Problems

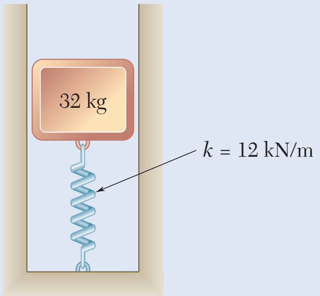

Fig. P19.4

19.1 A particle moves in simple harmonic motion. Knowing that the maximum velocity is 200 mm/s and the maximum acceleration is 4 m/s^2, determine the amplitude and frequency of the motion.

19.2 A particle moves in simple harmonic motion. Knowing that the amplitude is 15 in. and the maximum acceleration is 15 ft/s^2, determine the maximum velocity of the particle and the frequency of its motion.

19.3 Determine the amplitude and maximum acceleration of a particle that moves in simple harmonic motion with a maximum velocity of 4 ft/s and a frequency of 6 Hz.

19.4 A 32-kg block is attached to a spring and can move without friction in a slot as shown. The block is in its equilibrium position when it is struck by a hammer that imparts to the block an initial velocity of 250 mm/s. Determine (*a*) the period and frequency of the resulting motion, (*b*) the amplitude of the motion and the maximum acceleration of the block.

19.5 A 12-kg block is supported by the spring shown. If the block is moved vertically downward from its equilibrium position and released, determine (*a*) the period and frequency of the resulting motion, (*b*) the maximum velocity and acceleration of the block if the amplitude of its motion is 50 mm.

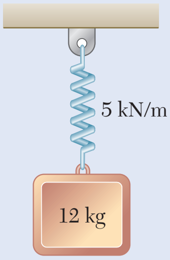

Fig. P19.5

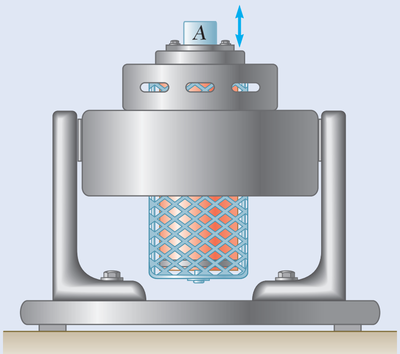

Fig. P19.6

19.6 An instrument package A is bolted to a shaker table as shown. The table moves vertically in simple harmonic motion at the same frequency as the variable-speed motor that drives it. The package is to be tested at a peak acceleration of 150 ft/s^2. Knowing that the amplitude of the shaker table is 2.3 in., determine (*a*) the required speed of the motor in rpm, (*b*) the maximum velocity of the table.

19.7 A simple pendulum consisting of a bob attached to a cord oscillates in a vertical plane with a period of 1.3 s. Assuming simple harmonic motion and knowing that the maximum velocity of the bob is 0.4 m/s, determine (*a*) the amplitude of the motion in degrees, (*b*) the maximum tangential acceleration of the bob.

19.8 A simple pendulum consisting of a bob attached to a cord of length l = 800 mm oscillates in a vertical plane. Assuming simple harmonic motion and knowing that the bob is released from rest when $\theta = 6°$, determine (*a*) the frequency of oscillation, (*b*) the maximum velocity of the bob.

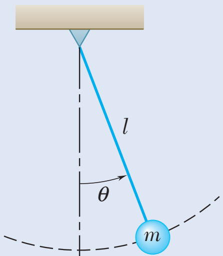

Fig. P19.7 and P19.8

19.9 A 10-lb block A rests on a 40-lb plate B that is attached to an unstretched spring with a constant of $k = 60$ lb/ft. Plate B is slowly moved 2.4 in. to the left and released from rest. Assuming that block A does not slip on the plate, determine (*a*) the amplitude and frequency of the resulting motion, (*b*) the corresponding smallest allowable value of the coefficient of static friction.

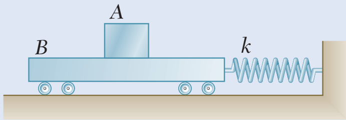

Fig. *P19.9*

19.10 A 5-kg fragile glass vase is surrounded by packing material in a cardboard box of negligible weight. The packing material has negligible damping and a force-deflection relationship as shown. Knowing that the box is dropped from a height of 1 m and the impact with the ground is perfectly plastic, determine (*a*) the amplitude of vibration for the vase, (*b*) the maximum acceleration the vase experiences in g's.

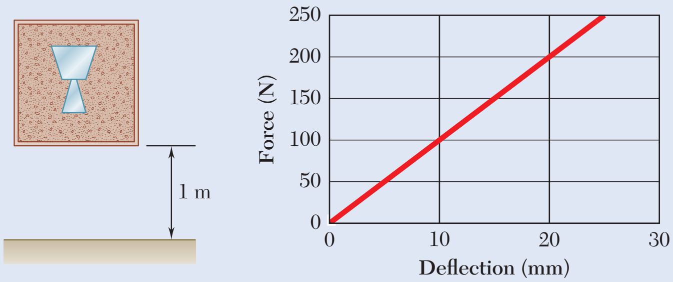

Fig. *P19.10*

19.11 A 3-lb block is supported as shown by a spring of constant $k = 2$ lb/in. that can act in tension or compression. The block is in its equilibrium position when it is struck from below by a hammer that imparts to the block an upward velocity of 90 in./s. Determine (*a*) the time required for the block to move 3 in. upward, (*b*) the corresponding velocity and acceleration of the block.

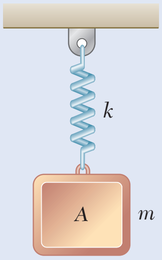

Fig. P19.11

19.12 In Prob. 19.11, determine the position, velocity, and acceleration of the block 0.90 s after it has been struck by the hammer.

19.13 The bob of a simple pendulum of length $l = 40$ in. is released from rest when $\theta = 5°$. Assuming simple harmonic motion, determine 1.6 s after release (*a*) the angle θ, (*b*) the magnitudes of the velocity and acceleration of the bob.

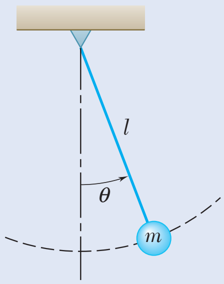

Fig. P19.13

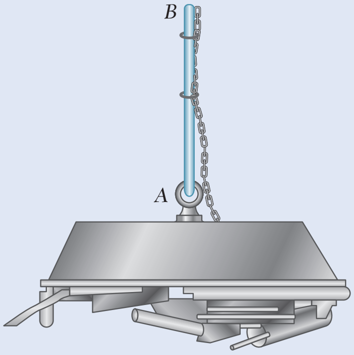

Fig. P19.14

19.14 A 150-kg electromagnet is at rest and is holding 100 kg of scrap steel when the current is turned off and the steel is dropped. Knowing that the cable and the supporting crane have a total stiffness equivalent to a spring of constant 200 kN/m, determine (*a*) the frequency, the amplitude, and the maximum velocity of the resulting motion, (*b*) the minimum tension that will occur in the cable during the motion, (*c*) the velocity of the magnet 0.03 s after the current is turned off.

19.15 A 5-kg collar C is released from rest in the position shown and slides without friction on a vertical rod until it hits a spring with a constant of $k = 720$ N/m that it compresses. The velocity of the collar is reduced to zero, and the collar reverses the direction of its motion and returns to its initial position. The cycle is then repeated. Determine (*a*) the period of the motion of the collar, (*b*) the velocity of the collar 0.4 s after it was released. (*Note:* This is a periodic motion, but it is not simple harmonic motion.)

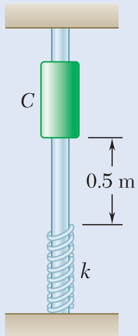

Fig. ***P19.15***

19.16 A small bob is attached to a cord of length 1.2 m and is released from rest when $\theta_A = 5°$. Knowing that $d = 0.6$ m, determine (*a*) the time required for the bob to return to point A, (*b*) the amplitude θ_C.

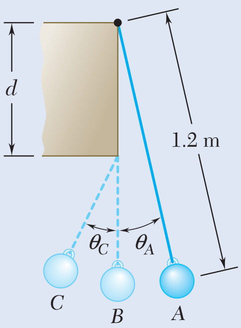

Fig. ***P19.16***

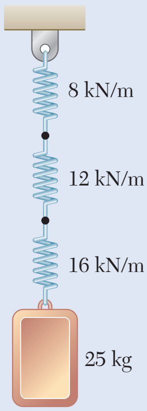

Fig. P19.17

19.17 A 25-kg block is supported by the spring arrangement shown. If the block is moved vertically downward from its equilibrium position and released, determine (*a*) the period and frequency of the resulting motion, (*b*) the maximum velocity and acceleration of the block if the amplitude of the motion is 30 mm.

19.18 A 11-lb block is attached to the lower end of a spring whose upper end is fixed and vibrates with a period of 7.2 s. Knowing that the constant k of a spring is inversely proportional to its length (e.g., if you cut a 10 lb/in. spring in half, the remaining two springs each have a spring constant of 20 lb/in.), determine the period of a 7-lb block that is attached to the center of the same spring if the upper and lower ends of the spring are fixed.

19.19 Block A has a mass m and is supported by the spring arrangement as shown. Knowing that the mass of the pulley is negligible and that the block is moved vertically downward from its equilibrium position and released, determine the frequency of the motion.

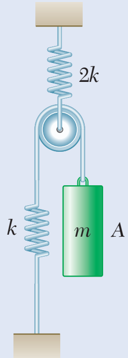

Fig. P19.19

19.20 A 13.6-kg block is supported by the spring arrangement shown. If the block is moved from its equilibrium position 44 mm vertically downward and released, determine (*a*) the period and frequency of the resulting motion, (*b*) the maximum velocity and acceleration of the block.

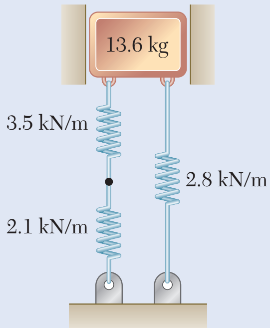

Fig. P19.20

19.21* and *19.22 A 50-kg block is supported by the spring arrangement shown. The block is moved vertically downward from its equilibrium position and released. Knowing that the amplitude of the resulting motion is 60 mm, determine (*a*) the period and frequency of the motion, (*b*) the maximum velocity and maximum acceleration of the block.

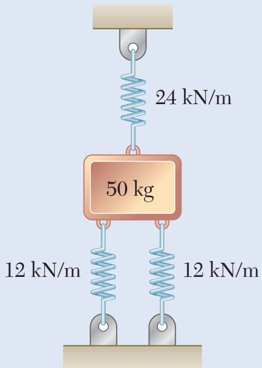

Fig. *P19.21*

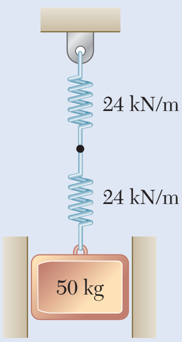

Fig. *P19.22*

19.23 Two springs with constants k_1 and k_2 are connected in series to a block A that vibrates in simple harmonic motion with a period of 5 s. When the same two springs are connected in parallel to the same block, the block vibrates with a period of 2 s. Determine the ratio k_1/k_2 of the two spring constants.

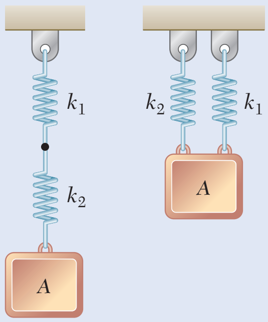

Fig. P19.23

19.24 The period of vibration of the system shown is observed to be 0.8 s. If block A is removed, the period is observed to be 0.7 s. Determine (a) the mass of block C, (b) the period of vibration when both blocks A and B have been removed.

