6 to stand the stresses. Make multiview sketches of your design and show all calculations. How long will it take to raise the load with your design?

*†9-29 Determine all possible two-stage compound gear combinations that will give an approximation to the Naperian base 2.71828. Limit tooth numbers to between 18 and 80. Determine the arrangement that gives the smallest error.

†9-30 Determine all possible two-stage compound gear combinations that will give an approximation to 2π. Limit tooth numbers to between 15 and 90. Determine the arrangement that gives the smallest error.

†9-31 Determine all possible two-stage compound gear combinations that will give an approximation to $\pi/2$. Limit tooth numbers to between 20 and 100. Determine the arrangement that gives the smallest error.

†9-32 Determine all possible two-stage compound gear combinations that will give an approximation to $3\pi/2$. Limit tooth numbers to between 20 and 100. Determine the arrangement that gives the smallest error.

†9-33 Figure P9-4a shows a reverted clock train. Design it using 25° nominal pressure angle gears of 24 p_d having between 12 and 150 teeth. Determine the tooth numbers and nominal center distance. If the center distance has a manufacturing tolerance of ± 0.006 in, what will the pressure angle and backlash at the minute hand be at each extreme of the tolerance?

†9-34 Figure P9-4b shows a three-speed shiftable transmission. The tooth numbers are indicated in the figure. Shaft F, with the cluster of gears E, G, and H, is capable of

* Answers in Appendix F.

† These problems are suited to solution using *Mathcad*, *Matlab*, or *TKSolver* equation solver programs.

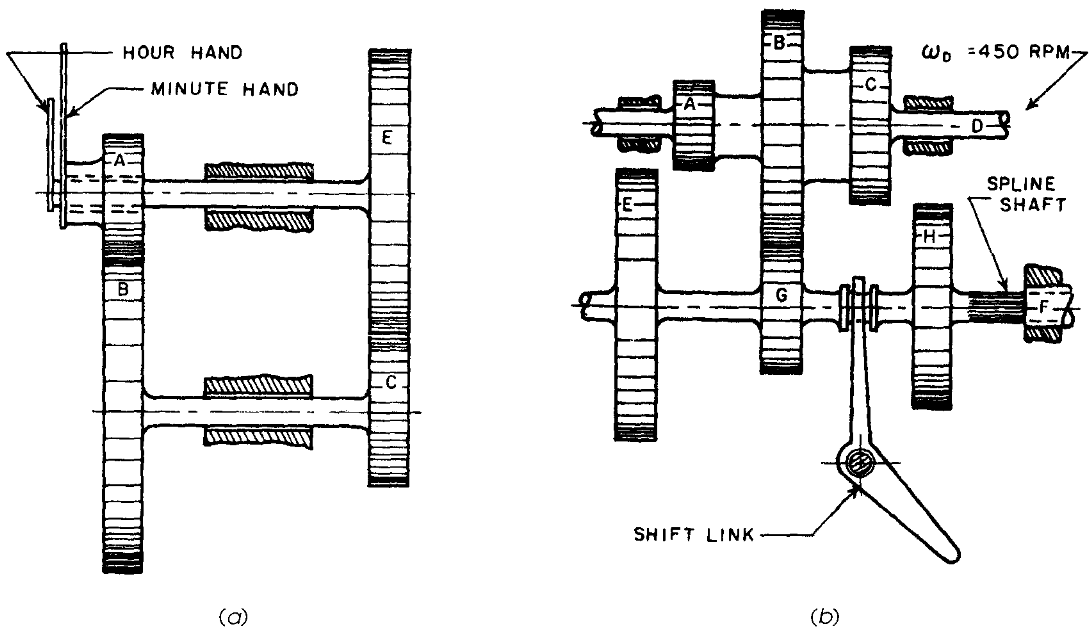


FIGURE P9-4

Problems 9-33 to 9-34 *From P. H. Hill and W. P. Rule, (1960), Mechanisms: Analysis and Design, with permission*

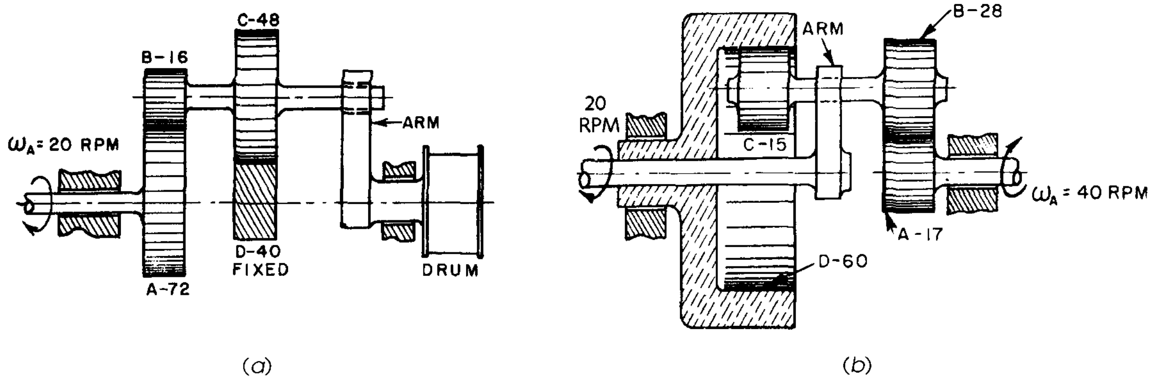


FIGURE P9-5

Problems 9-35 to 9-36 *From P. H. Hill and W. P. Rule. (1960). Mechanisms: Analysis and Design, with permission*

sliding left and right to engage and disengage the three gearsets in turn. Design the three reverted stages to give output speeds at shaft *F* of 150, 350, and 550 rpm for an input speed of 450 rpm to shaft *D*.

†9-35 Figure P9-5a shows a compound epicyclic train used to drive a winch drum. Gear *A* is driven at 20 rpm *CW* and gear *D* is fixed to ground. The tooth numbers are indicated in the figure. Determine the speed and direction of the drum. What is the efficiency of this train if the basic gearsets have $E_0 = 0.98$?

†9-36 Figure P9-5b shows a compound epicyclic train. The tooth numbers are indicated in the figure. The arm is driven *CCW* at 20 rpm. Gear *A* is driven *CW* at 40 rpm. Find the speed of the ring gear *D*. What is the efficiency of this train if the basic gearsets have $E_0 = 0.98$?

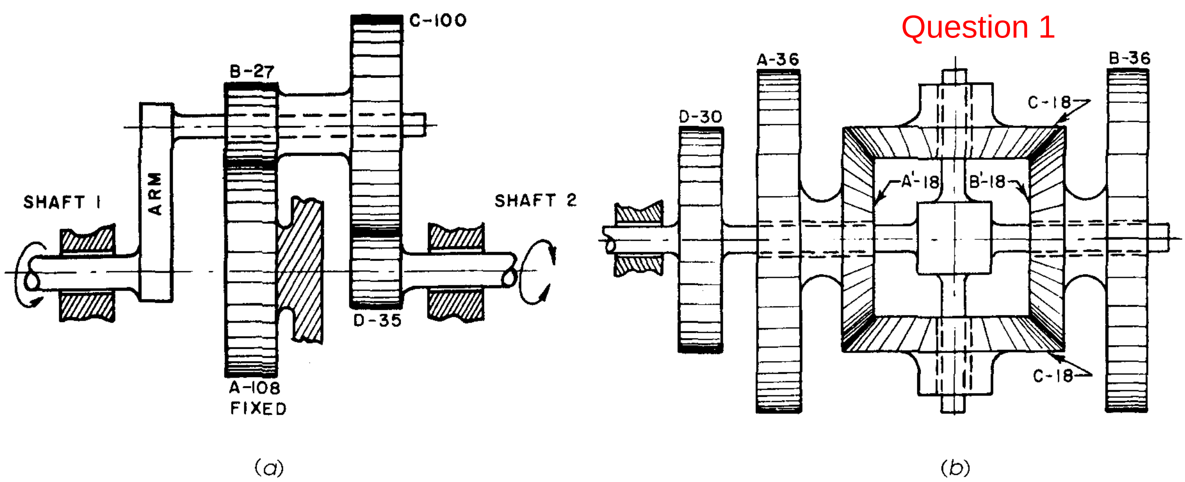
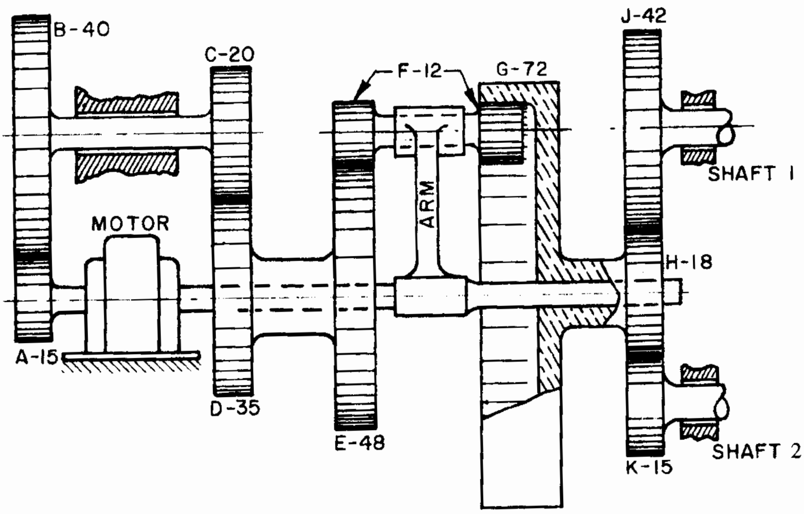


