Chapter 8: POTENTIAL ENERGY AND CONSERVATION OF ENERGY

1. Only if a force on a particle is conservative:
   A. is its work zero when the particle moves exactly once around any closed path
   B. is its work always equal to the change in the kinetic energy of the particle
   C. does it obey Newton's second law
   D. does it obey Newton's third law
   E. is it not a frictional force

   ans: A

2. A nonconservative force:
   A. violates Newton's second law
   B. violates Newton's third law
   C. cannot do any work
   D. must be perpendicular to the velocity of the particle on which it acts
   E. none of the above

   ans: E

3. The sum of the kinetic and potential energies of a system of objects is conserved:
   A. only when no external force acts on the objects
   B. only when the objects move along closed paths
   C. only when the work done by the resultant external force is zero
   D. always
   E. none of the above

   ans: E

4. A force on a particle is conservative if:
   A. its work equals the change in the kinetic energy of the particle
   B. it obeys Newton's second law
   C. it obeys Newton's third law
   D. its work depends on the end points of every motion, not on the path between
   E. it is not a frictional force

   ans: D

5. Two particles interact by conservative forces. In addition, an external force acts on each particle. They complete round trips, ending at the points where they started. Which of the following must have the same values at the beginning and end of this trip?
   A. the total kinetic energy of the two-particle system
   B. the potential energy of the two-particle system
   C. the mechanical energy of the two-particle system
   D. the total linear momentum of the two-particle system
   E. none of the above

   ans: B

6. Two objects interact with each other and with no other objects. Initially object A has a speed of 5 m/s and object B has a speed of 10 m/s. In the course of their motion they return to their initial positions. Then A has a speed of 4 m/s and B has a speed of 7 m/s. We can conclude:
   A. the potential energy changed from the beginning to the end of the trip
   B. mechanical energy was increased by nonconservative forces
   C. mechanical energy was decreased by nonconservative forces
   D. mechanical energy was increased by conservative forces
   E. mechanical energy was decreased by conservative forces

   ans: C

7. A good example of kinetic energy is provided by:
   A. a wound clock spring
   B. the raised weights of a grandfather's clock
   C. a tornado
   D. a gallon of gasoline
   E. an automobile storage battery

   ans: C

8. No kinetic energy is possessed by:
   A. a shooting star
   B. a rotating propeller on a moving airplane
   C. a pendulum at the bottom of its swing
   D. an elevator standing at the fifth floor
   E. a cyclone

   ans: D

9. The wound spring of a clock possesses:
   A. kinetic but no potential energy
   B. potential but no kinetic energy
   C. both potential and kinetic energy in equal amounts
   D. neither potential nor kinetic energy
   E. both potential and kinetic energy, but more kinetic energy than potential energy

   ans: B

10. A body at rest in a system is capable of doing work if:
    A. the potential energy of the system is positive
    B. the potential energy of the system is negative
    C. it is free to move in such a way as to decrease its kinetic energy
    D. it is free to move in such a way as to decrease the potential energy of the system
    E. it is free to move in such a way as to increase the potential energy of the system

    ans: D

11. Which one of the following five quantities CANNOT be used as a unit of potential energy?

A. watt·second
B. gram·cm/s^2
C. joule
D. kg·m^2/s^2
E. ft·lb

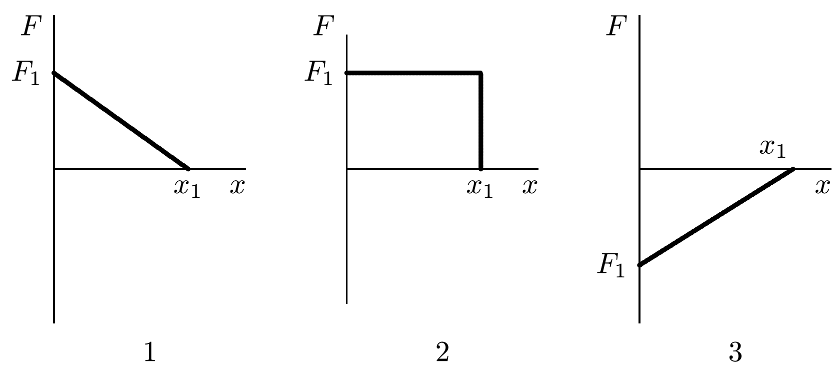
ans: B

12. Suppose that the fundamental dimensions are taken to be: force (F), velocity (V) and time (T). The dimensions of potential energy are then:

A. F/T
B. FVT
C. FV/T
D. F/T^2
E. FV^2/T^2

ans: B

13. The graphs below show the magnitude of the force on a particle as the particle moves along the positive x axis from the origin to $x = x_1$. The force is parallel to the x axis and is conservative. The maximum magnitude F_1 has the same value for all graphs. Rank the situations according to the change in the potential energy associated with the force, least (or most negative) to greatest (or most positive).



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

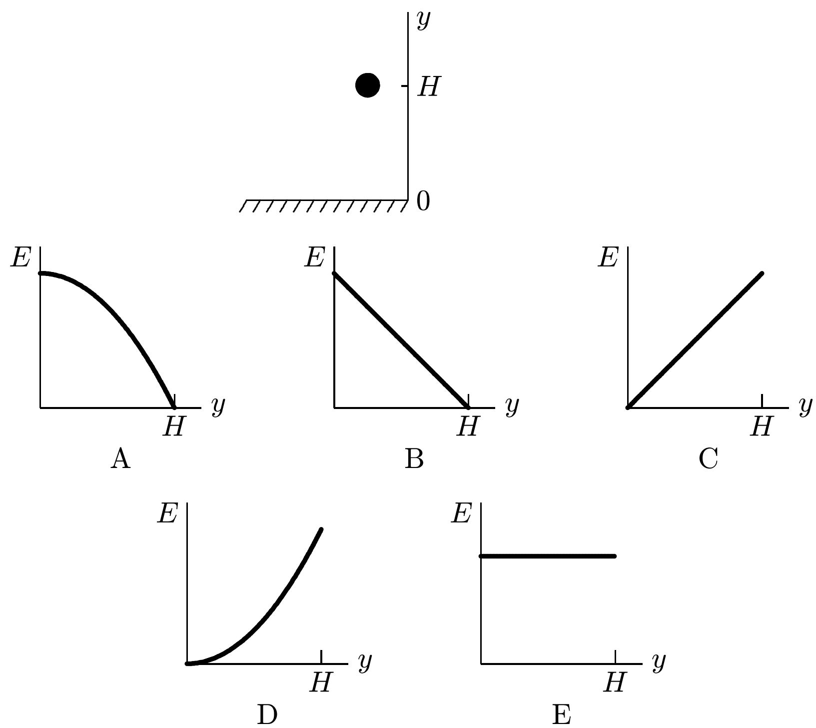
ans: E

14. A golf ball is struck by a golf club and falls on a green three meters above the tee. The potential energy of the Earth-ball system is greatest:

A. just before the ball is struck
B. just after the ball is struck
C. just after the ball lands on the green
D. when the ball comes to rest on the green
E. when the ball reaches the highest point in its flight

ans: E

15. A ball is held at a height H above a floor. It is then released and falls to the floor. If air resistance can be ignored, which of the five graphs below correctly gives the mechanical energy E of the Earth-ball system as a function of the altitude y of the ball?



ans: E

16. A 6.0-kg block is released from rest 80 m above the ground. When it has fallen 60 m its kinetic energy is approximately:

A. 4800 J
B. 3500 J
C. 1200 J
D. 120 J
E. 60 J

ans: B

17. A 2-kg block is thrown upward from a point 20 m above Earth's surface. At what height above Earth's surface will the gravitational potential energy of the Earth-block system have increased by 500 J?

