

Problems

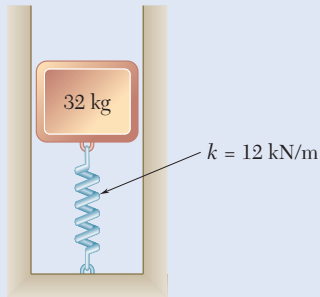


Fig. P19.4

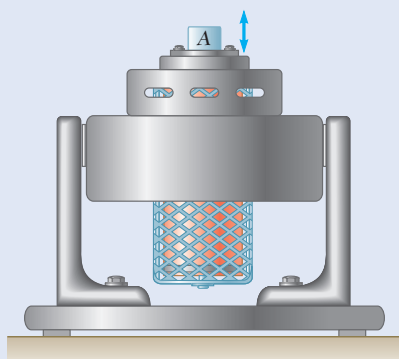


Fig. P19.6

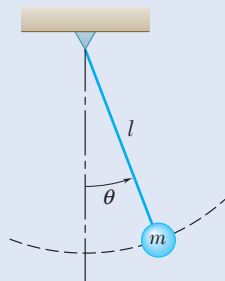


Fig. P19.7 and P19.8

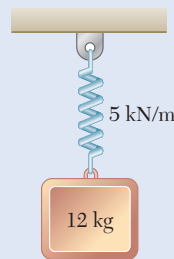


Fig. P19.5

- 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.

- 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 $l = 800 \text{ mm}$ oscillates in a vertical plane. Assuming simple harmonic motion and knowing that the bob is released from rest when $\theta = 6^\circ$, determine (a) the frequency of oscillation, (b) the maximum velocity of the bob.

- 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.

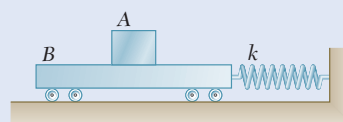


Fig. P19.9

- 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.

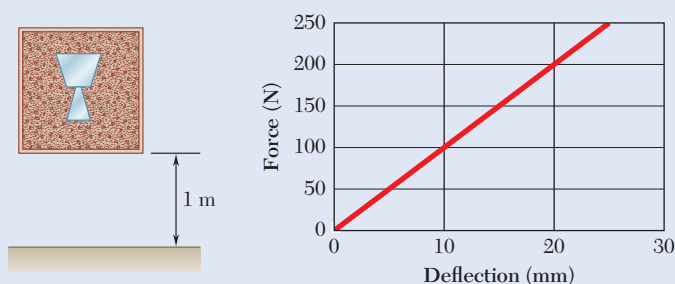


Fig. P19.10

- 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.

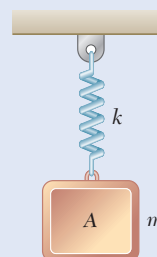


Fig. P19.11

- 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 $\theta = 5^\circ$. 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.

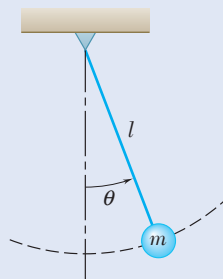


Fig. P19.13

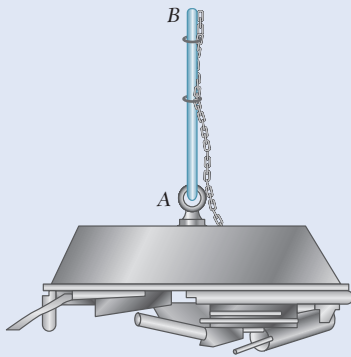


Fig. P19.14

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.)

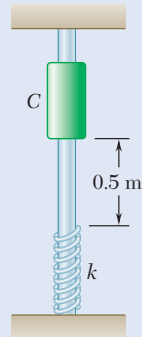


Fig. P19.15

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

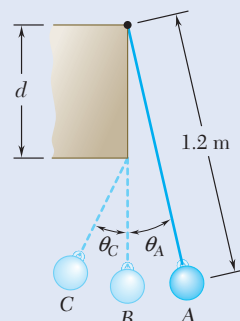


Fig. P19.16

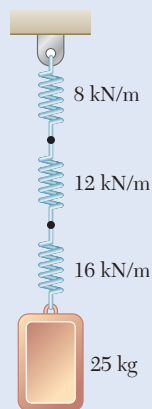


Fig. P19.17

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.

