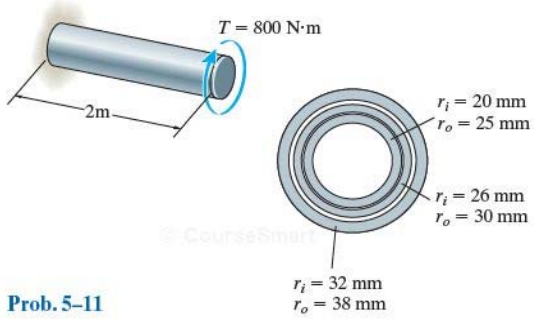
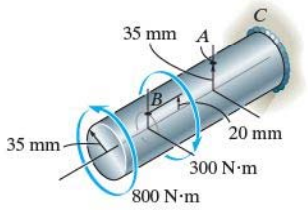
5–11. The shaft consists of three concentric tubes, each made from the same material and having the inner and outer radii shown. If a torque of $T = 800\ \text{N} \cdot \text{m}$ is applied to the rigid disk fixed to its end, determine the maximum shear stress in the shaft.



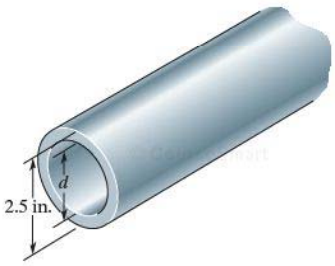
Prob. 5–11

***5–12.** The solid shaft is fixed to the support at C and subjected to the torsional loadings shown. Determine the shear stress at points A and B and sketch the shear stress on volume elements located at these points.



Prob. 5–12

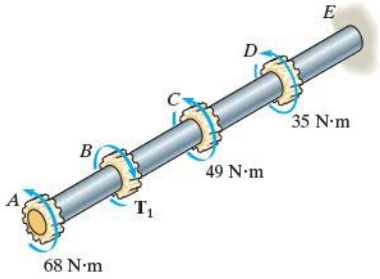
5–13. A steel tube having an outer diameter of 2.5 in. is used to transmit 3.50 hp when turning at 27 rev/min. Determine the inner diameter d of the tube to the nearest $\frac{1}{8}$ in. if the allowable shear stress is $\tau_{\text{allow}} = 10$ ksi.



Prob. 5–13

5–14. The solid aluminum shaft has a diameter of 50 mm and an allowable shear stress of $\tau_{\text{allow}} = 6$ MPa. Determine the largest torque T_1 that can be applied to the shaft if it is also subjected to the other torsional loadings. It is required that $\mathbf{T}_1$ act in the direction shown. Also, determine the maximum shear stress within regions CD and DE.

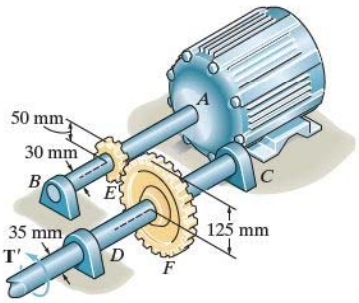
5–15. The solid aluminum shaft has a diameter of 50 mm. Determine the absolute maximum shear stress in the shaft and sketch the shear-stress distribution along a radial line of the shaft where the shear stress is maximum. Set $T_1 = 20\ \text{N} \cdot \text{m}$.



Probs. 5–14/15

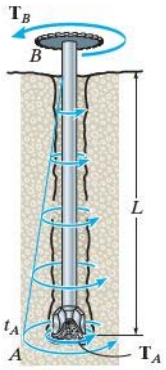
***5–16.** The motor delivers a torque of $50\ \text{N} \cdot \text{m}$ to the shaft AB. This torque is transmitted to shaft CD using the gears at E and F. Determine the equilibrium torque $\mathbf{T}'$ on shaft CD and the maximum shear stress in each shaft. The bearings B, C, and D allow free rotation of the shafts.

5–17. If the applied torque on shaft CD is $T' = 75\ \text{N} \cdot \text{m}$, determine the absolute maximum shear stress in each shaft. The bearings B, C, and D allow free rotation of the shafts, and the motor holds the shafts fixed from rotating.