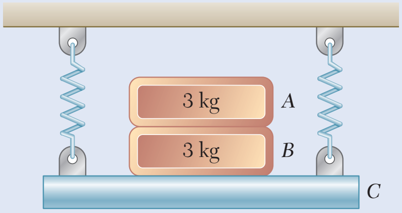

Fig. P19.24

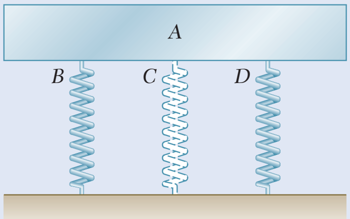

Fig. P19.25

19.25 The 100-lb platform A is attached to springs B and D, each of which has a constant $k = 120$ lb/ft. Knowing that the frequency of vibration of the platform is to remain unchanged when an 80-lb block is placed on it and a third spring C is added between springs B and D, determine the required constant of spring C.

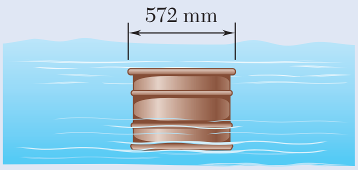

Fig. P19.26

19.26 The period of vibration for a barrel floating in salt water is found to be 0.58 s when the barrel is empty and 1.8 s when it is filled with 55 gallons of crude oil. Knowing that the density of the oil is 900 kg/m^3, determine (a) the mass of the empty barrel, (b) the density of the salt water, ρ_{sw}. [*Hint*: The force of the water on the bottom of the barrel can be modeled as a spring with constant $k = \rho_{sw}gA$.]

19.27 From mechanics of materials, it is known that for a simply supported beam of uniform cross section, a static load **P** applied at the center will cause a deflection of $\delta_A = PL^3/48EI$, where L is the length of the beam, E is the modulus of elasticity, and I is the moment of inertia of the cross-sectional area of the beam. Knowing that $L = 15$ ft, $E = 30 \times 10^6$ psi, and $I = 2 \times 10^{-3}$ ft^4, determine (a) the equivalent spring constant of the beam, (b) the frequency of vibration of a 1500-lb block attached to the center of the beam. Neglect the mass of the beam and assume that the load remains in contact with the beam.

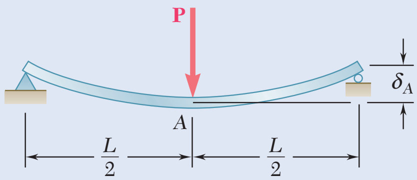

Fig. *P19.27*

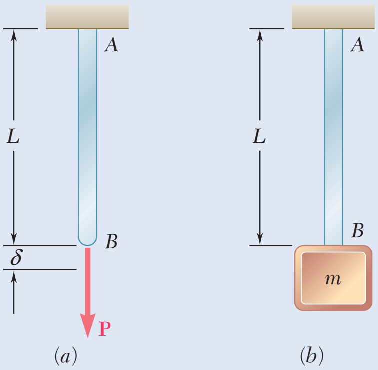

Fig. P19.28

19.28 From mechanics of materials it is known that when a static load **P** is applied at the end B of a uniform metal rod fixed at end A, the length of the rod will increase by an amount $\delta = PL/AE$, where L is the length of the undeformed rod, A is its cross-sectional area, and E is the modulus of elasticity of the metal. Knowing that $L = 450$ mm and $E = 200$ GPa and that the diameter of the rod is 8 mm, and neglecting the mass of the rod, determine (a) the equivalent spring constant of the rod, (b) the frequency of the vertical vibrations of a block of mass $m = 8$ kg attached to end B of the same rod.

19.29 Denoting by δ_{st} the static deflection of a beam under a given load, show that the frequency of vibration of the load is

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\delta_{st}}}$$

Neglect the mass of the beam, and assume that the load remains in contact with the beam.

19.30 A 40-mm deflection of the second floor of a building is measured directly under a newly installed 3500-kg piece of rotating machinery that has a slightly unbalanced rotor. Assuming that the deflection of the floor is proportional to the load it supports, determine (*a*) the equivalent spring constant of the floor system, (*b*) the speed in rpm of the rotating machinery that should be avoided if it is not to coincide with the natural frequency of the floor-machinery system.

19.31 If $h = 700$ mm and $d = 500$ mm and each spring has a constant $k = 600$ N/m, determine the mass m for which the period of small oscillations is (*a*) 0.50 s, (*b*) infinite. Neglect the mass of the rod and assume that each spring can act in either tension or compression.

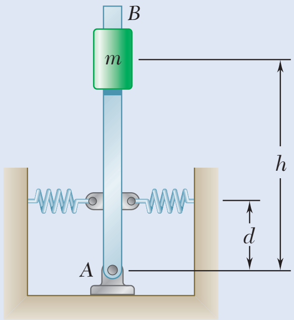

Fig. P19.31

19.32 The force–deflection equation for a nonlinear spring fixed at one end is $F = 1.5x^{1/2}$ where F is the force, expressed in newtons, applied at the other end and x is the deflection expressed in meters. (*a*) Determine the deflection x_0 if a 4-oz block is suspended from the spring and is at rest. (*b*) Assuming that the slope of the force–deflection curve at the point corresponding to this loading can be used as an equivalent spring constant, determine the frequency of vibration of the block if it is given a very small downward displacement from its equilibrium position and released.

***19.33** Expanding the integrand in Eq. (19.19) of Sec. 19.1C into a series of even powers of sin ϕ and integrating, show that the period of a simple pendulum of length l may be approximated by the formula

$$\tau = 2\pi\sqrt{\frac{l}{g}}\left(1 + \tfrac{1}{4}\sin^2\frac{\theta_m}{2}\right)$$

where θ_m is the amplitude of the oscillations.

***19.34** Using the formula given in Prob. 19.33, determine the amplitude θ_m for which the period of a simple pendulum is $\frac{1}{2}$ percent longer than the period of the same pendulum for small oscillations.

***19.35** Using the data of Table 19.1, determine the period of a simple pendulum of length $l = 750$ mm (*a*) for small oscillations, (*b*) for oscillations of amplitude $\theta_m = 60°$, (*c*) for oscillations of amplitude $\theta_m = 90°$.

***19.36** Using the data of Table 19.1, determine the length in inches of a simple pendulum that oscillates with a period of 2 s and an amplitude of 90°.

Problems

19.37 The uniform rod shown has mass 6 kg and is attached to a spring of constant $k = 700$ N/m. If end B of the rod is depressed 10 mm and released, determine (a) the period of vibration, (b) the maximum velocity of end B.

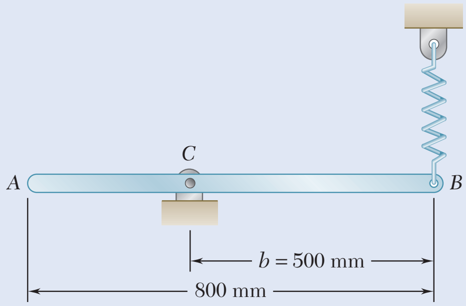

Fig. P19.37

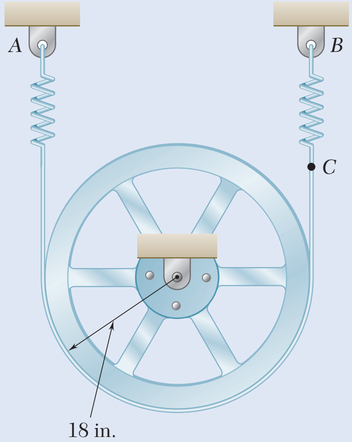

Fig. P19.38

19.38 A belt is placed around the rim of a 500-lb flywheel and attached as shown to two springs, each of constant $k = 85$ lb/in. If end C of the belt is pulled 1.5 in. down and released, the period of vibration of the flywheel is observed to be 0.5 s. Knowing that the initial tension in the belt is sufficient to prevent slipping, determine (a) the maximum angular velocity of the flywheel, (b) the centroidal radius of gyration of the flywheel.

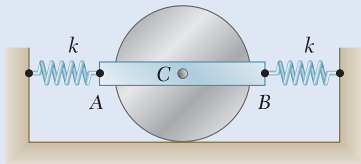

Fig. P19.39 and *P19.40*

19.39 A 6-kg uniform cylinder can roll without sliding on a horizontal surface and is attached by a pin at point C to the 4-kg horizontal bar AB. The bar is attached to two springs, each having a constant of $k = 5$ kN/m, as shown. Knowing that the bar is moved 12 mm to the right of the equilibrium position and released, determine (a) the period of vibration of the system, (b) the magnitude of the maximum velocity of bar AB.

19.40 A 6-kg uniform cylinder is assumed to roll without sliding on a horizontal surface and is attached by a pin at point C to the 4-kg horizontal bar AB. The bar is attached to two springs, each having a constant of $k = 3.5$ kN/m, as shown. Knowing that the coefficient of static friction between the cylinder and the surface is 0.5, determine the maximum amplitude of the motion of point C that is compatible with the assumption of rolling.

19.41 A 15-lb slender rod AB is riveted to a 12-lb uniform disk as shown. A belt is attached to the rim of the disk and to a spring that holds the rod at rest in the position shown. If end A of the rod is moved 0.75 in. down and released, determine (a) the period of vibration, (b) the maximum velocity of end A.

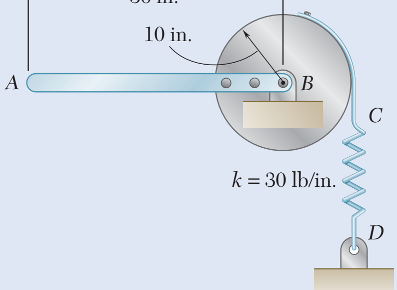

Fig. P19.41

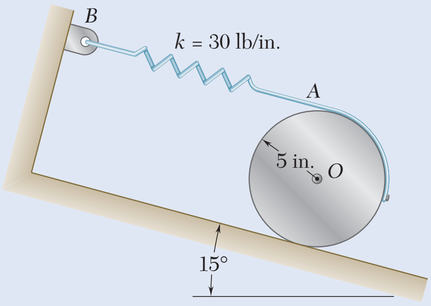

Fig. P19.42

19.42 A 30-lb uniform cylinder can roll without sliding on a 15° incline. A belt is attached to the rim of the cylinder, and a spring holds the cylinder at rest in the position shown. If the center of the cylinder is moved 2 in. down the incline and released, determine (*a*) the period of vibration, (*b*) the maximum acceleration of the center of the cylinder.

19.43 A square plate of mass m is held by eight springs, each of constant k. Knowing that each spring can act in either tension or compression, determine the frequency of the resulting vibration if (*a*) the plate is given a small vertical displacement and released, (*b*) the plate is rotated through a small angle about G and released.

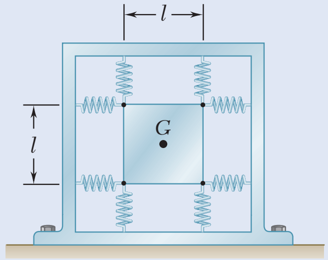

Fig. *P19.43*

19.44 Two small weights w are attached at A and B to the rim of a uniform disk of radius r and weight W. Denoting by τ_0 the period of small oscillations when $\beta = 0$, determine the angle β for which the period of small oscillations is $2\tau_0$.

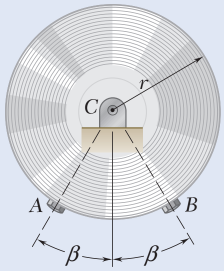

Fig. P19.44 and P19.45

19.45 Two 40-g weights are attached at A and B to the rim of a 1.5-kg uniform disk of radius $r = 100$ mm. Determine the frequency of small oscillations when $\beta = 60°$.

19.46 A three-blade wind turbine used for research is supported on a shaft so that it is free to rotate about O. One technique to determine the centroidal mass moment of inertia of an object is to place a known weight at a known distance from the axis of rotation and to measure the frequency of oscillations after releasing it from rest with a small initial angle. In this case, a weight of $W_{add} = 50$ lb is attached to one of the blades at a distance $R = 20$ ft from the axis of rotation. Knowing that when the blade with the added weight is displaced slightly from the vertical axis, and the system is found to have a period of 7.6 s, determine the centroidal mass moment of inertia of the three-blade rotor.

