ($m_{proton} = 1.67 \times 10^{-27}$ kg, $c = 3.00 \times 10^8$ m/s)
A) 220 keV
B) 150 keV
C) 290 keV
D) 360 keV
E) 440 keV
Answer: A

43) How fast must a nonrelativistic electron move so its de Broglie wavelength is the same as the wavelength of a 3.4–eV photon? ($m_{el} = 9.11 \times 10^{-31}$ kg, $c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J)
A) 2000 m/s
B) 1900 m/s
C) 1700 m/s
D) 1600 m/s
E) 1400 m/s
Answer: A

44) A nonrelativistic electron has a kinetic energy of 5.4 eV. What is the energy of a photon whose wavelength is the same as the de Broglie wavelength of the electron? ($m_{el} = 9.11 \times 10^{-31}$ kg, $c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J)
A) 2.4 keV
B) 2.2 keV
C) 2.0 keV
D) 2.5 keV
E) 2.7 keV
Answer: A

45) A single slit is illuminated at normal incidence with a parallel beam of light having a wavelength of 411 nm. The entire central band of the diffraction pattern is observed at ±90°. The illumination is now replaced by a nonrelativistic beam of electrons, each having a kinetic energy of 980 eV. When this beam hits the slit at normal incidence, at what angle will the first minimum of the electron diffraction pattern occur? ($h = 6.626 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg, 1 eV = 1.60×10^{-19} J)

A) 0.095 mrad
B) 0.071 mrad
C) 0.046 mrad
D) 0.12 mrad
E) 0.14 mrad

Answer: A

46) Light of wavelength 105 nm falls on a metal surface for which the work function is 5.00 eV. What is the minimum de Broglie wavelength of the photoelectrons emitted from this metal? ($h = 6.626 \times 10^{-34}$ J • s = 4.14×10^{-15} eV • s, $c = 3.00 \times 10^{8}$ m/s, $m_{el} = 9.11 \times 10^{-31}$ kg, 1 eV = 1.60×10^{-19} J)

A) 0.24 nm
B) 0.33 nm
C) 0.47 nm
D) 0.66 nm
E) 0.94 nm

Answer: C

47) A gas of helium atoms (each of mass 6.65×10^{-27} kg) are at room temperature of 20.0°C. What is the de Broglie wavelength of the helium atoms that are moving at the root-mean-square speed? ($h = 6.626 \times 10^{-34}$ J • s, the Boltzmann constant is 1.38×10^{-23} J/K)

A) 5.22×10^{-11} m
B) 7.38×10^{-11} m
C) 1.04×10^{-10} m
D) 2.82×10^{-10} m
E) 3.99×10^{-10} m

Answer: B

48) A nonrelativistic electron is accelerated from rest through a potential difference. After acceleration the electron has a de Broglie wavelength of 880 nm. What is the potential difference though which this electron was accelerated? ($h = 6.626 \times 10^{-34}$ J • s, $e = -1.60 \times 10^{-19}$ C●, $m_{el} = 9.11 \times 10^{-31}$ kg)

A) 1.9 μV
B) 1.7 μV
C) 2.2 μV
D) 2.5 μV

Answer: A

49) An electron inside a hydrogen atom is confined to within a space of 0.110 nm. What is the minimum uncertainty in the electron's velocity? ($\hbar = 1.055 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg)

A) 1.05×10^6 m/s
B) 1.50×10^6 m/s
C) 1.05×10^8 m/s
D) 1.50×10^8 m/s
E) 1.05×10^{10} m/s

Answer: A

50) A measurement of an electron's speed is 2.0×10^6 m/s and has an uncertainty of 10%. What is the minimum uncertainty in its position? ($\hbar = 1.055 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg)

A) 0.29 nm
B) 0.58 nm
C) 0.87 nm
D) 1.2 nm
E) 1.6 nm

Answer: B

51) A molecule of roughly spherical shape has a mass of 6.10×10^{-25} kg and a diameter of 0.70 nm. The uncertainty in the measured position of the molecule is equal to the molecular diameter. What is the minimum uncertainty in the speed of this molecule? ($\hbar = 1.055 \times 10^{-34}$ J • s)

A) 0.25 m/s
B) 2.5 m/s
C) 25 m/s
D) 0.025 m/s
E) 0.0025 m/s

Answer: A

52) A nonrelativistic electron is confined to a length of 500 pm on the x-axis. What is the kinetic energy of the electron if its speed is equal to the minimum uncertainty possible in its speed? ($\hbar = 1.055 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg, 1 eV $= 1.60 \times 10^{-19}$ J)

A) 0.0015 eV
B) 0.015 eV
C) 0.15 eV
D) 1.5 eV
E) 15 eV

Answer: C

53) A nonrelativistic proton is confined to a length of 2.0 pm on the x-axis. What is the kinetic energy of the proton if its speed is equal to the minimum uncertainty possible in its speed? (1 eV = 1.60×10^{-19} J, $\hbar = 1.055 \times 10^{-34}$ J • s, $m_{proton} = 1.67 \times 10^{-27}$ kg)

A) 0.52 eV
B) 5.2 eV
C) 52 eV
D) 520 eV
E) 5200 eV

Answer: B

54) A small dust particle of mass 7.90×10^{-6} g is being observed under a magnifying lens. Its position is determined to within 0.0050 mm. (1 y = 3.156×10^{7}, $\hbar = 1.055 \times 10^{-34}$ J • s)
(a) Find the minimum uncertainty in its velocity implied by the uncertainty in its position.
(b) Assuming the dust particle is moving at the speed you just found, how many years would it take for the particle to move 1.0 mm?

Answer: (a) 2.7×10^{-21} m/s (b) 1.2×10^{10} y

55) The excited state of a certain atom is 3.2 eV ± 0.21 eV. ($\hbar = 1.055 \times 10^{-34}$ J • s = 6.591×10^{-16} eV • s, 1 eV = 1.60×10^{-19} J)
(a) What is the average lifetime of this state?
(b) If the excited energy were doubled to 6.4 eV ± 0.21 eV, how would the lifetime be affected?

Answer: (a) 1.6 fs (b) unchanged since the uncertainty is still ±0.21 eV

56) A certain particle's energy is measured by a detector to within 1.0×10^{-18} J. What is the minimum uncertainty we can have in its arrival time at the detector? ($\hbar = 1.055 \times 10^{-34}$ J • s)

A) 1.1×10^{-15}
B) 1.1×10^{-14}
C) 1.1×10^{-13}
D) 1.1×10^{-12}
E) 1.1×10^{-16}

Answer: E

57) The energy of an electron state has an uncertainty of 0.500 eV. What is the minimum uncertainty in the lifetime of the level? ($\hbar = 1.055 \times 10^{-34}$ J • s = 6.591×10^{-16} eV • s, 1 eV = 1.60×10^{-19} J)

A) 1.32×10^{-15}
B) 8.28×10^{-15}
C) 1.32×10^{-11}
D) 8.28×10^{-11}
E) 1.32×10^{-8}

Answer: A

58) The lifetime of an excited nuclear state is 1.0 ns. What is the minimum uncertainty in the energy of this state? ($\hbar$ = 1.055 × 10^{-34} J • s = 6.591 × 10^{-16} eV • s, 1 eV = 1.60 × 10^{-19} J)
A) 1.0 × 10^{-9}
B) 1.0 × 10^{-25}
C) 6.6 × 10^{-25}
D) 3.3 × 10^{-7}
E) 6.6 × 10^{-7}
Answer: E

59) A laser produces a beam of 4000-nm light. A shutter allows a pulse of light, 30 ps in duration, to pass. Which of the following is closest to the uncertainty in the energy of a photon in the pulse? ($\hbar$ = 1.055 × 10^{-34} J • s = 6.59 × 10^{-16} eV • s)
A) 2 × 10^{-6} eV
B) 2 × 10^{-5} eV
C) 2 × 10^{-4} eV
D) 2 × 10^{-3} eV
E) 2 × 10^{-2} eV
Answer: B

60) An ultraviolet source produces a monochromatic beam of 200-nm light. A shutter allows a pulse to pass that is 10,000 wavelengths long. The uncertainty in the energy of a photon in this pulse is closest to which of the following? ($\hbar$ = 1.055 × 10^{-34} J • s = 6.59 × 10^{-16} eV • s, c = 3.00 × 10^{8} m/s)
A) 10^{-6} eV
B) 10^{-5} eV
C) 10^{-4} eV
D) 10^{-3} eV
E) 10^{-2} eV
Answer: C

61) A 440-nm spectral line is produced by a transition from an excited state to the ground state. The natural line width of the spectral line is 0.020 pm. The average time the atom spends in the excited state is closest to which of the following? ($\hbar$ = 1.055 × 10^{-34} J • s = 6.59 × 10^{-16} eV • s)
A) 5 × 10^{-6} s
B) 5 × 10^{-7} s
C) 5 × 10^{-8} s
D) 5 × 10^{-9} s
E) 5 × 10^{-10} s
Answer: D

62) An unstable particle produced in a high-energy collision is measured to have an energy of 483 MeV and an uncertainty in energy of 84 keV. Use the Heisenberg uncertainty principle to estimate the lifetime of this particle. ($\hbar$ = 1.055 × 10^{-34} J • s = 6.59 × 10^{-16} eV • s)
Answer: 7.8 × 10^{-21}

Chapter 35 Quantum Mechanics

35.1 Conceptual Questions

1) The square of the wave function of a particle, $|\psi(x)|^2$, gives the probability of finding the particle at the point x.
A) True
B) False

Answer: B

2) The smallest kinetic energy that an electron in a box (an infinite well) can have is zero.
A) True
B) False

Answer: B

3) The wave function for a particle must be normalizable because
A) the particle's momentum must be conserved.
B) the particle's angular momentum must be conserved.
C) the particle's charge must be conserved.
D) the particle must be somewhere.
E) the particle cannot be in two places at the same time.

Answer: D

4) A set of five possible wave functions is given below, where L is a positive real number.

$\psi_1(x) = Ae^{-x}$, for all x $\qquad$ $\psi_2(x) = A\cos x$, for all x

$$\psi_3(x) = \begin{cases} Ae^{x}, & 0 \le x \le L \\ 0, & \text{for all other } x \end{cases} \qquad \psi_4(x) = \begin{cases} A, & -L \le x \le L \\ 0, & \text{for all other } x \end{cases}$$

$$\psi_5(x) = \begin{cases} Ax, & x \ge L \\ 0, & \text{for all other } x \end{cases}$$

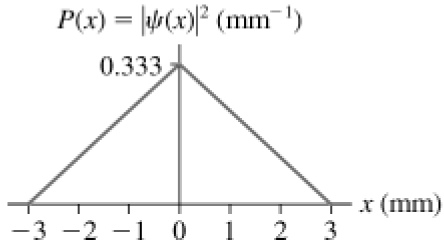
Which of the five possible wave functions are normalizable? (There may be more than one correct choice.)
A) $\psi_1(x)$
B) $\psi_2(x)$
C) $\psi_3(x)$
D) $\psi_4(x)$
E) $\psi_5(x)$

Answer: C, D

5) If an atom in a crystal is acted upon by a restoring force that is directly proportional to the distance of the atom from its equilibrium position in the crystal, then it is impossible for the atom to have zero kinetic energy.
   A) True
   B) False
   Answer: A

35.2 Problems

1) The probability density for an electron that has passed through an experimental apparatus is shown in the figure. If 4100 electrons pass through the apparatus, what is the expected number that will land in a 0.10 mm–wide strip centered at $x = 0.00$ mm?



