Section 10.1 The Ideal Spring and Simple Harmonic Motion

1. A 25-coil spring with a spring constant of 350 N/m is cut into five equal springs with five coils each. What is the spring constant of each of the 5-coil springs?
   (a) 14 N/m  (c) 350 N/m  (e) 1750 N/m
   (b) 70 N/m  (d) 700 N/m

2. A block is suspended from the ceiling by a long, thin strip of tungsten metal. The strip behaves as a spring. To produce a 0.25 m horizontal deflection of the block, a force of 6.5 N is required. Calculate the spring constant for the tungsten strip.
   (a) 0.038 N/m  (d) 13 N/m
   (b) 1.2 N/m  (e) 26 N/m
   (c) 1.6 N/m

3. In the produce section of a supermarket, five pears are placed on a spring scale. The placement of the pears stretches the spring and causes the dial to move from zero to a reading of 2.0 kg. If the spring constant is 450 N/m, what is the displacement of the spring due to the weight of the pears?
   (a) 0.0044 m
   (b) 0.0088 m
   (c) 0.018 m
   (d) 0.044 m
   (e) 0.088 m

4. Gina’s favorite exercise equipment at the gym consists of various springs. In one exercise, she pulls a handle grip attached to the free end of a spring to 0.80 m from its unstrained position. The other end of the spring (spring constant = 45 N/m) is held in place by the equipment frame. What is the magnitude of the force that Gina is applying to the handle grip?
   (a) 29 N  (c) 42 N  (e) 66 N
   (b) 36 N  (d) 54 N

5. A vertical block-spring system on earth has a period of 6.0 s. What is the period of this same system on the moon where the acceleration due to gravity is roughly 1/6 that of earth?
   (a) 1.0 s  (c) 6.0 s  (e) 36 s
   (b) 2.4 s  (d) 15 s

Section 10.2 Simple Harmonic Motion and the Reference Circle

6. Which one of the following statements is true concerning an object executing simple harmonic motion?
   (a) The object’s velocity is never zero.
   (b) The object’s acceleration is never zero.
   (c) The object’s velocity and acceleration are simultaneously zero.
   (d) The object’s velocity is zero when its acceleration is a maximum.
   (e) The object’s maximum acceleration is equal to its maximum velocity.
7. When a force of 20.0 N is applied to a spring, it elongates 0.20 m. Determine the period of oscillation of a 4.0-kg object suspended from this spring.
   (a) 0.6 s   (c) 3.1 s   (e) 6.3 s
   (b) 1.3 s   (d) 4.1 s

8. The position of a simple harmonic oscillator is given by \( x(t) = (0.50 \text{ m}) \cos \left( \frac{\pi}{t} \right) \) where \( t \) is in seconds. What is the maximum velocity of this oscillator?
   (a) 0.17 m/s   (c) 0.67 m/s   (e) 2.0 m/s
   (b) 0.52 m/s   (d) 1.0 m/s

9. The position of a simple harmonic oscillator is given by \( x(t) = (0.50 \text{ m}) \cos \left( \frac{\pi}{t} \right) \) where \( t \) is in seconds. What is the period of the oscillator?
   (a) 0.17 s   (c) 1.5 s   (e) 6.0 s
   (b) 0.67 s   (d) 3.0 s

10. A ball hung from a vertical spring oscillates in simple harmonic motion with an angular frequency of 2.6 rad/s and an amplitude of 0.075 m. What is the maximum acceleration of the ball?
    (a) 0.13 m/s\(^2\)   (c) 0.51 m/s\(^2\)   (e) 35 m/s\(^2\)
    (b) 0.20 m/s\(^2\)   (d) 2.6 m/s\(^2\)

11. The velocity of a certain simple harmonic oscillator is given by \( v = -(12 \text{ m/s}) \sin [(6.0 \text{ rad/s}) t] \). What is the amplitude of the simple harmonic motion?
    (a) 2.0 m   (c) 6.0 m   (e) 12 m
    (b) 4.0 m   (d) 8.0 m

12. The acceleration of a certain simple harmonic oscillator is given by \( a = -(15.8 \text{ m/s}^2) \cos (2.51t) \). What is the amplitude of the simple harmonic motion?
    (a) 2.51 m   (c) 6.30 m   (e) 15.8 m
    (b) 4.41 m   (d) 11.1 m

Section 10.3 Energy and Simple Harmonic Motion

13. A 1.0-kg object is suspended from a spring with \( k = 16 \text{ N/m} \). The mass is pulled 0.25 m downward from its equilibrium position and allowed to oscillate. What is the maximum kinetic energy of the object?
    (a) 0.25 J   (c) 1.0 J   (e) 4.0 J
    (b) 0.50 J   (d) 2.0 J

