Chapter 15: OSCILLATIONS

1. In simple harmonic motion, the restoring force must be proportional to the:
   A. amplitude
   B. frequency
   C. velocity
   D. displacement
   E. displacement squared

   ans: D

2. An oscillatory motion must be simple harmonic if:
   A. the amplitude is small
   B. the potential energy is equal to the kinetic energy
   C. the motion is along the arc of a circle
   D. the acceleration varies sinusoidally with time
   E. the derivative, dU/dx, of the potential energy is negative

   ans: D

3. In simple harmonic motion, the magnitude of the acceleration is:
   A. constant
   B. proportional to the displacement
   C. inversely proportional to the displacement
   D. greatest when the velocity is greatest
   E. never greater than g

   ans: B

4. A particle is in simple harmonic motion with period T. At time $t = 0$ it is at the equilibrium point. Of the following times, at which time is it furthest from the equilibrium point?
   A. $0.5T$
   B. $0.7T$
   C. T
   D. $1.4T$
   E. $1.5T$

   ans: B

5. A particle moves back and forth along the x axis from $x = -x_m$ to $x = +x_m$, in simple harmonic motion with period T. At time $t = 0$ it is at $x = +x_m$. When $t = 0.75T$:
   A. it is at $x = 0$ and is traveling toward $x = +x_m$
   B. it is at $x = 0$ and is traveling toward $x = -x_m$
   C. it at $x = +x_m$ and is at rest
   D. it is between $x = 0$ and $x = +x_m$ and is traveling toward $x = -x_m$
   E. it is between $x = 0$ and $x = -x_m$ and is traveling toward $x = -x_m$

   ans: A

6. A particle oscillating in simple harmonic motion is:
   A. never in equilibrium because it is in motion
   B. never in equilibrium because there is always a force
   C. in equilibrium at the ends of its path because its velocity is zero there
   D. in equilibrium at the center of its path because the acceleration is zero there
   E. in equilibrium at the ends of its path because the acceleration is zero there

   ans: D

7. An object is undergoing simple harmonic motion. Throughout a complete cycle it:
   A. has constant speed
   B. has varying amplitude
   C. has varying period
   D. has varying acceleration
   E. has varying mass

   ans: D

8. When a body executes simple harmonic motion, its acceleration at the ends of its path must be:
   A. zero
   B. less than g
   C. more than g
   D. suddenly changing in sign
   E. none of these

   ans: E

9. A particle is in simple harmonic motion with period T. At time $t = 0$ it is halfway between the equilibrium point and an end point of its motion, traveling toward the end point. The next time it is at the same place is:
   A. $t = T$
   B. $t = T/2$
   C. $t = T/4$
   D. $t = T/8$
   E. none of the above

   ans: E

10. An object attached to one end of a spring makes 20 complete oscillations in 10 s. Its period is:
   A. 2 Hz
   B. 10 s
   C. 0.5 Hz
   D. 2 s
   E. 0.50 s

   ans: E

11. An object attached to one end of a spring makes 20 vibrations in 10 s. Its frequency is:

A. 2 Hz
B. 10 s
C. 0.05 Hz
D. 2 s
E. 0.50 s

ans: A

12. An object attached to one end of a spring makes 20 vibrations in 10 s. Its angular frequency is:

A. 0.79 rad/s
B. 1.57 rad/s
C. 2.0 rad/s
D. 6.3 rad/s
E. 12.6 rad/s

ans: E

13. Frequency f and angular frequency ω are related by

A. $f = \pi\omega$
B. $f = 2\pi\omega$
C. $f = \omega/\pi$
D. $f = \omega/2\pi$
E. $f = 2\omega/\pi$

ans: D

14. A block attached to a spring oscillates in simple harmonic motion along the x axis. The limits of its motion are $x = 10$ cm and $x = 50$ cm and it goes from one of these extremes to the other in 0.25 s. Its amplitude and frequency are:

A. 40 cm, 2 Hz
B. 20 cm, 4 Hz
C. 40 cm, 2 Hz
D. 25 cm, 4 Hz
E. 20 cm, 2 Hz

ans: B

15. A weight suspended from an ideal spring oscillates up and down with a period T. If the amplitude of the oscillation is doubled, the period will be:

A. T
D. $1.5T$
B. $2T$
C. $T/2$
E. $4T$

ans: A

16. In simple harmonic motion, the magnitude of the acceleration is greatest when:
    A. the displacement is zero
    B. the displacement is maximum
    C. the speed is maximum
    D. the force is zero
    E. the speed is between zero and its maximum

    ans: B

17. In simple harmonic motion, the displacement is maximum when the:
    A. acceleration is zero
    B. velocity is maximum
    C. velocity is zero
    D. kinetic energy is maximum
    E. momentum is maximum

    ans: C

18. In simple harmonic motion:
    A. the acceleration is greatest at the maximum displacement
    B. the velocity is greatest at the maximum displacement
    C. the period depends on the amplitude
    D. the acceleration is constant
    E. the acceleration is greatest at zero displacement

    ans: A

19. The amplitude and phase constant of an oscillator are determined by:
    A. the frequency
    B. the angular frequency
    C. the initial displacement alone
    D. the initial velocity alone
    E. both the initial displacement and velocity

    ans: E

20. Two identical undamped oscillators have the same amplitude of oscillation only if:
    A. they are started with the same displacement x_0
    B. they are started with the same velocity v_0
    C. they are started with the same phase
    D. they are started so the combination $\omega^2 x_0^2 + v_0^2$ is the same
    E. they are started so the combination $x_0^2 + \omega^2 v_0^2$ is the same

    ans: D

21. The amplitude of any oscillator can be doubled by:
    A. doubling only the initial displacement
    B. doubling only the initial speed
    C. doubling the initial displacement and halving the initial speed
    D. doubling the initial speed and halving the initial displacement
    E. doubling both the initial displacement and the initial speed

    ans: E

22. It is impossible for two particles, each executing simple harmonic motion, to remain in phase with each other if they have different:

A. masses
B. periods
C. amplitudes
D. spring constants
E. kinetic energies

ans: B

23. The acceleration of a body executing simple harmonic motion leads the velocity by what phase?

A. 0
B. $\pi/8$ rad
C. $\pi/4$ rad
D. $\pi/2$ rad
E. π rad

ans: D

24. The displacement of an object oscillating on a spring is given by $x(t) = x_m \cos(\omega t + \phi)$. If the initial displacement is zero and the initial velocity is in the negative x direction, then the phase constant ϕ is:

A. 0
B. $\pi/2$ rad
C. π rad
D. $3\pi/2$ rad
E. 2π rad

ans: B

25. The displacement of an object oscillating on a spring is given by $x(t) = x_m \cos(\omega t + \phi)$. If the object is initially displaced in the negative x direction and given a negative initial velocity, then the phase constant ϕ is between:

A. 0 and $\pi/2$ rad
B. $\pi/2$ and π rad
C. π and $3\pi/2$ rad
D. $3\pi/2$ and 2π rad
E. none of the above (ϕ is exactly 0, $\pi/2$, π, or $3\pi/2$ rad)

ans: B

26. A certain spring elongates 9.0 mm when it is suspended vertically and a block of mass M is hung on it. The natural angular frequency of this block-spring system:

A. is 0.088 rad/s
B. is 33 rad/s
C. is 200 rad/s
D. is 1140 rad/s
E. cannot be computed unless the value of M is given

ans: B

27. An object of mass m, oscillating on the end of a spring with spring constant k, has amplitude A. Its maximum speed is:

A. $A\sqrt{k/m}$
B. A^2k/m
C. $A\sqrt{m/k}$
D. Am/k
E. A^2m/k

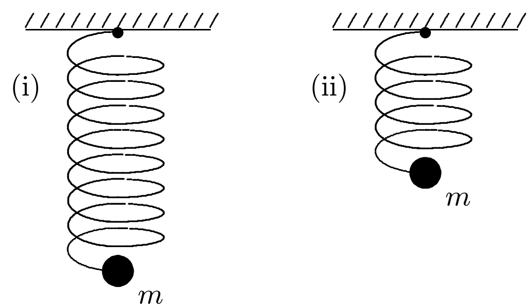
ans: A

28. A 0.20-kg object attached to a spring whose spring constant is 500 N/m executes simple harmonic motion. If its maximum speed is 5.0 m/s, the amplitude of its oscillation is:

A. 0.0020 m
B. 0.10 m
C. 0.20 m
D. 25 m
E. 250 m

ans: B

29. A simple harmonic oscillator consists of an particle of mass m and an ideal spring with spring constant k. Particle oscillates as shown in (i) with period T. If the spring is cut in half and used with the same particle, as shown in (ii), the period will be:



A. $2T$
B. $\sqrt{2}T$
C. $T/\sqrt{2}$
D. T
E. $T/2$

ans: C

30. A particle moves in simple harmonic motion according to $x = 2\cos(50t)$, where x is in meters and t is in seconds. Its maximum velocity in m/s is:

A. $100\sin(50t)$
B. $100\cos(50t)$
C. 100
D. 200
E. none of these

ans: C

31. A 3-kg block, attached to a spring, executes simple harmonic motion according to $x = 2\cos(50t)$ where x is in meters and t is in seconds. The spring constant of the spring is:

A. $1\,\mathrm{N/m}$
B. $100\,\mathrm{N/m}$
C. $150\,\mathrm{N/m}$
D. $7500\,\mathrm{N/m}$
E. none of these

ans: D

32. Let U be the potential energy (with the zero at zero displacement) and K be the kinetic energy of a simple harmonic oscillator. U_{avg} and K_{avg} are the average values over a cycle. Then:

A. $K_{\text{avg}} > U_{\text{avg}}$
B. $K_{\text{avg}} < U_{\text{avg}}$
C. $K_{\text{avg}} = U_{\text{avg}}$
D. $K = 0$ when $U = 0$
E. $K + U = 0$

ans: C

33. A particle is in simple harmonic motion along the x axis. The amplitude of the motion is x_m. At one point in its motion its kinetic energy is $K = 5\,\mathrm{J}$ and its potential energy (measured with $U = 0$ at $x = 0$) is $U = 3\,\mathrm{J}$. When it is at $x = x_m$, the kinetic and potential energies are:

A. $K = 5\,\mathrm{J}$ and $U = 3\,\mathrm{J}$
B. $K = 5\,\mathrm{J}$ and $U = -3\,\mathrm{J}$
C. $K = 8\,\mathrm{J}$ and $U = 0$
D. $K = 0$ and $U = 8\,\mathrm{J}$
E. $K = 0$ and $U = -8\,\mathrm{J}$

ans: D

34. A particle is in simple harmonic motion along the x axis. The amplitude of the motion is x_m. When it is at $x = x_1$, its kinetic energy is $K = 5\,\mathrm{J}$ and its potential energy (measured with $U = 0$ at $x = 0$) is $U = 3\,\mathrm{J}$. When it is at $x = -\frac{1}{2}x_1$, the kinetic and potential energies are:

A. $K = 5\,\mathrm{J}$ and $U = 3\,\mathrm{J}$
B. $K = 5\,\mathrm{J}$ and $U = -3\,\mathrm{J}$
C. $K = 8\,\mathrm{J}$ and $U = 0$
D. $K = 0$ and $U = 8\,\mathrm{J}$
E. $K = 0$ and $U = -8\,\mathrm{J}$

ans: A

35. A 0.25-kg block oscillates on the end of the spring with a spring constant of $200\,\mathrm{N/m}$. If the system has an energy of $6.0\,\mathrm{J}$, then the amplitude of the oscillation is:

A. $0.06\,\mathrm{m}$
B. $0.17\,\mathrm{m}$
C. $0.24\,\mathrm{m}$
D. $4.9\,\mathrm{m}$
E. $6.9\,\mathrm{m}$

ans: C

36. A 0.25-kg block oscillates on the end of the spring with a spring constant of 200 N/m. If the system has an energy of 6.0 J, then the maximum speed of the block is:

A. 0.06 m/s
B. 0.17 m/s
C. 0.24 m/s
D. 4.9 m/s
E. 6.9 m/s

ans: E

37. A 0.25-kg block oscillates on the end of the spring with a spring constant of 200 N/m. If the oscillation is started by elongating the spring 0.15 m and giving the block a speed of 3.0 m/s, then the maximum speed of the block is:

A. 0.13 m/s
B. 0.18 m/s
C. 3.7 m/s
D. 5.2 m/s
E. 13 m/s

ans: D

38. A 0.25-kg block oscillates on the end of the spring with a spring constant of 200 N/m. If the oscillation is started by elongating the spring 0.15 m and giving the block a speed of 3.0 m/s, then the amplitude of the oscillation is:

A. 0.13 m
B. 0.18 m
C. 3.7 m
D. 5.2 m
E. 13 m

ans: B

39. An object on the end of a spring is set into oscillation by giving it an initial velocity while it is at its equilibrium position. In the first trial the initial velocity is v_0 and in the second it is $4v_0$. In the second trial:

A. the amplitude is half as great and the maximum acceleration is twice as great
B. the amplitude is twice as great and the maximum acceleration is half as great
C. both the amplitude and the maximum acceleration are twice as great
D. both the amplitude and the maximum acceleration are four times as great
E. the amplitude is four times as great and the maximum acceleration is twice as great

ans: C

40. A block attached to a spring undergoes simple harmonic motion on a horizontal frictionless surface. Its total energy is 50 J. When the displacement is half the amplitude, the kinetic energy is:

A. zero
B. 12.5 J
C. 25 J
D. 37.5 J
E. 50 J

ans: D

41. A mass-spring system is oscillating with amplitude A. The kinetic energy will equal the potential energy only when the displacement is:

A. zero
B. $\pm A/4$
C. $\pm A/\sqrt{2}$
D. $\pm A/2$
E. anywhere between $-A$ and $+A$

ans: C

42. If the length of a simple pendulum is doubled, its period will:

A. halve
B. be greater by a factor of $\sqrt{2}$
C. be less by a factor of $\sqrt{2}$
D. double
E. remain the same

ans: B

43. The period of a simple pendulum is 1 s on Earth. When brought to a planet where g is one-tenth that on Earth, its period becomes:

A. 1 s
B. $1/\sqrt{10}$ s
C. $1/10$ s
D. $\sqrt{10}$ s
E. 10 s

ans: D

44. The amplitude of oscillation of a simple pendulum is increased from 1° to 4°. Its maximum acceleration changes by a factor of:

A. 1/4
B. 1/2
C. 2
D. 4
E. 16

ans: D

45. A simple pendulum of length L and mass M has frequency f. To increase its frequency to $2f$:

A. increase its length to $4L$
B. increase its length to $2L$
C. decrease its length to $L/2$
D. decrease its length to $L/4$
E. decrease its mass to $< M/4$

ans: D

46. A simple pendulum consists of a small ball tied to a string and set in oscillation. As the pendulum swings the tension force of the string is:

A. constant
B. a sinusoidal function of time
C. the square of a sinusoidal function of time
D. the reciprocal of a sinusoidal function of time
E. none of the above

ans: E

47. A simple pendulum has length L and period T. As it passes through its equilibrium position, the string is suddenly clamped at its midpoint. The period then becomes:

A. $2T$
B. T
C. $T/2$
D. $T/4$
E. none of these

ans: E

48. A simple pendulum is suspended from the ceiling of an elevator. The elevator is accelerating upwards with acceleration a. The period of this pendulum, in terms of its length L, g, and a is:

A. $2\pi\sqrt{L/g}$
B. $2\pi\sqrt{L/(g+a)}$
C. $2\pi\sqrt{L/(g-a)}$
D. $2\pi\sqrt{L/a}$
E. $(1/2\pi)\sqrt{g/L}$

ans: B

49. Three physical pendulums, with masses m_1, $m_2 = 2m_1$, and $m_3 = 3m_1$, have the same shape and size and are suspended at the same point. Rank them according to their periods, from shortest to longest.

A. 1, 2, 3
B. 3, 2, 1
C. 2, 3, 1
D. 2, 1, 3
E. All the same

ans: E

50. Five hoops are each pivoted at a point on the rim and allowed to swing as physical pendulums. The masses and radii are

hoop 1: $M = 150\,\text{g}$ and $R = 50\,\text{cm}$
hoop 2: $M = 200\,\text{g}$ and $R = 40\,\text{cm}$
hoop 3: $M = 250\,\text{g}$ and $R = 30\,\text{cm}$
hoop 4: $M = 300\,\text{g}$ and $R = 20\,\text{cm}$
hoop 5: $M = 350\,\text{g}$ and $R = 10\,\text{cm}$

Order the hoops according to the periods of their motions, smallest to largest.

A. 1, 2, 3, 4, 5
B. 5, 4, 3, 2, 1
C. 1, 2, 3, 5, 4
D. 1, 2, 5, 4, 3
E. 5, 4, 1, 2, 3

ans: B

51. A meter stick is pivoted at a point a distance a from its center and swings as a physical pendulum. Of the following values for a, which results in the shortest period of oscillation?