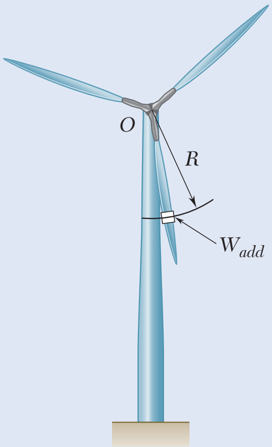

Fig. *P19.46*

19.47 A connecting rod is supported by a knife-edge at point A; the period of its small oscillations is observed to be 0.87 s. The rod is then inverted and supported by a knife edge at point B and the period of its small oscillations is observed to be 0.78 s. Knowing that $r_a + r_b = 10$ in., determine (*a*) the location of the mass center G, (*b*) the centroidal radius of gyration $\bar{k}$.

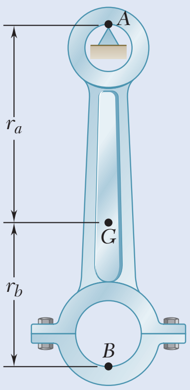

Fig. *P19.47*

19.48 A semicircular hole is cut in a uniform square plate that is attached to a frictionless pin at its geometric center O. Determine (*a*) the period of small oscillations of the plate, (*b*) the length of a simple pendulum that has the same period.

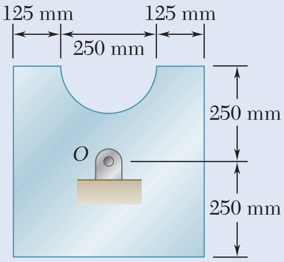

Fig. P19.48

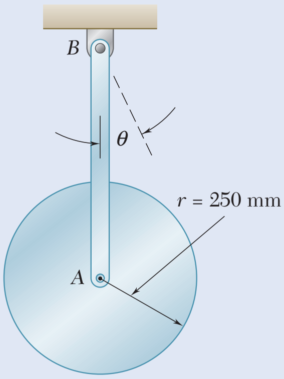

Fig. P19.49

19.49 A uniform disk of radius $r = 250$ mm is attached at A to a 650-mm rod AB of negligible mass that can rotate freely in a vertical plane about B. Determine the period of small oscillations (*a*) if the disk is free to rotate in a bearing at A, (*b*) if the rod is riveted to the disk at A.

19.50 A small collar of mass 1 kg is rigidly attached to a 3-kg uniform rod of length $L = 750$ mm. Determine (*a*) the distance d to maximize the frequency of oscillation when the rod is given a small initial displacement, (*b*) the corresponding period of oscillation.

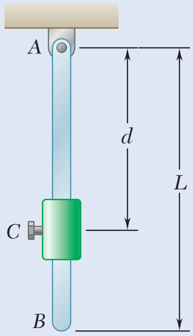

Fig. P19.50

19.51 A thin homogeneous wire is bent into the shape of an isosceles triangle of sides b, b, and $1.6b$. Determine the period of small oscillations if the wire (*a*) is suspended from point A as shown, (*b*) is suspended from point B.

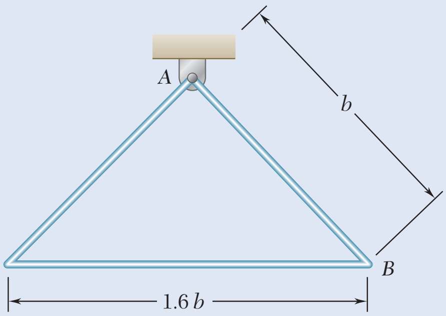

Fig. P19.51

19.52 A *compound pendulum* is defined as a rigid body that oscillates about a fixed point O, called the center of suspension. Show that the period of oscillation of a compound pendulum is equal to the period of a simple pendulum of length OA, where the distance from A to the mass center G is $GA = \bar{k}^2/\bar{r}$. Point A is defined as the center of oscillation and coincides with the center of percussion defined in Prob. 17.66.

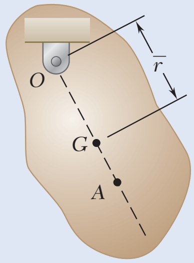

Fig. P19.52 and P19.53

19.53 A rigid slab oscillates about a fixed point O. Show that the smallest period of oscillation occurs when the distance $\bar{r}$ from point O to the mass center G is equal to $\bar{k}$.

19.54 Show that if the compound pendulum of Prob. 19.52 is suspended from A instead of O, the period of oscillation is the same as before and the new center of oscillation is located at O.

19.55 The 8-kg uniform bar AB is hinged at C and is attached at A to a spring of constant $k = 500$ N/m. If end A is given a small displacement and released, determine (*a*) the frequency of small oscillations, (*b*) the smallest value of the spring constant k for which oscillations will occur.

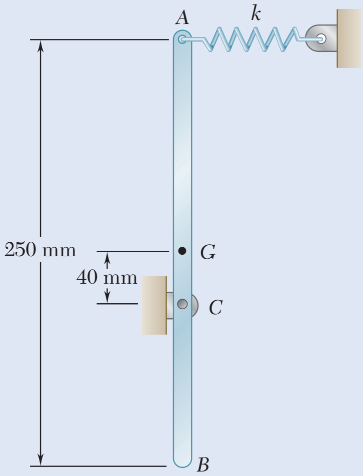

Fig. P19.55

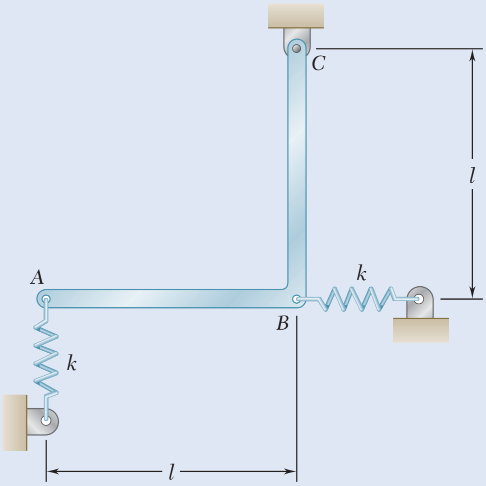

Fig. P19.56

19.56 Two uniform rods each have a mass m and length l and are welded together to form an L-shaped assembly. The assembly is constrained by two springs, each with a constant k, and is in equilibrium in a vertical plane in the position shown. Determine the frequency of small oscillations of the system.

19.57 A uniform disk with radius r and mass m can roll without slipping on a cylindrical surface and is attached to bar ABC with a length L and negligible mass. The bar is attached at point A to a spring with a constant k and can rotate freely about point B in the vertical plane. Knowing that end A is given a small displacement and released, determine the frequency of the resulting vibration in terms of m, L, k, and g.

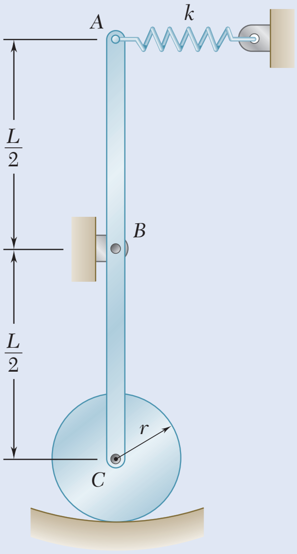

Fig. P19.57

19.58 A 1300-kg sports car has a center of gravity G located a distance h above a line connecting the front and rear axles. The car is suspended from cables that are attached to the front and rear axles as shown. Knowing that the periods of oscillation are 4.04 s when $L = 4$ m and 3.54 s when $L = 3$ m, determine h and the centroidal radius of gyration.

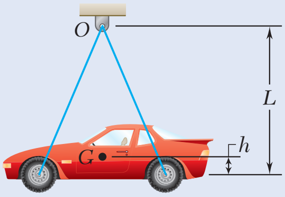

Fig. *P19.58*

19.59 A 6-lb slender rod is suspended from a steel wire that is known to have a torsional spring constant $K = 1.5$ ft·lb/rad. If the rod is rotated through 180° about the vertical and released, determine (*a*) the period of oscillation, (*b*) the maximum velocity of end A of the rod.

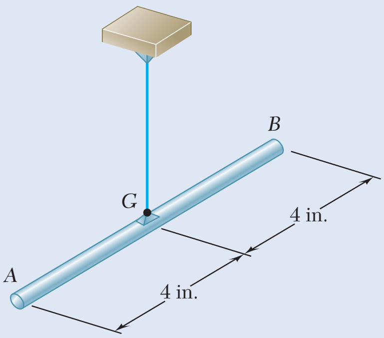

Fig. P19.59

19.60 A uniform disk of radius $r = 250$ mm is attached at A to a 650-mm rod AB of negligible mass that can rotate freely in a vertical plane about B. If the rod is displaced 2° from the position shown and released, determine the magnitude of the maximum velocity of point A, assuming that the disk is (*a*) free to rotate in a bearing at A, (*b*) riveted to the rod at A.

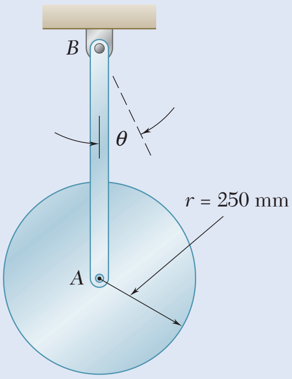

Fig. P19.60

19.61 Two uniform rods, each of mass m and length l, are welded together to form the T-shaped assembly shown. Determine the frequency of small oscillations of the assembly.

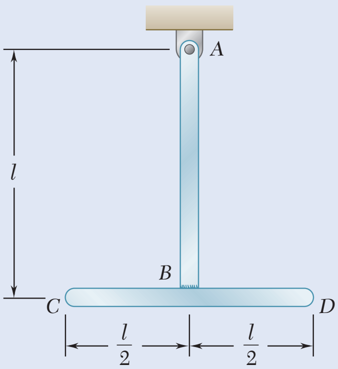

Fig. *P19.61*

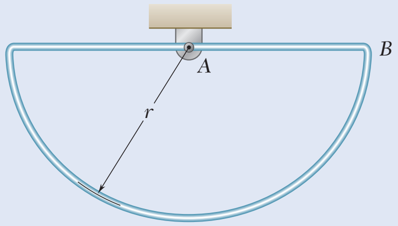

Fig. P19.62

19.62 A homogeneous wire bent to form the figure shown is attached to a pin support at A. Knowing that $r = 220$ mm and that point B is pushed down 20 mm and released, determine the magnitude of the velocity of B, 8 s later.

19.63 A horizontal platform P is held by several rigid bars that are connected to a vertical wire. The period of oscillation of the platform is found to be 2.2 s when the platform is empty and 3.8 s when an object A of unknown moment of inertia is placed on the platform with its mass center directly above the center of the plate. Knowing that the wire has a torsional constant $K = 27$ N·m/rad, determine the centroidal moment of inertia of object A.

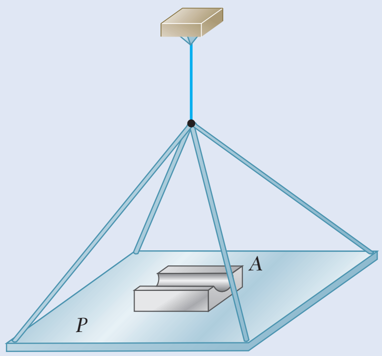

Fig. P19.63

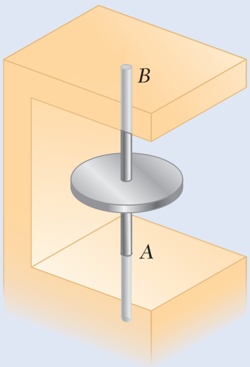

Fig. P19.64

19.64 A uniform disk of radius $r = 120$ mm is welded at its center to two elastic rods of equal length with fixed ends at A and B. Knowing that the disk rotates through an 8° angle when a 500-mN·m couple is applied to the disk and that it oscillates with a period of 1.3 s when the couple is removed, determine (*a*) the mass of the disk, (*b*) the period of vibration if one of the rods is removed.

19.65 A 5-kg uniform rod CD of length $l = 0.7$ m is welded at C to two elastic rods, which have fixed ends at A and B and are known to have a combined torsional spring constant $K = 24$ N·m/rad. Determine the period of small oscillations, if the equilibrium position of CD is (*a*) vertical as shown, (*b*) horizontal.