14. A spring required a force of 1.0 N to compress it 0.1 m. How much work is required to stretch the spring 0.4 m?
    (a) 0.4 J   (c) 0.8 J   (e) 4 J
    (b) 0.6 J   (d) 2 J

15. A certain spring compressed 0.20 m has 10 J of elastic potential energy. The spring is then cut into two halves and one of the halves is compressed by 0.20 m. How much potential energy is stored in the compressed half of the spring?
    (a) 5 J   (c) 14 J   (e) 40 J
    (b) 10 J   (d) 20 J
16. A 10-kg box is at rest at the end of an unstretched spring with constant \( k = 4000 \text{ N/m} \). The mass is struck with a hammer giving it a velocity of 6.0 m/s to the right across a frictionless surface. What is the amplitude of the resulting oscillation of this system?
(a) 0.3 m (d) 0.6 m
(b) 0.4 m (e) 2 m
(c) 0.5 m

17. A 1.0-kg block oscillates with a frequency of 10 Hz at the end of a certain spring. The spring is then cut into two halves. The 1.0-kg block is then made to oscillate at the end of one of the halves. What is the frequency of oscillation of the block?
(a) 5 Hz (c) 14 Hz (e) 40 Hz
(b) 10 Hz (d) 20 Hz

18. A 0.2-kg block is held in place by a force \( F \) that results in a 0.10-m compression of a spring beneath the block. The spring constant is \( 1.0 \times 10^2 \text{ N/m} \). Assuming the mass of the spring is negligible compared to that of the block, to what maximum height would the block rise if the force \( F \) were removed.
(a) 0.26 m (d) 5 m
(b) 0.52 m (e) 10 m
(c) 2.5 m

19. A spring with constant \( k = 40.0 \text{ N/m} \) is at the base of a frictionless, 30.0°-inclined plane. A 0.50-kg block is pressed against the spring, compressing it 0.20 m from its equilibrium position. The block is then released. If the block is not attached to the spring, how far up the incline will it travel before it stops?
(a) 0.080 m (c) 0.33 m (e) 3.2 m
(b) 0.16 m (d) 1.6 m

20. A ping-pong ball weighs 0.025 N. The ball is placed inside a cup that sits on top of a vertical spring. If the spring is compressed 0.055 m and released, the maximum height above the compressed position that the ball reaches is 2.84 m. Neglect air resistance and determine the spring constant.
(a) 47 N/m (c) 11 N/m (e) 2.6 N/m
(b) 24 N/m (d) 5.2 N/m

Questions 21 and 22 pertain to the situation described below:
A relaxed spring protrudes from an opening 0.0500 meters as shown in Figure A. A 1.00-kg block is found to just force the spring completely into the opening as shown in Figure B.
21. Determine the spring constant $k$.
   (a) 20.0 N/m  (c) 392 N/m  (e) 7840 N/m
   (b) 196 N/m  (d) 3920 N/m

22. How much potential energy is stored in the spring in Figure B?
   (a) 0.245 J  (c) 4.90 J  (e) 19.6 J
   (b) 0.490 J  (d) 9.80 J

23. The spring constant for the spring in a special cannon is 1800 N/m. In cocking the cannon, the spring is compressed 0.55 m. What is the initial speed of a 7.0-kg cannonball at rest on the free end of the spring when it is released?
   (a) 77 m/s  (c) 12 m/s  (e) 16 m/s
   (b) 140 m/s  (d) 8.8 m/s

24. A spring with a spring constant $k = 1600$ N/m is at rest on the bottom of an inclined plane. A 7.0-kg block slides down the plane and makes contact with the spring at point A as shown. After contact, the spring is compressed to point B, 0.20 m from point A, where the speed of the block is zero m/s. What was the speed of the block just before contact with the spring?
   (a) 3.2 m/s  (c) 2.4 m/s  (e) 4.2 m/s
   (b) 12 m/s  (d) 9.1 m/s

Section 10.4 The Pendulum

25. A pendulum is transported from sea-level, where the acceleration due to gravity $g$ is 9.80 m/s$^2$, to the bottom of Death Valley. At this location, the period of the pendulum is decreased by 3.00%. What is the value of $g$ in Death Valley?
   (a) 9.22 m/s$^2$  (c) 9.80 m/s$^2$  (e) 10.4 m/s$^2$
   (b) 9.51 m/s$^2$  (d) 10.1 m/s$^2$