   A) 140
   B) 1400
   C) 450
   D) 45
   Answer: A

2) The wave function for an electron that is confined to $x \geq 0$ nm is
$$\psi(x) = \begin{cases} 0, \text{ for } x < 0 \text{ nm} \\ be^{-x/(6.4 \text{ nm})}, \text{ for } x \geq \text{nm} \end{cases}$$
(a) What must be the value of b?
(b) What is the probability of finding the electron in a 0.010 nm–wide region centered at $x = 1.0$ nm?
   Answer: (a) 0.56 $(\text{nm})^{-1/2}$ (b) 0.0023

3) The wave function for an electron that is confined to $x \geq 0$ nm is
$$\psi(x) = \begin{cases} 0, \text{ for } x < 0 \text{ nm} \\ Ae^{-x/(2.3 \text{ nm})}, \text{ for } x \geq \text{nm} \end{cases}$$
(a) What must be the value of A?
(b) What is the probability of finding the electron in the interval 1.15 nm $\leq x \leq$ 1.84 nm?
   Answer: (a) 0.93 $(\text{nm})^{-1/2}$ (b) 0.17

4) Find the value of A to normalize the wave function $\psi(x) = \begin{cases} A, & -L \leq x \leq L \\ 0, & \text{for all other } x \end{cases}$.

A) $1/L$
B) $\dfrac{1}{2L}$
C) $1/L^2$
D) $1.\sqrt{L}$
E) $1/\sqrt{2L}$

Answer: E

5) Find the value of A to normalize the wave function $\psi(x) = \begin{cases} Ae^x, & -L \leq x \leq L \\ 0, & \text{for all other } x \end{cases}$.

A) $\dfrac{1}{\sqrt{e^L}}$
B) $\dfrac{2}{\sqrt{e^{2L}}}$
C) $\dfrac{2}{e^{2L} - 1}$
D) $\sqrt{\dfrac{2}{e^{2L} - 1}}$
E) $\sqrt{\dfrac{1}{e^L - 1}}$

Answer: D

6) A particle is confined to a one-dimensional box (an infinite well) on the x-axis between $x = 0$ and $x = L$. The potential height of the walls of the box is infinite. The normalized wave function of the particle, which is in the ground state, is given by $\psi(x) = \sqrt{\dfrac{2}{L}} \sin\left(\dfrac{\pi x}{L}\right)$, with $0 \leq x \leq L$. What is the probability of finding the particle between $x = 0$ and $x = L/3$?

A) 0.20
B) 0.22
C) 0.24
D) 0.26
E) 0.28

Answer: A

7) A particle is confined to a one-dimensional box (an infinite well) on the x-axis between $x = 0$ and $x = L$. The potential height of the walls of the box is infinite. The normalized wave function of the particle, which is in the ground state, is given by $\psi(x) = \sqrt{\frac{2}{L}}\sin\left(\frac{\pi x}{L}\right)$, with $0 \le x \le L$. What is the maximum probability per unit length of finding the particle?

A) $1/\sqrt{L}$
B) $\sqrt{2/L}$
C) $2/\sqrt{L}$
D) $1/L$
E) $2/L$

Answer: E

8) An electron is in an infinite square well (a box) that is 8.9 nm wide. What is the ground state energy of the electron? ($h = 6.626 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg, 1 eV = 1.60×10^{-19})

A) 0.0048 eV
B) 0.0057 eV
C) 0.0066 eV
D) 0.0076 eV
E) 0.0085 eV

Answer: A

9) An electron is in an infinite square well (a box) that is 2.0 nm wide. The electron makes a transition from the $n = 8$ to the $n = 7$ state, what is the wavelength of the emitted photon?($h = 6.626 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg, 1 eV = 1.60×10^{-19})

A) 880 nm
B) 750 nm
C) 610 nm
D) 1000 nm
E) 1100 nm

Answer: A

10) An electron is in an infinite square well that is 2.6 nm wide. What is the smallest value of the state quantum number n for which the energy level exceeds 100 eV? ($h = 6.626 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg, 1 eV = 1.60×10^{-19})

A) 43
B) 44
C) 45
D) 42
E) 41

Answer: A

11) An electron is bound in an infinite square–well potential (a box) on the x–axis. The width of the well is L and the well extends from $x = 0.00$ nm to $x = 3.8$ nm. In its present state, the normalized wave function of the electron is given by: $\psi(x) = \sqrt{2/L}\sin(2\pi x/L)$. What is the energy of the electron in this state?($h = 6.626 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg, 1 eV = 1.60×10^{-19})
   A) 0.10 eV
   B) 0.052 eV
   C) 0.13 eV
   D) 0.078 eV
   E) 0.026 eV

   Answer: A

12) An electron is in the ground state of an infinite well (a box) where its energy is 5.00 eV. In the next higher level, what would its energy be? (1 eV = 1.60×10^{-19} J)
   A) 1.25 eV
   B) 2.50 eV
   C) 10.0 eV
   D) 15.0 eV
   E) 20.0 eV

   Answer: D

13) The lowest energy level of a particle confined to a one–dimensional region of space (a box, or infinite well) with fixed length L is E_0. If an identical particle is confined to a similar region with fixed length $L/6$, what is the energy of the lowest energy level that the particles have in common? Express your answer in terms of E_0.

   Answer: $36E_0$

14) An electron is bound in an infinite well (a box) of width 0.10 nm. If the electron is initially in the $n = 8$ state and falls to the $n = 7$ state, find the wavelength of the emitted photon. ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg)

   Answer: 2.2 nm

15) An electron in an infinite potential well (a box) makes a transition from the $n = 3$ level to the ground state and in so doing emits a photon of wavelength 20.9 nm. ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$J • s, $m_{el} = 9.11 \times 10^{-31}$ kg)
   (a) What is the width of this well?
   (b) What wavelength photon would be required to excite the electron from its original level to the next higher one?

   Answer: (a) 0.225 nm (b) 23.9 nm

16) You want to confine an electron in a box (an infinite well) so that its ground state energy is 5.0×10^{-18} J. What should be the length of the box? ($h = 6.626 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg)
   A) 0.11 nm
   B) 0.22 nm
   C) 0.15 nm
   D) 0.18 nm

   Answer: A

17) A 10.0–g bouncy ball is confined in a 8.3–cm–long box (an infinite well). If we model the ball as a point particle, what is the minimum kinetic energy of the ball? ($h = 6.626 \times 10^{-34}$ J • s)

A) 8.0×10^{-64} J
B) 3.2×10^{-46} J
C) 1.3×10^{-20} J
D) zero

Answer: A

18) You want to have an electron in an energy level where its speed is no more than 66 m/s. What is the length of the smallest box (an infinite well) in which you can do this? ($h = 6.626 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg)

A) 5.5 μm
B) 11 μm
C) 2.8 μm
D) 1.4 μm

Answer: A

19) An electron is confined in a one–dimensional box (an infinite well). Two adjacent allowed energies of the electron are 1.068×10^{-18} J and 1.352×10^{-18} J. What is the length of the box? ($h = 6.626 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg)

A) 1.9 nm
B) 0.93 nm
C) 1.1 nm
D) 2.3 nm

Answer: A

20) An electron is trapped in an infinite square well (a box) of width 6.88 nm. Find the wavelength of photons emitted when the electron drops from the $n = 5$ state to the $n = 1$ state in this system. ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$J • s, $m_{el} = 9.11 \times 10^{-31}$ kg)

A) 6.49 μm
B) 5.45 μm
C) 5.91 μm
D) 7.07 μm

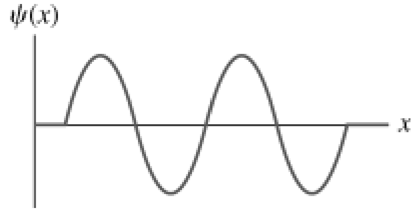
Answer: A

21) One fairly crude method of determining the size of a molecule is to treat the molecule as an infinite square well (a box) with an electron trapped inside, and to measure the wavelengths of emitted photons. If the photon emitted during the $n = 2$ to $n = 1$ transition has wavelength 1940 nm, what is the width of the molecule? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$J • s, $m_{el} = 9.11 \times 10^{-31}$ kg)

A) 1.33 nm
B) 1.12 nm
C) 1.21 nm
D) 1.45 nm

Answer: A

22) The wave function of an electron in a rigid box (infinite well) is shown in the figure. If the electron energy 98.0 eV, what is the energy of the electron's ground state?(m_{el} = 9.11 × 10^{-31} kg)



A) 6.13 eV
B) 3.92 eV
C) 10.9 eV
D) 24.5 eV

Answer: A

23) A particle confined in a rigid one-dimensional box (an infinite well) of length 17.0 fm has an energy level E_n = 24.0 MeV and an adjacent energy level E_{n+1} = 37.5 MeV. What is the value of the ground state energy? (1 eV = 1.60 × 10^{-19} J)

A) 1.50 MeV
B) 13.5 MeV
C) 0.500 MeV
D) 4.50 MeV

Answer: A

24) A lithium atom, mass 1.17 × 10^{-26} kg, vibrates with simple harmonic motion in a crystal lattice, where the effective force constant of the forces on the atom is k = 49.0 N/m. (c = 3.00 × 10^8 m/s, h = 6.626 × 10^{-34} J • s, $\hbar$ = 1.055 × 10^{-34} J • s, 1 eV = 1.60 × 10^{-19} J)
(a) What is the ground state energy of this system, in eV?
(b) What is the wavelength of the photon that could excite this system from the ground state to the first excited state?