A. 5 m
B. 25 m
C. 46 m
D. 70 m
E. 270 m

ans: C

18. An elevator is rising at constant speed. Consider the following statements:

I. the upward cable force is constant
II. the kinetic energy of the elevator is constant
III. the gravitational potential energy of the Earth-elevator system is constant
IV. the acceleration of the elevator is zero
V. the mechanical energy of the Earth-elevator system is constant

A. all five are true
B. only II and V are true
C. only IV and V are true
D. only I, II, and III are true
E. only I, II, and IV are true

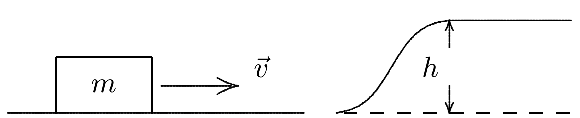
ans: E

19. A projectile of mass 0.50 kg is fired with an initial speed of 10 m/s at an angle of 60° above the horizontal. The potential energy of the projectile-Earth system (relative potential energy when the projectile is at ground level) is:

A. 25 J
B. 18.75 J
C. 12.5 J
D. 6.25 J
E. none of these

ans: B

20. For a block of mass m to slide without friction up the rise of height h shown, it must have a minimum initial kinetic energy of:



A. gh
B. mgh
C. $gh/2$
D. $mgh/2$
E. $2mgh$

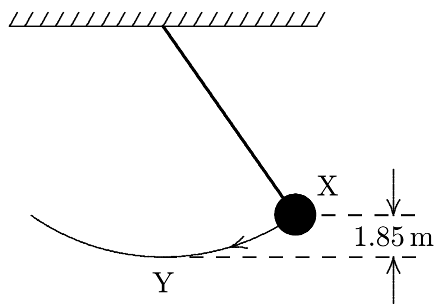
ans: B

21. A 2.2-kg block starts from rest on a rough inclined plane that makes an angle of 25° with the horizontal. The coefficient of kinetic friction is 0.25. As the block goes 2.0 m down the plane, the mechanical energy of the Earth-block system changes by:

A. 0
B. −9.8 J
C. 9.8 J
D. −18 J
E. 18 J

ans: B

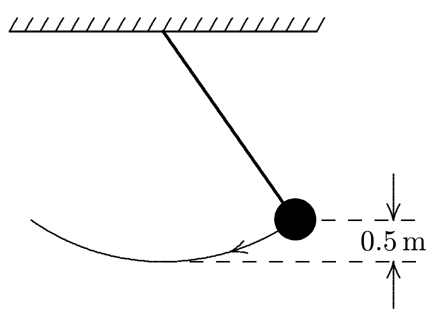
22. A simple pendulum consists of a 2.0-kg mass attached to a string. It is released from rest at X as shown. Its speed at the lowest point Y is about:



A. 0.90 m/s
B. $\sqrt{3.6}$ m/s
C. 3.6 m/s
D. 6.0 m/s
E. 36 m/s

ans: D

23. The long pendulum shown is drawn aside until the ball has risen 0.50 m. It is then given an initial speed of 3.0 m/s. The speed of the ball at its lowest position is:



A. zero
B. 0.89 m/s
C. 3.1 m/s
D. 3.7 m/s
E. 4.3 m/s

ans: E

24. A particle moves along the x axis under the influence of a stationary object. The net force on the particle is given by $F = (8\,\mathrm{N/m^3})x^3$. If the potential energy is taken to be zero for $x = 0$ then the potential energy is given by:

A. $(2\,\mathrm{J/m^4})x^4$
B. $(-2\,\mathrm{J/m^4})x^4$
C. $(24\,\mathrm{J/m^2}x^2$
D. $(-24\,\mathrm{J/m^2})x^2$
E. $5\,\mathrm{J} - (2\,\mathrm{J/m^4})x^4$

ans: B

25. A 0.20-kg particle moves along the x axis under the influence of a stationary object. The potential energy is given by

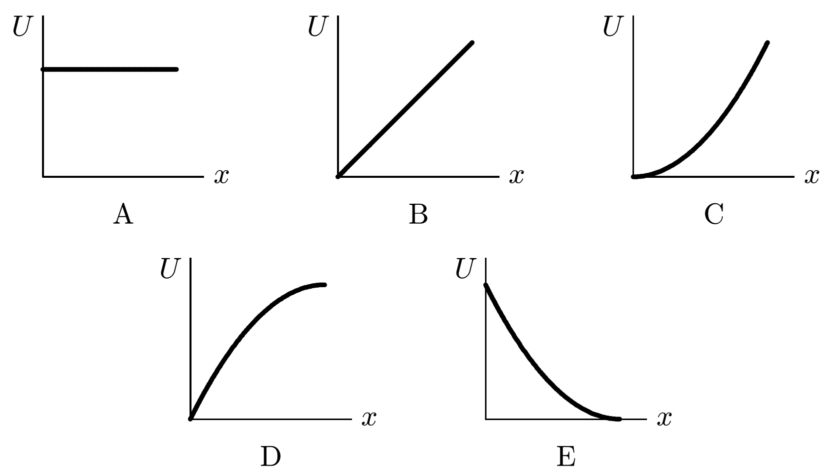
$$U(x) = (8.0\,\mathrm{J/m^2})x^2 + (2.0\,\mathrm{J/m^4})x^4\,,$$

where x is in coordinate of the particle. If the particle has a speed of $5.0\,\mathrm{m/s}$ when it is at $x = 1.0\,\mathrm{m}$, its speed when it is at the origin is:

A. 0
B. $2.5\,\mathrm{m/s}$
C. $5.7\,\mathrm{m/s}$
D. $7.9\,\mathrm{m/s}$
E. $11\,\mathrm{m/s}$

ans: E

26. Which of the five graphs correctly shows the potential energy of a spring as a function of its elongation x?



ans: C

27. A force of 10 N holds an ideal spring with a 20-N/m spring constant in compression. The potential energy stored in the spring is:

A. 0.5 J
B. 2.5 J
C. 5 J
D. 10 J
E. 200 J

ans: B

28. An ideal spring is used to fire a 15.0-g pellet horizontally. The spring has a spring constant of 20 N/m and is initially compressed by 7.0 cm. The kinetic energy of the pellet as it leaves the spring is:

A. zero
B. 2.5×10^{-2} J
C. 4.9×10^{-2} J
D. 9.8×10^{-2} J
E. 1.4 J

ans: C

29. A 0.50-kg block attached to an ideal spring with a spring constant of 80 N/m oscillates on a horizontal frictionless surface. The total mechanical energy is 0.12 J. The greatest extension of the spring from its equilibrium length is:

A. 1.5×10^{-3} m
B. 3.0×10^{-3} m
C. 0.039 m
D. 0.054 m
E. 18 m

ans: D

30. A 0.50-kg block attached to an ideal spring with a spring constant of 80 N/m oscillates on a horizontal frictionless surface. The total mechanical energy is 0.12 J. The greatest speed of the block is:

A. 0.15 m/s
B. 0.24 m/s
C. 0.49 m/s
D. 0.69 m/s
E. 1.46 m/s

ans: D

31. A 0.50-kg block attached to an ideal spring with a spring constant of 80 N/m oscillates on a horizontal frictionless surface. When the spring is 4.0 cm longer than its equilibrium length, the speed of the block is 0.50 m/s. The greatest speed of the block is:

A. 0.23 m/s
B. 0.32 m/s
C. 0.55 m/s
D. 0.71 m/s
E. 0.93 m/s

ans: D

32. A 0.5-kg block slides along a horizontal frictionless surface at 2 m/s. It is brought to rest by compressing a very long spring of spring constant 800 N/m. The maximum spring compression is:

A. 0
B. 3 cm
C. 5 cm
D. 80 cm
E. 80 m

ans: C

33. A block of mass m is initially moving to the right on a horizontal frictionless surface at a speed v. It then compresses a spring of spring constant k. At the instant when the kinetic energy of the block is equal to the potential energy of the spring, the spring is compressed a distance of:

A. $v\sqrt{m/2k}$
B. $(1/2)mv^2$
C. $(1/4)mv^2$
D. $mv^2/4k$
E. $(1/4)\sqrt{mv/k}$

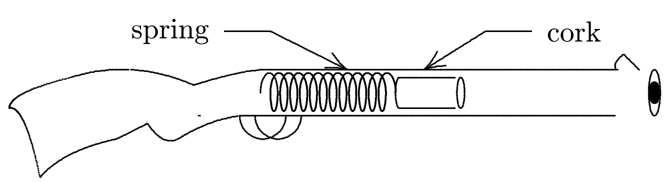
ans: A

34. A 700-N man jumps out of a window into a fire net 10 m below. The net stretches 2 m before bringing the man to rest and tossing him back into the air. The maximum potential energy of the net, compared to its unstretched potential energy, is:

A. 300 J
B. 710 J
C. 850 J
D. 7000 J
E. 8400 J

ans: E

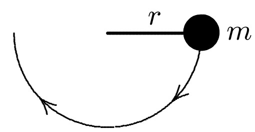
35. A toy cork gun contains a spring whose spring constant is 10.0 N/m. The spring is compressed 5.00 cm and then used to propel a 6.00-g cork. The cork, however, sticks to the spring for 1.00 cm beyond its unstretched length before separation occurs. The muzzle velocity of this cork is:



A. 1.02 m/s
B. 1.41 m/s
C. 2.00 m/s
D. 2.04 m/s
E. 4.00 m/s

ans: C

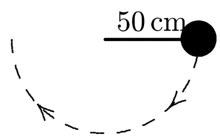
36. A small object of mass m, on the end of a light cord, is held horizontally at a distance r from a fixed support as shown. The object is then released. What is the tension force of the cord when the object is at the lowest point of its swing?



A. $mg/2$
B. mg
C. $2mg$
D. $3mg$
E. mgr

ans: D

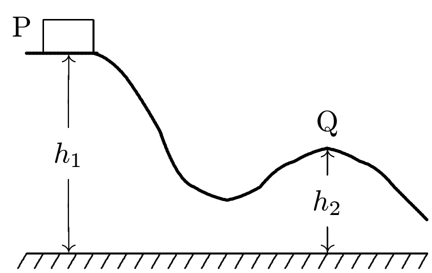
37. The string in the figure is 50 cm long. When the ball is released from rest, it swings along the dotted arc. How fast is it going at the lowest point in its swing?