FIGURE P9-6

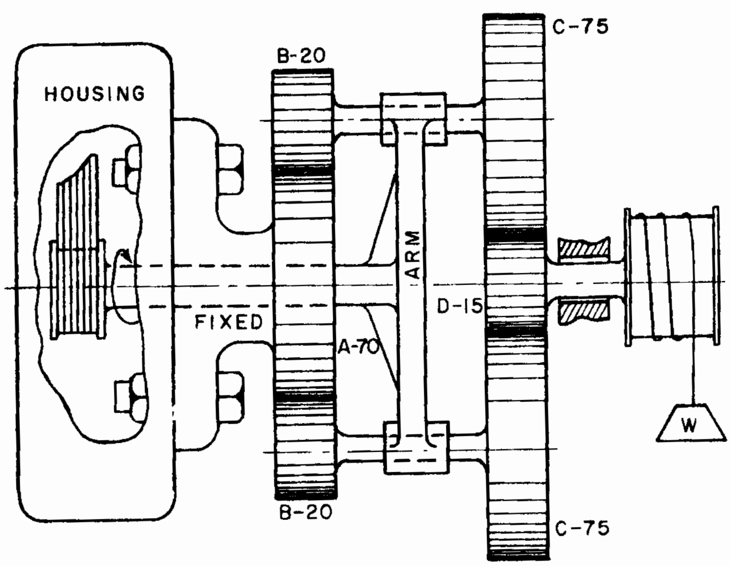
Problems 9-37 to 9-38 *From P. H. Hill and W. P. Rule. (1960). Mechanisms: Analysis and Design, with permission*

†9-37 Figure P9-6a shows a compound epicyclic train. The tooth numbers are indicated in the figure. The arm is driven *CW* at 60 rpm. Gear *A* is fixed to the frame. Find the speed of gear *D*. What is the efficiency of this train if the basic gearsets have $E_0 = 0.98$?

Question 2



(a)



(b)

FIGURE P9-7

Problems 9-39 to 9-40 *From P. H. Hill and W. P. Rule. (1960). Mechanisms: Analysis and Design*

† These problems are suited to solution using *Mathcad, Matlab,* or *TKSolver* equation solver programs.

Question 3

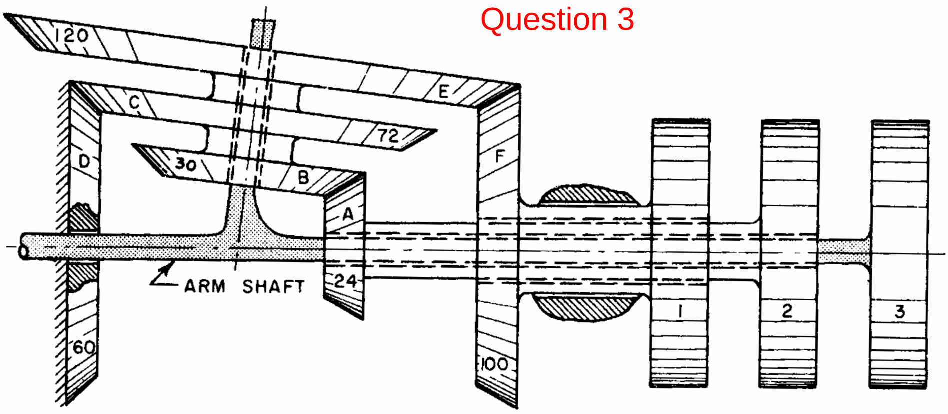


FIGURE P9-8

Problem 9-41 *From P. H. Hill and W. P. Rule. (1960). Mechanisms: Analysis and Design, with permission*

†9-38 Figure P9-6b shows a differential. The tooth numbers are indicated in the figure. Gear *A* is driven *CCW* at 10 rpm. Gear *B* is driven *CW* at 24 rpm. Find the speed of gear *D*. What is the efficiency of this train if the basic gearsets have $E_0 = 0.97$?

†9-39 Figure P9-7a shows a gear train containing both compound-reverted and epicyclic stages. The tooth numbers are indicated in the figure. The motor is driven *CCW* at 1750 rpm. Find the speeds of shafts 1 and 2.

†9-40 Figure P9-7b shows a compound epicyclic train used to drive a winch drum. The arm is driven at 250 rpm *CCW* and gear *A* is fixed to ground. The tooth numbers are indicated in the figure. Determine the speed and direction of the drum. What is the efficiency of this train if the basic gearsets have $E_0 = 0.98$?

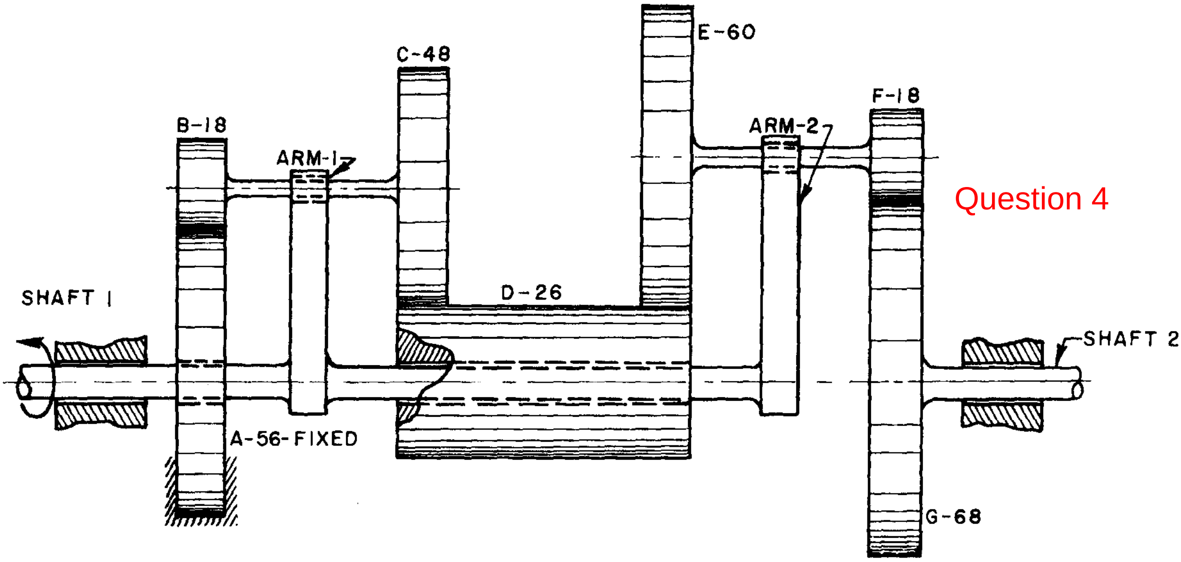
†9-41 Figure P9-8 shows a compound epicyclic train. Gear 2 is driven at 800 rpm *CCW* and gear *D* is fixed to ground. The tooth numbers are indicated in the figure. Determine the speed and direction of gears 1 and 3.

†9-42 Figure P9-9a shows a compound epicyclic train. Shaft 1 is driven at 300 rpm *CCW* and gear *A* is fixed to ground. The tooth numbers are indicated in the figure. Determine the speed and direction of shaft 2.