Answer: (a) 2.14 × 10^{-2} eV
(b) 2.91 × 10^{-5} m

25) The atoms in a nickel crystal vibrate as harmonic oscillators with an angular frequency of 2.3 × 10^{13} rad/s. The mass of a nickel atom is 9.75 × 10^{-26} kg. What is the difference in energy between adjacent vibrational energy levels of nickel? (h = 6.626 × 10^{-34} J • s, $\hbar$ = 1.055 × 10^{-34} J • s, 1 eV = 1.60 × 10^{-19} J)

A) 0.015 eV
B) 0.019 eV
C) 0.023 eV
D) 0.027 eV
E) 0.031 eV

Answer: A

26) The lowest energy level of a certain quantum harmonic oscillator is 5.00 eV. What is the energy of the next higher level?
A) 7.50 eV
B) 10.0 eV
C) 15.0 eV
D) 20.0 eV
E) 50.0 eV
Answer: C

27) Calculate the ground state energy of a harmonic oscillator with a classical frequency of 3.68×10^{15} Hz. (1 eV = 1.60×10^{-19} J, $\hbar = 1.055 \times 10^{-34}$ J • s, $h = 6.626 \times 10^{-34}$ J • s)
A) 7.62 eV
B) 15.2 eV
C) 11.4 eV
D) 5.71 eV
Answer: A

28) The energy of a particle in the second EXCITED state of a harmonic oscillator potential is 5.45 eV. What is the classical angular frequency of oscillation of this particle? (1 eV = 1.60×10^{-19} J, $\hbar = 1.055 \times 10^{-34}$ J • s, $h = 6.626 \times 10^{-34}$ J • s)
A) 3.31×10^{15} rad/s
B) 2.08×10^{16} rad/s
C) 4.96×10^{15} rad/s
D) 6.95×10^{15} rad/s
Answer: A

29) Find the wavelength of the photon emitted during the transition from the second EXCITED state to the ground state in a harmonic oscillator with a classical frequency of 3.72×10^{13} Hz. ($c = 3.00 \times 10^{8}$ m/s, 1 eV = 1.60×10^{-19} J, $\hbar = 1.055 \times 10^{-34}$ J • s, $h = 6.626 \times 10^{-34}$ J • s)
A) 4.03 μm
B) 2.26 μm
C) 2.98 μm
D) 5.24 μm
Answer: A

30) An electron is confined in a harmonic oscillator potential well. A photon is emitted when the electron undergoes a 3→1 quantum jump. What is the wavelength of the emission if the net force on the electron behaves as though it has a spring constant of 9.6 N/m? ($m_{el} = 9.11 \times 10^{-31}$ kg, $c = 3.00 \times 10^{8}$ m/s, 1 eV = 1.60×10^{-19} J, $\hbar = 1.055 \times 10^{-34}$ J • s, $h = 6.626 \times 10^{-34}$ J • s)
A) 290 nm
B) 150 nm
C) 190 nm
D) 580 nm
Answer: A

31) An electron is confined in a harmonic oscillator potential well. What is the longest wavelength of light that the electron can absorb if the net force on the electron behaves as though it has a spring constant of 74 N/m? (m_{el} = 9.11 × 10^{-31} kg, c = 3.00 × 10^{8} m/s, 1 eV = 1.60 × 10^{-19} J, $\hbar$ = 1.055 × 10^{-34} J • s, h = 6.626 × 10^{-34} J • s)

A) 210 nm
B) 200 nm
C) 220 nm
D) 230 nm

Answer: A

Chapter 36 Atomic Physics

36.1 Conceptual Questions

1) If two electrons in an atom have the same energy, then they must have the same four quantum numbers.
   A) true
   B) false
   C) They cannot both have the same energy.

   Answer: B

2) If two electrons in the same atom have the same four quantum numbers, then they must have the same energy.
   A) true
   B) false
   C) They cannot both have the same four quantum numbers.

   Answer: C

3) Consider the four quantum numbers of an electron in an atom, n, l, m_l, and m_s. The energy of an electron in an isolated atom depends on
   A) n only.
   B) n and l only.
   C) n, l, and m_l only.
   D) l, m_l, and m_s only.
   E) all four quantum numbers.

   Answer: A

4) For each value of the principal quantum number n, what are the possible values of the electron spin quantum number m_s? (There may be more than one correct choice.)
   A) 0
   B) +1/2
   C) −1/2
   D) +3/2
   E) −3/2

   Answer: B, C

5) Which of the following are characteristics of laser light? (There may be more than one correct choice.)
   A) It is coherent.
   B) It is produced by an inverted population of atoms.
   C) It contains a full spectrum of wavelengths.

   Answer: A, B

36.2 Problems

1) An electron in a hydrogen atom is in the $n = 7$ shell. How many possible values of the orbital quantum number l could it have?
A) 6
B) 7
C) 15
D) 33
E) 98

Answer: B

2) An electron in a hydrogen atom has orbital quantum number $l = 7$. How many possible values of the magnetic quantum number m_l could it have?
A) 6
B) 7
C) 15
D) 33
E) 98

Answer: C

3) An electron in a hydrogen atom has principal quantum number $n = 4$. How many possible values of the orbital quantum number l could it have?
A) 8
B) 9
C) 3
D) 4
E) 10

Answer: D

4) An electron in a hydrogen atom has orbital quantum number $l = 4$. How many possible values of the magnetic quantum number m_l could it have?
A) 4
B) 10
C) 5
D) 9
E) 3

Answer: D

5) If the orbital quantum number is $l = 4$, which one of the following is a possible value for the principal quantum number n?
A) 1
B) 2
C) 3
D) 4
E) 8

Answer: E

6) If the principal quantum number of an electron is $n = 5$, which one of the following is NOT an allowed magnetic quantum number m_l for the electron?
A) 0
B) 2
C) 3
D) 4
E) 5
Answer: E

7) If an electron has spin quantum number $m_s = -\frac{1}{2}$ what is the possible value for the orbital quantum number l of the electron?
A) 0
B) 1
C) 2
D) 11
E) All of the above numbers are possible.
Answer: E

8) In the ground state, the quantum numbers (n, l, m_l, m_s) for hydrogen are, respectively
A) 1, 1, 1, 1
B) 1, 0, 0, 0
C) 1, 0, 0, $\pm\frac{1}{2}$
D) 1, 1, 1, $\pm\frac{1}{2}$
E) 1, 1, 0, $\pm\frac{1}{2}$
Answer: C

9) The binding energy of the hydrogen atom in its ground state is −13.6 eV. What is the energy when it is in the $n = 5$ state?
A) 2.72 eV
B) −2.72 eV
C) 0.544 eV
D) −0.544 eV
E) −68 eV
Answer: D

10) What is the energy of an incident photon that is just enough to excite a hydrogen atom from its ground state to its $n = 4$ state?
A) 12.75 eV
B) 10.20 eV
C) 3.40 eV
D) 0.85 eV
Answer: A

11) How fast must a hydrogen atom be traveling for its kinetic energy to be just enough to excite the ground-state atom to its first excited state in a collision? (1 eV = 1.60×10^{-19} J, $m_H \approx m_{proton} = 1.67 \times 10^{-27}$ kg)
A) 44.2 km/s
B) 21.7 km/s
C) 66.5 km/s
D) 113 km/s
E) 51.0 km/s
Answer: A

12) What is the minimum speed needed by a ground-state hydrogen atom for its kinetic energy to be enough to ionize the atom in a collision? (1 eV = 1.60×10^{-19} J, $m_H \approx m_{proton} = 1.67 \times 10^{-27}$ kg)
A) 44.2 km/s
B) 21.7 km/s
C) 66.5 km/s
D) 113 km/s
E) 51.0 km/s
Answer: E

13) The normalized wave function for a hydrogen atom in the 1s state is given by $\psi(r) = \frac{1}{\sqrt{\pi \alpha_0{}^3}} e^{-r/\alpha 0}$ where α_0 is the Bohr radius, which is equal to 5.29×10^{-11} m. What is the probability of finding the electron at a distance greater than 7.8 α_0 from the proton?
A) 2.3×10^{-5}
B) 1.2×10^{-5}
C) 1.7×10^{-5}
D) 4.6×10^{-5}
E) 3.5×10^{-5}
Answer: A

14) What is the greatest magnitude of the orbital angular momentum L for an electron in a state with principal quantum number $n = 5$?
A) $4.47\hbar$
B) $4.90\hbar$
C) $5\hbar$
D) $5.48\hbar$
Answer: A

15) What is the greatest total angular momentum J for an electron in the $n = 2$ shell?
A) $1.9\hbar$
B) $2.5\hbar$
C) $0.50\hbar$
D) $3.5\hbar$
E) $1.5\hbar$
Answer: A

16) The magnitude of the orbital angular momentum L of an electron in a certain atom is equal to $3.464\hbar$. What is the orbital quantum number l of the electron?
A) 1
B) 2
C) 3
D) 4
E) 5

Answer: C

17) The magnitude of the orbital angular momentum L of an electron in a certain atom is equal to $3.464\hbar$. Which one of the following numbers could be the principal quantum number n of the electron?
A) 0
B) 1
C) 2
D) 3
E) 4

Answer: E

18) The magnitude of the orbital angular momentum L of an electron in a certain atom is equal to $3.464\hbar$. Which of the following angles could NOT be the angle between the orbital angular momentum vector of the electron and an arbitrary z–direction?
A) 107°
B) 90.0°
C) 73.2°
D) 54.7°
E) 0.00°

Answer: E

19) How many electrons can be found with principal quantum number $n = 3$ in a suitably heavy atom?
A) 18
B) 6
C) 20
D) 9

Answer: A

20) An atom has completely filled inner shells and a single valence electron in an excited p state. The filled inner shells have an orbital momentum equal to zero. What is the magnitude of the orbital angular momentum L of the atom?
A) $1.0\hbar$
B) $1.2\hbar$
C) $1.4\hbar$
D) $1.7\hbar$
E) $2.0\hbar$

Answer: C

21) An atom has completely filled inner shells and a single valence electron in an excited p state. The filled inner shells have an orbital momentum equal to zero. A magnetic field is applied, defining the z–axis along the field. Which of the following sets of angles are possible angles between the magnetic field and the orbital angular momentum?
A) 45°
B) 90°
C) 45°, 90°
D) 45°, 135°
E) 45°, 90°, 135°

Answer: E

22) The only VALID electron state and shell designation among the following is
A) 1p, K.
B) 2s, K.
C) 1s, L.
D) 2p, L.
E) 3f, M.

Answer: D

23) The only INVALID electron state and shell designation among the following is
A) 1s, K.
B) 2s, L.
C) 2d, L.
D) 3s, M.
E) 3d, M.

Answer: C

24) The correct ground state electron configuration of boron, which has 5 electrons, is
A) $1s^2 2s^2 2p$.
B) $1s^2 2s^2 2p^3$.
C) $1s^2 1p^2 2s$.
D) $1s^2 2p^2 3s$.
E) $1s^2 2p^3$.

Answer: A

25) Consider the $n = 9$ shell.
(a) What is the largest value of the orbital quantum number, l, in this shell?
(b) How many electrons can be placed in this shell?

Answer: (a) 8 (b) 162

26) An atom with 5 electrons is in its ground state. How many electrons are in its outermost shell?

Answer: 3

27) How many electrons does it take to fill the d subshell?
A) 10
B) 6
C) 14
D) 4
E) 8
Answer: A

28) How many possible sets of quantum numbers (electron states) are there in the $5f$ subshell?
A) 2
B) 6
C) 8
D) 10
E) 14
Answer: E

29) A neutral atom has an electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^2$. How many protons does it have in its nucleus?
A) 5
B) 11
C) 14
D) 20
E) 26
Answer: C

30) What is the electron configuration for ground state Li, which has 3 electrons?
A) $1s^3$
B) $1s^1 2s^2$
C) $1s^2 2s^1$
D) $1s^2 1p^1$
E) $1s^1 1p^2$
Answer: C

31) What is the correct electronic configuration for ground state carbon, which has 6 electrons?
A) $1s^2 2s^2 2p^2$
B) $1s^1 2p^1$
C) $1s^1 2s^2 2p^1$
D) $1s^1 2s^1 2p^1$
E) $1s^2 2s^2 2p^4$
Answer: A

32) What is the correct electronic configuration for the ground state sodium atom, which has 11 electrons?