A. $a = 0.1\,\text{m}$
B. $a = 0.2\,\text{m}$
C. $a = 0.3\,\text{m}$
D. $a = 0.4\,\text{m}$
E. $a = 0.5\,\text{m}$

ans: C

52. The rotational inertia of a uniform thin rod about its end is $ML^2/3$, where M is the mass and L is the length. Such a rod is hung vertically from one end and set into small amplitude oscillation. If $L = 1.0\,\text{m}$ this rod will have the same period as a simple pendulum of length:

A. 33 cm
B. 50 cm
C. 67 cm
D. 100 cm
E. 150 cm

ans: C

53. Two uniform spheres are pivoted on horizontal axes that are tangent to their surfaces. The one with the longer period of oscillation is the one with:

A. the larger mass
B. the smaller mass
C. the larger rotational inertia
D. the smaller rotational inertia
E. the larger radius

ans: E

54. The x and y coordinates of a point each execute simple harmonic motion. The result might be a circular orbit if:

A. the amplitudes are the same but the frequencies are different
B. the amplitudes and frequencies are both the same
C. the amplitudes and frequencies are both different
D. the phase constants are the same but the amplitudes are different
E. the amplitudes and the phase constants are both different

ans: B

55. The x and y coordinates of a point each execute simple harmonic motion. The frequencies are the same but the amplitudes are different. The resulting orbit might be:

A. an ellipse
B. a circle
C. a parabola
D. a hyperbola
E. a square

ans: A

56. For an oscillator subjected to a damping force proportional to its velocity:

A. the displacement is a sinusoidal function of time.
B. the velocity is a sinusoidal function of time.
C. the frequency is a decreasing function of time.
D. the mechanical energy is constant.
E. none of the above is true.

ans: E

57. Five particles undergo damped harmonic motion. Values for the spring constant k, the damping constant b, and the mass m are given below. Which leads to the smallest rate of loss of mechanical energy?

A. $k = 100\,\mathrm{N/m}$, $m = 50\,\mathrm{g}$, $b = 8\,\mathrm{g/s}$
B. $k = 150\,\mathrm{N/m}$, $m = 50\,\mathrm{g}$, $b = 5\,\mathrm{g/s}$
C. $k = 150\,\mathrm{N/m}$, $m = 10\,\mathrm{g}$, $b = 8\,\mathrm{g/s}$
D. $k = 200\,\mathrm{N/m}$, $m = 8\,\mathrm{g}$, $b = 6\,\mathrm{g/s}$
E. $k = 100\,\mathrm{N/m}$, $m = 2\,\mathrm{g}$, $b = 4\,\mathrm{g/s}$

ans: B

58. A sinusoidal force with a given amplitude is applied to an oscillator. To maintain the largest amplitude oscillation the frequency of the applied force should be:

A. half the natural frequency of the oscillator
B. the same as the natural frequency of the oscillator
C. twice the natural frequency of the oscillator
D. unrelated to the natural frequency of the oscillator
E. determined from the maximum speed desired

ans: B

59. A sinusoidal force with a given amplitude is applied to an oscillator. At resonance the amplitude of the oscillation is limited by:

A. the damping force
B. the initial amplitude
C. the initial velocity
D. the force of gravity
E. none of the above

ans: A

60. An oscillator is subjected to a damping force that is proportional to its velocity. A sinusoidal force is applied to it. After a long time:

A. its amplitude is an increasing function of time
B. its amplitude is a decreasing function of time
C. its amplitude is constant
D. its amplitude is a decreasing function of time only if the damping constant is large
E. its amplitude increases over some portions of a cycle and decreases over other portions

ans: C

61. A block on a spring is subjected to a damping force that is proportional to its velocity and to an applied sinusoidal force. The energy dissipated by damping is supplied by:

A. the potential energy of the spring
B. the kinetic energy of the mass
C. gravity
D. friction
E. the applied force

ans: E

62. The table below gives the values of the spring constant k, damping constant b, and mass m for a particle in damped harmonic motion. Which of these takes the longest time for its mechanical energy to decrease to one-fourth of its initial value?

	k	b	m
A	k_0	b_0	m_0
B	$3k_0$	$2b_0$	m_0
C	$k_0/2$	$6b_0$	$2m_0$
D	$4k_0$	b_0	$2m_0$
E	k_0	b_0	$10m_0$

ans: E