A. 2.0 m/s
B. 2.2 m/s
C. 3.1 m/s
D. 4.4 m/s
E. 6.0 m/s

ans: C

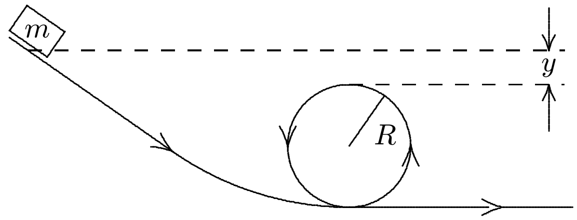
38. A block is released from rest at point P and slides along the frictionless track shown. At point Q, its speed is:



A. $2g\sqrt{h_1 - h_2}$
B. $2g(h_1 - h_2)$
C. $(h_1 - h_2)/2g$
D. $\sqrt{2g(h_1 - h_2)}$
E. $(h_1 - h_2)^2/2g$

ans: D

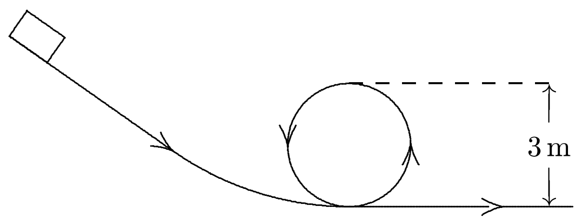
39. A small object of mass m starts from rest at the position shown and slides along the frictionless loop-the-loop track of radius R. What is the smallest value of y such that the object will slide without losing contact with the track?



A. $R/4$
B. $R/2$
C. R
D. $2R$
E. zero

ans: B

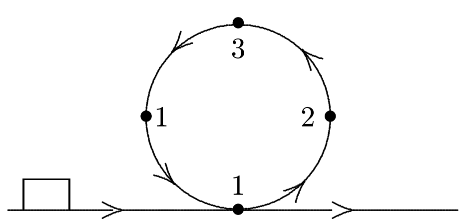
40. A small object slides along the frictionless loop-the-loop with a diameter of 3 m. What minimum speed must it have at the top of the loop?



A. 1.9 m/s
B. 3.8 m/s
C. 5.4 m/s
D. 15 m/s
E. 29 m/s

ans: B

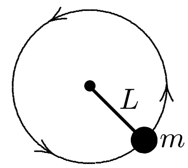
41. A rectangular block is moving along a frictionless path when it encounters the circular loop as shown. The block passes points 1, 2, 3, 4, 1 before returning to the horizontal track. At point 3:



A. its mechanical energy is a minimum
B. the forces on it are balanced
C. it is not accelerating
D. its speed is a minimum
E. it experiences a net upward force

ans: D

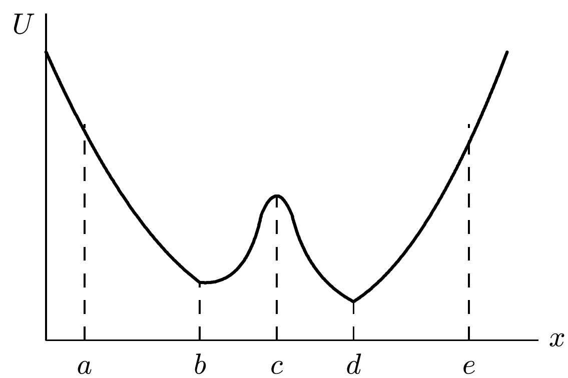
42. A ball of mass m, at one end of a string of length L, rotates in a vertical circle just fast enough to prevent the string from going slack at the top of the circle. The speed of the ball at the bottom of the circle is:



A. $\sqrt{2gL}$
B. $\sqrt{3gL}$
C. $\sqrt{4gL}$
D. $\sqrt{5gL}$
E. $\sqrt{7gL}$

ans: D

43. A particle is released from rest at the point $x = a$ and moves along the x axis subject to the potential energy function $U(x)$ shown. The particle:



A. moves to a point to the left of $x = e$, stops, and remains at rest
B. moves to a point to $x = e$, then moves to the left
C. moves to infinity at varying speed
D. moves to $x = b$, where it remains at rest
E. moves to $x = e$ and then to $x = d$, where it remains at rest

ans: B

44. The potential energy of a particle moving along the x axis is given by

$$U(x) = (8.0\,\text{J/m}^2)x^2 + (2.0\,\text{J/m}^4)x^4\,.$$

If the total mechanical energy is 9.0 J, the limits of motion are:

A. -0.96 m; $+0.96$ m
B. -2.2 m; $+2.2$ m
C. -1.6 m; $+1.6$ m
D. -0.96 m; $+2.2$ m
E. -0.96 m; $+1.6$ m

ans: A

45. The potential energy of a 0.20-kg particle moving along the x axis is given by

$$U(x) = (8.0\,\mathrm{J/m^2})x^2 + (2.0\,\mathrm{J/m^4})x^4 .$$

When the particle is at $x = 1.0\,\mathrm{m}$ it is traveling in the positive x direction with a speed of $5.0\,\mathrm{m/s}$. It next stops momentarily to turn around at $x =$

A. 0
B. $-1.1\,\mathrm{m}$
C. $1.1\,\mathrm{m}$
D. $-2.3\,\mathrm{m}$
E. $2.3\,\mathrm{m}$

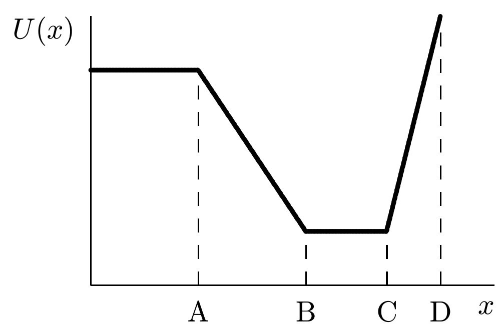
ans: C

46. Given a potential energy function $U(x)$, the corresponding force $\vec{F}$ is in the positive x direction if:

A. U is positive
B. U is negative
C. U is an increasing function of x
D. U is a decreasing function of x
E. it is impossible to obtain the direction of $\vec{F}$ from U

ans: D

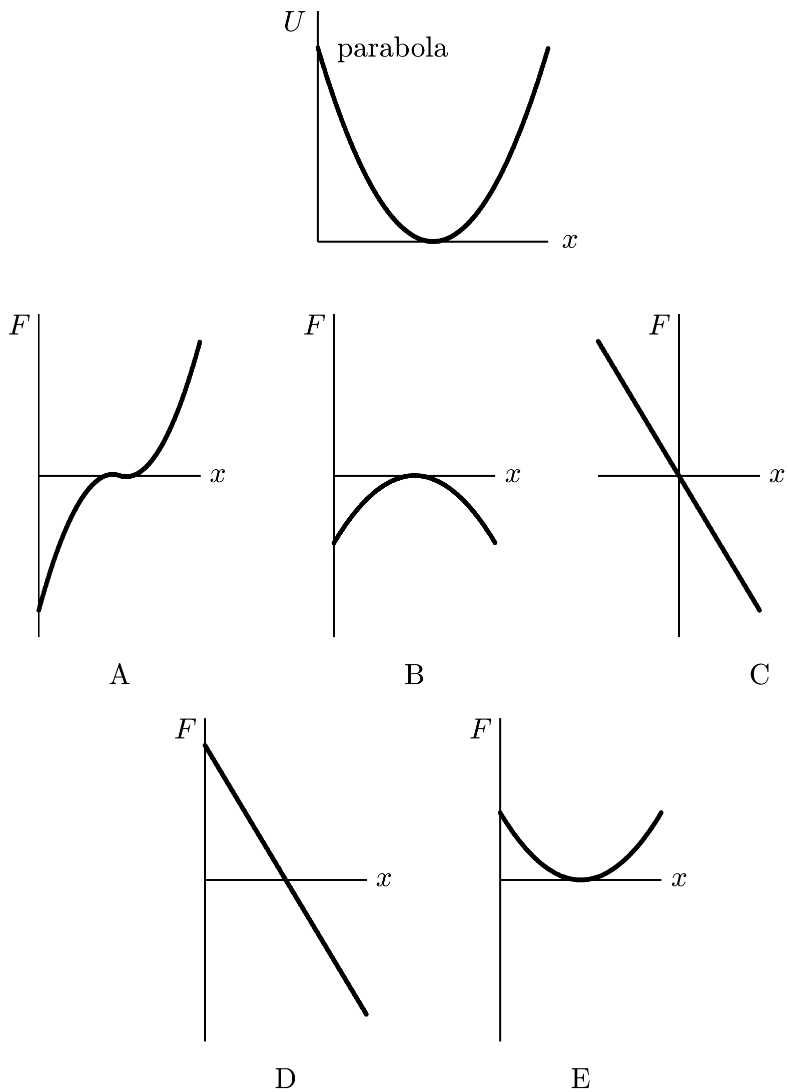
47. As a particle moves along the x axis it is acted upon by a conservative force. The potential energy is shown below as a function of the coordinate x of the particle. Rank the labeled regions according to the magnitude of the force, least to greatest.