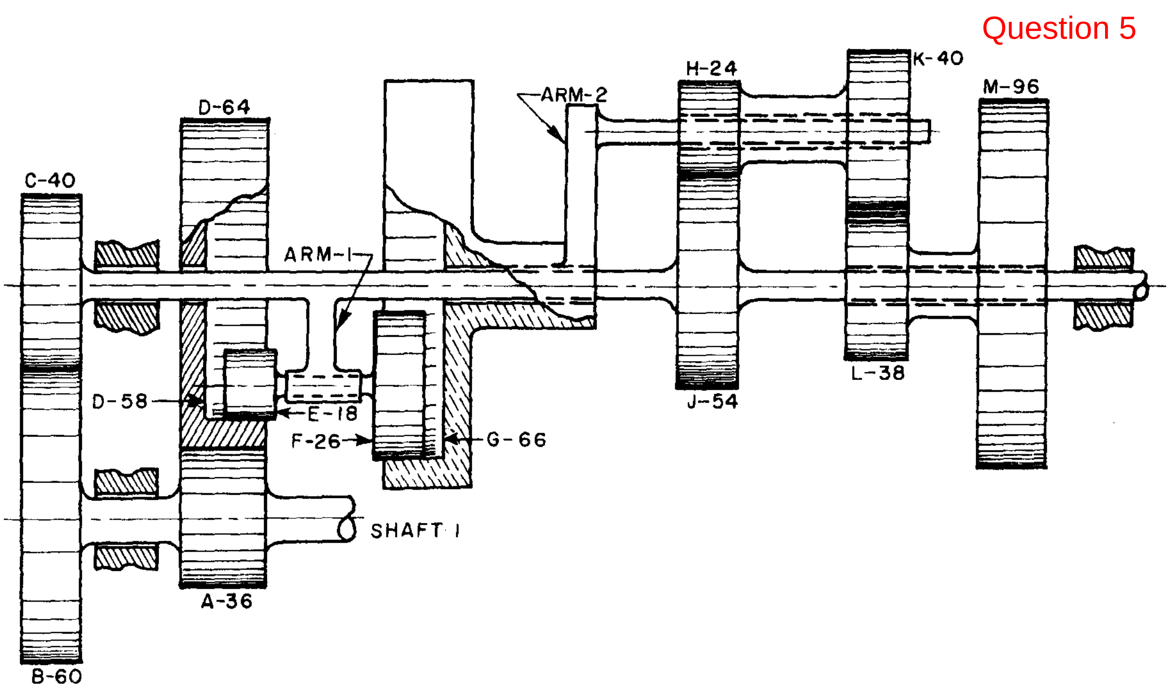
†9-43 Figure P9-9b shows a compound epicyclic train. Shaft 1 is driven at 40 rpm. The tooth numbers are indicated in the figure. Determine the speed and direction of gears *G* and *M*.

†9-44 Calculate the ratios in the Model T transmission shown in Figure 9-46 (p. 476).

† These problems are suited to solution using *Mathcad, Matlab,* or *TKSolver* equation solver programs.



(a)



(b)

FIGURE P9-9

Problems 9-42 to 9-43 *From P. H. Hill and W. P. Rule. (1960). Mechanisms: Analysis and Design, with permission*

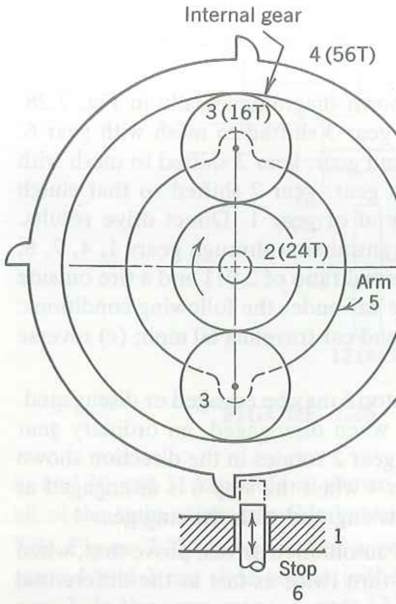


FIGURE 7.29

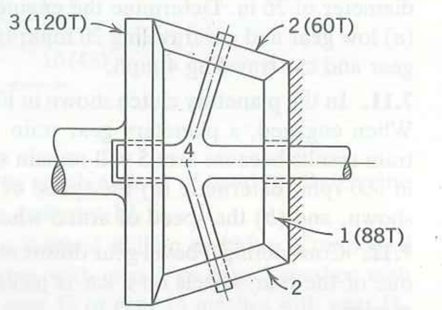


FIGURE 7.30

of the arm in the direction shown, find the number of revolutions of gears 3, 4, and 5 and their directions of rotation. The gears are nonstandard.

7.17. Shaft A rotates in the direction shown in Fig. 7.33 at 640 rpm. If shaft B is to rotate at 8 rpm in the direction shown, calculate the angular-velocity ratio ω_2/ω_4. What would the ratio ω_2/ω_4 have to be for shaft B to rotate at 8 rpm in the opposite direction?

7.18. In the mechanism in Fig. 7.34, gear 2 rotates at 60 rpm in the direction shown. Determine the speed and direction of rotation of gear 12.

7.19. A mechanism known as Humpage's gear is shown in Fig. 7.35. Find the angular velocity ratio ω_A/ω_B.

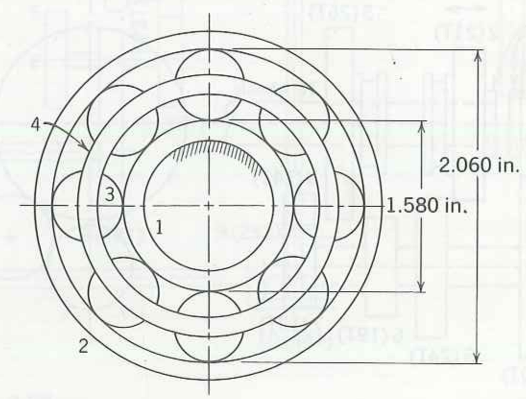


FIGURE 7.31

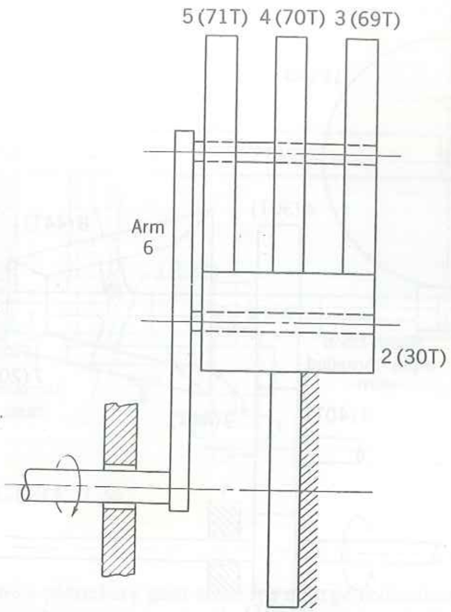


FIGURE 7.32

7.20. In the planetary gear train shown in Fig. 7.36, determine the angular-velocity ratio ω_2/ω_7. Compare this ratio with that obtained if the arm 4 is connected directly to the output shaft and gears 5, 6, and 7 are omitted.

7.21. In the gear train for Problem 7.20, gear 2 rotates at 600 rpm in the direction shown and gear 1 (and gear 6) rotates at 300 rpm in the opposite direction. Calculate the speed and direction of rotation of gear 7.