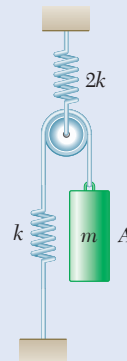


Fig. P19.19

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.

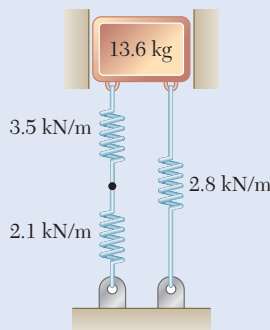


Fig. P19.20

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.

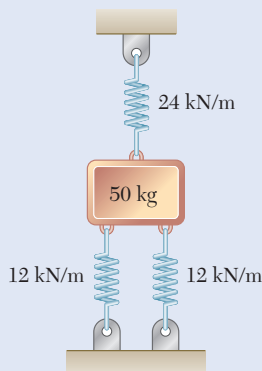


Fig. P19.21

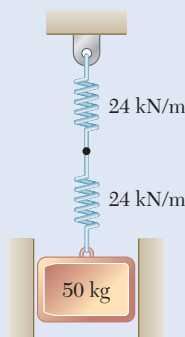


Fig. P19.22

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.

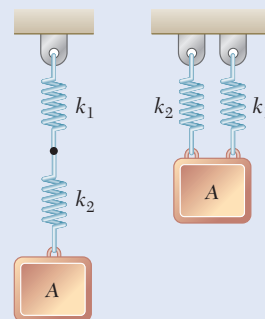


Fig. P19.23

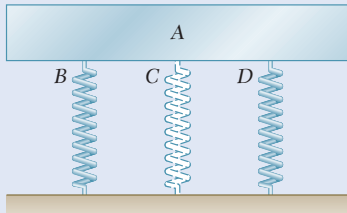


Fig. P19.25



Fig. P19.26

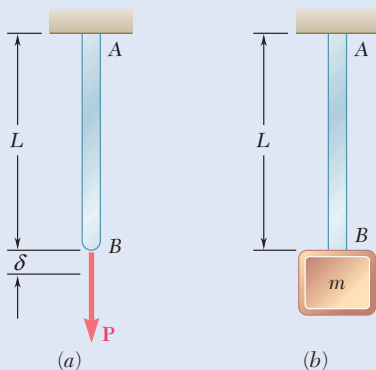


Fig. P19.28

- 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.

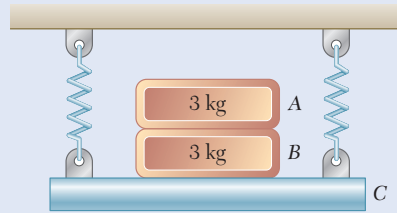


Fig. P19.24

- 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.

- 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 $k = \rho_{\text{sw}}gA$.]

- 19.27** From mechanics of materials, it is known that for a simply supported beam of uniform cross section, a static load \mathbf{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 $I = 2 \times 10^{-3} \text{ ft}^4$, 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.

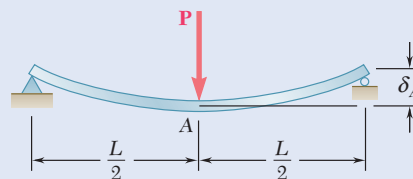


Fig. P19.27

- 19.28** From mechanics of materials it is known that when a static load \mathbf{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.

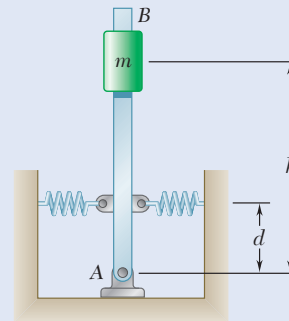


Fig. P19.31

- 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 $\sin \phi$ and integrating, show that the period of a simple pendulum of length l may be approximated by the formula

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

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 $\theta_m = 60^\circ$, (c) for oscillations of amplitude $\theta_m = 90^\circ$.
- *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° .