A. AB, BC, CD
B. AB, CD, BC
C. BC, CD, AB
D. BC, AB, CD
E. CD, BC, AB

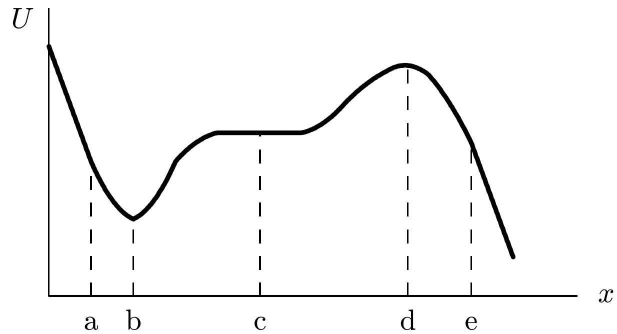
ans: D

48. The first graph shows the potential energy $U(x)$ for a particle moving on the x axis. Which of the other five graphs correctly gives the force F exerted on the particle?



ans: D

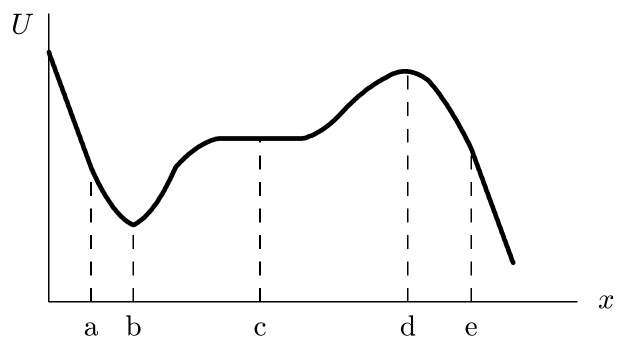
49. The diagram shows a plot of the potential energy as a function of x for a particle moving along the x axis. The points of stable equilibrium are:



A. only a
B. only b
C. only c
D. only d
E. b and d

ans: B

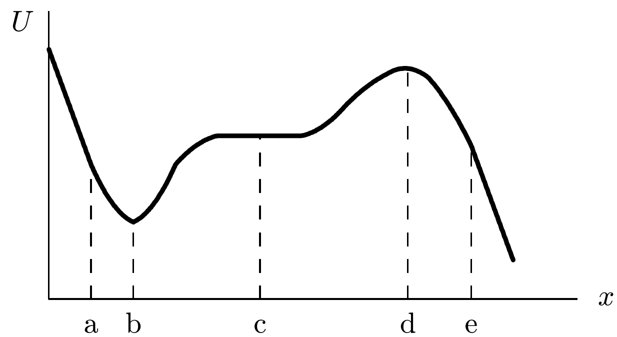
50. The diagram shows a plot of the potential energy as a function of x for a particle moving along the x axis. The points of unstable equilibrium are:



A. only a
B. only b
C. only c
D. only d
E. b and d

ans: D

51. The diagram shows a plot of the potential energy as a function of x for a particle moving along the x axis. Of the labeled points, the points of neutral equilibrium are:



A. only a
B. only b
C. only c
D. only d
E. b and d

ans: C

52. The potential energy of a body of mass m is given by $U = -mgx + \frac{1}{2}kx^2$. The corresponding force is:

A. $-mgx^2/2 + kx^3/6$
B. $mgx^2/2 - kx^3/6$
C. $-mg + kx/2$
D. $-mg + kx$
E. $mg - kx$

ans: E

53. The potential energy of a 0.20-kg particle moving along the x axis is given by

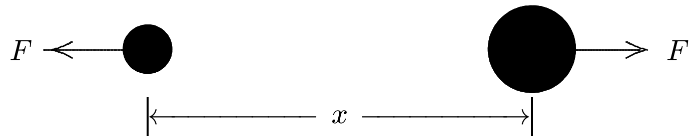
$$U(x) = (8.0\,\mathrm{J/m^2})x^2 + (2.0\,\mathrm{J/m^4})x^4 \,.$$

When the particle is at $x = 1.0\,\mathrm{m}$ the magnitude of its acceleration is:

A. 0
B. $-8\,\mathrm{m/s^2}$
C. $8\,\mathrm{m/s^2}$
D. $-40\,\mathrm{m/s^2}$
E. $40\,\mathrm{m/s^2}$

ans: D

54. The potential energy for the interaction between the two atoms in a diatomic molecule is $U = A/x^{12} - B/x^6$, where A and B are constants and x is the interatomic distance. The magnitude of the force of one atom on the other is:



A. $12A/|x|^{13} - 6B/|x|^7$
B. $-13A/|x|^{13} + 7B/|x|^7$
C. $-11A/|x|^{11} + 5B/|x|^5$
D. $72A/|x|^{12} - 72B/|x|^6$
E. $A/|x|^{13} - B/|x|^7$

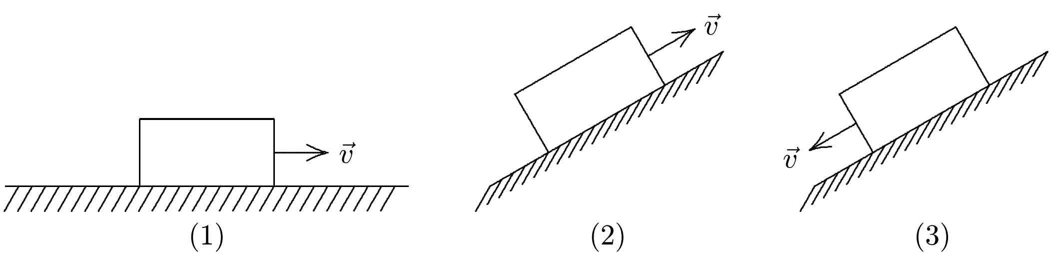
ans: A

55. The thermal energy of a system consisting of a thrown ball, Earth, and the air is most closely associated with:

A. the gravitational interaction of Earth and the ball
B. the kinetic energy of the ball as a whole
C. motions of the individual particles within the ball
D. motions of individual particles within the ball and the air
E. the kinetic energy of Earth as a whole

ans: D

56. Three identical blocks move either on a horizontal surface, up a plane, or down a plane, as shown below. They start with different speeds and continue to move until brought to rest by friction. They all move the same distance. Rank the three situations according to the initial speeds, least to greatest.



A. The same for all cases
B. 1, 2, 3
C. 1, then 2 and 3 tie
D. 3, 1, 2
E. 2, 1, 3

ans: D

57. Objects A and B interact with each other via both conservative and nonconservative forces. Let K_A and K_B be the kinetic energies, U be the potential energy, and E_{int} be the thermal energy. If no external agent does work on the objects then:

A. $K_A + U$ is conserved
B. $K_A + U + E_{\text{int}}$ is conserved
C. $K_A + K_B + E_{\text{int}}$ is conserved
D. $K_A + K_B + U$ is conserved
E. $K_A + K_B + U + E_{\text{int}}$ is conserved

ans: E

58. A block slides across a rough horizontal table top. The work done by friction changes:

A. only the kinetic energy
B. only the potential energy
C. only the internal energy
D. only the kinetic and potential energies
E. only the kinetic and internal energies

ans: E

59. A 25-g ball is released from rest 80 m above the surface of Earth. During the fall the total internal energy of the ball and air increases by 15 J. Just before it hits the surface its speed is

A. 19 m/s
B. 36 m/s
C. 40 m/s
D. 45 m/s
E. 53 m/s

ans: A

60. A 5-kg projectile is fired over level ground with a velocity of 200 m/s at an angle of 25° above the horizontal. Just before it hits the ground its speed is 150 m/s. Over the entire trip the change in the internal energy of the projectile and air is:

A. $+19,000$ J
B. $-19,000$ J
C. $+44,000$ J
D. $-44,000$ J
E. 0

ans: C

61. A 0.75-kg block slides on a rough horizontal table top. Just before it hits a horizontal ideal spring its speed is 3.5 m/s. It compresses the spring 5.7 cm before coming to rest. If the spring constant is 1200 N/m, the internal energy of the block and the table top must have:

A. not changed
B. decreased by 1.9 J
C. decreased by 2.6 J
D. increased by 1.9 J
E. increased by 2.6 J

ans: C

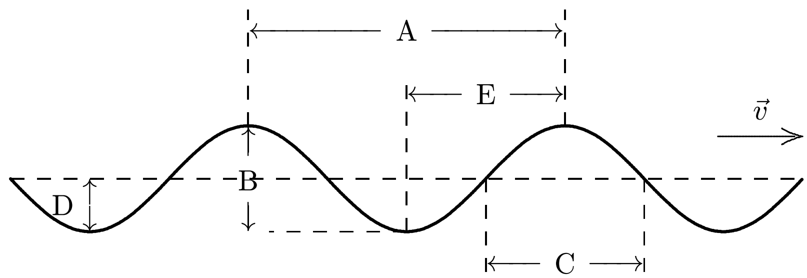
Chapter 16: WAVES — I

1. For a transverse wave on a string the string displacement is described by $y(x,t) = f(x - at)$, where f is a given function and a is a positive constant. Which of the following does NOT necessarily follow from this statement?