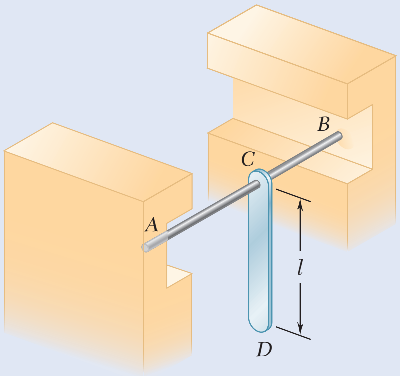

Fig. ***P19.65***

19.66 A uniform equilateral triangular plate with a side b is suspended from three vertical wires of the same length l. Determine the period of small oscillations of the plate when (*a*) it is rotated through a small angle about a vertical axis through its mass center G, (*b*) it is given a small horizontal displacement in a direction perpendicular to AB.

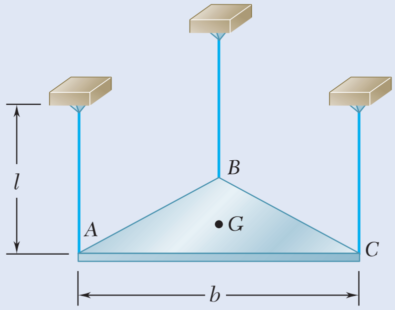

Fig. P19.66

19.67 A period of 6.00 s is observed for the angular oscillations of a 4-oz gyroscope rotor suspended from a wire as shown. Knowing that a period of 3.80 s is obtained when a 1.25-in.-diameter steel sphere is suspended in the same fashion, determine the centroidal radius of gyration of the rotor. (Specific weight of steel = 490 lb/ft^3.)

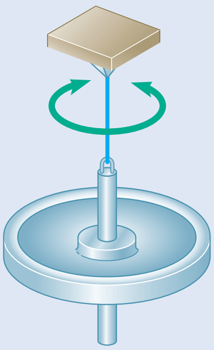

Fig. P19.67

19.68 The centroidal radius of gyration $\bar{k}_y$ of an airplane is determined by suspending the airplane by two 12-ft-long cables as shown. The airplane is rotated through a small angle about the vertical through G and then released. Knowing that the observed period of oscillation is 3.3 s, determine the centroidal radius of gyration $\bar{k}_y$.

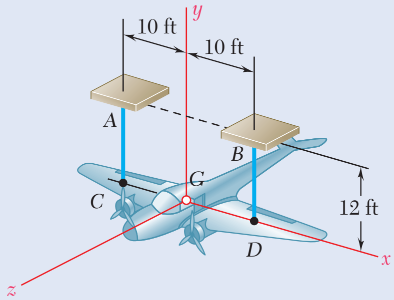

Fig. P19.68

Problems

19.69 Two blocks each have a mass 1.5 kg and are attached to links that are pin-connected to bar *BC* as shown. The masses of the links and bar are negligible, and the blocks can slide without friction. Block *D* is attached to a spring of constant $k = 720$ N/m. Knowing that block *A* is at rest when it is struck horizontally with a mallet and given an initial velocity of 250 mm/s, determine the magnitude of the maximum displacement of block *D* during the resulting motion.

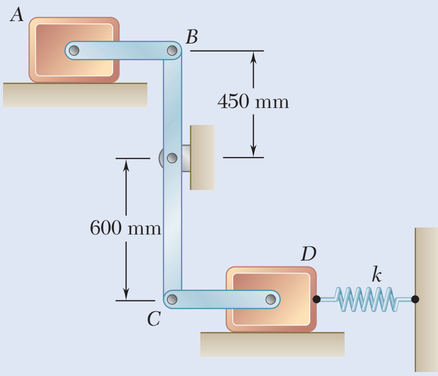

Fig. P19.69

19.70 Two small spheres, *A* and *C*, each have a mass *m* and are attached to rod *AB* that is supported by a pin and bracket at *B* and by a spring *CD* with constant *k*. Knowing that the mass of the rod is negligible and that the system is in equilibrium when the rod is horizontal, determine the frequency of the small oscillations of the system.

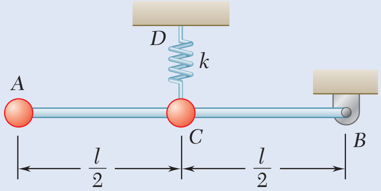

Fig. P19.70

19.71 A 14-oz sphere *A* and a 10-oz sphere *C* are attached to the ends of a rod *AC* of negligible weight that can rotate in a vertical plane about an axis at *B*. Determine the period of small oscillations of the rod.

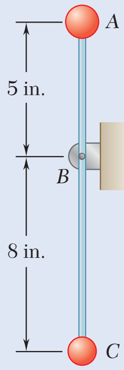

Fig. P19.71

19.72 Determine the period of small oscillations of a small particle that moves without friction inside a cylindrical surface of radius *R*.

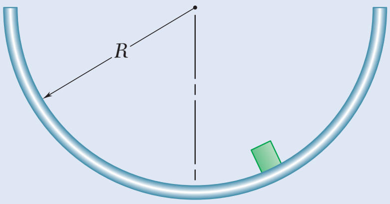

Fig. P19.72

19.73 The inner rim of an 85-lb flywheel is placed on a knife edge, and the period of its small oscillations is found to be 1.26 s. Determine the centroidal moment of inertia of the flywheel.

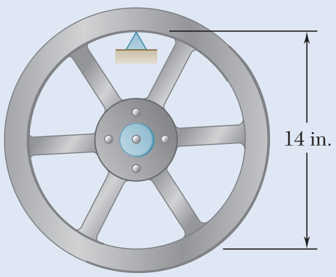

Fig. ***P19.73***

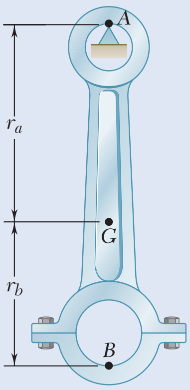

Fig. *P19.74*

19.74 A connecting rod is supported by a knife edge at point A; the period of its small oscillations is observed to be 1.03 s. Knowing that the distance r_a is 6 in., determine the centroidal radius of gyration of the connecting rod.

19.75 A uniform rod AB can rotate in a vertical plane about a horizontal axis at C located at a distance c above the mass center G of the rod. For small oscillations determine the value of c for which the frequency of the motion will be maximum.

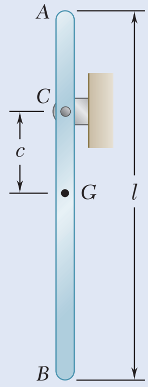

Fig. P19.75

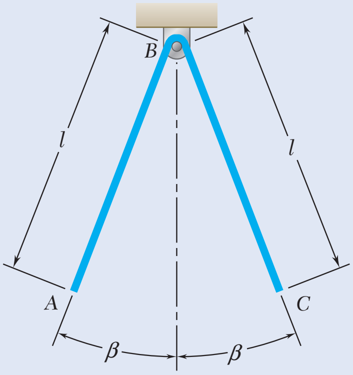

Fig. P19.76

19.76 A homogeneous wire of length $2l$ is bent as shown and allowed to oscillate about a frictionless pin at B. Denoting by τ_0 the period of small oscillations when $\beta = 0$, determine the angle β for which the period of small oscillations is $2\tau_0$.

19.77 A uniform disk of radius r and mass m can roll without slipping on a cylindrical surface and is attached to bar ABC of length L and negligible mass. The bar is attached to a spring of constant k and can rotate freely in the vertical plane about point B. Knowing that end A is given a small displacement and released, determine the frequency of the resulting oscillations in terms of m, L, k, and g.

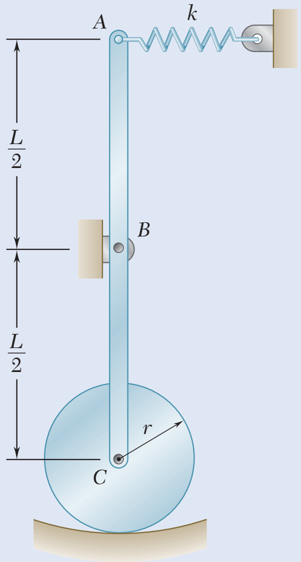

Fig. P19.77

19.78 Two uniform rods, each of weight $W = 1.2$ lb and length $l = 8$ in., are welded together to form the assembly shown. Knowing that the constant of each spring is $k = 0.6$ lb/in. and that end A is given a small displacement and released, determine the frequency of the resulting motion.

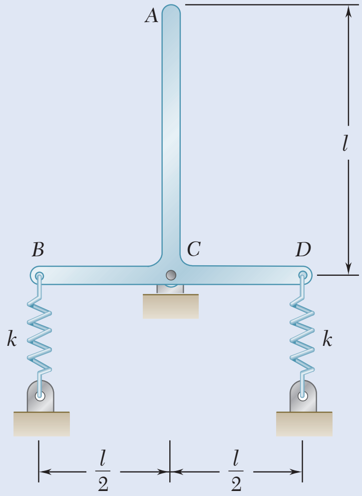

Fig. P19.78

19.79 A 15-lb uniform cylinder can roll without sliding on an incline and is attached to a spring AB as shown. If the center of the cylinder is moved 0.4 in. down the incline and released, determine (*a*) the period of vibration, (*b*) the maximum velocity of the center of the cylinder.

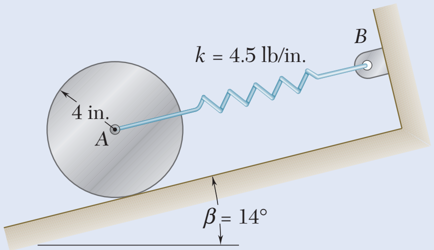

Fig. P19.79

19.80 A 3-kg slender rod AB is bolted to a 5-kg uniform disk. A spring of constant 280 N/m is attached to the disk and is unstretched in the position shown. If end B of the rod is given a small displacement and released, determine the period of vibration of the system.

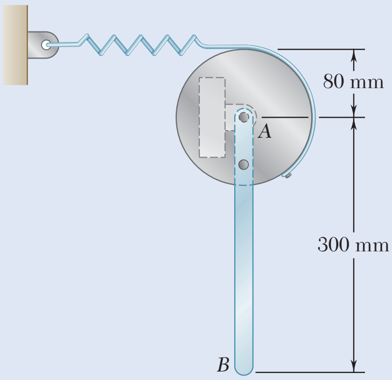

Fig. P19.80

19.81 A slender 10-kg bar AB with a length of $l = 0.6$ m is connected to two collars of negligible weight. Collar A is attached to a spring with a constant of $k = 1.5$ kN/m and can slide on a horizontal rod, while collar B can slide freely on a vertical rod. Knowing that the system is in equilibrium when bar AB is vertical and that collar A is given a small displacement and released, determine the period of the resulting vibrations.

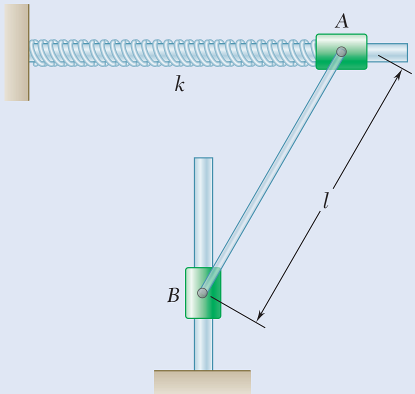

Fig. *P19.81* and *P19.82*

19.82 A slender 5-kg bar AB with a length of $l = 0.6$ m is connected to two collars, each of mass 2.5 kg. Collar A is attached to a spring with a constant of $k = 1.5$ kN/m and can slide on a horizontal rod, while collar B can slide freely on a vertical rod. Knowing that the system is in equilibrium when bar AB is vertical and that collar A is given a small displacement and released, determine the period of the resulting vibrations.

19.83 An 800-g rod AB is bolted to a 1.2-kg disk. A spring of constant $k = 12$ N/m is attached to the center of the disk at A and to the wall at C. Knowing that the disk rolls without sliding, determine the period of small oscillations of the system.