Probs. 5–16/17

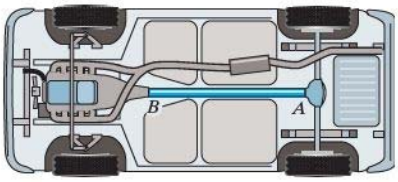
5–31. When drilling a well at constant angular velocity, the bottom end of the drill pipe encounters a torsional resistance T_A. Also, soil along the sides of the pipe creates a distributed frictional torque along its length, varying uniformly from zero at the surface B to t_A at A. Determine the minimum torque T_B that must be supplied by the drive unit to overcome the resisting torques, and compute the maximum shear stress in the pipe. The pipe has an outer radius r_o and an inner radius r_i.



Prob. 5–31

*5–32. The drive shaft AB of an automobile is made of a steel having an allowable shear stress of $\tau_{allow} = 8$ ksi. If the outer diameter of the shaft is 2.5 in. and the engine delivers 200 hp to the shaft when it is turning at 1140 rev/min, determine the minimum required thickness of the shaft's wall.

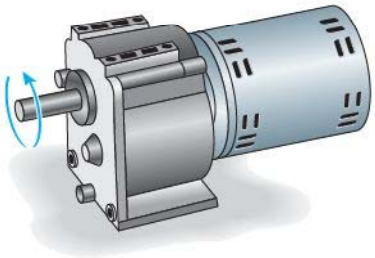
5–33. The drive shaft AB of an automobile is to be designed as a thin-walled tube. The engine delivers 150 hp when the shaft is turning at 1500 rev/min. Determine the minimum thickness of the shaft's wall if the shaft's outer diameter is 2.5 in. The material has an allowable shear stress of $\tau_{allow} = 7$ ksi.



Probs. 5–32/33

5–34. The gear motor can develop 1/10 hp when it turns at 300 rev/min. If the shaft has a diameter of $\frac{1}{2}$ in., determine the maximum shear stress that will be developed in the shaft.

5–35. The gear motor can develop 1/10 hp when it turns at 80 rev/min. If the allowable shear stress for the shaft is $\tau_{allow} = 4$ ksi, determine the smallest diameter of the shaft to the nearest $\frac{1}{8}$ in. that can be used.

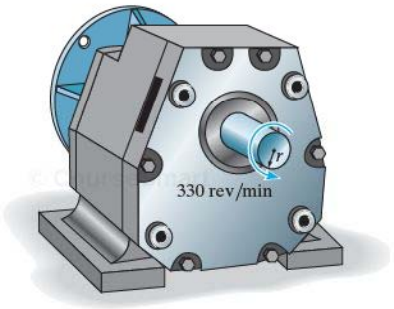


Probs. 5–34/35

*5–36. The drive shaft of a tractor is made of a steel tube having an allowable shear stress of $\tau_{allow} = 6$ ksi. If the outer diameter is 3 in. and the engine delivers 175 hp to the shaft when it is turning at 1250 rev/min, determine the minimum required thickness of the shaft's wall.

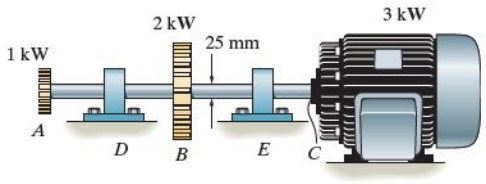
5–37. The 3-hp reducer motor can turn at 330 rev/min. If the shaft has a diameter of $\frac{3}{4}$ in., determine the maximum shear stress that will be developed in the shaft.

5–38. The 3-hp reducer motor can turn at 330 rev/min. If the allowable shear stress for the shaft is $\tau_{allow} = 8$ ksi, determine the smallest diameter of the shaft to the nearest $\frac{1}{8}$ in. that can be used.



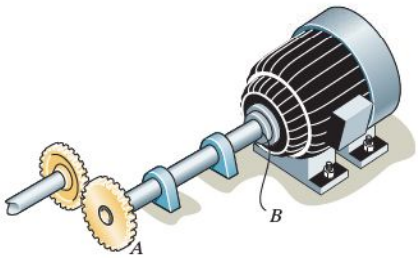
Probs. 5–37/38

5–39. The solid steel shaft AC has a diameter of 25 mm and is supported by smooth bearings at D and E. It is coupled to a motor at C, which delivers 3 kW of power to the shaft while it is turning at 50 rev/s. If gears A and B remove 1 kW and 2 kW, respectively, determine the maximum shear stress developed in the shaft within regions AB and BC. The shaft is free to turn in its support bearings D and E.