26. In a certain clock, a pendulum of length $L_1$ has a period $T_1 = 0.95$ s. The length of the pendulum is adjusted to a new value $L_2$ such that $T_2 = 1.0$ s. What is the ratio $L_2/L_1$?
   (a) 0.90  (c) 1.0  (e) 1.3
   (b) 0.95  (d) 1.1

27. What is the period of a pendulum consisting of a 6-kg object oscillating on a 4-m string?
   (a) 0.25 s  (c) 1.0 s  (e) 4.0 s
   (b) 0.50 s  (d) 2.0 s

28. A simple pendulum consists of a ball of mass $m$ suspended from the ceiling using a string of length $L$. The ball is displaced from its equilibrium position by a small angle $\theta$. What is the magnitude of the restoring force that moves the ball toward its equilibrium position and produces simple harmonic motion?
   (a) $kx$  (c) $mg(\cos \theta)$  (e) $mgL(\sin \theta)$
   (b) $mg$  (d) $mg(\sin \theta)$

29. A simple pendulum on earth has a period of 6.0 s. What is the approximate period of this pendulum on the moon where the acceleration due to gravity is roughly 1/6 that of earth?
   (a) 1.0 s  (c) 6.0 s  (e) 36 s
   (b) 2.4 s  (d) 15 s
30. An iron ball hangs from a 24-m steel cable and is used in the demolition of a building at a location where the acceleration due to gravity is 9.9 m/s². The ball is swung outward from its equilibrium position for a distance of 4.5 m. Assuming the system behaves as a simple pendulum, find the maximum speed of the ball during its swing.

(a) 1.9 m/s  (c) 11 m/s  (e) 9.8 m/s
(b) 2.9 m/s  (d) 7.0 m/s

31. A thin, circular hoop with a radius of 0.22 m is hanging on a nail. Adam notices that the hoop is oscillating back and forth through small angles like a physical pendulum. The moment of inertia of the hoop for the rotational axis passing through the nail is \( I = 2mr^2 \). What is the period of the hoop?

(a) 1.3 s  (c) 0.59 s  (e) 0.21 s
(b) 0.94 s  (d) 0.42 s

Section 10.5 Damped Harmonic Motion
Section 10.6 Driven Harmonic Motion and Resonance

32. Which one of the following terms is used to describe a system in which the degree of damping is just enough to stop the system from oscillating?

(a) critically damped  (c) slightly damped  (e) resonance
(b) underdamped  (d) overdamped

33. Complete the following sentence: Resonance occurs in harmonic motion when

(a) the system is overdamped.
(b) the system is critically damped.
(c) the energy in the system is a minimum.
(d) the driving frequency is the same as the natural frequency of the system.
(e) the energy in the system is proportional to the square of the motion's amplitude.

Section 10.7 Elastic Deformation
Section 10.8 Stress, Strain, and Hooke’s Law

35. What are the SI units of the shear modulus?

(a) N/m²  (c) N·m  (e) N·m²
(b) N/m  (d) N/m³

36. Complete the following statement: Young's modulus cannot be applied to

(a) a stretched wire.  (c) a bending beam.  (e) a stretched rubber band.
(b) a compressed rod.  (d) a compressed liquid.

37. A cable stretches by an amount \( d \) when it supports a crate of mass \( M \). The cable is then cut in half. If the same crate is supported by either half of the cable, by how much will the cable stretch?

(a) \( d \)  (c) \( d/4 \)  (e) \( 4d \)
(b) \( d/2 \)  (d) \( 2d \)
38. A cable stretches by an amount $d$ as it supports a crate of mass $M$. The cable is cut in half. What is the mass of the load that can be supported by either half of the cable if the cable stretches by an amount $d$?
(a) $M/4$  
(b) $M/2$  
(c) $M$  
(d) $2M$  
(e) $4M$

39. A cable stretches by an amount $d$ when it supports a crate of mass $M$. The cable is replaced by another cable of the same material having the same length and twice the diameter. If the same crate is supported by the thicker cable, by how much will the cable stretch?
(a) $d/4$  
(b) $d/2$  
(c) $d$  
(d) $2d$  
(e) $4d$

40. A cable stretches by an amount $d$ when it supports a crate of mass $M$. The cable is replaced by another cable of the same material having the same length and twice the diameter. What is the mass of the load that can be supported by the thicker cable if it stretches by an amount $d$?
(a) $M/4$  
(b) $M/2$  
(c) $M$  
(d) $2M$  
(e) $4M$

41. The maximum compressional stress that a bone can withstand is $1.6 \times 10^8$ N/m$^2$ before it breaks. A thighbone (femur), which is the largest and longest bone in the human body, has a cross sectional area of $7.7 \times 10^{-4}$ m$^2$. What is the maximum compressional force that can be applied to the thighbone?
(a) $2.1 \times 10^{11}$ N  
(b) $1.2 \times 10^5$ N  
(c) $4.8 \times 10^5$ N  
(d) $3.0 \times 10^3$ N  
(e) This cannot be determined since Young’s modulus is not given.