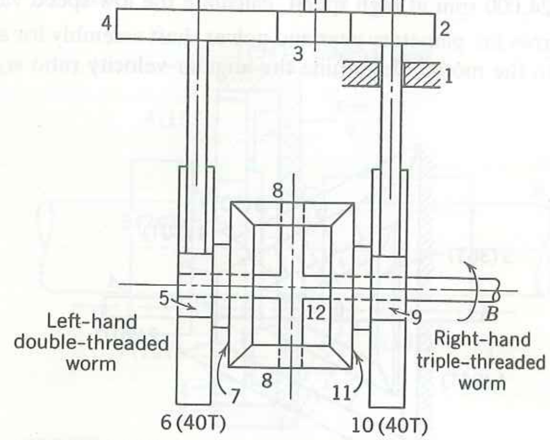


FIGURE 7.33

Question #6

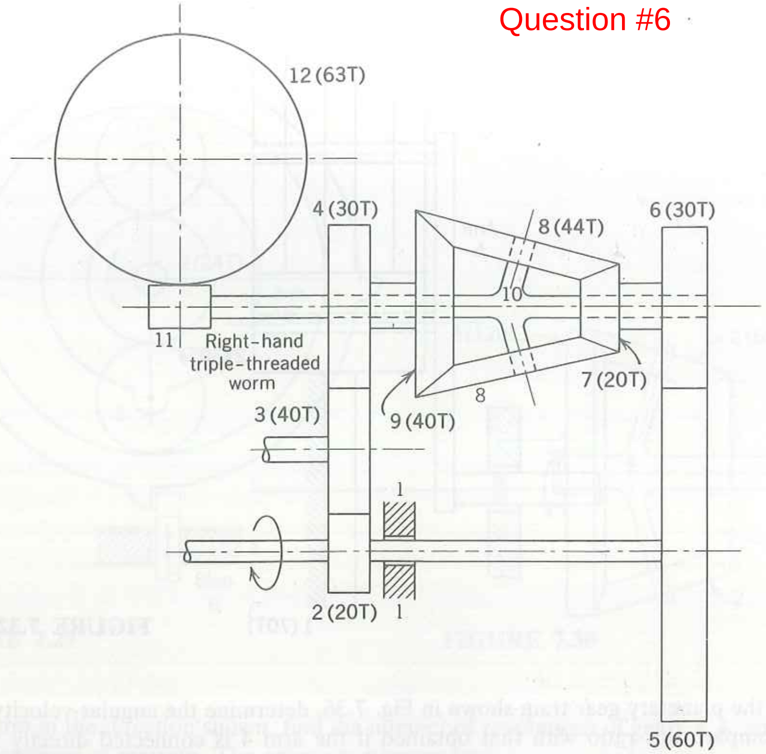


FIGURE 7.34

7.22. A planetary gear train for a two-speed aircraft supercharger drive is shown in Fig. 7.37. Gear 2 is driven by a 63-tooth gear (not shown) which operates at 2400 rpm. At high speed, gear 2 connects to the supercharger shaft through additional gearing. At low speed, gear 7 is held stationary and shaft B is connected to the supercharger shaft with the same gear ratio as was used between gear 2 and the supercharger shaft. If the supercharger operates at 24,000 rpm at high speed, calculate the low-speed value.

7.23. Figure 7.38 shows the planetary gear and power shaft assembly for an aircraft servo. If shaft A connects to the motor, determine the angular-velocity ratio ω_A/ω_B.

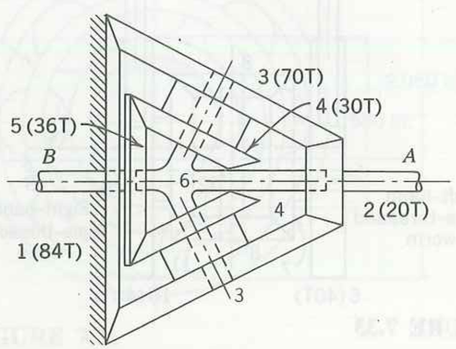


FIGURE 7.35

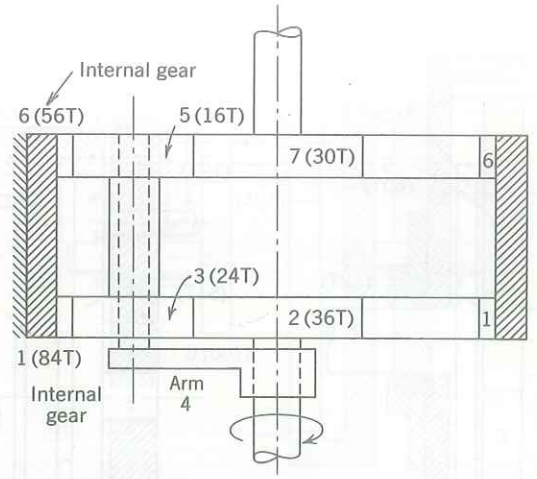


FIGURE 7.36

7.24. Figure 7.39 shows a planetary gear train for a large reduction. (*a*) If shaft A connects to the motor, determine the angular-velocity ratio ω_A/ω_B. (*b*) Will gears 2, 3, and 4 and gears 5, 6, and 7 be standard or nonstandard? Why? (*c*) If the number of teeth in gear 3 is changed from 51 teeth to 52 teeth, calculate the angular-velocity ratio ω_A/ω_B.

7.25. An aircraft propeller reduction drive is shown diagrammatically in Fig. 7.40. Determine the propeller speed in magnitude and direction if the engine turns at 2450 rpm in the direction indicated.

7.26. In the planetary reduction unit shown in Fig. 7.41, gear 2 turns at 300 rpm in the direction indicated. Determine the speed and direction of rotation of gear 5.

7.27. In the gear train for Problem 7.26, gear 2 turns at 300 rpm in the direction shown, and gear 1 rotates at 50 rpm in the opposite direction. Calculate the speed and direction of rotation of gear 5.

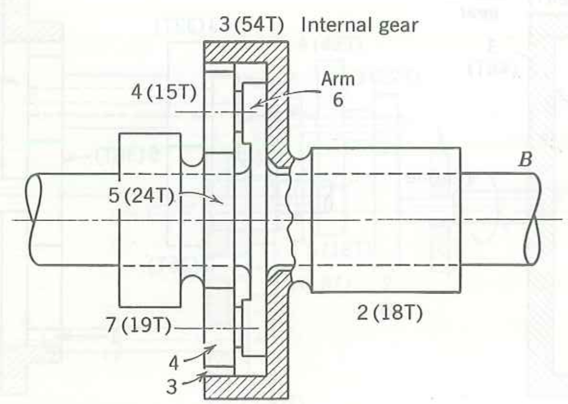


FIGURE 7.37

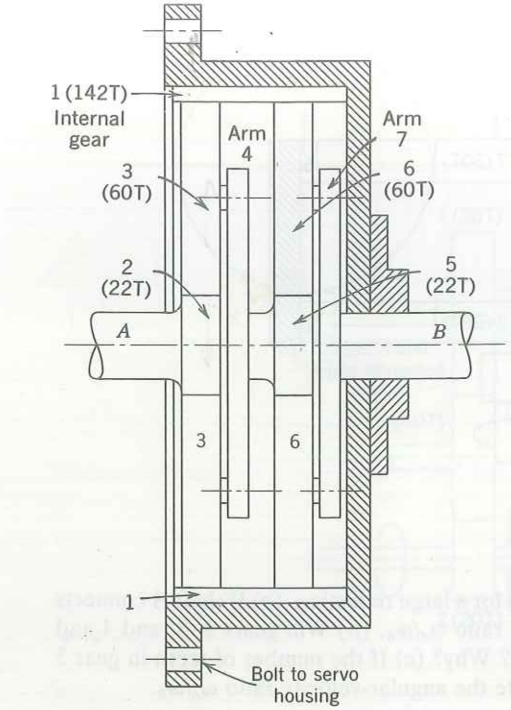


FIGURE 7.38

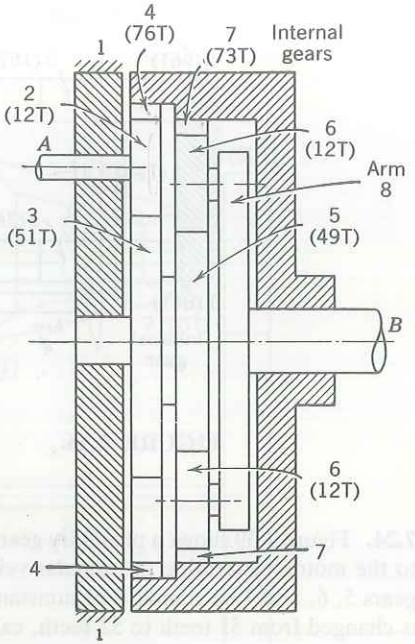


FIGURE 7.39

7.28. In the planetary gear train shown in Fig. 7.42, gear 2 turns at 600 rpm in the direction indicated. Determine the speed and direction of rotation of arm 6 if gear 5 rotates at 350 rpm in the same direction as gear 2.