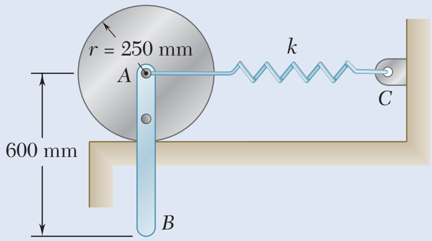

Fig. P19.83

19.84 Three identical 3.6-kg uniform slender bars are connected by pins as shown and can move in a vertical plane. Knowing that bar BC is given a small displacement and released, determine the period of vibration of the system.

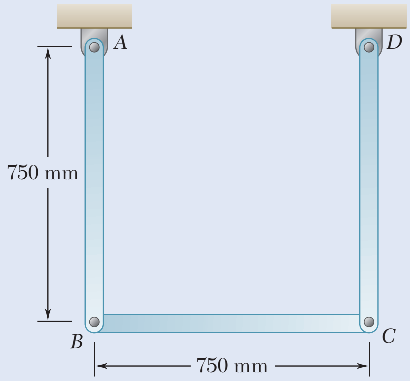

Fig. *P19.84*

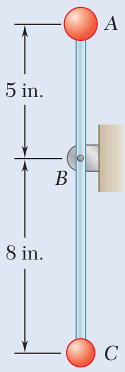

Fig. P19.85

19.85 A 14-oz sphere A and a 10-oz sphere C are attached to the ends of a 20-oz rod AC that can rotate in a vertical plane about an axis at B. Determine the period of small oscillations of the rod.

19.86 A 10-lb uniform rod CD is welded at C to a shaft of negligible mass that is welded to the centers of two 20-lb uniform disks A and B. Knowing that the disks roll without sliding, determine the period of small oscillations of the system.

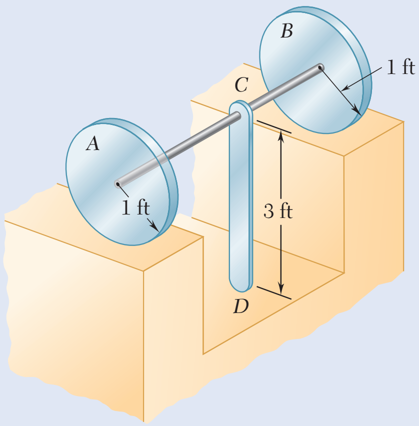

Fig. P19.86

19.87 and *19.88* Two uniform rods AB and CD, each of length l and mass m, are attached to gears as shown. Knowing that the mass of gear C is m and that the mass of gear A is $4m$, determine the period of small oscillations of the system.

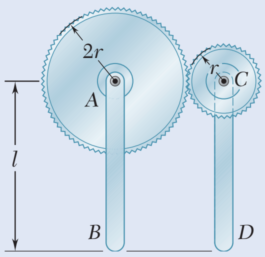

Fig. P19.87

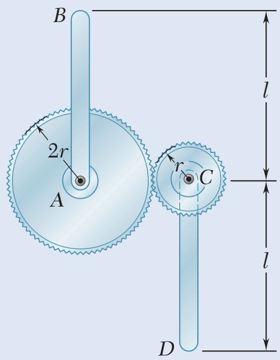

Fig. *P19.88*

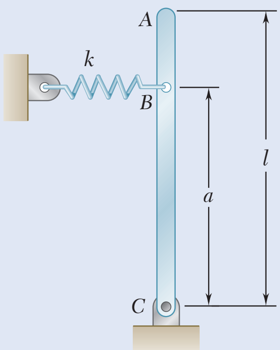

Fig. P19.89

19.89 An inverted pendulum consisting of a rigid bar ABC of length l and mass m is supported by a pin and bracket at C. A spring of constant k is attached to the bar at B and is undeformed when the bar is in the vertical position shown. Determine (a) the frequency of small oscillations, (b) the smallest value of a for which these oscillations will occur.

19.90 Two 12-lb uniform disks are attached to the 20-lb rod *AB* as shown. Knowing that the constant of the spring is 30 lb/in. and that the disks roll without sliding, determine the frequency of vibration of the system.

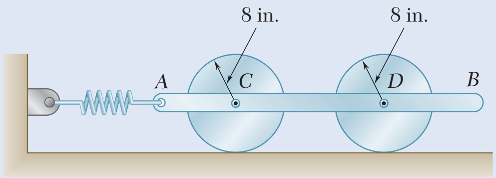

Fig. P19.90

19.91 The 20-lb rod *AB* is attached to two 8-lb disks as shown. Knowing that the disks roll without sliding, determine the frequency of small oscillations of the system.

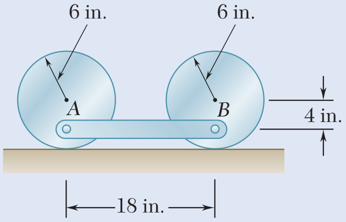

Fig. P19.91

19.92 A half section of a uniform cylinder of radius r and mass m rests on two casters *A* and *B*, each of which is a uniform cylinder of radius $r/4$ and mass $m/8$. Knowing that the half cylinder is rotated through a small angle and released and that no slipping occurs, determine the frequency of small oscillations.

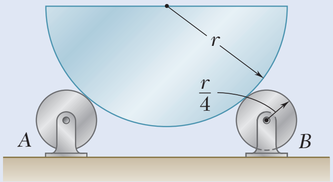

Fig. P19.92

19.93 The motion of the uniform rod *AB* is guided by the cord *BC* and by the small roller at *A*. Determine the frequency of oscillation when the end *B* of the rod is given a small horizontal displacement and released.

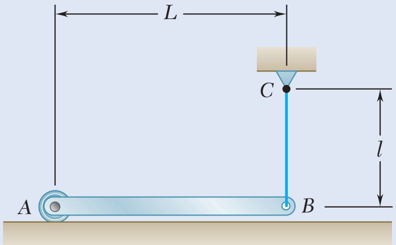

Fig. *P19.93*

19.94 A uniform rod of length L is supported by a ball-and-socket joint at *A* and by a vertical wire *CD*. Derive an expression for the period of oscillation of the rod if end *B* is given a small horizontal displacement and then released.

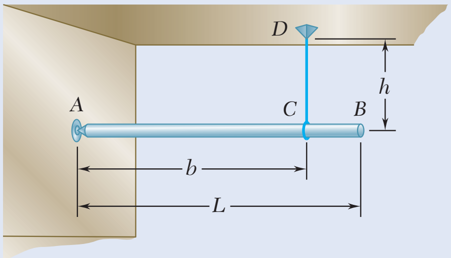

Fig. *P19.94*

19.95 A section of uniform pipe is suspended from two vertical cables attached at *A* and *B*. Determine the frequency of oscillation when the pipe is given a small rotation about the centroidal axis OO' and released.

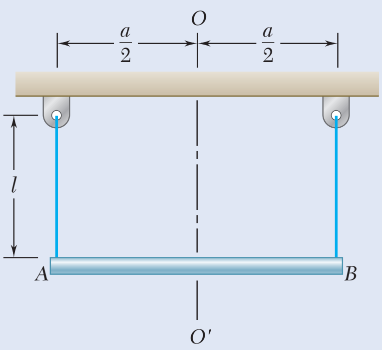

Fig. P19.95

19.96 Three collars each have a mass m and are connected by pins to bars AC and BC, each having length l and negligible mass. Collars A and B can slide without friction on a horizontal rod and are connected by a spring of constant k. Collar C can slide without friction on a vertical rod and the system is in equilibrium in the position shown. Knowing that collar C is given a small displacement and released, determine the frequency of the resulting motion of the system.

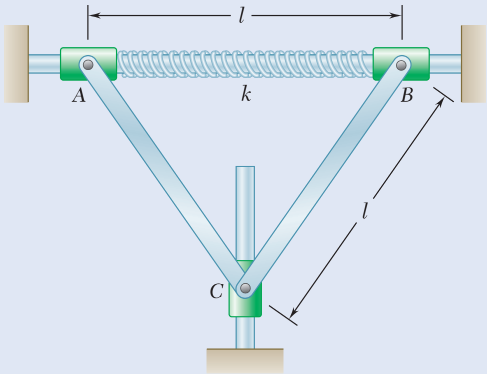

Fig. P19.96

***19.97** A thin plate of length l rests on a half cylinder of radius r. Derive an expression for the period of small oscillations of the plate.

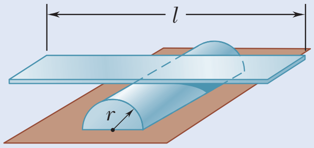

Fig. P19.97

***19.98** As a submerged body moves through a fluid, the particles of the fluid flow around the body and thus acquire kinetic energy. In the case of a sphere moving in an ideal fluid, the total kinetic energy acquired by the fluid is $\frac{1}{4}\rho V v^2$, where ρ is the mass density of the fluid, V is the volume of the sphere, and v is the velocity of the sphere. Consider a 500-g hollow spherical shell of radius 80 mm that is held submerged in a tank of water by a spring of constant 500 N/m. (*a*) Neglecting fluid friction, determine the period of vibration of the shell when it is displaced vertically and then released. (*b*) Solve part *a*, assuming that the tank is accelerated upward at the constant rate of 8 m/s^2.

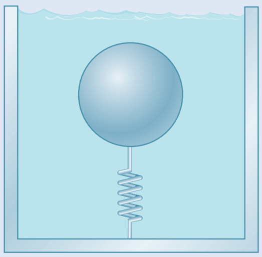

Fig. P19.98

Problems

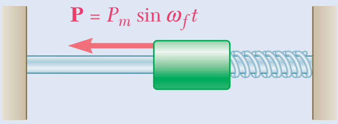

Fig. P19.99, P19.100 and P19.101

19.99 A 4-kg collar can slide on a frictionless horizontal rod and is attached to a spring with a constant of 450 N/m. It is acted upon by a periodic force with a magnitude of $P = P_m \sin \omega_f t$, where $P_m = 13$ N. Determine the amplitude of the motion of the collar if (*a*) $\omega_f = 5$ rad/s, (*b*) $\omega_f = 10$ rad/s.

19.100 A 4-kg collar can slide on a frictionless horizontal rod and is attached to a spring with constant k. It is acted upon by a periodic force of magnitude $P = P_m \sin \omega_f t$, where $P_m = 9$ N and $\omega_f = 5$ rad/s. Determine the value of the spring constant k knowing that the motion of the collar has an amplitude of 150 mm and is (*a*) in phase with the applied force, (*b*) out of phase with the applied force.

19.101 A collar with mass m that slides on a frictionless horizontal rod is attached to a spring with constant k and is acted upon by a periodic force with a magnitude of $P = P_m \sin \omega_f t$. Determine the range of values of ω_f for which the amplitude of the vibration exceeds three times the static deflection caused by a constant force with a magnitude of P_m.

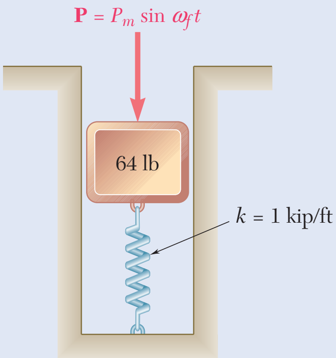

Fig. P19.102

19.102 A 64-lb block is attached to a spring with a constant of $k = 1$ kip/ft and can move without friction in a vertical slot as shown. It is acted upon by a periodic force with a magnitude of $P = P_m \sin \omega_f t$, where $\omega_f = 10$ rad/s. Knowing that the amplitude of the motion is 0.75 in., determine P_m.

19.103 A small 20-kg block A is attached to the rod BC of negligible mass that is supported at B by a pin and bracket and at C by a spring of constant $k = 2$ kN/m. The system can move in a vertical plane and is in equilibrium when the rod is horizontal. The rod is acted upon at C by a periodic force **P** of magnitude $P = P_m \sin \omega_f t$, where $P_m = 6$ N. Knowing that $b = 200$ mm, determine the range of values of ω_f for which the amplitude of vibration of block A exceeds 3.5 mm.