42. Young’s modulus of nylon is $5 \times 10^9$ N/m$^2$. A force of $5 \times 10^5$ N is applied to a 2-m length of nylon of cross sectional area 0.1 m$^2$. By what amount does the nylon stretch?
(a) $2 \times 10^{-1}$ m  
(b) $2 \times 10^{-2}$ m  
(c) $2 \times 10^{-3}$ m  
(d) $2 \times 10^{-4}$ m  
(e) $2 \times 10^{-5}$ m

43. The radius of a sphere of lead ($B = 4.2 \times 10^{10}$ N/m$^2$) is 1.000 m on the surface of the earth where the pressure is $1.01 \times 10^5$ N/m$^2$. The sphere is taken by submarine to the deepest part of the ocean to a depth of $1.10 \times 10^4$ m where it is exposed to a pressure is $1.25 \times 10^8$ N/m$^2$. What is the volume of the sphere at the bottom of the ocean?
(a) 4.176 m$^3$  
(b) 4.189 m$^3$  
(c) $1.25 \times 10^{-2}$ m$^3$  
(d) 0.134 m$^3$  
(e) 0.988 m$^3$

44. The shear modulus of aluminum is $2.4 \times 10^{10}$ N/m$^2$. An aluminum nail of radius $7.5 \times 10^{-4}$ m projects 0.035 m horizontally outward from a wall. A man hangs a wet raincoat of weight 25.5 N from the end of the nail. Assuming the wall holds its end of the nail, what is the vertical deflection of the other end of the nail?
(a) $1.8 \times 10^{-3}$ m  
(b) $3.3 \times 10^{-2}$ m  
(c) $7.9 \times 10^{-6}$ m  
(d) $4.2 \times 10^{-4}$ m  
(e) $2.1 \times 10^{-5}$ m

Questions 45 through 47 pertain to the situation described below:

A $5.0 \times 10^2$-N object is hung from the end of a wire of cross-sectional area 0.010 cm$^2$. The wire stretches from its original length of 200.00 cm to 200.50 cm.

45. What is the stress on the wire?
(a) $5.0 \times 10^2$ N/m$^2$  
(b) $1.0 \times 10^6$ N/m$^2$  
(c) $1.0 \times 10^8$ N/m$^2$  
(d) $5.0 \times 10^6$ N/m$^2$  
(e) $5.0 \times 10^8$ N/m$^2$
46. What is the elongation strain on the wire?
(a) $1.0 \times 10^2$  
(b) $1.0 \times 10^{-2}$
(c) $5.0 \times 10^2$  
(d) $2.5 \times 10^{-3}$  
(e) $4.0 \times 10^2$

47. Determine the Young's modulus of the wire.
(a) $1.0 \times 10^{11}$ N/m$^2$  
(b) $1.0 \times 10^8$ N/m$^2$  
(c) $2.0 \times 10^{11}$ N/m$^2$  
(d) $2.0 \times 10^9$ N/m$^2$  
(e) $5.0 \times 10^{12}$ N/m$^2$

Questions 48 and 49 pertain to the situation described below:

A plastic box has an initial volume of 2.00 m$^3$. It is then submerged below the surface of a liquid and its volume decreases to 1.96 m$^3$.

48. What is the volume strain on the box?
(a) 0.02  
(b) 0.04  
(c) 0.2  
(d) 0.4  
(e) 0.98

49. Complete the following statement: In order to calculate the "stress" on the box, in addition to the information given, one must also know
(a) the mass of the box.  
(b) the bulk modulus of the material from which the box is made.  
(c) the shear modulus of the material from which the box is made.  
(d) the Young's modulus of the material from which the box is made.  
(e) the bulk modulus of the liquid.

50. Complete the following statement: In general, the term stress refers to
(a) a change in volume.  
(b) a change in length.  
(c) a force per unit area.  
(d) a fractional change in length.  
(e) a force per unit length.

51. Which one of the following statements concerning Hooke's law is false?
(a) Hooke’s law relates stress and strain.  
(b) Hooke’s law is valid only for springs.  
(c) Hooke’s law can be verified experimentally.  
(d) Hooke’s law can be applied to a wide range of materials.  
(e) Hooke's law is valid only within the elastic limit of a given material.