Prob. 5–39

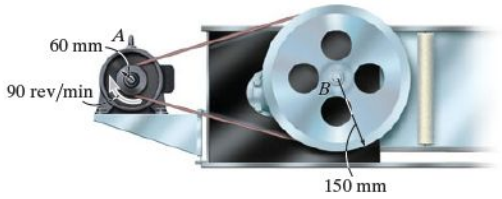
5–42. The motor delivers 500 hp to the steel shaft AB, which is tubular and has an outer diameter of 2 in. and an inner diameter of 1.84 in. Determine the *smallest* angular velocity at which it can rotate if the allowable shear stress for material is $\tau_{allow} = 25$ ksi.



Prob. 5–42

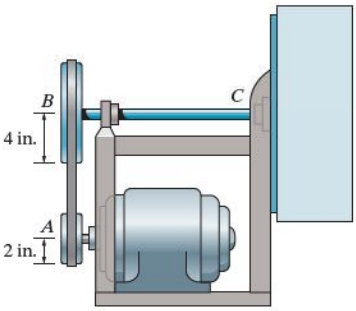
***5–40.** A ship has a propeller drive shaft that is turning at 1500 rev/min while developing 1800 hp. If it is 8 ft long and has a diameter of 4 in., determine the maximum shear stress in the shaft caused by torsion.

5–41. The motor A develops a power of 300 W and turns its connected pulley at 90 rev/min. Determine the required diameters of the steel shafts on the pulleys at A and B if the allowable shear stress is $\tau_{allow} = 85$ MPa.



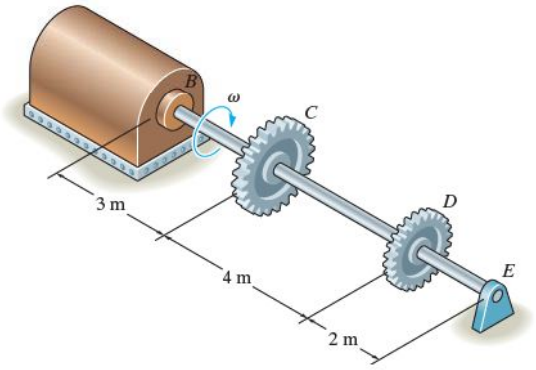
Prob. 5–41

5–43. The motor delivers 50 hp while turning at a constant rate of 1350 rpm at A. Using the belt and pulley system this loading is delivered to the steel blower shaft BC. Determine to the nearest $\frac{1}{8}$ in. the smallest diameter of this shaft if the allowable shear stress for steel if $\tau_{allow} = 12$ ksi.



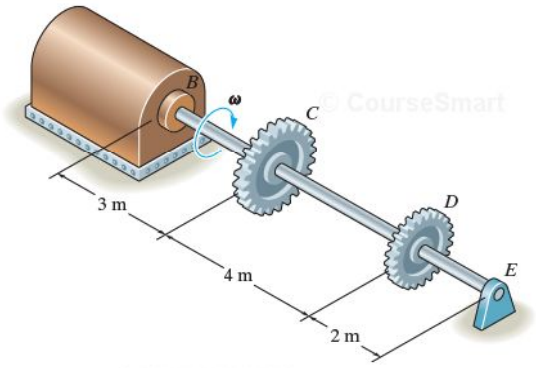
Prob. 5–43

5–53. The turbine develops 150 kW of power, which is transmitted to the gears such that C receives 70% and D receives 30%. If the rotation of the 100-mm-diameter A-36 steel shaft is $\omega = 800$ rev/min., determine the absolute maximum shear stress in the shaft and the angle of twist of end E of the shaft relative to B. The journal bearing at E allows the shaft to turn freely about its axis.



Prob. 5–53

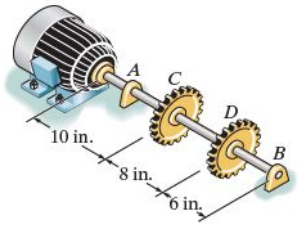
5–54. The turbine develops 150 kW of power, which is transmitted to the gears such that both C and D receive an equal amount. If the rotation of the 100-mm-diameter A-36 steel shaft is $\omega = 500$ rev/min., determine the absolute maximum shear stress in the shaft and the rotation of end B of the shaft relative to E. The journal bearing at C allows the shaft to turn freely about its axis.