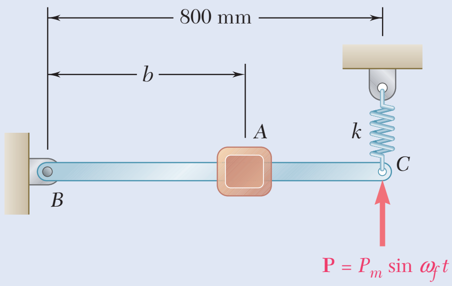

Fig. *P19.103*

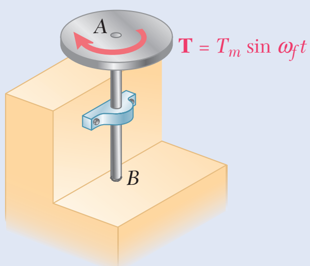

Fig. *P19.104*

19.104 An 8-kg uniform disk of radius 200 mm is welded to a vertical shaft with a fixed end at B. The disk rotates through an angle of 3° when a static couple of magnitude 50 N·m is applied to it. If the disk is acted upon by a periodic torsional couple of magnitude $T = T_m \sin \omega_f t$, where $T_m = 60$ N·m, determine the range of values of ω_f for which the amplitude of the vibration is less than the angle of rotation caused by a static couple of magnitude T_m.

19.105 An 18-lb block A slides in a vertical frictionless slot and is connected to a moving support B by means of a spring AB of constant $k = 10$ lb/in. Knowing that the displacement of the support is $\delta = \delta_m \sin \omega_f t$, where $\delta_m = 6$ in., determine the range of values of ω_f for which the amplitude of the fluctuating force exerted by the spring on the block is less than 30 lb.

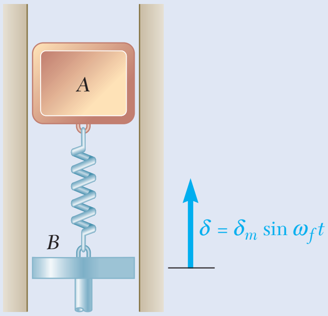

Fig. P19.105

19.106 A beam ABC is supported by a pin connection at A and by rollers at B. A 120-kg block placed on the end of the beam causes a static deflection of 15 mm at C. Assuming that the support at A undergoes a vertical periodic displacement $\delta = \delta_m \sin \omega_f t$, where $\delta_m = 10$ mm and $\omega_f = 18$ rad/s, and the support at B does not move, determine the maximum acceleration of the block at C. Neglect the weight of the beam and assume that the block does not leave the beam.

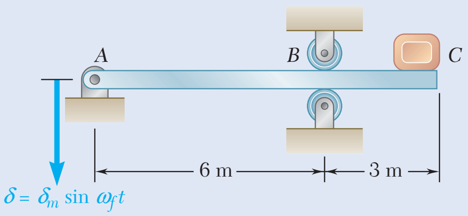

Fig. P19.106

19.107 A small 2-kg sphere B is attached to the bar AB of negligible mass that is supported at A by a pin and bracket and connected at C to a moving support D by means of a spring of constant $k = 3.6$ kN/m. Knowing that support D undergoes a vertical displacement $\delta = \delta_m \sin \omega_f t$, where $\delta_m = 3$ mm and $\omega_f = 15$ rad/s, determine (*a*) the magnitude of the maximum angular velocity of bar AB, (*b*) the magnitude of the maximum acceleration of sphere B.

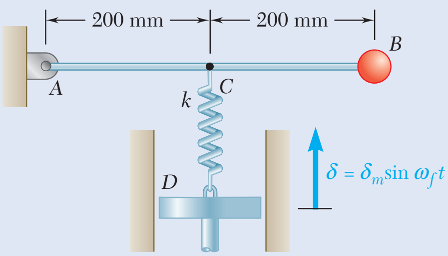

Fig. P19.107

19.108 The crude-oil pumping rig shown is driven at 20 rpm. The inside diameter of the well pipe is 2 in., and the diameter of the pump rod is 0.75 in. The length of the pump rod and the length of the column of oil lifted during the stroke are essentially the same, and equal to 6000 ft. During the downward stroke, a valve at the lower end of the pump rod opens to let a quantity of oil into the well pipe, and the column of oil is then lifted to obtain a discharge into the connecting pipeline. Thus, the amount of oil pumped in a given time depends upon the stroke of the lower end of the pump rod. Knowing that the upper end of the rod at D is essentially sinusoidal with a stroke of 45 in. and the specific weight of crude oil is 56.2 lb/ft^3, determine (*a*) the output of the well in ft^3/min if the shaft is rigid, (*b*) the output of the well in ft^3/min if the stiffness of the rod is 2210 N/m, the equivalent mass of the oil and shaft is 290 kg, and damping is negligible.

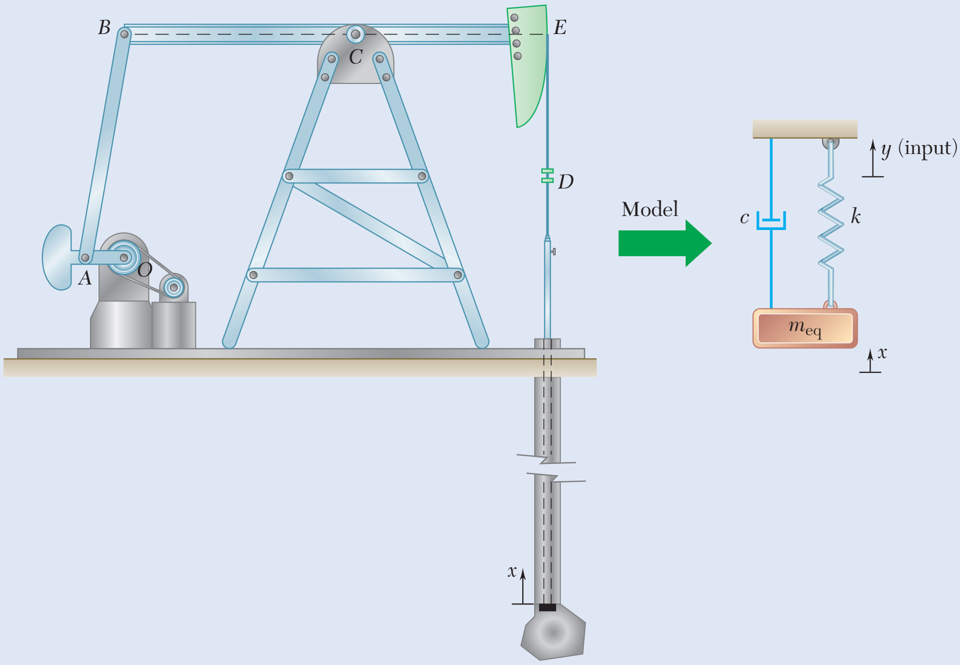

Fig. *P19.108*

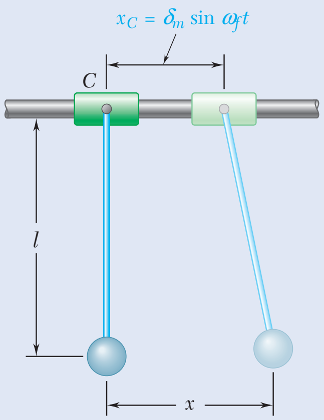

Fig. P19.109 and P19.110

19.109 A simple pendulum of length l is suspended from collar C that is forced to move horizontally according to the relation $x_C = \delta_m \sin \omega_f t$. Determine the range of values of ω_f for which the amplitude of the motion of the bob is less than δ_m. (Assume that δ_m is small compared with the length l of the pendulum.)

19.110 The 2.75-lb bob of a simple pendulum of length $l = 24$ in. is suspended from a 3-lb collar C. The collar is forced to move according to the relation $x_C = \delta_m \sin \omega_f t$, with an amplitude $\delta_m = 0.4$ in. and a frequency $f_f = 0.5$ Hz. Determine (*a*) the amplitude of the motion of the bob, (*b*) the force that must be applied to collar C to maintain the motion.

19.111 An 18-lb block A slides in a vertical frictionless slot and is connected to a moving support B by means of a spring AB of constant $k = 8$ lb/ft. Knowing that the acceleration of the support is $a = a_m \sin \omega_f t$, where $a_m = 5$ ft/s^2 and $\omega_f = 6$ rad/s, determine (*a*) the maximum displacement of block A, (*b*) the amplitude of the fluctuating force exerted by the spring on the block.

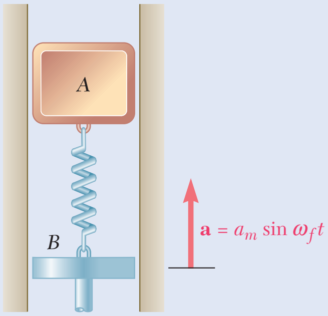

Fig. *P19.111*

19.112 A variable-speed motor is rigidly attached to a beam BC. When the speed of the motor is less than 600 rpm or more than 1200 rpm, a small object placed at A is observed to remain in contact with the beam. For speeds between 600 and 1200 rpm, the object is observed to "dance" and actually to lose contact with the beam. Determine the speed at which resonance will occur.

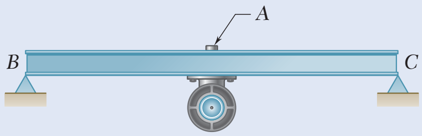

Fig. P19.112

19.113 A motor of mass M is supported by springs with an equivalent spring constant k. The unbalance of its rotor is equivalent to a mass m located at a distance r from the axis of rotation. Show that when the angular velocity of the motor is ω_f, the amplitude x_m of the motion of the motor is

$$x_m = \frac{r(m/M)(\omega_f/\omega_n)^2}{1 - (\omega_f/\omega_n)^2}$$

where $\omega_n = \sqrt{k/M}$.

19.114 As the rotational speed of a spring-supported 100-kg motor is increased, the amplitude of the vibration due to the unbalance of its 15-kg rotor first increases and then decreases. It is observed that as very high speeds are reached, the amplitude of the vibration approaches 3.3 mm. Determine the distance between the mass center of the rotor and its axis of rotation. (*Hint:* Use the formula derived in Prob. 19.113.)

19.115 A motor of weight 40 lb is supported by four springs, each of constant 225 lb/in. The motor is constrained to move vertically, and the amplitude of its motion is observed to be 0.05 in. at a speed of 1200 rpm. Knowing that the weight of the rotor is 9 lb, determine the distance between the mass center of the rotor and the axis of the shaft.

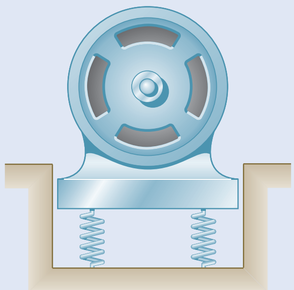

Fig. P19.115

19.116 A motor weighing 400 lb is supported by springs having a total constant of 1200 lb/in. The unbalance of the rotor is equivalent to a 1-oz weight located 8 in. from the axis of rotation. Determine the range of allowable values of the motor speed if the amplitude of the vibration is not to exceed 0.06 in.

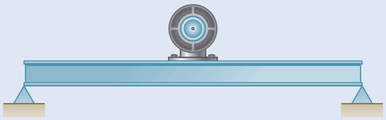

Fig. P19.117

19.117 A 180-kg motor is bolted to a light horizontal beam. The unbalance of its rotor is equivalent to a 28-g mass located 150 mm from the axis of rotation, and the static deflection of the beam due to the weight of the motor is 12 mm. The amplitude of the vibration due to the unbalance can be decreased by adding a plate to the base of the motor. If the amplitude of vibration is to be less than 60 μm for motor speeds above 300 rpm, determine the required mass of the plate.

19.118 The unbalance of the rotor of a 400-lb motor is equivalent to a 3-oz weight located 6 in. from the axis of rotation. In order to limit to 0.2 lb the amplitude of the fluctuating force exerted on the foundation when the motor is run at speeds of 100 rpm and above, a pad is to be placed between the motor and the foundation. Determine (*a*) the maximum allowable spring constant k of the pad, (*b*) the corresponding amplitude of the fluctuating force exerted on the foundation when the motor is run at 200 rpm.