7.29. If in the gear train for Problem 7.28, gear 2 rotates at 1000 rpm in the direction shown and gear 5 is held stationary, arm 6 will rotate at 625 rpm in the same direction

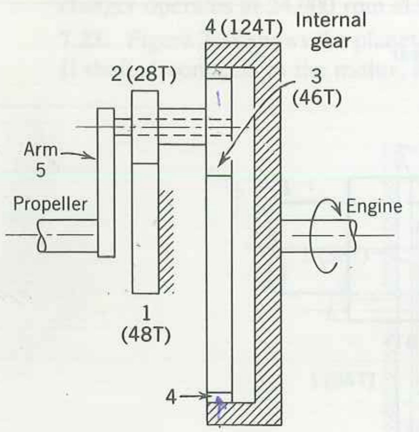


FIGURE 7.40

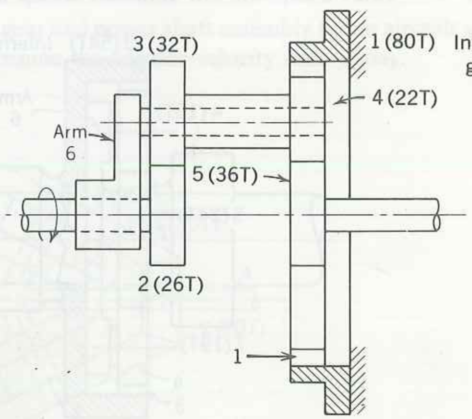


FIGURE 7.41

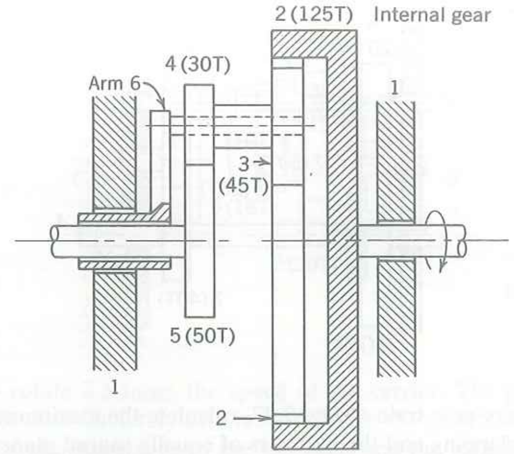


FIGURE 7.42

as gear 2. Determine the speed and direction of rotation which must be given to gear 5 to make arm 6 stand still if gear 2 continues to rotate at 1000 rpm.

7.30. For the gear train of Fig. 7.43, shaft *A* rotates at 300 rpm and shaft *B* at 600 rpm in the directions shown. Determine the speed and direction of rotation of shaft *C*.

7.31. In Fig. 7.44, shaft *A* turns at 100 rpm in the direction shown. Calculate the speed of shaft *B* and give its direction of rotation.

7.32. In the planetary gear train shown in Fig. 7.45, shaft *A* rotates at 450 rpm and shaft *B* at 600 rpm in the directions shown. Calculate the speed of shaft *C* and give its direction of rotation.

7.33. Shaft *A* rotates in Fig. 7.46 at 350 rpm and shaft *B* at 400 rpm in the directions shown. Determine the speed and direction of rotation of shaft *C*.

7.34. In the bevel gear planetary train shown in Fig. 7.47, shaft *A* rotates in the direction shown at 1250 rpm and shaft *B* in the direction shown at 600 rpm. Determine the speed of shaft *C* in magnitude and direction.

Question #7

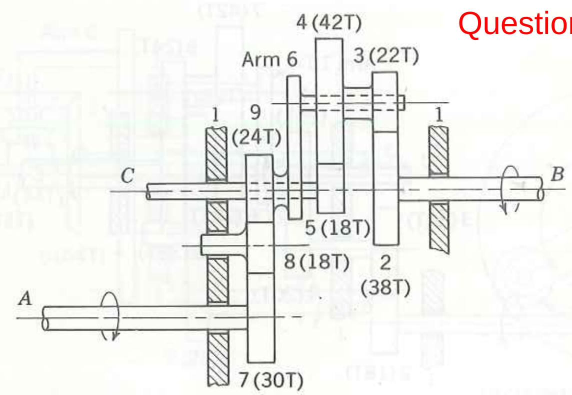


FIGURE 7.43

Question #8

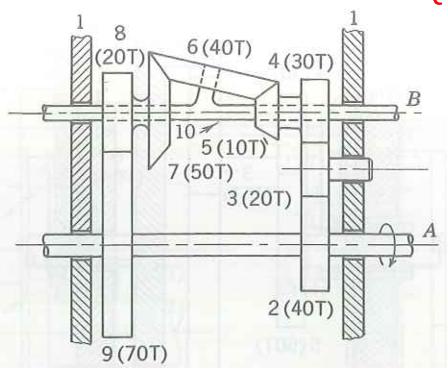


FIGURE 7.44

7.35. For the planetary gear train of Fig. 7.37, calculate the maximum number of planets possible without overlapping and the numbers of equally spaced planets that can be used in the train.

7.36. In a planetary train similar to that of Fig. 7.15, gear 1 has 41 teeth, gear 2 has 18 teeth, and gear 3 has 78 teeth. Gears 1 and 3 are standard and gear 2 is nonstandard. Determine the maximum number of equally spaced planets that can be used.

7.37. Calculate the maximum number of equally spaced compound planets that can be used in the gear train of Fig. 7.36.

7.38. For the planetary gear train shown in Fig. 7.41, calculate the maximum number of compound planets that can be used.

7.39. In the planetary gear train shown in Fig. 7.48, the carrier (link 4) is the driving member and the sun gear (link 3) is the driven member. The internal gear is held stationary. The sun gear is to rotate 2.5 times the speed of the carrier. The pitch diameter of the internal gear is to be approximately 280 mm. (*a*) Design the gear train by determining the numbers of teeth for the internal gear, the sun gear, and the planets using 2.5-module, 20° standard spur gear teeth. Hold the 280-mm pitch diameter as closely as possible. (*b*) Determine whether three equally spaced planets can be used.

7.40. In the planetary gear train shown in Fig. 7.48, the carrier (link 4) is the driving member and the sun gear (link 3) is the driven member. The internal gear is held stationary.

Question #9

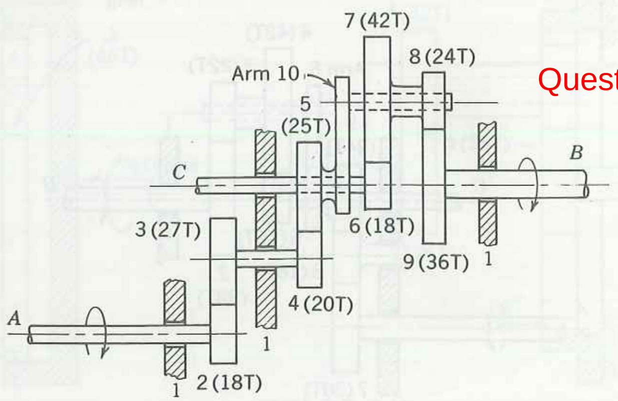


FIGURE 7.45

Question #10

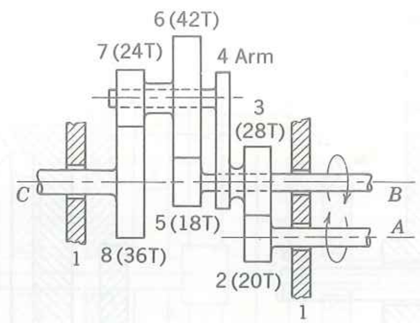


FIGURE 7.46

The sun gear is to rotate 2.5 times the speed of the carrier. The pitch diameter of the internal gear is to be approximately 11.0 in. (*a*) Design the gear train by determining the numbers of teeth for the internal gear, the sun gear, and the planets using 10 diametral-pitch 20° full-depth spur gear teeth. Hold the 11.0-in. pitch diameter as closely as possible. (*b*) Determine whether three equally spaced planets can be used in this drive.

7.41. In the planetary gear train shown in Fig. 7.48, the carrier (link 4) is the driving member and the sun gear (link 3) is the driven member. The internal gear is held stationary. The sun gear is to rotate 2.5 times the speed of the carrier. The pitch diameter of the internal gear is to be approximately 12.5 in. (*a*) Design the gear train by determining the numbers of teeth for the internal gear, the sun gear, and the planets using 8 diametral-pitch, 20° full-depth spur gear teeth. Hold the 12.5-in. pitch diameter as closely as possible. (*b*) Determine whether three equally spaced planets can be used in this drive.

7.42. Design a three-gear planetary train having an output to input speed ratio of 1:8, with the output shaft turning in the same direction as the input. Use the configuration of Fig. 7.49 and indicate which shaft is the input. Select the smallest gears possible from the following available stock sizes: even tooth numbers from 12 to 100 and every fourth number from 100 to 160. Also find the maximum number of planets (gear 2) that could be used.

7.43. Refer to the three-gear planetary train with bevel gears of Fig. 7.50 and find the most conservative design to reduce an input of 125 rpm to 75 rpm. Use the same range of tooth sizes available in Problem 7.42.