A) $1s^1 2s^2 3p^6 2s^2$
B) $1s^2 2s^1 3p^6 2s^2$
C) $1s^1 2s^2 2p^6$
D) $1s^2 2s^2 2p^6 3s^2$
E) $1s^2 2s^2 2p^6 3s^1$

Answer: E

33) A collection of atoms has 20% of the sample in a state 5.9 eV above the ground state. If these emit coherent radiation, what is the wavelength of the laser light produced? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J)

A) 210 nm
B) 91 nm
C) 340 nm
D) 34 nm

Answer: A

34) How many photons per second emerge from a laser of power 2.00 mW with wavelength 605 nm? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J • s)

A) 6.09×10^{15} photons/s
B) 5.03×10^{12} photons/s
C) 3.07×10^{15} photons/s
D) 3.07×10^{13} photons/s

Answer: A

35) You need 14 W of infrared laser light power with wavelength 1270 nm to bore a hole in a diamond. How many downward atomic transitions per second must occur in the laser if all of them result in light directed onto the diamond? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J • s)

A) 8.9×10^{19}
B) 8.9×10^{18}
C) 5.9×10^{19}
D) 2.7×10^{18}

Answer: A

36) The wavelength of a ruby laser is 694.3 nm. What is the energy difference between the two energy states involved in laser action? ($c = 2.9979 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J • s, 1 eV = 1.6022×10^{-19} J)

A) 1.537 eV
B) 1.646 eV
C) 1.786 eV
D) 1.812 eV
E) 3.572 eV

Answer: C

37) In a ruby laser, an electron jumps from a higher energy level to a lower one. If the energy difference between the two levels is 1.8 eV, what is the wavelength of the emitted photon? (c = 3.00×10^8 m/s, $h = 6.626 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J)

A) 350 nm
B) 470 nm
C) 650 nm
D) 690 nm
E) 960 nm

Answer: D

38) An s state ($l = 0$) energy level is split into two levels by an applied magnetic field. A photon of microwave radiation having frequency 60 GHz induces a transition between the two levels. What is the magnitude of the applied magnetic field? ($h = 6.626 \times 10^{-34}$ J • s, Bohr magneton = $\mu_B = 9.27 \times 10^{-24}$ J/T)

A) 2.1 T
B) 0.34 T
C) 1.2 T
D) 2.8 T
E) 13 T

Answer: A

Chapter 37 Molecules and Solids

37.1 Conceptual Questions

1) Covalent bonding is due to
   A) the sharing of electrons between atoms.
   B) the transfer of electrons between atoms.
   C) atoms bonding to hydrogen molecules.
   D) atoms bonding to oxygen molecules.

   Answer: A

2) Ionic bonding is due to
   A) the sharing of electrons between atoms.
   B) the transfer of electrons between atoms.
   C) atoms bonding to hydrogen molecules.
   D) atoms bonding to oxygen molecules.

   Answer: B

3) A rotating diatomic molecule has rotational quantum number l. The energy DIFFERENCE between adjacent energy levels
   A) increases as l increases.
   B) decreases as l increases.
   C) is the same for all changes in l.
   D) is independent of l.

   Answer: A

4) A rotating diatomic molecule in its $l = 1$ quantum state has energy E. What is the energy of the same molecule in its $l = 2$ quantum state?
   A) $2E$
   B) $3E$
   C) $4E$
   D) $6E$
   E) $8E$

   Answer: B

5) A vibrating diatomic molecule has vibrational quantum number n. The energy DIFFERENCE between adjacent energy levels
   A) increases as n increases.
   B) decreases as n increases.
   C) is the same for all changes in n.
   D) is independent of n.

   Answer: D

6) A vibrating diatomic molecule in its ground state has energy E. What is the energy of the same molecule in its second EXCITED state?
A) E
B) $2E$
C) $3E$
D) $5E$
E) $9E$

Answer: D

7) A p-type semiconductor has a net positive charge.
A) True
B) False

Answer: B

8) An unfilled electron state in the valence band is called
A) a hole.
B) an empty electron.
C) a conduction electron.
D) a positron.
E) an empty positron.

Answer: A

9) In a p-type semiconductor, a hole is
A) a donor atom.
B) an extra electron supplied by a donor atom.
C) an extra proton supplied by a donor atom.
D) a missing atom in the crystalline structure.
E) a region where an electron is missing.

Answer: E

37.2 Problems

1) A diatomic has a moment of inertia of 7.73×10^{-45} kg• m^2. What is its rotational energy in the quantum state characterized by $l = 2$? ($h = 6.626 \times 10^{-34}$ J • s, $\hbar = 1.055 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J)
A) 22.7 μeV
B) 27.0 μeV
C) 587 μeV
D) 72.2 μeV
E) 87.1 μeV

Answer: B

2) A diatomic molecule has 2.6×10^{-5} eV of rotational energy in the $l = 2$ quantum state. What is its rotational energy in the $l = 1$ quantum state?
A) 3.4 μeV
B) 4.1 μeV
C) 5.3 μeV
D) 7.8 μeV
E) 8.7 μeV
Answer: E

3) A diatomic molecule has 18×10^{-5} eV of rotational energy in the $l = 2$ quantum state. What is its rotational energy in the $l = 0$ quantum state?
A) 90 μeV
B) 60 μeV
C) 30 μeV
D) 15 μeV
E) 0 eV
Answer: E

4) The spacing of the atoms (treated as point masses) in the H_2 molecule is 7.4×10^{-11} m. What is the energy of the $l = 1$ rotational level? (1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J • s, $\hbar = 1.055 \times 10^{-34}$ J • s, $m_H \approx m_{proton} = 1.67 \times 10^{-27}$ kg)
A) 0.090 eV
B) 0.070 eV
C) 0.045 eV
D) 0.030 eV
E) 0.015 eV
Answer: E

5) Estimate the rotational energy (in eV) for a diatomic hydrogen molecule in the $l = 2$ quantum state. (The equilibrium separation for the H_2 molecule is 0.074 nm.) (1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J • s, $\hbar = 1.055 \times 10^{-34}$ J • s, $m_H \approx m_{proton} = 1.67 \times 10^{-27}$ kg)
A) 0.011 eV
B) 0.026 eV
C) 0.032 eV
D) 0.046 eV
E) 0.055 eV
Answer: D

6) The moment of inertia of a fluorine (F_2) molecule is 3.167×10^{-46}. What is the rotational energy of a fluorine molecule for the l = 19 state? ($h = 6.626 \times 10^{-34}$ J • s, $\hbar = 1.055 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J)
   A) 4.2×10^{-2} eV
   B) 2.1×10^{-3} eV
   C) 4.6×10^{-2} eV
   D) 5.1×10^{-2} eV
   E) 5.6×10^{-2} eV
   Answer: A

7) A certain molecule has 2.00 eV of rotational energy in the $l = 1$ state. In the $l = 4$ state, what would its rotational energy be?
   A) 8.00 eV
   B) 16.0 eV
   C) 20.0 eV
   D) 30.0 eV
   E) 32.0 eV
   Answer: C

8) When a certain diatomic molecule undergoes a transition from the $l = 5$ to the $l = 3$ rotational level, the emitted photon has wavelength 2.87×10^{-4} m.Calculate the moment of inertia of the molecule. ($c = 3.00 \times 10^{8}$ m/s, $e = 1.60 \times 10^{-19}$ C, $h = 6.626 \times 10^{-34}$ J • s, $\hbar = 1.055 \times 10^{-34}$ J • s)
   Answer: 1.45×10^{-46} kg • m^2

9) The vibrational frequency of an HF molecule is 8.72×10^{13} Hz and the reduced mass of the molecule is 1.589×10^{-27} kg. What is the ground state vibrational energy of an HF molecule? (1 eV = 1.60×10^{-19} J, $\hbar = 1.055 \times 10^{-34}$ J • s, $h = 6.626 \times 10^{-34}$ J • s)
   A) 0.12 eV
   B) 0.18 eV
   C) 0.24 eV
   D) 0.30 eV
   E) 0.36 eV
   Answer: B

10) A diatomic molecule is vibrating in its first excited quantum state above the ground state. In that excited state, its frequency is 2.0×10^{13} Hz. What is the energy of the molecule in this state? ($h = 6.626 \times 10^{-34}$ J • s, $\hbar = 1.055 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J
   A) 0.041 eV
   B) 0.083 eV
   C) 0.12 eV
   D) 0.15 eV
   E) 0.17 eV

   Answer: C

11) A certain diatomic molecule emits a photon of energy 1.20 eV when it makes a transition from the $n = 1$ vibrational state to the next lower vibrational state. What is the frequency of vibration of the molecule? ($h = 6.626 \times 10^{-34}$ J • s, $\hbar = 1.055 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J)

A) 1.93×10^{14} Hz
B) 2.90×10^{14} Hz
C) 4.35×10^{14} Hz
D) 1.82×10^{15} Hz
E) 2.73×10^{15} Hz

Answer: B

12) A certain diatomic molecule emits a photon of energy 1.20 eV when it makes a transition from the $n = 1$ vibrational state to the next lower vibrational state. If the molecule made a transition from the $n = 2$ state to the $n = 1$ state, what would be the energy of the photon it would emit? ($h = 6.626 \times 10^{-34}$ J • s, $\hbar = 1.055 \times 10^{-34}$ J • s, 1 eV = 1.60×10^{-19} J)

A) 3.60 eV
B) 2.40 eV
C) 1.20 eV
D) 0.60 eV
E) 0.30 eV

Answer: C

13) Approximately how many states in the range from 5.0 eV to 5.2 eV are there in a copper bar of volume 5.3 cm^3? ($h = 6.626 \times 10^{-34}$ J • s, $\hbar = 1.055 \times 10^{-34}$ J • s, $m_{el} = 9.11 \times 10^{-31}$ kg, 1 eV = 1.60×10^{-19} J)

A) 5.1×10^{22}
B) 3.2×10^{22}
C) 1.6×10^{22}
D) 8.2×10^{21}
E) 3.2×10^{21}

Answer: C

14) The energy gap between the valence and conduction bands in a certain semiconductor is 1.25 eV. What is the threshold wavelength for optical absorption in this substance? ($c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J • s)

A) 599 nm
B) 639 nm
C) 959 nm
D) 873 nm
E) 994 nm

Answer: E

Chapter 38 Nuclear Physics

38.1 Conceptual Questions

1) Consider two different isotopes of the same neutral element. Which statements about these isotopes are true? (There may be more than one correct choice.)
A) Both isotopes contain the same number of neutrons.
B) Both isotopes contain the same number of protons.
C) Both isotopes contain the same number of nucleons.
D) Both isotopes contain the same number of orbital electrons.
E) The sum of the protons and neutrons is the same for both isotopes.