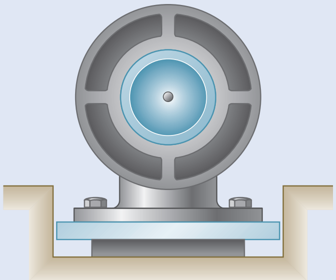

Fig. *P19.118*

19.119 A counter-rotating eccentric mass exciter consisting of two rotating 100-g masses describing circles of radius r at the same speed but in opposite senses is placed on a machine element to induce a steady-state vibration of the element. The total mass of the system is 300 kg, the constant of each spring is k = 600 kN/m, and the rotational speed of the exciter is 1200 rpm. Knowing that the amplitude of the total fluctuating force exerted on the foundation is 160 N, determine the radius r.

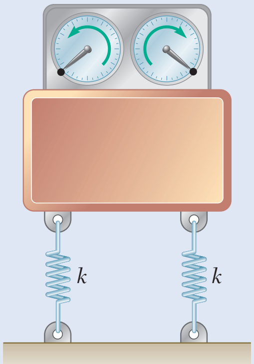

Fig. P19.119

19.120 A 360-lb motor is supported by springs of total constant 12.5 kips/ft. The unbalance of the rotor is equivalent to a 0.9-oz weight located 7.5 in. from the axis of rotation. Determine the range of speeds of the motor for which the amplitude of the fluctuating force exerted on the foundation is less than 5 lb.

19.121 Figures (1) and (2) show how springs can be used to support a block in two different situations. In Fig. (1), they help decrease the amplitude of the fluctuating force transmitted by the block to the foundation. In Fig. (2), they help decrease the amplitude of the fluctuating displacement transmitted by the foundation to the block. The ratio of the transmitted force to the impressed force or the ratio of the transmitted displacement to the impressed displacement is called the *transmissibility*. Derive an equation for the transmissibility for each situation. Give your answer in terms of the ratio ω_f/ω_n of the frequency ω_f of the impressed force or impressed displacement to the natural frequency ω_n of the spring-mass system. Show that in order to cause any reduction in transmissibility, the ratio ω_f/ω_n must be greater than $\sqrt{2}$.

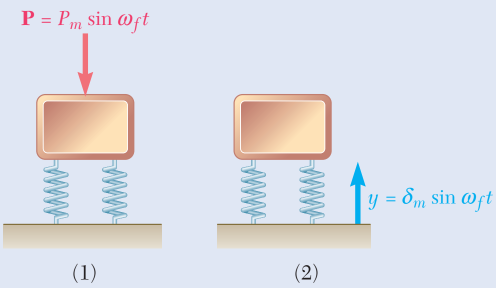

Fig. P19.121

19.122 A vibrometer used to measure the amplitude of vibrations consists essentially of a box containing a mass-spring system with a known natural frequency of 120 Hz. The box is rigidly attached to a surface that is moving according to the equation $y = \delta_m \sin \omega_f t$. If the amplitude z_m of the motion of the mass relative to the box is used as a measure of the amplitude δ_m of the vibration of the surface, determine (*a*) the percent error when the frequency of the vibration is 600 Hz, (*b*) the frequency at which the error is zero.

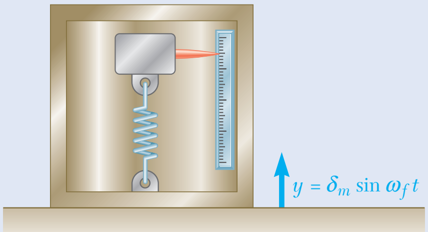

Fig. P19.122 and P19.123

19.123 A certain accelerometer consists essentially of a box containing a mass-spring system with a known natural frequency of 2200 Hz. The box is rigidly attached to a surface that is moving according to the equation $y = \delta_m \sin \omega_f t$. If the amplitude z_m of the motion of the mass relative to the box times a scale factor ω_n^2 is used as a measure of the maximum acceleration $\alpha_m = \delta_m \omega_f^2$ of the vibrating surface, determine the percent error when the frequency of the vibration is 600 Hz.

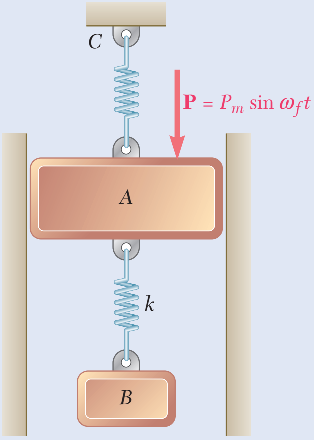

Fig. *P19.124*

19.124 Block A can move without friction in the slot as shown and is acted upon by a vertical periodic force of magnitude $P = P_m \sin \omega_f t$, where $\omega_f = 2$ rad/s and $P_m = 20$ N. A spring of constant k is attached to the bottom of block A and to a 22-kg block B. Determine (*a*) the value of the constant k that will prevent a steady-state vibration of block A, (*b*) the corresponding amplitude of the vibration of block B.

19.125 A 60-lb disk is attached with an eccentricity $e = 0.006$ in. to the midpoint of a vertical shaft AB that revolves at a constant angular velocity ω_f. Knowing that the spring constant k for horizontal movement of the disk is 40,000 lb/ft, determine (*a*) the angular velocity ω_f at which resonance will occur, (*b*) the deflection r of the shaft when $\omega_f = 1200$ rpm.

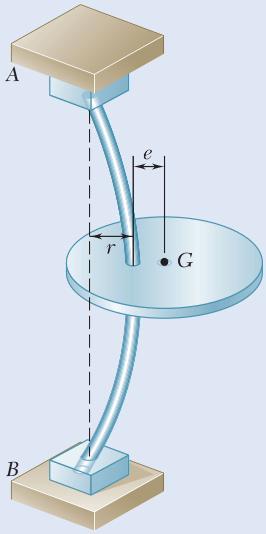

Fig. P19.125

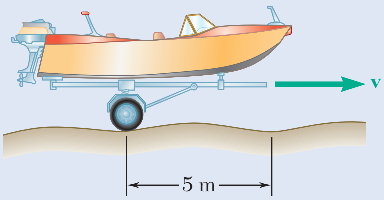

Fig. *P19.126*

19.126 A small trailer and its load have a total mass of 250 kg. The trailer is supported by two springs, each of constant 10 kN/m, and is pulled over a road, the surface of which can be approximated by a sine curve with an amplitude of 40 mm and a wavelength of 5 m (i.e., the distance between successive crests is 5 m and the vertical distance from crest to trough is 80 mm). Determine (*a*) the speed at which resonance will occur, (*b*) the amplitude of the vibration of the trailer at a speed of 50 km/h.

Problems

19.127 Show that in the case of heavy damping ($c > c_c$), a body never passes through its position of equilibrium O if it is (*a*) released with no initial velocity from an arbitrary position, (*b*) started from O with an arbitrary initial velocity.

19.128 Show that in the case of heavy damping ($c > c_c$), a body released from an arbitrary position with an arbitrary initial velocity cannot pass more than once through its equilibrium position.

19.129 In the case of light damping ($c < c_c$), the displacements x_1, x_2, x_3, shown in Fig. 19.11 may be assumed equal to the maximum displacements. Show that the ratio of any two successive maximum displacements x_n and x_{n+1} is a constant and that the natural logarithm of this ratio, called the *logarithmic decrement,* is

$$\ln \frac{x_n}{x_{n+1}} = \frac{2\pi(c/c_c)}{\sqrt{1 - (c/c_c)^2}}$$

19.130 In practice, it is often difficult to determine the logarithmic decrement of a system with light damping defined in Prob. 19.129 by measuring two successive maximum displacements. Show that the logarithmic decrement can also be expressed as (1/k) $\ln(x_n/x_{n+k})$, where k is the number of cycles between readings of the maximum displacement.

19.131 In an underdamped system ($c < c_c$), the period of vibration is commonly defined as the time interval $\tau_d = 2\pi/\omega_d$ corresponding to two successive points where the displacement–time curve touches one of the limiting curves shown in Fig. 19.11. Show that the interval of time (*a*) between a maximum positive displacement and the following maximum negative displacement is $\frac{1}{2}\tau_d$, (*b*) between two successive zero displacements is $\frac{1}{2}\tau_d$, (*c*) between a maximum positive displacement and the following zero displacement is greater than $\frac{1}{4}\tau_d$.

19.132 A loaded railroad car weighing 30,000 lb is rolling at a constant velocity $\mathbf{v}_0$ when it couples with a spring and dashpot bumper system (Fig. 1). The recorded displacement–time curve of the loaded railroad car after coupling is as shown (Fig. 2). Determine (*a*) the damping constant, (*b*) the spring constant. (*Hint:* Use the definition of logarithmic decrement given in 19.129.)

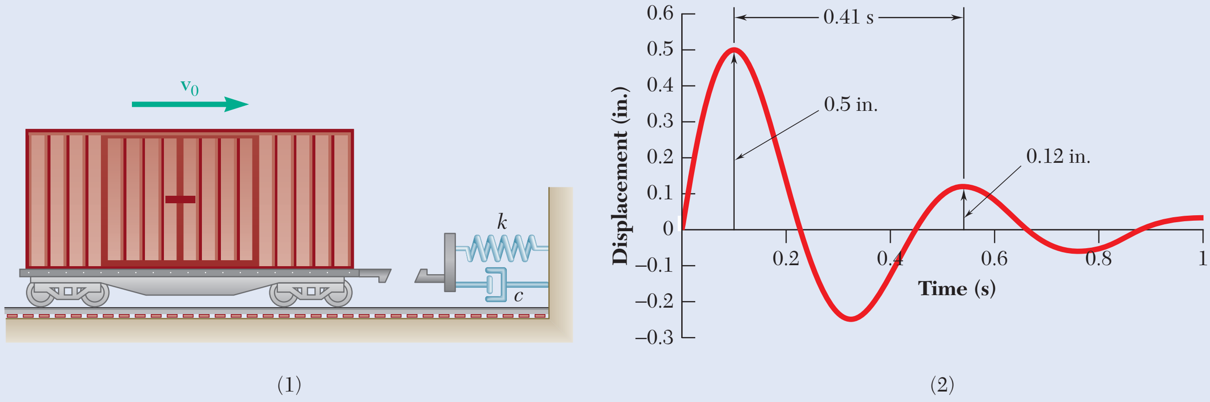

Fig. P19.132

19.133 A torsional pendulum has a centroidal mass moment of inertia of 0.3 kg·m^2 and when given an initial twist and released is found to have a frequency of oscillation of 200 rpm. Knowing that when this pendulum is immersed in oil and when given the same initial condition it is found to have a frequency of oscillation of 180 rpm, determine the damping constant for the oil.

19.134 The barrel of a field gun weighs 1500 lb and is returned into firing position after recoil by a recuperator of constant c = 1100 lb·s/ft. Determine (*a*) the constant k that should be used for the recuperator to return the barrel into firing position in the shortest possible time without any oscillation, (*b*) the time needed for the barrel to move back two-thirds of the way from its maximum-recoil position to its firing position.

19.135 A 2-kg block is supported by a spring with a constant of k = 128 N/m and a dashpot with a coefficient of viscous damping of c = 0.6 N·s/m. The block is in equilibrium when it is struck from below by a hammer that imparts to the block an upward velocity of 0.4 m/s. Determine (*a*) the logarithmic decrement, (*b*) the maximum upward displacement of the block from equilibrium after two cycles.

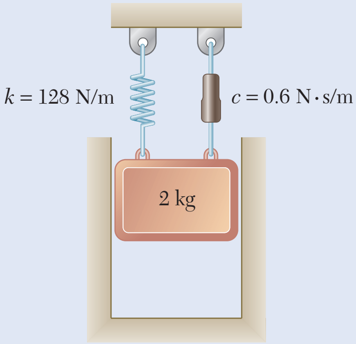

Fig. P19.135

19.136 A 4-kg block A is dropped from a height of 800 mm onto a 9-kg block B that is at rest. Block B is supported by a spring of constant k = 1500 N/m and is attached to a dashpot of damping coefficient c = 230 N·s/m. Knowing that there is no rebound, determine the maximum distance the blocks will move after the impact.