Question #11

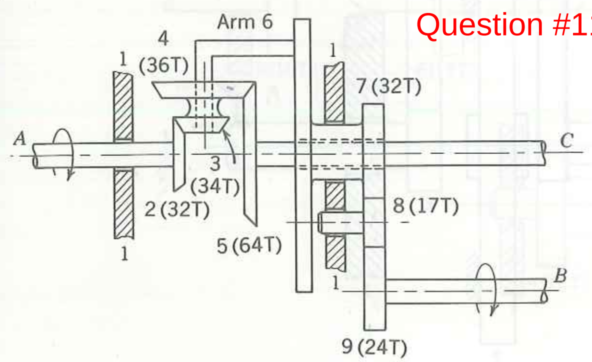


FIGURE 7.47

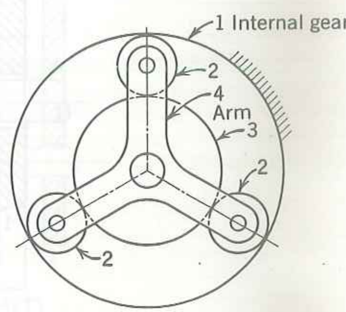


FIGURE 7.48

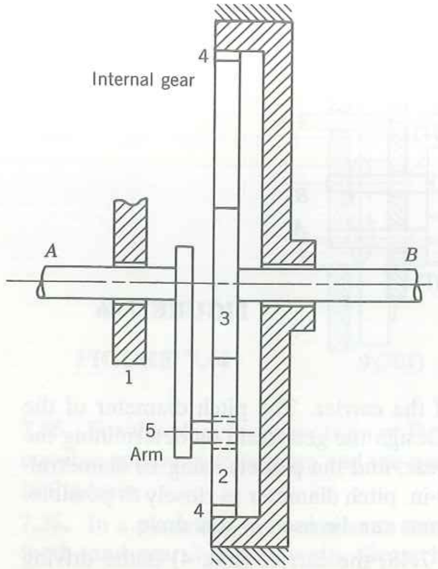


FIGURE 7.49

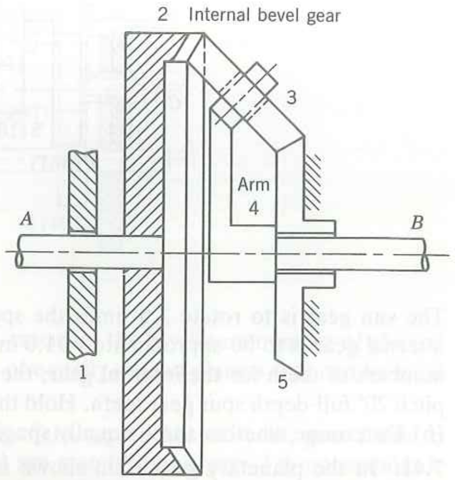


FIGURE 7.50

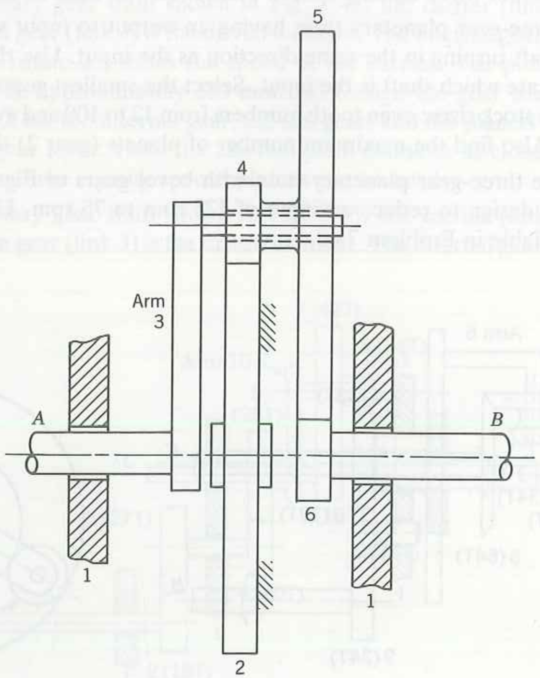


FIGURE 7.51

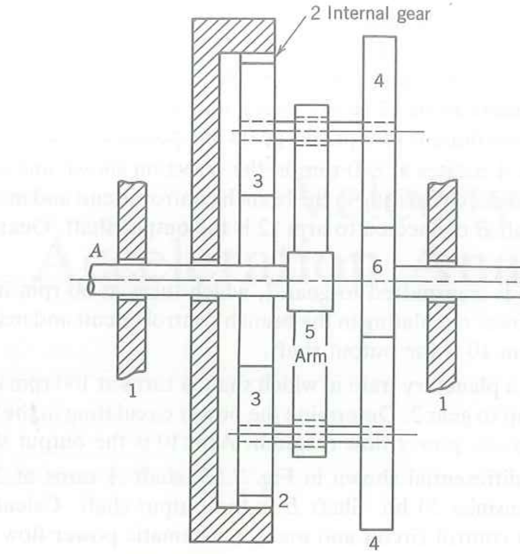


FIGURE 7.52

7.44. Design a planetary gear train with an output to input speed ratio of 1:142, with the output shaft turning opposite the input. Use the three-gear configurations of Fig. 7.49 and Fig. 7.50 or the basic four-gear planetary train shown in Fig. 7.51. Available stock sizes for bevel and spur gears are as follows: all tooth numbers from 12 to 40 and even tooth numbers from 40 to 180. Sketch the selected gear train and indicate the input shaft.

Question #12

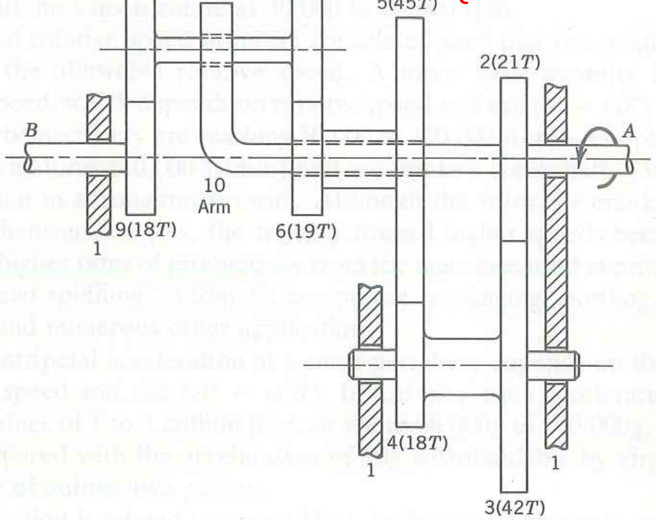


FIGURE 7.53

7.45. Design the smallest possible four-gear planetary train with a fixed annular gear as in Fig. 7.52 to reduce an input of 265 rpm to 15 rpm. Indicate which shaft is chosen as the input. Specifications required gear 2 to have 150 teeth. Available stock sizes are as follows: even tooth numbers from 12 to 40, every four from 40 to 100, and every five from 100 to 150. Also determine if two planet gears are possible as shown.

7.46. In Fig. 7.33, shaft *A* rotates at 640 rpm in the direction shown and transmits 10 hp to gear 2. Calculate the power circulating in the branch control circuit and make a schematic power flow diagram. Shaft *B* connected to arm 12 is the output shaft. Gear 2 has 20 teeth and gear 4 has 40 teeth.

7.47. In Fig. 7.34, 5 hp is transmitted to gear 2, which turns at 60 rpm in the direction shown. Determine the power circulating in the branch control circuit and make a schematic power flow diagram. Arm 10 is the output shaft.

7.48. Figure 7.44 shows a planetary train in which shaft *A* turns at 100 rpm in the direction shown and transmits 20 hp to gear 2. Determine the power circulating in the branch control circuit and make a schematic power flow diagram. Arm 10 is the output shaft.

7.49. In the spur gear differential shown in Fig. 7.53, shaft *A* turns at 250 rpm in the direction shown and transmits 30 hp. Shaft *B* is the output shaft. Calculate the power circulating in the branch control circuit and make a schematic power flow diagram.