Prob. 5–54

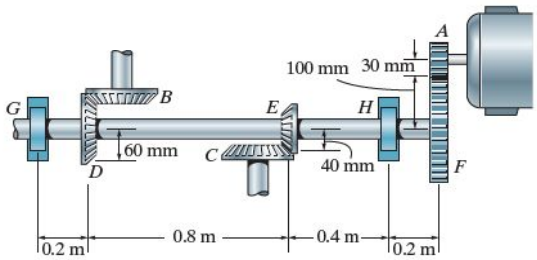
5–55. The motor delivers 40 hp to the 304 stainless steel shaft while it rotates at 20 Hz. The shaft is supported on smooth bearings at A and B, which allow free rotation of the shaft. The gears C and D fixed to the shaft remove 25 hp and 15 hp, respectively. Determine the diameter of the shaft to the nearest $\frac{1}{8}$ in. if the allowable shear stress is $\tau_{allow} = 8$ ksi and the allowable angle of twist of C with respect to D is 0.20°.

***5–56.** The motor delivers 40 hp to the 304 stainless steel solid shaft while it rotates at 20 Hz. The shaft has a diameter of 1.5 in. and is supported on smooth bearings at A and B, which allow free rotation of the shaft. The gears C and D fixed to the shaft remove 25 hp and 15 hp, respectively. Determine the absolute maximum stress in the shaft and the angle of twist of gear C with respect to gear D.



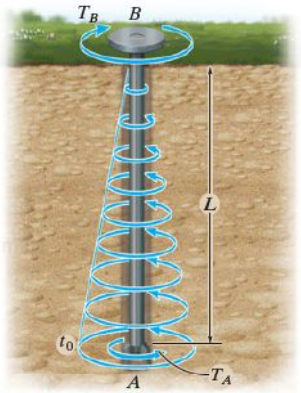
Probs. 5–55/56

5–57. The motor produces a torque of $T = 20\ \text{N}\cdot\text{m}$ on gear A. If gear C is suddenly locked so it does not turn, yet B can freely turn, determine the angle of twist of F with respect to E and F with respect to D of the L2-steel shaft, which has an inner diameter of 30 mm and an outer diameter of 50 mm. Also, calculate the absolute maximum shear stress in the shaft. The shaft is supported on journal bearings at G and H.



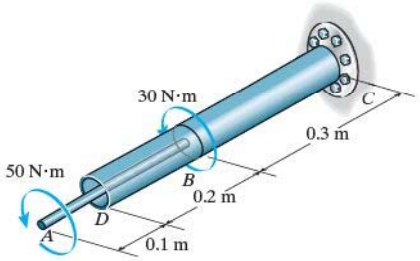
Prob. 5–57

5–63. When drilling a well, the deep end of the drill pipe is assumed to encounter a torsional resistance T_A. Furthermore, soil friction along the sides of the pipe creates a linear distribution of torque per unit length, varying from zero at the surface B to t_0 at A. Determine the necessary torque T_B that must be supplied by the drive unit to turn the pipe. Also, what is the relative angle of twist of one end of the pipe with respect to the other end at the instant the pipe is about to turn? The pipe has an outer radius r_o and an inner radius r_i. The shear modulus is G.



Prob. 5–63

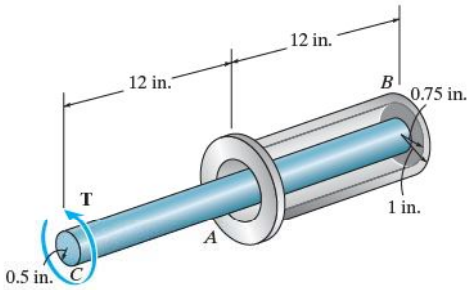
*5–64. The assembly is made of A-36 steel and consists of a solid rod 15 mm in diameter connected to the inside of a tube using a rigid disk at B. Determine the angle of twist at A. The tube has an outer diameter of 30 mm and wall thickness of 3 mm.



Prob. 5–64

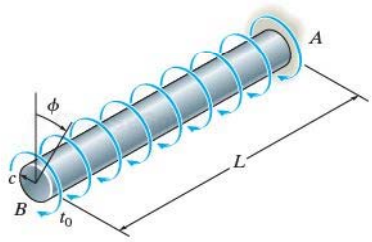
5–65. The device serves as a compact torsional spring. It is made of A-36 steel and consists of a solid inner shaft CB which is surrounded by and attached to a tube AB using a rigid ring at B. The ring at A can also be assumed rigid and is fixed from rotating. If a torque of $T = 2$ kip · in. is applied to the shaft, determine the angle of twist at the end C and the maximum shear stress in the tube and shaft.