   A. The shape of the string at time $t = 0$ is given by $f(x)$.
   B. The shape of the waveform does not change as it moves along the string.
   C. The waveform moves in the positive x direction.
   D. The speed of the waveform is a.
   E. The speed of the waveform is x/t.

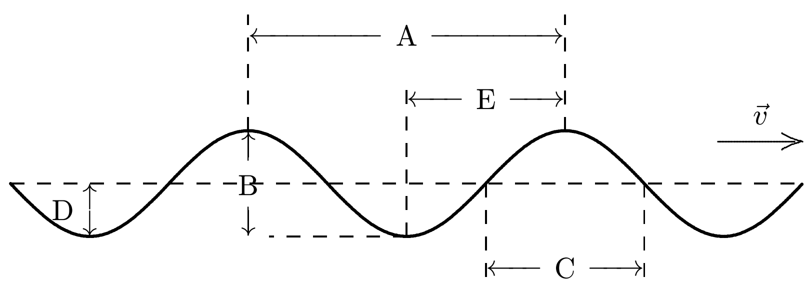
   ans: E

2. A sinusoidal wave is traveling toward the right as shown. Which letter correctly labels the amplitude of the wave?



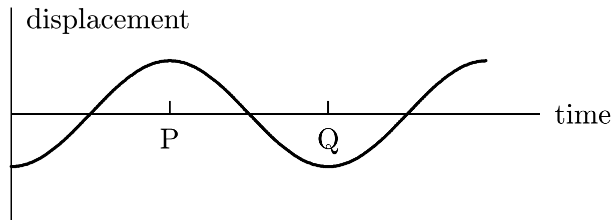
   ans: D

3. A sinusoidal wave is traveling toward the right as shown. Which letter correctly labels the wavelength of the wave?



   ans: A

4. In the diagram below, the interval PQ represents:



A. wavelength/2
B. wavelength
C. $2 \times$ amplitude
D. period/2
E. period

ans: D

5. Let f be the frequency, v the speed, and T the period of a sinusoidal traveling wave. The correct relationship is:

A. $f = 1/T$
B. $f = v + T$
C. $f = vT$
D. $f = v/T$
E. $f = T/v$

ans: A

6. Let f be the frequency, v the speed, and T the period of a sinusoidal traveling wave. The angular frequency is given by:

A. $1/T$
B. $2\pi/T$
C. vT
D. f/T
E. T/f

ans: B

7. The displacement of a string is given by

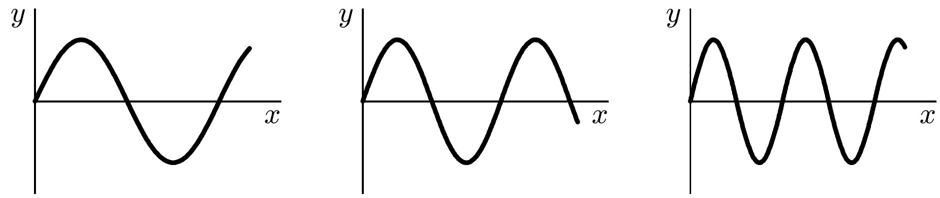
$$y(x,t) = y_m \sin(kx + \omega t)\,.$$

The wavelength of the wave is:

A. $2\pi k/\omega$
B. k/ω
C. ωk
D. $2\pi/k$
E. $k/2\pi$

ans: D

8. Three traveling sinusoidal waves are on identical strings, with the same tension. The mathematical forms of the waves are $y_1(x,t) = y_m \sin(3x - 6t)$, $y_2(x,t) = y_m \sin(4x - 8t)$, and $y_3(x,t) = y_m \sin(6x - 12t)$, where x is in meters and t is in seconds. Match each mathematical form to the appropriate graph below.



i ii iii

A. y_1: i, y_2: ii, y_3: iii
B. y_1: iii, y_2: ii, y_3: i
C. y_1: i, y_2: iii, y_3: ii
D. y_1: ii, y_2: i, y_3: iii
E. y_1: iii, y_2: i, y_3: ii

ans: A

9. The displacement of a string is given by

$$y(x,t) = y_m \sin(kx + \omega t)\,.$$

The speed of the wave is:

A. $2\pi k/\omega$
B. ω/k
C. ωk
D. $2\pi/k$
E. $k/2\pi$

ans: B

10. A wave is described by $y(x,t) = 0.1 \sin(3x + 10t)$, where x is in meters, y is in centimeters, and t is in seconds. The angular wave number is:

A. $0.10\,\mathrm{rad/m}$
B. $3\pi\,\mathrm{rad/m}$
C. $10)\,\mathrm{rad/m}$
D. $10\pi)\,\mathrm{rad/m}$
E. $3.0\,\mathrm{rad/cm}$

ans: E

11. A wave is described by $y(x,t) = 0.1 \sin(3x - 10t)$, where x is in meters, y is in centimeters, and t is in seconds. The angular frequency is:

A. $0.10\,\mathrm{rad/s}$
B. $3.0\pi\,\mathrm{rad/s}$
C. $10\pi\,\mathrm{rad/s}$
D. $20\pi\,\mathrm{rad/s}$
E. $(10\,\mathrm{rad/s}$

ans: E

12. Water waves in the sea are observed to have a wavelength of 300 m and a frequency of 0.07 Hz. The speed of these waves is:

A. 0.00021 m/s
B. 2.1 m/s
C. 21 m/s
D. 210 m/s
E. none of these

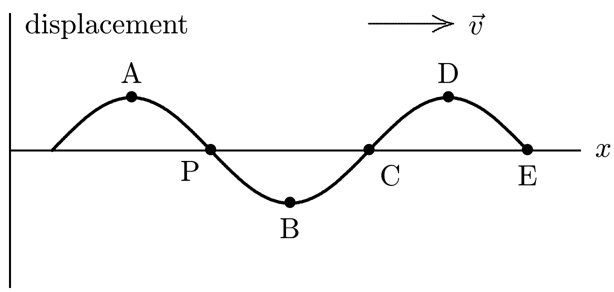
ans: C

13. Sinusoidal water waves are generated in a large ripple tank. The waves travel at 20 cm/s and their adjacent crests are 5.0 cm apart. The time required for each new whole cycle to be generated is:

A. 100 s
B. 4.0 s
C. 2.0 s
D. 0.5 s
E. 0.25 s

ans: E

14. A traveling sinusoidal wave is shown below. At which point is the motion 180° out of phase with the motion at point P?



ans: C

15. The displacement of a string carrying a traveling sinusoidal wave is given by

$$y(x,t) = y_m \sin(kx - \omega t - \phi)\,.$$

At time $t = 0$ the point at $x = 0$ has a displacement of 0 and is moving in the positive y direction. The phase constant ϕ is:

A. 45°
B. 90°
C. 135°
D. 180°
E. 270°

ans: D

16. The displacement of a string carrying a traveling sinusoidal wave is given by

$$y(x,t) = y_m \sin(kx - \omega t - \phi)\,.$$

At time $t = 0$ the point at $x = 0$ has a velocity of 0 and a positive displacement. The phase constant ϕ is:

A. 45°
B. 90°
C. 135°
D. 180°
E. 270°

ans: E

17. The displacement of a string carrying a traveling sinusoidal wave is given by

$$y(x,t) = y_m \sin(kx - \omega t - \phi)\,.$$

At time $t = 0$ the point at $x = 0$ has velocity v_0 and displacement y_0. The phase constant ϕ is given by $\tan\phi =$:

A. $v_0/\omega y_0$
B. $\omega y_0/v_0$
C. $\omega v_0/y_0$
D. $y_0/\omega v_0$
E. $\omega v_0 y_0$

ans: B

18. A sinusoidal transverse wave is traveling on a string. Any point on the string:

A. moves in the same direction as the wave
B. moves in simple harmonic motion with a different frequency than that of the wave
C. moves in simple harmonic motion with the same angular frequency as the wave
D. moves in uniform circular motion with a different angular speed than the wave
E. moves in uniform circular motion with the same angular speed as the wave

ans: C

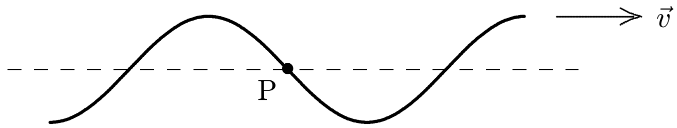
19. Here are the equations for three waves traveling on separate strings. Rank them according to the maximum transverse speed, least to greatest.