In all questions estimate the number of teeth taking a scale of 1mm = 1 tooth.
w_1= 100 rpm
w_2= 200 rpm
Find the angular velocity of the last gear
Make any necessary assumption

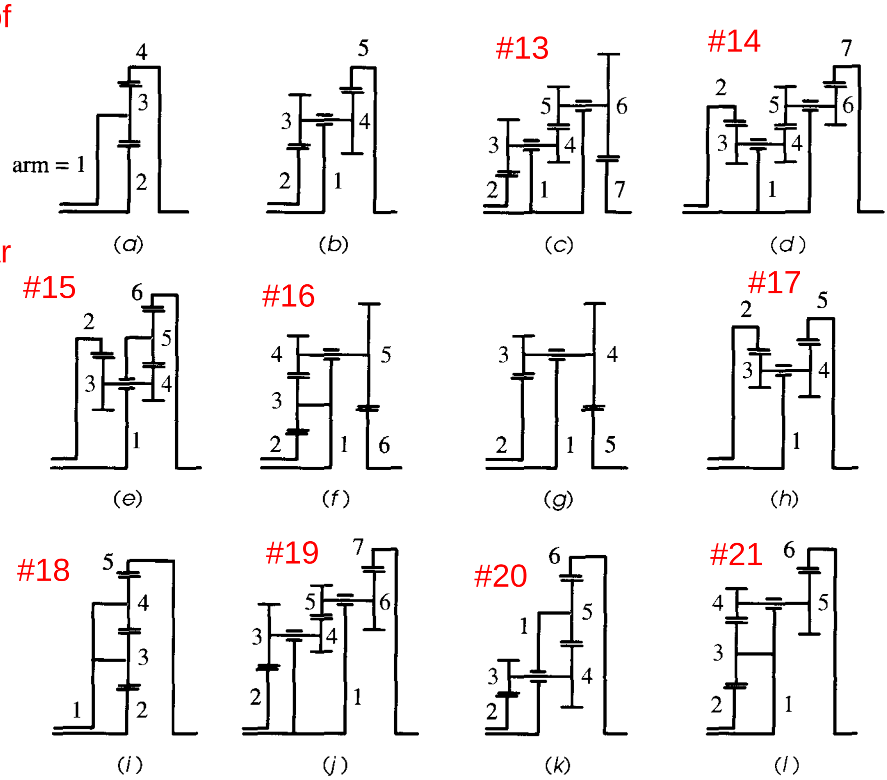


FIGURE 9-34
Levai's 12 possible epicyclic trains (3)

While it is relatively easy to visualize the power flow through a conventional gear train and observe the directions of motion for its member gears, it is very difficult to determine the behavior of a planetary train by observation. We must do the necessary calculations to determine its behavior and may be surprised at the often counterintuitive results. Since the gears are rotating with respect to the arm and the arm itself has motion, we have a velocity difference problem here which requires equation 6.5 (p. 243) be applied to this problem. Rewriting the velocity difference equation in terms of angular velocities specific to this system, we get:

$$\omega_{gear} = \omega_{arm} + \omega_{gear/arm} \tag{9.12}$$

Equations 9.12 and 9.5a (p. 442) are all that are needed to solve for the velocities in an epicyclic train, provided that the tooth numbers and two input conditions are known.

The Tabular Method

One approach to the analysis of velocities in an epicyclic train is to create a table which represents equation 9.12 for each gear in the train.

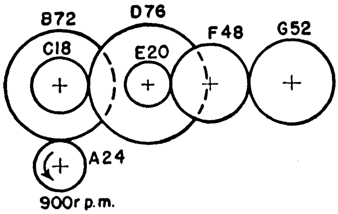


Fig. P 11.1

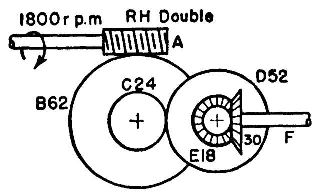


Fig. P 11.2

11.2. Determine the speed and direction of rotation of shaft F in the gear train shown in Fig. P 11.2.

11.3. Gear H in the train shown in Fig. P 11.3 is to rotate at approximately 14.3 rpm. Determine the number of teeth on gear H. Do H and A rotate in the same or opposite directions?

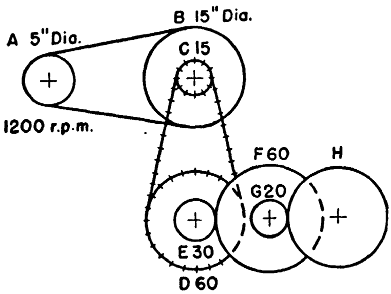


Fig. P 11.3

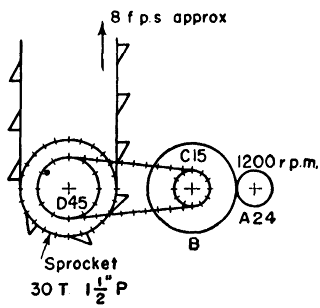


Fig. P 11.4

11.4. A conveyor belt, Fig. P 11.4, is to move with the velocity shown. Determine the number of teeth on gear B and the direction of rotation of gear A.

11.5. The train value of the reverted train shown in Fig. P 11.5 is to be 12. The diametral pitches of gears A and B is 8, and of gears C and D is 10. Determine suitable numbers of teeth for the gears. No gear is to have less than 24 teeth.

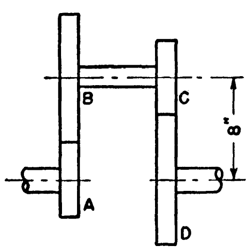


Fig. P 11.5

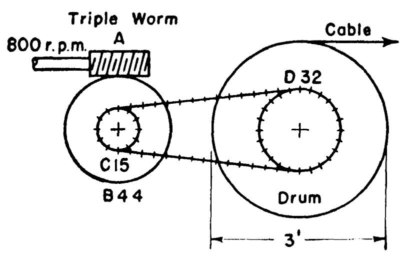


Fig. P 11.6

11.6. Determine the speed of the cable shown in Fig. P 11.6.

11.7. Determine the mechanical advantage of the cable-winding mechanism shown in Fig. P 11.7.

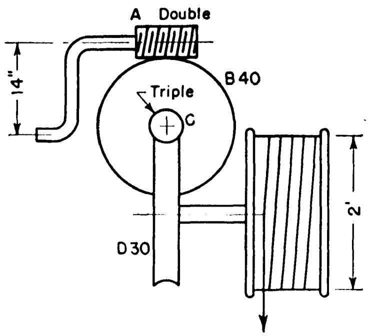


Fig. P 11.7

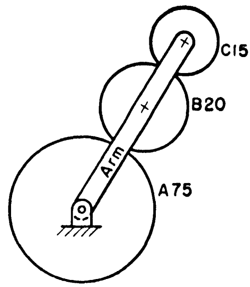


Fig. P 11.8

11.8. In Fig. P 11.8, gear *A* is fixed and the arm is turned 3 revolutions in a clockwise direction. Determine the number and direction of absolute turns of gear *C*.

11.9. In Fig. P 11.8, gear *A* turns 2 revolutions in a counterclockwise direction while the arm turns 4 revolutions in a clockwise direction. Determine the directions and absolute turns of gears *B* and *C*.

11.10. In Fig. P 11.10, gear *A* is fixed. The arm is turned once in a clockwise direction. Determine the number of absolute turns and directions of gears *B*, *C*, *D*, and *E*.

11.11. In Fig. P 11.10, gear *B* is fixed. The arm is turned once in a clockwise direction. Determine the number of absolute turns and directions of gears *A*, *C*, *D*, and *E*.

11.12. Determine the speed and direction of rotation of gear *F* in Fig. P 11.12.

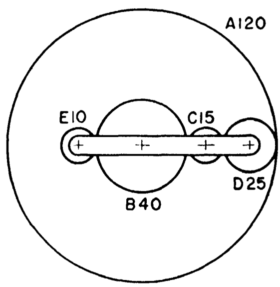


Fig. P 11.10

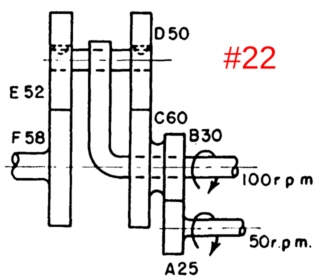


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Fig. P 11.12

11.13. A ball bearing is shown in Fig. P 11.13. The inner race rotates with the shaft at 1000 rpm. Assume pure rolling between the rollers and races. Determine the speed of the roller cage.

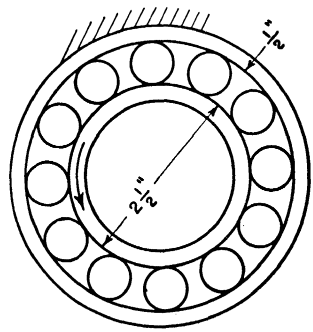

Fig. P 11.13

11.14. In Fig. P 11.14, the diameter of the hand-chain sprocket *A* is 14 in. and the diameter of the hoisting chain sprocket *E* is 5 in. Determine the mechanical advantage of the hoist.