Answer: B, D

2) Consider the short-lived neutral isotope represented by $^{25}_{15}X$. Which of the following statements about this isotope are correct? (There may be more than one correct choice.)
A) The isotope has 25 nucleons.
B) The isotope has 25 protons.
C) The isotope has 25 neutrons.
D) The isotope has 15 orbital electrons.
E) The isotope has 15 protons.
F) The isotope has 10 neutrons.

Answer: A, D, E, F

3) Which of the following statements about the atomic nucleus is correct? (There may be more than one correct choice.)
A) Large nuclei are denser than light nuclei.
B) All nuclei have nearly the same density.
C) The nucleus is held together more by the electrical force than by the gravitational force.
D) A nucleus containing 20 nucleons will have approximately twice the radius as a nucleus containing 10 nucleons.
E) As the number of nucleons increases the binding energy per nucleon always increases.

Answer: B

4) For a $^{93}_{41}Nb$ atom, the number of protons, neutrons, and electrons in the atom is
A) 41, 52, 93.
B) 41, 52, 52.
C) 41, 52, 41.
D) 41, 52, 0.
E) 52, 41, 0.

Answer: C

5) The iron nucleus has the greatest binding energy of any nucleus.
A) True
B) False

Answer: B

6) Going from medium mass nuclei to heavy nuclei, the average binding energy per nucleon
   A) decreases.
   B) behaves randomly with no clear pattern.
   C) does not change.
   D) increases.
   E) doubles.

   Answer: A

7) Heavier stable nuclei tend to have
   A) half as many protons as neutrons.
   B) the same number of neutrons and protons.
   C) more neutrons than protons.
   D) no clear trend in the relative number of neutrons and protons.
   E) more protons than neutrons.

   Answer: C

8) Which of the following statements about the strong nuclear force are correct? (There may be more than one correct choice.)
   A) It acts equally on protons and neutrons but not on electrons.
   B) It acts equally on protons, neutrons, and electrons.
   C) It has a much longer range than the electric force.
   D) It keeps electrons in their orbits around the nucleus.
   E) Because of its very short range, there is a limit to how large the nucleus can be.

   Answer: A, E

9) If a nucleus decays by β^- decay to a daughter nucleus, which of the following statements about this decay are correct? (There may be more than one correct choice.)
   A) The daughter nucleus has more protons than the original nucleus.
   B) The daughter nucleus has more neutrons than the original nucleus.
   C) The daughter nucleus has the same number of nucleons as the original nucleus.
   D) The daughter nucleus has fewer protons than the original nucleus.
   E) The daughter nucleus has fewer neutrons than the original nucleus.

   Answer: A, C, E

10) If a nucleus decays by alpha decay to a daughter nucleus, which of the following statements about this decay are correct? (There may be more than one correct choice.)
   A) The daughter nucleus has more protons than the original nucleus.
   B) The daughter nucleus has more neutrons than the original nucleus.
   C) The daughter nucleus has the same number of nucleons as the original nucleus.
   D) The daughter nucleus has fewer protons than the original nucleus.
   E) The daughter nucleus has fewer neutrons than the original nucleus.

   Answer: D, E

11) If a nucleus decays by gamma decay to a daughter nucleus, which of the following statements about this decay are correct? (There may be more than one correct choice.)
A) The daughter nucleus has more protons than the original nucleus.
B) The daughter nucleus has more neutrons than the original nucleus.
C) The daughter nucleus has the same number of nucleons as the original nucleus.
D) The daughter nucleus has fewer protons than the original nucleus.
E) The daughter nucleus has fewer neutrons than the original nucleus.

Answer: C

12) If a nucleus decays by β^+ decay to a daughter nucleus, which of the following statements about this decay are correct? (There may be more than one correct choice.)
A) The daughter nucleus has more protons than the original nucleus.
B) The daughter nucleus has more neutrons than the original nucleus.
C) The daughter nucleus has the same number of nucleons as the original nucleus.
D) The daughter nucleus has fewer protons than the original nucleus.
E) The daughter nucleus has fewer neutrons than the original nucleus.

Answer: B, C, D

13) Which of the following statements about β^+ decay are correct? (There may be more than one correct choice.) During β^+ decay
A) an orbital electron is captured by the nucleus.
B) a proton is emitted from the nucleus.
C) a neutron in the nucleus decays to a proton and an electron.
D) a proton in the nucleus decays to a positron and a neutron.
E) the atomic number Z of the isotope increases by one unit but the atomic weight A remains unchanged.

Answer: D

14) A radioactive isotope decays by β^- emission with a half-life of 1.0 min. During the first 1.0 min, a particular sample emits 1000 β^- particles. During the next 1.0 min, the number of β^- particles this sample will emit will be closest to
A) 250.
B) 500.
C) 1000.
D) 1500.
E) 2000.

Answer: B

15) A radioisotope has a half-life of τ at a temperature of 150 K. If its temperature is increased to 300 K, what will its half-life be?
A) 4τ
B) $2\ \tau$
C) τ
D) $\tau/2$
E) $\tau/4$

Answer: C

16) The decay rate of an isotope is initially R_0, but after one half-life has gone by, the rate is $R_0/2$. At the end of the NEXT half-life, what will the decay rate be?
A) 0
B) $R_0/16$
C) R_0/e
D) $R_0/4$
E) R_0/e^2

Answer: D

17) The half-life of cobalt-60 is 5.3 years, while that of strontium-90 is 28 years. Suppose you have a sample of each, such that they initially contain equal numbers of atoms of these nuclides. How will the activities (number of decays per second) of the samples compare?
A) The activity of the cobalt-60 sample will be greater.
B) The activities cannot be compared without more information.
C) The activities will be equal.
D) The activity of the strontium-90 sample will be greater.

Answer: A

18) The half-life of cobalt-60 is 5.3 years, while that of strontium-90 is 28 years. Suppose that samples of cobalt-60 and strontium-90 are such that they initially have the same activity (number of decays per second). What is true about the initial numbers of cobalt-60 and strontium-90 nuclei in these samples?
A) There are more strontium-90 than cobalt-60 nuclei.
B) There are equal numbers of cobalt-60 and strontium-90 nuclei.
C) There are more cobalt-60 than strontium-90 nuclei.
D) It is not possible to compare numbers of nuclei without knowing the masses of the samples.

Answer: A

19) A radioactive nuclide of atomic number Z emits an electron, then the daughter nuclide emits a gamma ray. What is the atomic number of the resulting nuclide after both processes?
A) $Z + 1$
B) $Z - 1$
C) $Z - 2$
D) $Z - 3$
E) $Z + 2$

Answer: A

20) Modern nuclear bomb tests have created an extra high level of ^{14}C in our atmosphere. Suppose that future archaeologists date samples from our era, but do not know about this testing. Will their dates be too young, too old, or still correct? If correct they are correct, why?
A) too young
B) too old
C) correct, because ^{14}C from bomb tests is different from that produced naturally
D) correct, because modern biological materials do not gather ^{14}C from bomb tests

Answer: A

21) Which of the following descriptions best describes the process by which energy is released in a conventional nuclear reactor?
A) The radiation given off by a naturally radioactive substance, uranium, is collected and used to make steam.
B) Uranium is reacted with oxygen in a combustion process that releases large amounts of radioactivity and heat.
C) Deuterium and tritium are joined together to form helium.
D) Uranium, when bombarded by neutrons, splits into fragments and releases two or three neutrons, and these neutrons in turn strike more uranium nuclei that split, thereby setting off a chain reaction that releases energy.
E) A uranium nucleus is energized to an excited state by neutron irradiation, and it then decays by emitting beta rays and gamma rays that heat water and create steam.

Answer: D

22) The primary source of the energy radiated by a star, such as the sun, is
A) beta decay.
B) alpha decay.
C) fission reactions involving uranium.
D) fusion reactions in which hydrogen is fused to form helium.
E) fusion reactions in which helium is fused to form iron.

Answer: D

23) A fusion reaction releases energy because the binding energy of the resulting nucleus
A) is greater than the binding energy of the original nuclei.
B) is equal to the binding energy of the original nuclei.
C) is less than the binding energy of the original nuclei.
D) is released in the process.
E) is absorbed in the process.

Answer: A

24) How does the mass of the products of a nuclear fusion reaction compare to the mass of the original elements?
A) The mass of the products is greater than the mass of the original elements.
B) The mass of the products is less than the mass of the original elements.
C) The mass of the products is equal to the mass of the original elements.
D) The mass of the products is unrelated to the mass of the original elements.

Answer: B

25) In massive stars, three helium nuclei fuse together, forming a carbon nucleus. This reaction heats the core of the star. The net mass of the three helium nuclei must therefore be
A) higher than that of the carbon nucleus.
B) less than that of the carbon nucleus.
C) the same as that of the carbon nucleus since mass is always conserved.
D) the same as that of the carbon nucleus since energy is always conserved.

Answer: A

38.2 Problems

1) A certain nucleus containing 8 protons and 7 neutrons has a radius R. Which of the following values would be closest to the expected value of the radius of a nucleus having 51 protons and 69 neutrons?
   A) $1.85R$
   B) $2.00R$
   C) $2.14R$
   D) $6.38R$
   E) $8.00R$

   Answer: B

2) A certain nucleus containing 8 protons and 7 neutrons has a density ρ. Which of the following values would be closest to the expected value of the density of a nucleus having 51 protons and 69 neutrons?
   A) $1.00\ \rho$
   B) $1.85\ \rho$
   C) $2.00\ \rho$
   D) $2.14\ \rho$
   E) $8.00\ \rho$

   Answer: A

3) What would be the expected radius of a nucleus having 82 protons and 125 neutrons?
   A) 5.2 fm
   B) 5.9 fm
   C) 6.0 fm
   D) 7.1 fm
   E) 17 fm

   Answer: D

4) What would be the expected radius of the nucleus of $^{90}_{38}Sr$?
   A) 4.0 fm
   B) 1.2 fm
   C) 5.4 fm
   D) 0.11 pm
   E) 0.54 pm

   Answer: C

5) If a nucleus had a diameter of 8.0 fm, what would be its expected mass, in atomic mass units?
   A) 7 u
   B) 296 u
   C) 37 u
   D) 64 u
   E) 128 u

   Answer: C

6) Two identical nuclei of mass 18 u are made to unite to make a single nucleus of mass 36 u. What is the radius of the result of this fusion?
A) 4.0 fm
B) 6.3 fm
C) 4.5 fm
D) 7.2 fm
Answer: A

7) The following masses are known:

${}^{1}_{0}n$ (neutron)	1.008665 u
${}^{1}_{1}H$	1.007825 u
${}^{57}_{26}Fe$	56.935399 u

What is the binding energy of ${}^{57}_{26}Fe$, in MeV? (1 u = 1.6605×10^{-27} kg = 931.5 MeV/c^2)
A) 500 MeV
B) 550 MeV
C) 610 MeV
D) 660 MeV
E) 710 MeV
Answer: A