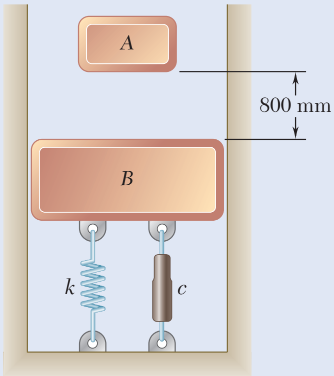

Fig. P19.136

19.137 A 0.9-kg block B is connected by a cord to a 2.4-kg block A that is suspended as shown from two springs, each with a constant of k = 180 N/m, and a dashpot with a damping coefficient of c = 7.5 N·s/m. Knowing that the system is at rest when the cord connecting A and B is cut, determine the minimum tension that will occur in each spring during the resulting motion.

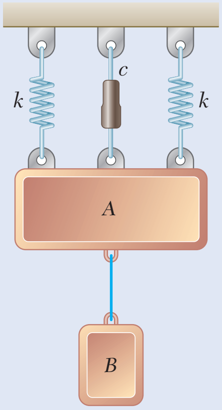

Fig. P19.137 and P19.138

19.138 A 0.9-kg block B is connected by a cord to a 2.4-kg block A that is suspended as shown from two springs, each with a constant of k = 180 N/m, and a dashpot with a damping coefficient of c = 60 N·s/m. Knowing that the system is at rest when the cord connecting A and B is cut, determine the velocity of block A after 0.1 s.

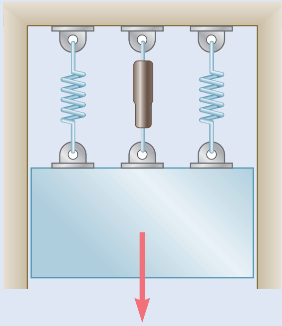

Fig. P19.139

19.139 A machine element weighing 800 lb is supported by two springs, each having a constant of 200 lb/in. A periodic force of maximum value 30 lb is applied to the element with a frequency of 2.5 cycles per second. Knowing that the coefficient of damping is 8 lb·s/in., determine the amplitude of the steady-state vibration of the element.

19.140 In Prob. 19.139, determine the required value of the coefficient of damping if the amplitude of the steady-state vibration of the element is to be 0.15 in.

19.141 In the case of the forced vibration of a system, determine the range of values of the damping factor c/c_c for which the magnification factor will always decrease as the frequency ratio ω_f/ω_n increases.

19.142 Show that for a small value of the damping factor c/c_c, the maximum amplitude of a forced vibration occurs when $\omega_f \approx \omega_n$ and that the corresponding value of the magnification factor is $\frac{1}{2}(c/c_c)$.

19.143 A counter-rotating eccentric mass exciter consisting of two rotating 14-oz weights describing circles of 6-in. radius at the same speed but in opposite senses is placed on a machine element to induce a steady-state vibration of the element and to determine some of the dynamic characteristics of the element. At a speed of 1200 rpm, a stroboscope shows the eccentric masses to be exactly under their respective axes of rotation and the element to be passing through its position of static equilibrium. Knowing that the amplitude of the motion of the element at that speed is 0.6 in. and that the total weight of the system is 300 lb, determine (*a*) the combined spring constant k, (*b*) the damping factor c/c_c.

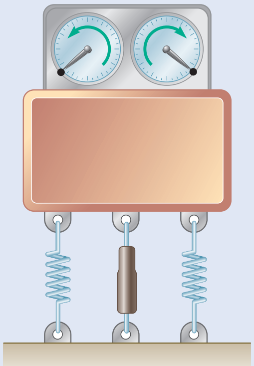

Fig. P19.143

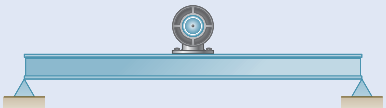

Fig. P19.144 and P19.145

19.144 A 36-lb motor is bolted to a light horizontal beam that has a static deflection of 0.075 in. due to the weight of the motor. Knowing that the unbalance of the rotor is equivalent to a weight of 0.64 oz located 6.25 in. from the axis of rotation, determine the amplitude of the vibration of the motor at a speed of 900 rpm, assuming (*a*) that no damping is present, (*b*) that the damping factor c/c_c is equal to 0.055.

19.145 A 45-kg motor is bolted to a light horizontal beam that has a static deflection of 6 mm due to the weight of the motor. The unbalance of the motor is equivalent to a mass of 110 g located 75 mm from the axis of rotation. Knowing that the amplitude of the vibration of the motor is 0.25 mm at a speed of 300 rpm, determine (*a*) the damping factor c/c_c, (*b*) the coefficient of damping c.

19.146 The unbalance of the rotor of a 180-kg motor is equivalent to a mass of 85 g located 150 mm from the axis of rotation. The pad that is placed between the motor and the foundation is equivalent to a spring with a constant of $k = 7.5$ kN/m in parallel with a dashpot with constant c. Knowing that the magnitude of the maximum acceleration of the motor is 9 mm/s^2 at a speed of 100 rpm, determine the damping factor c/c_c.

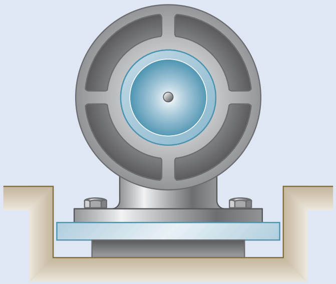

Fig. P19.146

19.147 A machine element is supported by springs and is connected to a dashpot as shown. Show that if a periodic force of magnitude $P = P_m \sin \omega_f t$ is applied to the element, the amplitude of the fluctuating force transmitted to the foundation is

$$F_m = P_m \sqrt{\frac{1 + [2(c/c_c)(\omega_f/\omega_n)]^2}{[1 - (\omega_f/\omega_n)^2]^2 + [2(c/c_c)(\omega_f/\omega_n)]^2}}$$

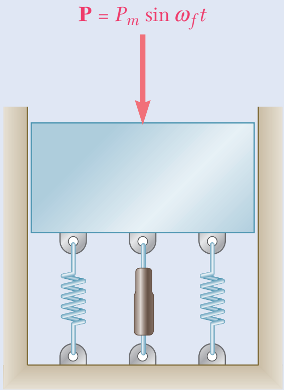

Fig. P19.147 and P19.148

19.148 A 91-kg machine element supported by four springs, each of constant $k = 175$ N/m, is subjected to a periodic force of frequency 0.8 Hz and amplitude 89 N. Determine the amplitude of the fluctuating force transmitted to the foundation if (*a*) a dashpot with a coefficient of damping $c = 365$ N·s/m is connected to the machine element and to the ground, (*b*) the dashpot is removed.

19.149 A simplified model of a washing machine is shown. A bundle of wet clothes forms a weight w_b of 20 lb in the machine and causes a rotating unbalance. The rotating weight is 40 lb (including w_b) and the radius of the washer basket e is 9 in. Knowing the washer has an equivalent spring constant $k = 70$ lb/ft and damping ratio $\zeta = c/c_c = 0.05$ and during the spin cycle the drum rotates at 250 rpm, determine the amplitude of the motion and the magnitude of the force transmitted to the sides of the washing machine.

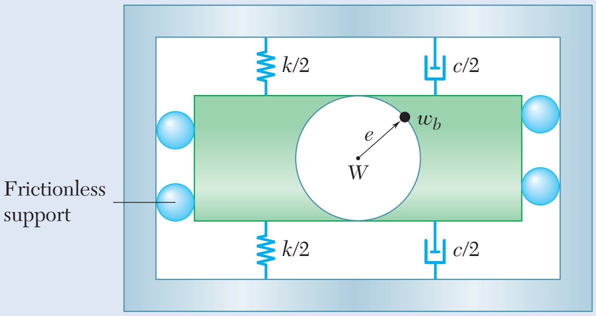

Fig. P19.149

***19.150** For a steady-state vibration with damping under a harmonic force, show that the mechanical energy dissipated per cycle by the dashpot is $E = \pi c x_m^2 \omega_f$, where c is the coefficient of damping, x_m is the amplitude of the motion, and ω_f is the circular frequency of the harmonic force.

***19.151** The suspension of an automobile can be approximated by the simplified spring-and-dashpot system shown. (*a*) Write the differential equation defining the vertical displacement of the mass m when the system moves at a speed v over a road with a sinusoidal cross section of amplitude δ_m and wave length L. (*b*) Derive an expression for the amplitude of the vertical displacement of the mass m.

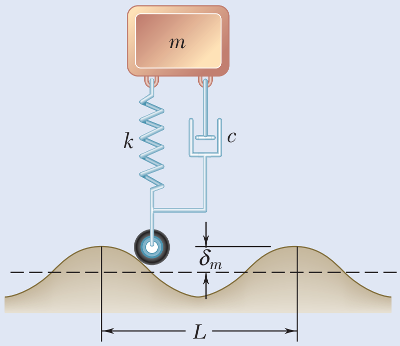

Fig. P19.151

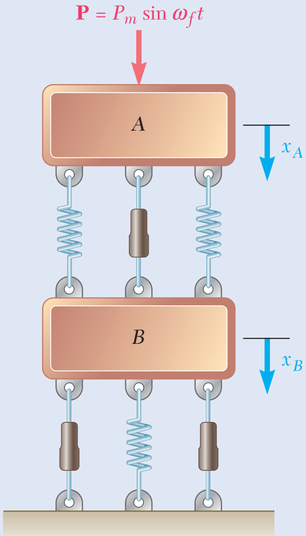

Fig. *P19.152*

***19.152** Two blocks A and B, each of mass m, are supported as shown by three springs of the same constant k. Blocks A and B are connected by a dashpot and block B is connected to the ground by two dashpots, each dashpot having the same coefficient of damping c. Block A is subjected to a force of magnitude $P = P_m \sin \omega_f t$. Write the differential equations defining the displacements x_A and x_B of the two blocks from their equilibrium positions.

19.153 Express in terms of L, C, and E the range of values of the resistance R for which oscillations will take place in the circuit shown when switch S is closed.

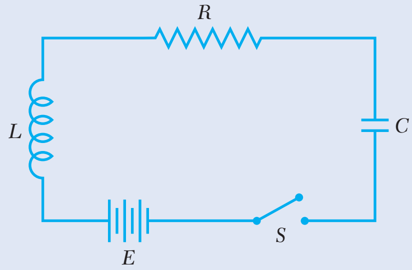

Fig. P19.153

19.154 Consider the circuit of Prob. 19.153 when the capacitor C is removed. If switch S is closed at time $t = 0$, determine (*a*) the final value of the current in the circuit, (*b*) the time t at which the current will have reached $(1 - 1/e)$ times its final value. (The desired value of t is known as the *time constant* of the circuit.)

19.155 and 19.156 Draw the electrical analogue of the mechanical system shown. (*Hint:* Draw the loops corresponding to the free bodies m and A.)

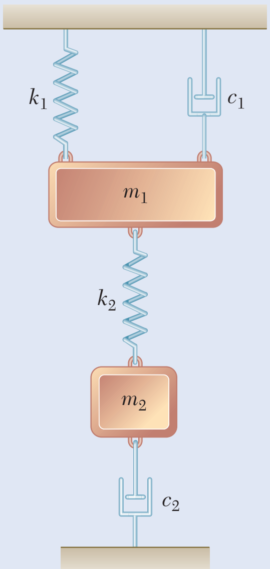

Fig. P19.156 and *P19.158*

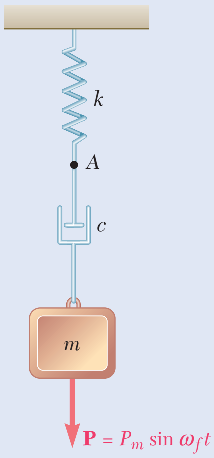

Fig. P19.155 and P19.157

19.157 and *19.158* Write the differential equations defining (*a*) the displacements of the mass m and of the point A, (*b*) the charges on the capacitors of the electrical analogue.