wave 1: $y(x,t) = (2.0\,\text{mm})\sin[(4.0\,\text{m}^{-1})x - (3.0\,\text{s}^{-1})t]$
wave 2: $y(x,t) = (1.0\,\text{mm})\sin[(8.0\,\text{m}^{-1})x - (4.0\,\text{s}^{-1})t]$
wave 3: $y(x,t) = (1.0\,\text{mm})\sin[(4.0\,\text{m}^{-1})x - (8.0\,\text{s}^{-1})t]$

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

ans: C

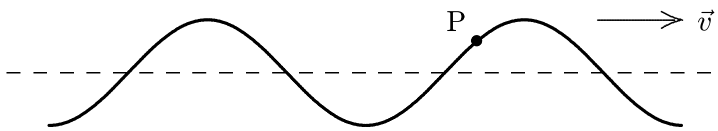
20. The transverse wave shown is traveling from left to right in a medium. The direction of the instantaneous velocity of the medium at point P is:



A. ↑
B. ↓
C. →
D. ↗
E. no direction since $v = 0$

ans: A

21. A wave traveling to the right on a stretched string is shown below. The direction of the instantaneous velocity of the point P on the string is:



A. ↑
B. ↓
C. →
D. ↗
E. no direction since $v = 0$

ans: B

22. Sinusoidal waves travel on five different strings, all with the same tension. Four of the strings have the same linear mass density, but the fifth has a different linear mass density. Use the mathematical forms of the waves, given below, to identify the string with the different linear mass density. In the expressions x and y are in centimeters and t is in seconds.

A. $y(x,t) = (2\,\text{cm})\sin(2x - 4t)$
B. $y(x,t) = (2\,\text{cm})\sin(4x - 10t)$
C. $y(x,t) = (2\,\text{cm})\sin(6x - 12t)$
D. $y(x,t) = (2\,\text{cm})\sin(8x - 16t)$
E. $y(x,t) = (2\,\text{cm})\sin(10x - 20t)$

ans: B

23. Any point on a string carrying a sinusoidal wave is moving with its maximum speed when:

A. the magnitude of its acceleration is a maximum
B. the magnitude of its displacement is a maximum
C. the magnitude of its displacement is a minimum
D. the magnitude of its displacement is half the amplitude
E. the magnitude of its displacement is one-fourth the amplitude

ans: C

24. The mathematical forms for three sinusoidal traveling waves are given by

wave 1: $y(x,t) = (2\,\text{cm})\sin(3x - 6t)$
wave 2: $y(x,t) = (3\,\text{cm})\sin(4x - 12t)$
wave 3: $y(x,t) = (4\,\text{cm})\sin(5x - 11t)$

where x is in meters and t is in seconds. Of these waves:

A. wave 1 has the greatest wave speed and the greatest maximum transverse string speed
B. wave 2 has the greatest wave speed and wave 1 has the greatest maximum transverse string speed
C. wave 3 has the greatest wave speed and the greatest maximum transverse string speed
D. wave 2 has the greatest wave speed and wave 3 has the greatest maximum transverse string speed
E. wave 3 has the greatest wave speed and wave 2 has the greatest maximum transverse string speed

ans: D

25. Suppose the maximum speed of a string carrying a sinusoidal wave is v_s. When the displacement of a point on the string is half its maximum, the speed of the point is:

A. $v_s/2$
B. $2v_s$
C. $v_s/4$
D. $3v_s/4$
E. $\sqrt{3}v_s/2$

ans: E

26. A string carries a sinusoidal wave with an amplitude of 2.0 cm and a frequency of 100 Hz. The maximum speed of any point on the string is:

A. 2.0 m/s
B. 4.0 m/s
C. 6.3 m/s
D. 13 m/s
E. unknown (not enough information is given)

ans: D

27. A transverse traveling sinusoidal wave on a string has a frequency of 100 Hz, a wavelength of 0.040 m, and an amplitude of 2.0 mm. The maximum velocity in m/s of any point on the string is:

A. 0.2
B. 1.3
C. 4
D. 15
E. 25

ans: B

28. A transverse traveling sinusoidal wave on a string has a frequency of 100 Hz, a wavelength of 0.040 m, and an amplitude of 2.0 mm. The maximum acceleration in m/s^2 of any point on the string is:

A. 0
B. 130
C. 395
D. 790
E. 1600

ans: D

29. The speed of a sinusoidal wave on a string depends on:

A. the frequency of the wave
B. the wavelength of the wave
C. the length of the string
D. the tension in the string
E. the amplitude of the wave

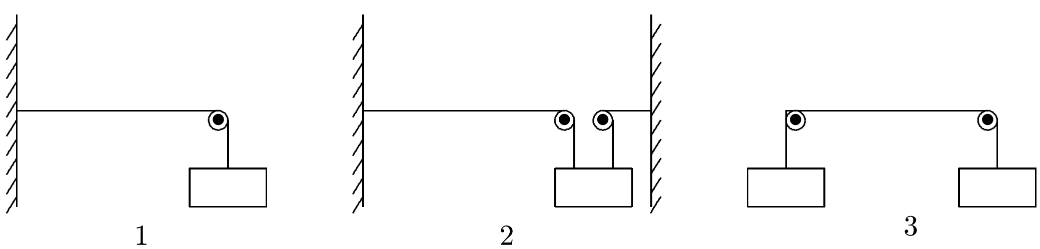
ans: D

30. The time required for a small pulse to travel from A to B on a stretched cord shown is NOT altered by changing:

A. the linear mass density of the cord
B. the length between A and B
C. the shape of the pulse
D. the tension in the cord
E. none of the above (changes in all alter the time)

ans: C

31. The diagrams show three identical strings that have been put under tension by suspending blocks of 5 kg each. For which is the wave speed the greatest?



A. 1
B. 2
C. 3
D. 1 and 3 tie
E. 2 and 3 tie

ans: D

32. For a given medium, the frequency of a wave is:

A. independent of wavelength
B. proportional to wavelength
C. inversely proportional to wavelength
D. proportional to the amplitude
E. inversely proportional to the amplitude

ans: C

33. The tension in a string with a linear mass density of 0.0010 kg/m is 0.40 N. A sinusoidal wave with a wavelength of 20 cm on this string has a frequency of:

A. 0.0125 Hz
B. 0.25 Hz
C. 100 Hz
D. 630 Hz
E. 2000 Hz

ans: C

34. When a 100-Hz oscillator is used to generate a sinusoidal wave on a certain string the wavelength is 10 cm. When the tension in the string is doubled the generator produces a wave with a frequency and wavelength of:

A. 200 Hz and 20 cm
B. 141 Hz and 10 cm
C. 100 Hz and 20 cm
D. 100 Hz and 14 cm
E. 50 Hz and 14 cm

ans: D

35. A source of frequency f sends waves of wavelength λ traveling with speed v in some medium. If the frequency is changed from f to $2f$, then the new wavelength and new speed are (respectively):

A. 2λ, v
B. $\lambda/2$, v
C. λ, $2v$
D. λ, $v/2$
E. $\lambda/2$, $2v$

ans: B

36. A long string is constructed by joining the ends of two shorter strings. The tension in the strings is the same but string I has 4 times the linear mass density of string II. When a sinusoidal wave passes from string I to string II:

A. the frequency decreases by a factor of 4
B. the frequency decreases by a factor of 2
C. the wavelength decreases by a factor of 4
D. the wavelength decreases by a factor of 2
E. the wavelength increases by a factor of 2

ans: D

37. Three separate strings are made of the same material. String 1 has length L and tension τ, string 2 has length $2L$ and tension 2τ, and string 3 has length $3L$ and tension 3τ. A pulse is started at one end of each string. If the pulses start at the same time, the order in which they reach the other end is:

A. 1, 2, 3
B. 3, 2, 1
C. 2, 3, 1
D. 3, 1, 2
E. they all take the same time

ans: A

38. A long string is constructed by joining the ends of two shorter strings. The tension in the strings is the same but string I has 4 times the linear mass density of string II. When a sinusoidal wave passes from string I to string II:

A. the frequency decreases by a factor of 4
B. the frequency decreases by a factor of 2
C. the wave speed decreases by a factor of 4
D. the wave speed decreases by a factor of 2
E. the wave speed increases by a factor of 2

ans: E

39. Two identical but separate strings, with the same tension, carry sinusoidal waves with the same frequency. Wave A has a amplitude that is twice that of wave B and transmits energy at a rate that is ______ that of wave B.

A. half
B. twice
C. one-fourth
D. four times
E. eight times

ans: D

40. Two identical but separate strings, with the same tension, carry sinusoidal waves with the same frequency. Wave A has an amplitude that is twice that of wave B and transmits energy at a rate that is ______ that of wave B.