8) The neutral deuterium atom, ${}^{2}_{1}H$, has a mass of 2.014102 u; a neutral hydrogen atom has a mass of 1.007825 u; a neutron has a mass of 1.008665 u; and a proton has a mass of 1.007277 u. What is the binding energy of the ${}^{2}_{1}H$ nucleus? (1 u = 931.494 MeV/c^2)
A) 1.1 MeV
B) 1.7 MeV
C) 2.2 MeV
D) 2.9 MeV
E) 3.4 MeV
Answer: C

9) What is the binding energy per nucleon for ${}^{27}_{13}Al$? The neutral ${}^{27}_{13}Al$ atom has a mass of 26.981539 u; a neutral hydrogen atom has a mass of 1.007825 u; a neutron has a mass of 1.008665 u; and a proton has a mass of 1.007277 u. (1 u = 931.494 MeV/c^2)
A) 8.3 MeV
B) 6.7 MeV
C) 5.4 MeV
D) 3.4 MeV
E) 2.8 MeV
Answer: A

10) Uranium–238 decays into thorium–234 plus an alpha particle. How much energy is released in this process? 1 u = 931.494 MeV/c^2, and the relevant mass values are

$^{4}_{2}$He: 4.002603 u

$^{234}_{90}$Th: 234.043583 u

$^{238}_{92}$U: 238.050786 u

A) 4.28 MeV
B) 3.76 MeV
C) 3.18 MeV
D) 2.89 MeV
E) 5.05 MeV

Answer: A

11) Radium–226 decays into radon–222 plus an alpha particle. How much energy is released in this process? 1 u = 931.494 MeV/c^2, and the relevant mass values are

$^{4}_{2}$He: 4.002603 u

$^{222}_{86}$Rn: 222.017570 u

$^{226}_{88}$Ra: 226.025402 u

A) 4.24 MeV
B) 3.76 MeV
C) 4.87 MeV
D) 5.05 MeV
E) 5.39 MeV

Answer: C

12) Plutonium–239 decays into uranium–235 plus an alpha particle. The energy released in the process is 5.24 MeV. Given the following mass values

$^{4}_{2}$He: 4.002603 u

$^{235}_{92}$U: 235.043924 u

what is the mass of $^{239}_{94}$Pu in atomic mass units? (1 u = 931.494 MeV/c^2)

A) 239.05215 u
B) 239.02775 u
C) 239.00189 u
D) 238.99919 u
E) 238.98884 u

Answer: A

13) A stationary plutonium-239 nucleus decays into a uranium-235 nucleus plus an alpha particle. The energy released in the process is 5.24 MeV. Given the following mass values

$^{4}_{2}$He: 4.002603 u

$^{235}_{92}$U: 235.043924 u

what is the kinetic energy of the $^{235}_{92}$U nucleus? (1 u =931.494 MeV/c^2)

A) 0.0829 MeV
B) 0.0837 MeV
C) 0.0852 MeV
D) 0.0863 MeV
E) 0.0877 MeV

Answer: E

14) The carbon in your body was formed in nuclear reactions in long-dead stars. How much energy was released when three ^{4}He nuclei combined to make ^{12}C? The mass of ^{4}He is 4.002603 u, the mass of ^{12}C is 12.0000 u, and 1 u = 931.494 MeV/c^2.

A) 7.274 MeV
B) 3716 MeV
C) 8.424 MeV
D) 2.106 MeV

Answer: A

15) How much energy is released when 1.40 μg of ^{3}H have decayed to ^{3}He? The mass of ^{3}He is 3.016029 u, the mass of ^{3}H is 3.016049 u, and 1 u = 931.494 MeV/c^2.

A) 830 J
B) 11,900 J
C) 7970 J
D) 71,700 J
E) 23,900 J

Answer: A

16) The set of nuclear reactions that power our sun can be summarized a $4p^+ \rightarrow {}^4He^{+2} + 2e^+$. The masses of the particles involved are 938.272 MeV/c^2 (proton, p^+), 3727.38 MeV/c^2 (alpha particle, $^4He^{+2}$), and 0.511 MeV/c^2 (positron, e^+). How much energy is released by each set of these reactions?

A) 24.69 MeV
B) 28.3 MeV
C) 2790 MeV
D) 279 MeV

Answer: A

17) A sphere made of a radioactive isotope initially has a mass of 6.88 kg. The half-life of this isotope is 1.34 h, and it decays by β^- emission. At the end of 2.68 h, what is the mass of this sphere?
A) 6.88 kg
B) 3.44 kg
C) 1.72 kg
D) 2.53 kg

Answer: A

18) A radioactive atom has 98 protons and 249 nucleons. If it undergoes alpha decay, what are the number of protons and nucleons, respectively, in the daughter nucleus?
A) 100, 245
B) 94, 247
C) 96, 245
D) 96, 247
E) 100, 249

Answer: C

19) Scandium, $^{44}_{21}\mathrm{Sc}$, decays by emitting a positron. What is the nuclide that is the product of the decay?
A) $^{43}_{21}\mathrm{Sc}$
B) $^{45}_{21}\mathrm{Sc}$
C) $^{44}_{20}\mathrm{Ca}$
D) $^{43}_{21}\mathrm{Ca}$
E) $^{44}_{20}\mathrm{Sc}$

Answer: C

20) The stability of ${}^{11}_{6}C$ with respect to alpha, β^+, and β^- decay is to be determined. Do not consider the possibility of decay by electron capture. The following atomic masses are known:

${}^{4}_{2}He$:	4.002603 u
${}^{7}_{4}Be$:	7.016928 u
${}^{11}_{5}B$:	11.009305 u
${}^{11}_{6}C$:	11.011433 u
${}^{11}_{7}N$:	11.026742 u

The ${}^{11}_{6}C$ nuclide is

A) not subject to alpha, β^+, or β^- decay.
B) subject to alpha decay only.
C) subject to β^+ decay only.
D) subject to β^- decay only.
E) subject to β^+ or β^- decay, but not to alpha decay.

Answer: C

21) The stability of ${}^{47}_{21}Sc$ with respect to alpha, β^+, and β^- decay is to be determined. Do not consider the possibility of decay by electron capture. The following atomic masses are known:

${}^{4}_{2}He$:	4.002603 u
${}^{43}_{19}K$:	42.960717 u
${}^{47}_{20}Ca$:	46.954543 u
${}^{47}_{21}Sc$	46.952409 u
${}^{47}_{22}Ti$:	46.951764 u

The ${}^{47}_{21}Sc$ nuclide is

A) not subject to alpha, β^+, or β^- decay.
B) subject to alpha decay only.
C) subject to β^+ decay only.
D) subject to β^- decay only.
E) subject to β^+ or β^- decay, but not to alpha decay.

Answer: D

22) The stability of $^{56}_{26}Fe$ with respect to alpha, β^+, and β^- decay is to be determined. Do not consider the possibility of decay by electron capture. The following atomic masses are known:

$^{4}_{2}He$: 4.002603 u

$^{52}_{24}Cr$: 51.944768 u

$^{56}_{25}Mn$: 55.938907 u

$^{56}_{26}Fe$: 55.934939 u

$^{56}_{27}Co$: 55.939841 u

The $^{56}_{26}Fe$ nuclide is

A) not subject to alpha, β^+, or β^- decay.
B) subject to alpha decay only.
C) subject to β^+decay only.
D) subject to β^- decay only.
E) subject to β^+ or β^- decay, but not to alpha decay.

Answer: A

23) A certain substance has a half-life of 5.0 hours. How many nuclei of the substance are required to give an initial activity of 6.0 μCi? 1 Ci = 3.7×10^{10} Bq.

A) 5.8×10^9
B) 8.5×10^8
C) 6.3×10^8
D) 3.2×10^9
E) 2.4×10^9

Answer: A

24) What mass of ^{14}C (having a half-life of 5730 years) do you need to provide a decay rate of 280.0 Bq? (1 u = 1.6605×10^{-27} kg)

A) 1.70×10^{-12} kg
B) 5.38×10^{-19} kg
C) 3.84×10^{-20} kg
D) 8.68×10^{-13} kg

Answer: A

25) How many days are required for a radioactive sample, with a half–life of 5.7 d and an initial activity of 1.07×10^5 Bq, to decay to an activity of 100 Bq?
A) 57 d
B) 46 d
C) 68 d
D) 39 d
Answer: A

26) A hospital patient has been given some ^{131}I (half–life = 8.04 d) which decays at 4.2 times the acceptable level for exposure to the general public. How long must the patient wait for the decay rate to reach the acceptable level? Assume that the material merely decays and is not excreted by the body.
A) 17 d
B) 12 d
C) 8.0 d
D) 7.2 d
Answer: A

27) The material used in certain nuclear bombs is ^{239}Pu, which has a half–life of about 20,000 years. How long must we wait for a buried stockpile of this substance to decay to 4.0% of its original ^{239}Pu mass?
A) 93,000 y
B) 64,000 y
C) 45,000 y
D) 800 y
Answer: A

28) An air sample is contaminated with ^{15}O, which has a half–life of 2.03 min. One possible way to minimize its hazard is to pass it through a long pipe to allow it to decay inside the pipe until it can be safely released into the atmosphere. If the oxygen moves at a speed of 1.1 m/s in the pipe, how long must the pipe be for the sample to have decayed to 3.0% of its original activity just as it leaves the pipe?
A) 680 m
B) 8.0 m
C) 7.0 m
D) 2.0 m
Answer: A

29) Rutherfordium–261 has a half–life of 1.08 min. How long will it take for a sample of rutherfordium to lose one–third of its nuclei?
A) 1.02 min
B) 1.62 min
C) 0.632 min
D) 2.70 min
E) 3.24 min
Answer: C

30) A radioactive sample has a half-life of 10 min. What fraction of the sample is left after 40 min?
A) 1/2
B) 1/4
C) 1/8
D) 1/16
E) 1/32

Answer: D

31) Fermium-253 has a half-life of 3.00 d. A sample of fermium contains 7.37×10^7 nuclei. How long will it take for there to be only 3.36×10^6 fermium nuclei in this sample?
A) 2.75 d
B) 9.80 d
C) 13.4 d
D) 15.7 d
E) 58.6 d

Answer: C

32) In a laboratory accident a work area is contaminated with radioactive material. Health physicists monitor the area during a 30-day period and, after correcting for the background rate, obtain the data shown in the table.

Time (days)	0	2	6	11	19	30
Counts/min	1000	899	727	557	364	202

The accident occurred at $t = 0$. They determine that it will not be safe for workers to enter the area until the radioactivity level has dropped to 133 counts per minute. Of the choices listed below, which one is the earliest time that workers could safely return?
A) 38 days
B) 44 days
C) 50 days
D) 32 days
E) 24 days

Answer: A

33) The unstable isotope ^{234}Th decays by β emission with a half-life of 24.5 days. The initial decay rate of the sample was 9.9×10^{13} Bq. (1 u = 1.6605×10^{-27} kg)
(a) What mass of ^{234}Th was initially present?
(b) What is the decay rate after 68 days?