11.15. Determine the speed and direction of rotation of gear *E* in Fig. P 11.15.

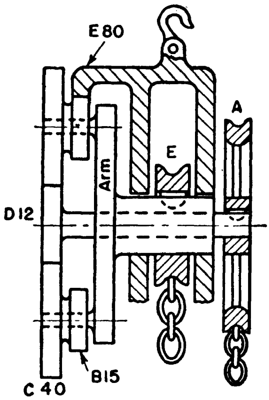

Fig. P 11.14

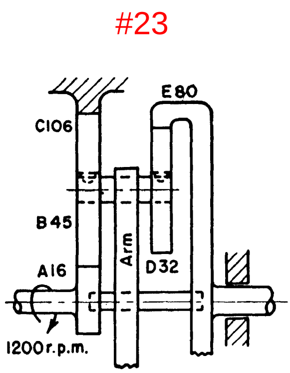

Fig. P 11.15

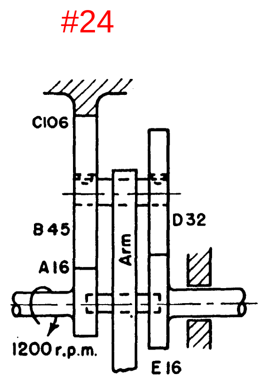

Fig. P 11.16

11.16. Determine the speed and direction of rotation of gear *E* in Fig. P 11.16.

11.17. Determine the speed and direction of rotation of gear *A* in Fig. P 11.17. Gears *B*, *C*, and *E* are one rigid unit.

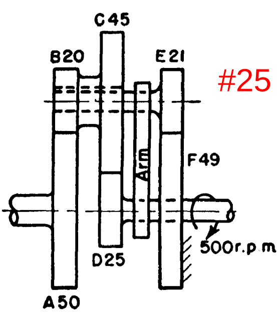

Fig. P 11.17

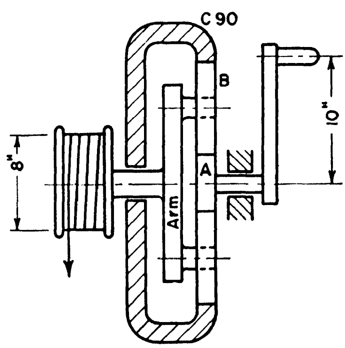

Fig. P 11.18

11.18. The mechanical advantage of the hoist shown in Fig. P 11.18 is to be approximately 25. Determine the numbers of teeth on gears *A* and *B*.

11.19. The mechanism shown in Fig. P 11.19 is similar to that of Fig. 8.9. Cone *B* turns 10 times and cone *D* turns 4 times. Determine the number and directions of the turns of *E*.

11.20. In Fig. P 11.20, gears *A* and *C* turn once. Determine the number and directions of the turns of gear *L*.

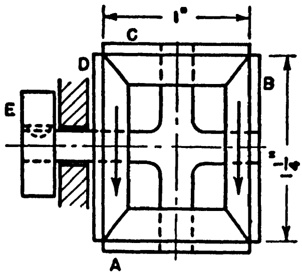

Fig. P 11.19

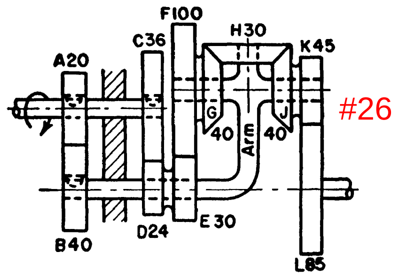

Fig. P 11.20

11.21. In Fig. P 11.21, gears *A* and *H* turn once. Determine the number and direction of the turns of the arm.

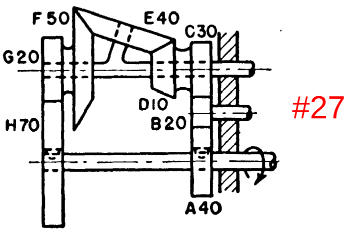

Fig. P 11.21

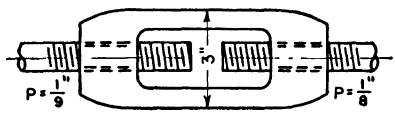

Fig. P 11.23

11.22. The pitch of the screwjack thread (Fig. 11.15) is $\frac{3}{8}$ in. and the radius of the handle is 12 in. Determine the mechanical advantage.

11.23. The turnbuckle (Fig. P 11.23) is to be turned without the use of a lever or wrench. Determine the mechanical advantage when: (a) the threads are the same hand, (b) the threads are of opposite hand.

11.24. A differential screw press is shown in Fig. P 11.24. How many times must the handwheel be turned to lower the plate $\frac{1}{16}$ in.

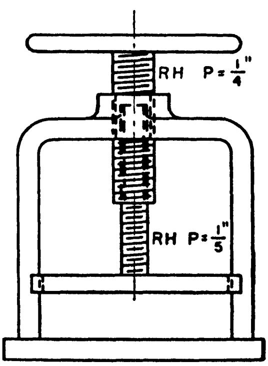

Fig. P 11.24

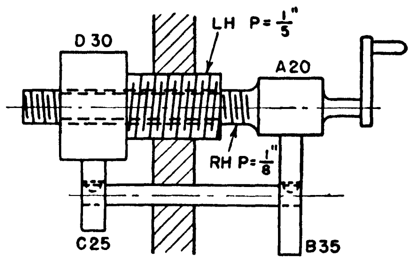

Fig. P 11.25

11.25. The crank in Fig. P 11.25 is turned once in a clockwise direction when viewed from the right. Determine the direction and distance that the small screw moves relative to the frame.

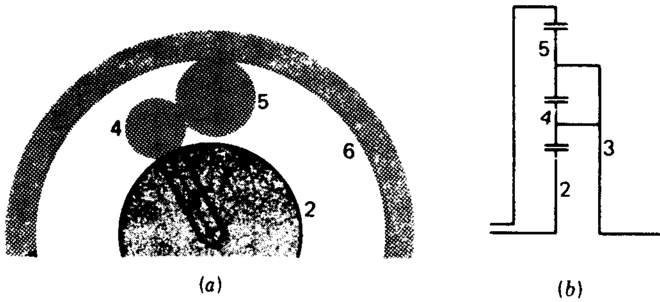

Figure 9-9 Epicyclic train with two planets.

In all questions estimate the number of teeth taking a scale of 1mm = 1 tooth.
w_2= 100 rpm
w_3= 200 rpm
Find the angular velocity of the last gear
Make any necessary assumption

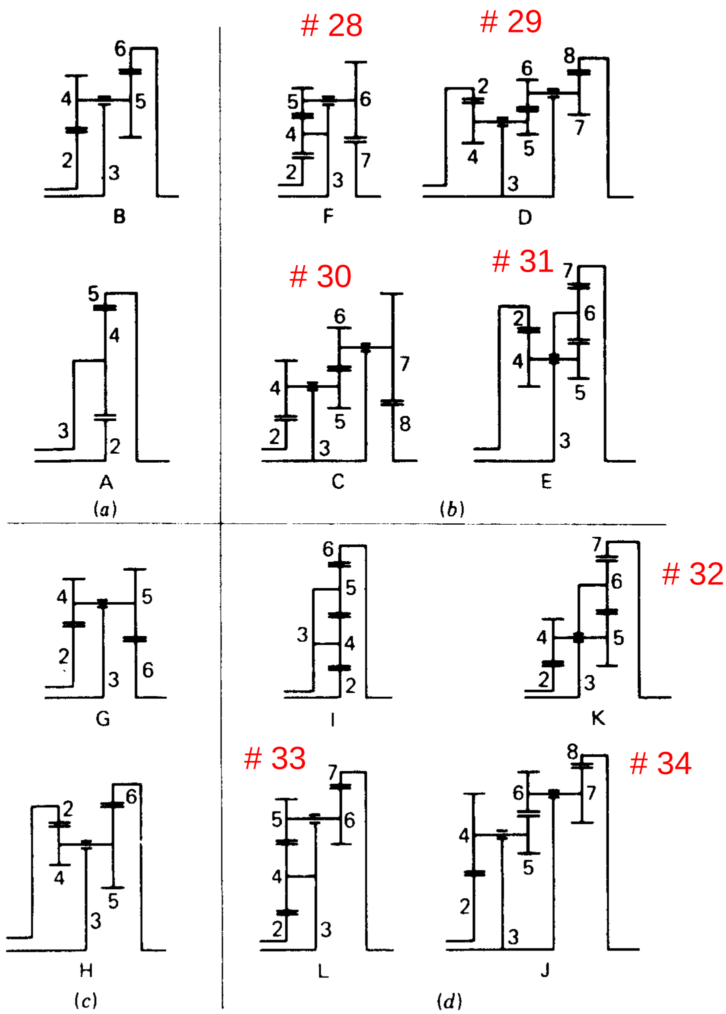

Figure 9-10 All 12 possible epicyclic gear types according to Lévai.