52. A cylinder with a radius of 0.120 m is placed between the plates of a hydraulic press as illustrated in the drawing. A $4.45 \times 10^5$-N force is applied to the cylinder. What is the pressure on the end of the cylinder due to the applied force?
(a) $9.84 \times 10^6$ Pa  
(b) $3.13 \times 10^5$ Pa  
(c) $6.18 \times 10^5$ Pa  
(d) $5.34 \times 10^4$ Pa  
(e) $3.71 \times 10^5$ Pa

Additional Problems

53. A 0.750-kg object hanging from a vertical spring is observed to oscillate with a period of 2.00 s. When the 0.750-kg object is removed and replaced by a 1.25-kg object, what will be the period of oscillation?
(a) 1.55 s  
(b) 2.58 s  
(c) 3.32 s  
(d) 4.38 s  
(e) 7.45 s
54. A 0.800-kg block is placed on top of a vertically oriented spring as shown. The block is not attached to the spring, but the spring is attached to the floor. The block oscillates in simple harmonic motion. If the spring constant is 95.0 N/m, determine the amplitude at which the block loses contact with the spring.

(a) 0.0505 m (d) 0.0825 m
(b) 0.0615 m (e) 0.0945 m
(c) 0.0735 m

Questions 55 through 61 pertain to the situation described below:

When a 0.20-kg block is suspended from a vertically hanging spring, it stretches the spring from its original length of 0.050 m to 0.060 m. The same block is attached to the same spring and placed on a horizontal, frictionless surface as shown. The block is then pulled so that the spring stretches to a total length of 0.10 m. The block is released at time \( t = 0 \) s and undergoes simple harmonic motion.

55. What is the frequency of the motion?
(a) 0.50 Hz (c) 5.0 Hz (e) 31 Hz
(b) 1.00 Hz (d) 10.0 Hz

56. Complete the following statement: In order to increase the frequency of the motion, one would have to
(a) reduce the spring constant.
(b) decrease the mass of the block on the end of the spring.
(c) increase the length of the spring.
(d) reduce the distance that the spring is initially stretched.
(e) increase the distance that the spring is initially stretched.

57. Which one of the following statements is true concerning the motion of the block?
(a) Its acceleration is constant.
(b) The period of its motion depends on its amplitude.
(c) Its acceleration is greatest when the spring returns to the 5.0 cm position.
(d) Its velocity is greatest when the mass has reached its maximum displacement.
(e) Its acceleration is greatest when the mass has reached its maximum displacement.

58. Which one of the following expressions gives the displacement of the block as a function of time?
Let \( x \) be in cm and \( t \) in seconds.

(a) \( x = 5 \cos(10\pi t) \) (c) \( x = 10 \cos(5\pi t) \) (e) \( x = 10 \cos(10\pi t) \)
(b) \( x = 5 \sin(10\pi t) \) (d) \( x = 10 \sin(5\pi t) \)

59. What is the speed of the block each time the spring is 5.0 cm long?

(a) zero cm/s (c) 16 cm/s (e) 160 cm/s
(b) 5 cm/s (d) 120 cm/s

60. What is the maximum acceleration of the block?

(a) 1.6 m/s^2 (c) 49 m/s^2 (e) 160 m/s^2
(b) 3.1 m/s^2 (d) 98 m/s^2

61. What is the total mechanical energy of the system at any instant?

(a) 0.25 J (c) 0.98 J (e) 9.8 J
(b) 0.49 J (d) 4.9 J
62. A 2.0-kg object is attached to a spring \((k = 55.6 \text{ N/m})\) that hangs vertically from the ceiling. The object is displaced 0.045 m vertically. When the object is released, the system undergoes simple harmonic motion. What is the magnitude of the maximum acceleration of the object?

(a) 1.3 m/s\(^2\)  
(b) 2.3 m/s\(^2\)  
(c) 4.4 m/s\(^2\)  
(d) 9.8 m/s\(^2\)  
(e) 11 m/s\(^2\)

63. The brick shown in the drawing is glued to the floor. A 3500-N force is applied to the top surface of the brick as shown. If the brick has a shear modulus of \(5.4 \times 10^9 \text{ N/m}^2\), how far to the right does the top face move relative to the stationary bottom face?

(a) \(5.8 \times 10^{-6} \text{ m}\)  
(b) \(2.6 \times 10^{-6} \text{ m}\)  
(c) \(1.1 \times 10^{-6} \text{ m}\)  
(d) \(6.5 \times 10^{-7} \text{ m}\)  
(e) \(3.4 \times 10^{-7} \text{ m}\)