Answer: (a) 0.12 g (b) 1.4×10^{13} Bq

34) An isotope of Tc having a half-life of 6.0 h is used in bone scans. If a certain amount of this Tc is injected into the body, how long does it take for its initial decay rate to decrease BY 99%?
A) 0.060 h
B) 3.3 h
C) 33 h
D) 40 h
E) slightly more than a month

Answer: D

35) The radioactivity due to carbon–14 measured in a piece of a wood from an ancient site was found to produce 20 counts per minute from a given sample, whereas the same amount of carbon from a piece of living wood produced 160 counts per minute. The half–life of carbon–14, a beta emitter, is 5730 y. The age of the artifact is closest to

A) 5700 y
B) 12,000 y
C) 15,000 y
D) 17,000 y
E) 23,000 y

Answer: D

36) Carbon–14 has a half–life of 5730 y. A sample of wood has been recovered by an archaeologist. The sample is sent to a laboratory, where it is determined that the activity of the sample is 0.144 Bq/g. By comparing this activity with the activity of living organic matter, 0.230 Bq/g, the scientist determines how old the wood sample is, or more precisely, when the tree that the sample came from died. How old is the sample of wood?

A) 3870 y
B) 4250 y
C) 4590 y
D) 2630 y
E) 2940 y

Answer: A

37) Living matter has 1.3×10^{-10} % of its carbon in the form of ^{14}C which has a half–life of 5730 y. A mammoth bone has a 300–g sample of carbon separated from it, and the sample is found to have an activity of 20 decays per second. How old is the bone?

A) 15,000 y
B) 10,900 y
C) 11,500 y
D) 7600 y
E) 6400 y

Answer: B

38) An archaeologist finds the ^{14}C in a sample of 3.10 g of material to be decaying at 107 counts per second. A modern 1.00–g sample of the same material decays at 151 counts per second. The half–life of ^{14}C is 5730 y. How old is the sample?

A) 12,200 y
B) 8460 y
C) 25,100 y
D) 12,600 y

Answer: A

39) An ancient rock is found to contain ^{40}Ar gas, indicating that 77% of the ^{40}K in the rock has decayed since the rock solidified. Any argon would have boiled out of liquid rock. The half-life of ^{40}K is 1.25 billion years. How long ago did the rock solidify?
A) 2.6 billion years
B) 0.50 billion years
C) 1.8 billion years
D) 0.30 billion years

Answer: A

40) Today, the uranium found on Earth contains 0.720% ^{235}U (with a half-life of 0.700 billion years) and 99.28% ^{238}U (with a half-life of 4.50 billion years). At a time 2.20 billion years ago, what percent of the uranium on Earth was ^{238}U (assuming that no other uranium isotopes were present)?
A) 95.6%
B) 2.18%
C) 6.29%
D) 8.68%
E) 4.53%

Answer: A

41) In the nuclear reaction ${}^{10}_{5}\mathrm{B} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{1}_{1}\mathrm{H} + \mathrm{X}$, which of the following is the missing nuclear product X?
A) ${}^{12}_{9}\mathrm{F}$
B) ${}^{21}_{7}\mathrm{N}$
C) ${}^{13}_{6}\mathrm{C}$
D) ${}^{13}_{7}\mathrm{N}$
E) ${}^{14}_{7}\mathrm{N}$

Answer: C

42) In the nuclear reaction

$$n + {}^{238}_{92}\mathrm{U} \rightarrow \mathrm{X} + 2e^{-}$$

n is a neutron and e^{-} is an electron, and the neutrinos have not been shown. Determine the atomic mass and atomic number of the missing nuclear product X, and write X in the standard form. It is NOT necessary to identify which atom X is.

Answer: A = 239, $Z = 94$, ${}^{239}_{94}\mathrm{X}$

43) For the missing product X in the nuclear reaction

$$\text{neutron} + {}^{16}_{8}\text{O} \rightarrow \text{X} + \text{alpha particle}$$

determine the atomic mass and atomic number of X, and write X in the standard form. It is NOT necessary to identify which atom X is.

Answer: A = 13, Z = 6, ${}^{13}_{6}\text{X}$

44) For the missing product X in the reaction

$$\text{neutron} + {}^{235}_{92}\text{U} \rightarrow {}^{141}_{56}\text{Ba} + \text{X} + 3\text{ neutrons}$$

determine the atomic mass and atomic number of X, and write X in the standard form. It is NOT necessary to identify which atom X is.

Answer: A = 92, Z = 36, ${}^{92}_{36}\text{X}$

45) A proton strikes an ${}^{18}_{8}\text{O}$ nucleus producing ${}^{18}_{9}\text{F}$ and another particle. What is the other particle?

A) a neutron
B) an alpha particle
C) a β^- particle
D) a β^+ particle
E) a gamma ray

Answer: A

46) How much energy is released in the total fission of 2.0 g of ^{235}U? The average energy per fission is 200.0 MeV. (1 u = 931.5 MeV/c^2 = 1.6605 × 10^{-27} kg, 1 eV = 1.60 × 10^{-19} J)

A) 1.6 × 10^{11} J
B) 3.9 × 10^{13} J
C) 1.6 × 10^{5} J
D) 3.9 × 10^{10} J

Answer: A

47) An excited ${}^{236}_{92}U^*$ nucleus undergoes fission into two fragments, as shown:

$${}^{236}_{92}U^* \rightarrow {}^{144}_{56}Ba + {}^{92}_{36}Kr$$

The following atomic masses are known:

${}^{92}_{36}Kr$: 91.926270 u

${}^{144}_{56}Ba$: 143.922845 u

${}^{236}_{92}U^*$: 236.045563 u

What is the reaction energy, in MeV, for this process? (1 u = 1.6605×10^{-27} kg = 931.5 MeV/c^2)

A) 150 MeV
B) 160 MeV
C) 170 MeV
D) 180 MeV
E) 190 MeV

Answer: D

48) An excited ${}^{236}_{92}U^*$ nucleus undergoes fission into two fragments, as shown:

$${}^{236}_{92}U^* \rightarrow {}^{144}_{56}Ba + {}^{92}_{36}Kr$$

The following atomic masses are known:

${}^{92}_{36}Kr$: 91.926270 u

${}^{144}_{56}Ba$: 143.922845 u

${}^{236}_{92}U^*$: 236.045563 u

Assume, at a given instant, that the two fission fragments are spherical, just barely in contact, and carry spherically symmetric charge distributions. At that instant, what is the electrostatic interaction energy of the two fragments, in MeV? (1 u = 1.6605×10^{-27} kg = 931.5 MeV/c^2, $1/4\pi\varepsilon_0 = 9.0 \times 10^9$ N * m^2/C^2)

A) 230 MeV
B) 240 MeV
C) 250 MeV
D) 260 MeV
E) 270 MeV

Answer: C

49) In the fission reaction $^{235}_{92}U + \text{neutron} \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + x$ neutrons, what is the number x of neutrons produced?

A) 0
B) 4
C) 1
D) 3
E) 2

Answer: D

50) When a neutron (n) collides with a uranium–235 nucleus it can induce a variety of fission reactions. One such reaction is $^{235}_{92}U + n \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + 2n$. How much energy is released in this reaction, given the following mass values:

$^{140}_{54}Xe$: 139.921620 u

$^{94}_{38}Sr$: 93.915367 u

$^{235}_{92}U$: 235.043924 u

n: 1.008665 u

(1 u = 931.494 MeV/c^2)

A) 185 MeV
B) 202 MeV
C) 32.6 MeV
D) 65.7 MeV
E) 98.6 MeV

Answer: A

51) If a 2.0–MeV neutron released in a fission reaction loses half of its energy in each moderator collision, how many collisions are needed to reduce its energy to (1/25) eV?

A) 6
B) 18
C) 26
D) 30
E) 4

Answer: C

52) Calculate the amount of energy that is released in the fusion reaction $^2H + {}^2H \rightarrow {}^4He$, given the masses:

^2H: 2.014102 u

^4He: 4.002603 u

(1 u = 931.5 MeV/c^2)

A) 24 MeV
B) 18 MeV
C) 13 MeV
D) 12 MeV
E) 36 MeV

Answer: A

53) The reaction $^2H + ^2H \to ?\ ^3H + ^1H$ releases 4.03 MeV of energy. If 1.0 kg of deuterium were to go through this reaction, how much energy would be produced? (1 eV = 1.60×10^{-19} J, $m_{\text{deuterium}}$ = 2.012 u, 1 u = 931.5 MeV/c^2 = 1.6605×10^{-27} kg)

A) 9.7×10^7 J
B) 9.7×10^{13} J
C) 1.9×10^7 J
D) 1.9×10^{14} J
E) 1.9×10^{11} J

Answer: B

54) Two deuterium nuclei, ${}_1^2H$, fuse to produce a tritium nucleus, ${}_1^3H$, and a hydrogen nucleus. A neutral deuterium atom has a mass of 2.014102 u; a neutral tritium atom has a mass of 3.016049 u; a neutral hydrogen atom has a mass of 1.007825 u; a neutron has a mass of 1.008665 u; and a proton has a mass of 1.007276 u. How much energy is released in the process? (1 u = 931.494 MeV/c^2)

A) 3.03 MeV
B) 3.53 MeV
C) 4.03 MeV
D) 4.53 MeV
E) 6.58 MeV

Answer: C

55) Consider the fusion reaction

$${}_1^2H + {}_1^2H + {}_1^2H \to {}_2^4He + {}_1^1H + {}_0^1n$$

The atomic masses are:

${}_1^2H$: 2.01410 u

${}_2^4He$: 4.00260 u

${}_1^1H$, 1.00783 u

${}_0^1n$: 1.008665 u

What mass of deuterium fuel, ${}_1^2H$, is used up in producing 8.2×10^{13} J of energy by this reaction? (1u = 1.6605×10^{-27} kg = 931.5 MeV/c^2)

Answer: 0.24 kg

56) Two deuterium nuclei, ${}^{2}_{1}H$, fuse to produce a helium nucleus, ${}^{3}_{2}H$, and a neutron. A neutral deuterium atom has a mass of 2.014102 u; a neutral helium atom has a mass of 3.016030 u; a neutral hydrogen atom has a mass of 1.007825 u; a neutron has a mass of 1.008665 u; and a proton has a mass of 1.007276 u. How much energy is released in the process? (1 u = 931.494 MeV/c^2)

A) 3.27 MeV
B) 3.57 MeV
C) 4.00 MeV
D) 4.50 MeV
E) 5.68 MeV

Answer: A

57) A 70-kg laboratory technician absorbs 2.9 mJ of 0.50-MeV gamma rays in a workday. How many gamma-ray photons does the technician absorb in a workday?