A. half
B. twice
C. one-fourth
D. four times
E. eight times

ans: D

41. A sinusoidal wave is generated by moving the end of a string up and down periodically. The generator must supply the greatest power when the end of the string

A. has its greatest acceleration
B. has its greatest displacement
C. has half its greatest displacement
D. has one-fourth its greatest displacement
E. has its least displacement

ans: E

42. A sinusoidal wave is generated by moving the end of a string up and down periodically. The generator does not supply any power when the end of the string

A. has its least acceleration
B. has its greatest displacement
C. has half its greatest displacement
D. has one-fourth its greatest displacement
E. has its least displacement

ans: B

43. The sum of two sinusoidal traveling waves is a sinusoidal traveling wave only if:

A. their amplitudes are the same and they travel in the same direction.
B. their amplitudes are the same and they travel in opposite directions.
C. their frequencies are the same and they travel in the same direction.
D. their frequencies are the same and they travel in opposite directions.
E. their frequencies are the same and their amplitudes are the same.

ans: C

44. Two traveling sinusoidal waves interfere to produce a wave with the mathematical form

$$y(x,t) = y_m \sin(kx + \omega t + \alpha)\,.$$

If the value of ϕ is appropriately chosen, the two waves might be:

A. $y_1(x,t) = (y_m/3)\sin(kx + \omega t)$ and $y_2(x,t) = (y_m/3)\sin(kx + \omega t + \phi)$
B. $y_1(x,t) = 0.7y_m \sin(kx - \omega t)$ and $y_2(x,t) = 0.7y_m \sin(kx - \omega t + \phi)$
C. $y_1(x,t) = 0.7y_m \sin(kx - \omega t)$ and $y_2(x,t) = 0.7y_m \sin(kx + \omega t + \phi)$
D. $y_1(x,t) = 0.7y_m \sin[(kx/2) - (\omega t/2)]$ and $y_2(x,t) = 0.7y_m \sin[(kx/2) - (\omega t/2) + \phi]$
E. $y_1(x,t) = 0.7y_m \sin(kx + \omega t)$ and $y_2(x,t) = 0.7y_m \sin(kx + \omega t + \phi)$

ans: E

45. Fully constructive interference between two sinusoidal waves of the same frequency occurs only if they:

A. travel in opposite directions and are in phase
B. travel in opposite directions and are 180° out of phase
C. travel in the same direction and are in phase
D. travel in the same direction and are 180° out of phase
E. travel in the same direction and are 90° out of phase

ans: C

46. Fully destructive interference between two sinusoidal waves of the same frequency and amplitude occurs only if they:

A. travel in opposite directions and are in phase
B. travel in opposite directions and are 180° out of phase
C. travel in the same direction and are in phase
D. travel in the same direction and are 180° out of phase
E. travel in the same direction and are 90° out of phase

ans: D

47. Two sinusoidal waves travel in the same direction and have the same frequency. Their amplitudes are y_{1m} and y_{2m}. The smallest possible amplitude of the resultant wave is:

A. $y_{1m} + y_{2m}$ and occurs if they are 180° out of phase
B. $|y_{1m} - y_{2m}|$ and occurs if they are 180° out of phase
C. $y_{1m} + y_{2m}$ and occurs if they are in phase
D. $|y_{1m} - y_{2m}|$ and occurs if they are in phase
E. $|y_{1m} - y_{2m}|$ and occurs if they are 90° out of phase

ans: B

48. Two sinusoidal waves have the same angular frequency, the same amplitude y_m, and travel in the same direction in the same medium. If they differ in phase by 50°, the amplitude of the resultant wave is given by:

A. $0.64y_m$
B. $1.3y_m$
C. $0.91y_m$
D. $1.8y_m$
E. $0.35y_m$

ans: D

49. Two separated sources emit sinusoidal traveling waves that have the same wavelength λ and are in phase at their respective sources. One travels a distance ℓ_1 to get to the observation point while the other travels a distance ℓ_2. The amplitude is a minimum at the observation point if $\ell_1 - \ell_2$ is:

A. an odd multiple of $\lambda/2$
B. an odd multiple of $\lambda/4$
C. a multiple of λ
D. an odd multiple of $\pi/2$
E. a multiple of π

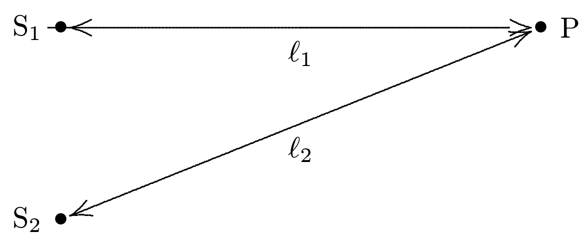
ans: A

50. Two separated sources emit sinusoidal traveling waves that have the same wavelength λ and are in phase at their respective sources. One travels a distance ℓ_1 to get to the observation point while the other travels a distance ℓ_2. The amplitude is a maximum at the observation point if $\ell_1 - \ell_2$ is:

A. an odd multiple of $\lambda/2$
B. an odd multiple of $\lambda/4$
C. a multiple of λ
D. an odd multiple of $\pi/2$
E. a multiple of π

ans: C

51. Two sources, S_1 and S_2, each emit waves of wavelength λ in the same medium. The phase difference between the two waves, at the point P shown, is $(2\pi/\lambda)(\ell_2 - \ell_1) + \epsilon$. The quantity ϵ is:



A. the distance S_1S_2
B. the angle S_1PS_2
C. $\pi/2$
D. the phase difference between the two sources
E. zero for transverse waves, π for longitudinal waves

ans: D

52. A wave on a stretched string is reflected from a fixed end P of the string. The phase difference, at P, between the incident and reflected waves is:

A. zero
B. π rad
C. $\pi/2$ rad
D. depends on the velocity of the wave
E. depends on the frequency of the wave

ans: B

53. The sinusoidal wave

$$y(x,t) = y_m \sin(kx - \omega t)$$

is incident on the fixed end of a string at $x = L$. The reflected wave is given by:

A. $y_m \sin(kx + \omega t)$
B. $-y_m \sin(kx + \omega t)$
C. $y_m \sin(kx + \omega t - kL)$
D. $y_m \sin(kx + \omega t - 2kL)$
E. $-y_m \sin(kx + \omega t + 2kL)$

ans: D

54. A wave on a string is reflected from a fixed end. The reflected wave:

A. is in phase with the original wave at the end
B. is 180° out of phase with the original wave at the end
C. has a larger amplitude than the original wave
D. has a larger speed than the original wave
E. cannot be transverse

ans: B

55. A standing wave:

A. can be constructed from two similar waves traveling in opposite directions
B. must be transverse
C. must be longitudinal
D. has motionless points that are closer than half a wavelength
E. has a wave velocity that differs by a factor of two from what it would be for a traveling wave

ans: A

56. Which of the following represents a standing wave?

A. $y = (6.0\,\text{mm})\sin[(3.0\,\text{m}^{-1})x + (2.0\,\text{s}^{-1})t] - (6.0\,\text{mm})\cos[(3.0\,\text{m}^{-1})x + 2.0]$
B. $y = (6.0\,\text{mm})\cos[(3.0\,\text{m}^{-1})x - (2.0\,\text{s}^{-1})t] + (6.0\,\text{mm})\cos[(2.0\,\text{s}^{-1})t + 3.0\,\text{m}^{-1})x]$
C. $y = (6.0\,\text{mm})\cos[(3.0\,\text{m}^{-1})x - (2.0\,\text{s}^{-1})t] - (6.0\,\text{mm})\sin[(2.0\,\text{s}^{-1})t - 3.0]$
D. $y = (6.0\,\text{mm})\sin[(3.0\,\text{m}^{-1})x - (2.0\,\text{s}^{-1})t] - (6.0\,\text{mm})\cos[(2.0\,\text{s}^{-1})t + 3.0\,\text{m}^{-1})x]$
E. $y = (6.0\,\text{mm})\sin[(3.0\,\text{m}^{-1})x] + (6.0\,\text{mm})\cos[(2.0\,\text{s}^{-1})t]$

ans: B

57. When a certain string is clamped at both ends, the lowest four resonant frequencies are 50, 100, 150, and 200 Hz. When the string is also clamped at its midpoint, the lowest four resonant frequencies are:

A. 50, 100, 150, and 200 Hz
B. 50, 150, 250, and 300 Hz
C. 100, 200, 300, and 400 Hz
D. 25, 50, 75, and 100 Hz
E. 75, 150, 225, and 300 Hz

ans: C

58. When a certain string is clamped at both ends, the lowest four resonant frequencies are measured to be 100, 150, 200, and 250 Hz. One of the resonant frequencies (below 200 Hz) is missing. What is it?