5–66. The device serves as a compact torsion spring. It is made of A-36 steel and consists of a solid inner shaft CB which is surrounded by and attached to a tube AB using a rigid ring at B. The ring at A can also be assumed rigid and is fixed from rotating. If the allowable shear stress for the material is $\tau_{allow} = 12$ ksi and the angle of twist at C is limited to $\phi_{allow} = 3°$, determine the maximum torque T that can be applied at the end C.



Probs. 5–65/66

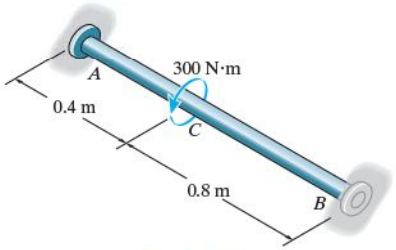
5–67. The shaft has a radius c and is subjected to a torque per unit length of t_0, which is distributed uniformly over the shaft's entire length L. If it is fixed at its far end A, determine the angle of twist ϕ of end B. The shear modulus is G.



Prob. 5–67

PROBLEMS

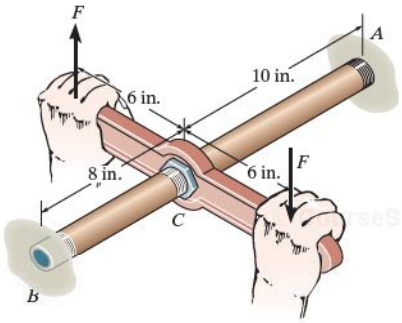
5–73. The A-36 steel shaft has a diameter of 50 mm and is fixed at its ends *A* and *B*. If it is subjected to the couple, determine the maximum shear stress in regions *AC* and *CB* of the shaft.



Prob. 5–73

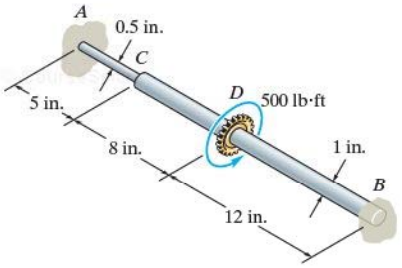
5–74. The bronze C86100 pipe has an outer diameter of 1.5 in. and a thickness of 0.125 in. The coupling on it at *C* is being tightened using a wrench. If the torque developed at *A* is 125 lb · in., determine the magnitude *F* of the couple forces. The pipe is fixed supported at end *B*.

5–75. The bronze C86100 pipe has an outer diameter of 1.5 in. and a thickness of 0.125 in. The coupling on it at *C* is being tightened using a wrench. If the applied force is $F = 20$ lb, determine the maximum shear stress in the pipe.



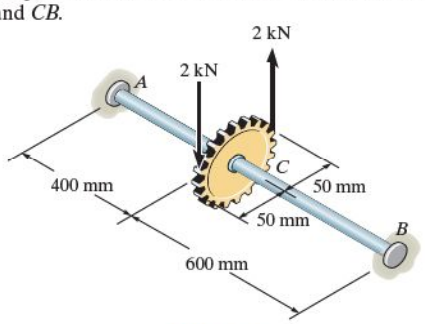
Probs. 5–74/75

*5–76. The steel shaft is made from two segments: *AC* has a diameter of 0.5 in, and *CB* has a diameter of 1 in. If it is fixed at its ends *A* and *B* and subjected to a torque of 500 lb · ft, determine the maximum shear stress in the shaft. $G_{st} = 10.8(10^3)$ ksi.



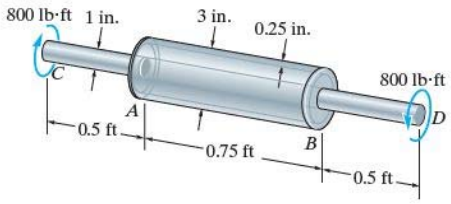
Prob. 5–76

5–77. The shaft is made of L2 tool steel, has a diameter of 40 mm, and is fixed at its ends *A* and *B*. If it is subjected to the couple, determine the maximum shear stress in regions *AC* and *CB*.



Prob. 5–77

5–78. The composite shaft consists of a mid-section that includes the 1-in.-diameter solid shaft and a tube that is welded to the rigid flanges at *A* and *B*. Neglect the thickness of the flanges and determine the angle of twist of end *C* of the shaft relative to end *D*. The shaft is subjected to a torque of 800 lb · ft. The material is A-36 steel.



Prob. 5–78