A) 3.6×10^{10}
B) 3.6×10^{9}
C) 3.6×10^{8}
D) 1.0×10^{9}
E) 1.0×10^{8}

Answer: A

58) The radioactive nuclei ${}^{60}Co$ is widely used in medical applications. It undergoes beta decay, and the total energy of the decay process is 2.82 MeV per decay event. The half-life of this nucleus is 272 days. Suppose that a patient is given a dose of 6.9 μCi of ${}^{60}Co$. If all of this material decayed while in the patient's body, what would be the total energy deposited there? (1 Ci = 3.70×10^{10} decays/s)

A) 11 J
B) 8.6 GJ
C) 3.9 J
D) 24 J
E) 4.15 MJ

Answer: C

Chapter 39 From Quarks to the Cosmos

39.1 Conceptual Questions

1) Which of the following particles are leptons? (There may be more than one correct choice.)
A) positron
B) muon
C) π-meson
D) neutron
E) electron

Answer: A, B, E

2) Particles that do not interact via the strong force but do interact via the weak nuclear force (and presumably by the much weaker gravitation force) are called
A) baryons.
B) mesons.
C) hadrons.
D) leptons.
E) nucleons.

Answer: D

3) What type of particle is an electron? (There may be more than one correct choice.)
A) lepton
B) meson
C) baryon
D) nucleon
E) hadron

Answer: A

4) What type of particle is a proton? (There may be more than one correct choice.)
A) lepton
B) meson
C) baryon
D) nucleon
E) hadron

Answer: C, D, E

5) What type of particle is a neutron? (There may be more than one correct choice.)
A) lepton
B) meson
C) baryon
D) nucleon
E) hadron

Answer: C, D, E

6) Hadrons are divided into two subgroups called
A) baryons and leptons.
B) leptons and mesons.
C) mesons and baryons.
D) nucleons and leptons.
E) mesons and leptons.

Answer: C

7) How many different kinds of leptons are known to exist, including antiparticles as different kinds?
A) 4
B) 6
C) 8
D) 2
E) 12

Answer: E

8) Consider the possibility that a neutron could decay into a proton and a pion. What, if any, of the following conservation laws would this process violate?
A) conservation of energy
B) conservation of lepton number
C) conservation of charge
D) conservation of baryon number
E) None of the above laws would be violated.

Answer: A

9) Consider the decay $\pi^0 \rightarrow \mu^- + e^+$. This decay is
A) allowed.
B) forbidden because conservation of energy is violated.
C) forbidden because conservation of baryon number is violated.
D) forbidden because conservation of mass is violated.
E) forbidden because conservation of lepton numbers is violated.

Answer: E

10) Consider the decay $\pi^+ \rightarrow \mu^+ + \gamma$. This decay is
A) allowed.
B) forbidden because conservation of energy is violated.
C) forbidden because conservation of baryon number is violated.
D) forbidden because conservation of mass is violated.
E) forbidden because conservation of lepton numbers is violated.

Answer: E

11) The reaction $p + e^- \rightarrow \overline{p} + e^+$ is not possible because
A) baryon number is not conserved.
B) lepton number is not conserved.
C) charge is not conserved.
D) energy is not conserved.
E) This reaction IS possible.

Answer: A

12) The reaction $p + \overline{n} \rightarrow e^{+} + \gamma$ is not possible because
A) baryon number is not conserved.
B) lepton number is not conserved.
C) charge is not conserved.
D) energy is not conserved.
E) This reaction IS possible.

Answer: B

13) The decay $n \rightarrow p^{+} + e^{-} + \gamma$ does not occur because it would violate conservation of
A) baryon number.
B) lepton number.
C) charge.
D) energy.

Answer: B

14) What is the quark composition of the proton?
A) $\boldsymbol{u\overline{u}d}$
B) $\boldsymbol{uud}$
C) $\boldsymbol{udd}$
D) $\boldsymbol{u\overline{dd}}$
E) $\boldsymbol{u\overline{d}d}$

Answer: B

15) Composite particles that are composed of a quark and antiquark pair are called
A) leptons.
B) hadrons.
C) mesons.
D) nucleons.
E) baryons.

Answer: C

16) Composite particles that are composed of three quarks are called
A) leptons.
B) hadrons.
C) mesons.
D) bosons.
E) baryons.

Answer: E

17) Which of the following particles are made up of quarks? (There may be more than one correct choice.)
A) nucleons
B) hadrons
C) neutrinos
D) muons
E) mesons

Answer: A, B, E

18) Which of the following particles is NOT made up of quarks? (There may be more than one correct choice.)
A) proton
B) neutron
C) electron
D) π-meson
E) neutrino
Answer: C, E

19) Given that the reaction $n + \pi^+ \rightarrow p$ can occur and that the quark composition of the neutron is ***udd*** and that of the proton is ***uud***, what must be the quark composition of the π^+ meson?
A) $u\bar{u}$
B) $\bar{u}d$
C) $d\bar{d}$
D) $u\bar{d}$
E) $\bar{u}d\bar{d}$
Answer: D

20) The cosmic background radiation corresponds to a temperature of about
A) 1.4 K.
B) 2.7 K.
C) 3.8 K.
D) 4.9 K.
E) 5.5 K.
Answer: B

39.2 Problems

1) Suppose you were to try to create a proton–antiproton pair by annihilation of two very high–energy gamma rays of the same wavelength heading toward each other. The proton and the anti–proton have the same masses, but opposite charges. What would be the minimum energy needed for each photon? ($e = 1.60 \times 10^{-19}$ C, $m_{\text{proton}} = 1.67 \times 10^{-27}$ kg, $c = 3.00 \times 10^8$ m/s)
A) 1.022 MeV
B) 12.2 MeV
C) 1880 MeV
D) 939 MeV
E) 223 MeV
Answer: D

2) A neutral η^0 (having mass 0.642 u) that is at rest decays into two gamma ray photons. What is the energy in MeV of each photon? (1 u = 931.5 MeV/c^2)
A) 299 MeV
B) 597 MeV
C) 1190 MeV
D) 199 MeV
E) 149 MeV
Answer: A

3) Is the decay $\Sigma^+ \rightarrow p + \pi^+$ allowed?
A) Yes, because it conserves energy.
B) No, because charge is not conserved.
C) No, because mass is created.
D) No, because lepton number is not conserved.
Answer: B

4) Is the decay $\pi^0 \rightarrow \mu^+ + v_\mu$ allowed?
A) Yes, because it conserves energy.
B) No, because charge is not conserved.
C) No, because mass is created.
D) No, because lepton number is not conserved.
Answer: B

5) Which one of the following decays CAN occur?
A) $\pi^+ \rightarrow \mu^+ + v_\mu$
B) $p + n \rightarrow p + p + \overline{p}$
C) $K^+ \rightarrow \pi^0$
D) $\mu^- \rightarrow e^- + v_e + v_\mu$
E) $K^+ \rightarrow 2\pi^0$
Answer: A

6) Which one of the following processes CANNOT occur?
A) $\pi^+ \rightarrow \mu^+ + v_\mu$
B) $\pi^0 \rightarrow 2\gamma$
C) $\pi^+ + p \rightarrow K^+ + \Sigma^+$
D) $\pi^- + p \rightarrow n + \gamma$
E) $\Sigma^- \rightarrow \pi^- + p$
Answer: E

7) How many quarks are in a deuteron, ^2H?
A) 1
B) 2
C) 3
D) 4
E) 6
Answer: E

8) Consider the negative pion, π^-.
(a) What combination of up and down quarks makes up this particle?
(b) Is the π^- a baryon or a meson?
(c) Is the π^- a lepton or a hadron?
Answer: (a) $\overline{u}d$ (b) meson (c) hadron

9) If a galaxy is receding from us at $0.10c$. Use Hubble's law to estimate the distance to this galaxy if the Hubble constant is 22 km/s per million light-years. ($c = 3.00 \times 10^8$ m/s, 1 ly = 9.461×10^{15} m, 1 y = 3.156×10^7 s)
A) 1.4×10^9 ly
B) 6.6×10^5 ly
C) 6.6×10^5 Mly
D) 2.2 Mly
E) 1.4×10^7 Mly
Answer: A

10) If the Hubble constant is 25 km/s per million light-years, use it to estimate the age of the universe? ($c = 3.00 \times 10^8$ m/s, 1 ly = 9.461×10^{15} m, 1 y = 3.156×10^7 s)
A) 10 Gy
B) 12 Gy
C) 15 Gy
D) 20 Gy
E) 25 Gy
Answer: B

11) If a galaxy is moving away from us at 1.0% of the speed of light, use Hubble's law to estimate how far away it is from us if the Hubble constant is 22 km/s per million light-years. ($c = 3.00 \times 10^8$ m/s, 1 ly = 9.461×10^{15} m, 1 y = 3.156×10^7 s)
A) 14 ly
B) 140 ly
C) 140 thousand ly
D) 140 million ly
E) 140 billion ly
Answer: D

12) Estimate the speed of a galaxy away from us if it is 10 billion light-years from us and if the Hubble constant is 22 km/s per million light-years. ($c = 3.00 \times 10^8$ m/s, 1 ly = 9.461×10^{15} m, 1 y = 3.156×10^7 s)
A) $0.1c$
B) $0.3c$
C) $0.5c$
D) $0.7c$
E) $0.9c$
Answer: D

13) A giant star in another galaxy exploded 67 million years ago, forming a supernova. The event is observed by an astronomer on Earth. Estimate the speed at which the supernova (and its galaxy) recedes from Earth if the Hubble constant is 22 km/s per million light-years. ($c = 3.00 \times 10^8$ m/s, 1 ly = 9.461×10^{15} m, 1 y = 3.156×10^7 s)
A) 1200 km/s
B) 670 km/s
C) 1500 km/s
D) 2700 km/s
E) 4700 km/s
Answer: C

14) A galaxy is observed receding from Earth with a speed of 2800 km/s. If the Hubble constant is 22 km/s per million light-years, estimate how many years ago the light that we presently see from the galaxy actually left the galaxy. ($c = 3.00 \times 10^8$ m/s, 1 ly = 9.461×10^{15} m, 1 y = 3.156×10^7 s)
A) 1.3×10^8 y
B) 4.2×10^8 y
C) 4.2×10^7 y
D) 1.4×10^7 y
E) 4.2×10^6 y
Answer: A

15) The background microwave radiation, discovered in 1965 by Penzias and Wilson, has its peak intensity at a wavelength of 1.06 mm. What blackbody temperature does this wavelength imply for the universe? ($\sigma = 5.670 \times 10^{-8}$ W/m$^2 \cdot$ K^4, Wien displacement law constant is 2.90×10^{-3} m $\cdot$ K)
A) 2.7°C
B) -270°C
C) 0.0027 K
D) 0.00°C
E) -2.7°C
Answer: B

16) Suppose that the Hubble constant had the value 35.0 km/s per million light-years. (1 y = 3.156×10^7 s$\bullet$, $m_H \approx m_{proton} = 1.67 \times 10^{-27}$ kg, $c = 3.00 \times 10^8$ m/s, 1 light-year = 9.461×10^{15} m, $G = 6.67 \times 10^{-11}$ N $\cdot$ m^2/kg^2)
(a) What would be the maximum density the universe could have that would still allow it to expand forever?
(b) Under the conditions of part (a), how many hydrogen atoms would we expect to find, on the average, in a volume of space measuring 3.00 m by 8.00 m by 8.00 m?
Answer: (a) 2.45×10^{-26} kg/m^3 (b) 2820 atoms