

## 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  $\omega$  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.  $\pi$  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  $\phi$  is:
- A. 0
  - B.  $\pi/2$  rad
  - C.  $\pi$  rad
  - D.  $3\pi/2$  rad
  - E.  $2\pi$  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  $\phi$  is between:
- A. 0 and  $\pi/2$  rad
  - B.  $\pi/2$  and  $\pi$  rad
  - C.  $\pi$  and  $3\pi/2$  rad
  - D.  $3\pi/2$  and  $2\pi$  rad
  - E. none of the above ( $\phi$  is exactly 0,  $\pi/2$ ,  $\pi$ , 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.  $A^2m/k$

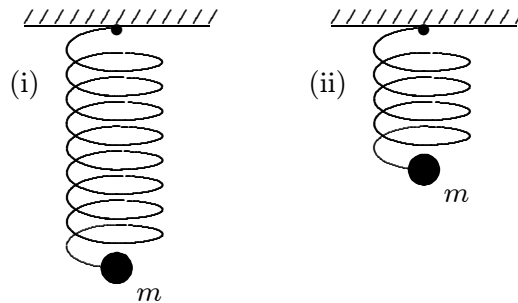
ans: A

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 a 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 N/m
  - B. 100 N/m
  - C. 150 N/m
  - D. 7500 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.  $U_{\text{avg}}$  and  $K_{\text{avg}}$  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  $K = 5 \text{ J}$  and its potential energy (measured with  $U = 0$  at  $x = 0$ ) is  $U = 3 \text{ J}$ . When it is at  $x = x_m$ , the kinetic and potential energies are:
- A.  $K = 5 \text{ J}$  and  $U = 3 \text{ J}$
  - B.  $K = 5 \text{ J}$  and  $U = -3 \text{ J}$
  - C.  $K = 8 \text{ J}$  and  $U = 0$
  - D.  $K = 0$  and  $U = 8 \text{ J}$
  - E.  $K = 0$  and  $U = -8 \text{ J}$
- 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  $K = 5 \text{ J}$  and its potential energy (measured with  $U = 0$  at  $x = 0$ ) is  $U = 3 \text{ J}$ . When it is at  $x = -\frac{1}{2}x_1$ , the kinetic and potential energies are:
- A.  $K = 5 \text{ J}$  and  $U = 3 \text{ J}$
  - B.  $K = 5 \text{ J}$  and  $U = -3 \text{ J}$
  - C.  $K = 8 \text{ J}$  and  $U = 0$
  - D.  $K = 0$  and  $U = 8 \text{ J}$
  - E.  $K = 0$  and  $U = -8 \text{ J}$
- ans: A
35. 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 amplitude of the oscillation is:
- A. 0.06 m
  - B. 0.17 m
  - C. 0.24 m
  - D. 4.9 m
  - E. 6.9 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  $1^\circ$  to  $4^\circ$ . 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:  $M = 150$  g and  $R = 50$  cm  
hoop 2:  $M = 200$  g and  $R = 40$  cm  
hoop 3:  $M = 250$  g and  $R = 30$  cm  
hoop 4:  $M = 300$  g and  $R = 20$  cm  
hoop 5:  $M = 350$  g and  $R = 10$  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.  $a = 0.1$  m
- B.  $a = 0.2$  m
- C.  $a = 0.3$  m
- D.  $a = 0.4$  m
- E.  $a = 0.5$  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  $L = 1.0$  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.  $k = 100 \text{ N/m}$ ,  $m = 50 \text{ g}$ ,  $b = 8 \text{ g/s}$
  - B.  $k = 150 \text{ N/m}$ ,  $m = 50 \text{ g}$ ,  $b = 5 \text{ g/s}$
  - C.  $k = 150 \text{ N/m}$ ,  $m = 10 \text{ g}$ ,  $b = 8 \text{ g/s}$
  - D.  $k = 200 \text{ N/m}$ ,  $m = 8 \text{ g}$ ,  $b = 6 \text{ g/s}$
  - E.  $k = 100 \text{ N/m}$ ,  $m = 2 \text{ g}$ ,  $b = 4 \text{ g/s}$
- 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:
- the damping force
  - the initial amplitude
  - the initial velocity
  - the force of gravity
  - 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:
- its amplitude is an increasing function of time
  - its amplitude is a decreasing function of time
  - its amplitude is constant
  - its amplitude is a decreasing function of time only if the damping constant is large
  - 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:
- the potential energy of the spring
  - the kinetic energy of the mass
  - gravity
  - friction
  - 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