A. 25 Hz
B. 50 Hz
C. 75 Hz
D. 125 Hz
E. 225 Hz

ans: B

59. Two traveling waves $y_1 = A\sin[k(x - vt)]$ and $y_2 = A\sin[k(x + vt)]$ are superposed on the same string. The distance between the adjacent nodes is:

A. vt/π
B. $vt/2\pi$
C. $\pi/2k$
D. π/k
E. $2\pi/k$

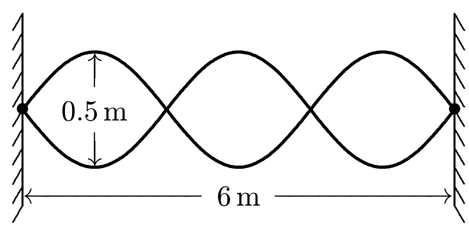
ans: D

60. If λ is the wavelength of each of the component sinusoidal traveling waves that form a standing wave, the distance between adjacent nodes in the standing wave is:

A. $\lambda/4$
B. $\lambda/2$
C. $3\lambda/4$
D. λ
E. 2λ

ans: B

61. A standing wave pattern is established in a string as shown. The wavelength of one of the component traveling waves is:



A. 0.25 m
B. 0.5 m
C. 1 m
D. 2 m
E. 4 m

ans: E

62. Standing waves are produced by the interference of two traveling sinusoidal waves, each of frequency 100 Hz. The distance from the second node to the fifth node is 60 cm. The wavelength of each of the two original waves is:

A. 50 cm
B. 40 cm
C. 30 cm
D. 20 cm
E. 15 cm

ans: B

63. A string of length 100 cm is held fixed at both ends and vibrates in a standing wave pattern. The wavelengths of the constituent traveling waves CANNOT be:

A. 400 cm
B. 200 cm
C. 100 cm
D. 66.7 cm
E. 50 cm

ans: A

64. A string of length L is clamped at each end and vibrates in a standing wave pattern. The wavelengths of the constituent traveling waves CANNOT be:

A. L
B. $2L$
C. $L/2$
D. $2L/3$
E. $4L$

ans: E

65. Two sinusoidal waves, each of wavelength 5 m and amplitude 10 cm, travel in opposite directions on a 20-m long stretched string that is clamped at each end. Excluding the nodes at the ends of the string, how many nodes appear in the resulting standing wave?

A. 3
B. 4
C. 5
D. 7
E. 8

ans: D

66. A string, clamped at its ends, vibrates in three segments. The string is 100 cm long. The wavelength is:

A. 33.3 cm
B. 66.7 cm
C. 150 cm
D. 300 cm
E. need to know the frequency

ans: B

67. A stretched string, clamped at its ends, vibrates in its fundamental frequency. To double the fundamental frequency, one can change the string tension by a factor of:

A. 2
B. 4
C. $\sqrt{2}$
D. $1/2$
E. $1/\sqrt{2}$

ans: B

68. When a string is vibrating in a standing wave pattern the power transmitted across an antinode, compared to the power transmitted across a node, is:

A. more
B. less
C. the same (zero)
D. the same (non-zero)
E. sometimes more, sometimes less, and sometimes the same

ans: C

69. A 40-cm long string, with one end clamped and the other free to move transversely, is vibrating in its fundamental standing wave mode. The wavelength of the constituent traveling waves is:

A. 10 cm
B. 20 cm
C. 40 cm
D. 80 cm
E. 160 cm

ans: E

70. A 30-cm long string, with one end clamped and the other free to move transversely, is vibrating in its second harmonic. The wavelength of the constituent traveling waves is:

A. 10 cm
B. 30 cm
C. 40 cm
D. 60 cm
E. 120 cm

ans: C

71. A 40-cm long string, with one end clamped and the other free to move transversely, is vibrating in its fundamental standing wave mode. If the wave speed is 320 cm/s the frequency is:

A. 32 Hz
B. 16 Hz
C. 8 Hz
D. 4 Hz
E. 2 Hz

ans: E

Chapter 17: WAVES — II

1. The speed of a sound wave is determined by:
   A. its amplitude
   B. its intensity
   C. its pitch
   D. number of harmonics present
   E. the transmitting medium

   ans: E

2. Take the speed of sound to be 340 m/s. A thunder clap is heard about 3 s after the lightning is seen. The source of both light and sound is:
   A. moving overhead faster than the speed of sound
   B. emitting a much higher frequency than is heard
   C. emitting a much lower frequency than is heard
   D. about 1000 m away
   E. much more than 1000 m away

   ans: D

3. A sound wave has a wavelength of 3.0 m. The distance from a compression center to the adjacent rarefaction center is:
   A. 0.75 m
   B. 1.5 m
   C. 3.0 m
   D. need to know wave speed
   E. need to know frequency

   ans: B

4. A fire whistle emits a tone of 170 Hz. Take the speed of sound in air to be 340 m/s. The wavelength of this sound is about:
   A. 0.5 m
   B. 1.0 m
   C. 2.0 m
   D. 3.0 m
   E. 340 m

   ans: C

5. During a time interval of exactly one period of vibration of a tuning fork, the emitted sound travels a distance:
   A. equal to the length of the tuning fork
   B. equal to twice the length of the tuning fork
   C. of about 330 m
   D. which decreases with time
   E. of one wavelength in air

   ans: E

6. At points in a sound wave where the gas is maximally compressed, the pressure
   A. is a maximum
   B. is a minimum
   C. is equal to the ambient value
   D. is greater than the ambient value but less than the maximum
   E. is less than the ambient value but greater than the minimum

   ans: A

7. You are listening to an "A" note played on a violin string. Let the subscript "s" refer to the violin string and "a" refer to the air. Then:
   A. $f_s = f_a$ but $\lambda_s \neq \lambda_a$
   B. $f_s = f_a$ and $\lambda_s = \lambda_a$
   C. $\lambda_s = \lambda_a$ but $f_s \neq f_a$
   D. $\lambda_s \neq \lambda_a$ and $f_s \neq f_a$
   E. linear density of string = volume density of air

   ans: A

8. "Beats" in sound refer to:
   A. interference of two waves of the same frequency
   B. combination of two waves of slightly different frequency
   C. reversal of phase of reflected wave relative to incident wave
   D. two media having slightly different sound velocities
   E. effect of relative motion of source and observer

   ans: B

9. To produce beats it is necessary to use two waves:
   A. traveling in opposite directions
   B. of slightly different frequencies
   C. of equal wavelengths
   D. of equal amplitudes
   E. whose ratio of frequencies is an integer

   ans: B

10. In order for two sound waves to produce audible beats, it is essential that the two waves have:
    A. the same amplitude
    B. the same frequency
    C. the same number of harmonics
    D. slightly different amplitudes
    E. slightly different frequencies

    ans: E

11. The largest number of beats per second will be heard from which pair of tuning forks?

A. 200 and 201 Hz
B. 256 and 260 Hz
C. 534 and 540 Hz
D. 763 and 774 Hz
E. 8420 and 8422 Hz

ans: D

12. Two stationary tuning forks (350 and 352 Hz) are struck simultaneously. The resulting sound is observed to:

A. beat with a frequency of 2 beats/s
B. beat with a frequency of 351 beats/s
C. be loud but not beat
D. be Doppler shifted by 2 Hz
E. have a frequency of 702 Hz

ans: A

13. When listening to tuning forks of frequency 256 Hz and 260 Hz, one hears the following number of beats per second:

A. zero
B. 2
C. 4
D. 8
E. 258

ans: C

14. Two identical tuning forks vibrate at 256 Hz. One of them is then loaded with a drop of wax, after which 6 beats/s are heard. The period of the loaded tuning fork is:

A. 0.006 s
B. 0.005 s
C. 0.004 s
D. 0.003 s
E. none of these

ans: C

15. Which of the following properties of a sound wave determine its "pitch"?

A. Amplitude
B. Distance from source to detector
C. Frequency
D. Phase
E. Speed

ans: C

16. Two notes are an "octave" apart. The ratio of their frequencies is:

A. 8
B. 10
C. $\sqrt{8}$
D. 2
E. $\sqrt{2}$

ans: D

17. Consider two imaginary spherical surfaces with different radii, each centered on a point sound source emitting spherical waves. The power transmitted across the larger sphere is ______ the power transmitted across the smaller and the intensity at a point on the larger sphere is ______ the intensity at a point on the smaller.

A. greater than, the same as
B. greater than, greater than
C. greater than, less than
D. the same as, less than
E. the same as, the same as

ans: D

18. The sound intensity 5.0 m from a point source is $0.50\,\mathrm{W/m^2}$. The power output of the source is:

A. 39 W
B. 160 W
C. 266 W
D. 320 W
E. 390 W

ans: B

19. The standard reference sound level is about:

A. the threshold of human hearing at 1000 Hz
B. the threshold of pain for human hearing at 1000 Hz
C. the level of sound produced when the 1 kg standard mass is dropped 1 m onto a concrete floor
D. the level of normal conversation
E. the level of sound emitted by a standard 60 Hz tuning fork

ans: A

20. The intensity of sound wave A is 100 times that of sound wave B. Relative to wave B the sound level of wave A is:

A. −2 db
B. +2 db
C. +10 db
D. +20 db
E. +100 db

ans: D

21. The intensity of a certain sound wave is $6\,\mu\text{W/cm}^2$. If its intensity is raised by 10 db, the new intensity (in $\mu\text{W/cm}^2$) is:

A. 60
B. 6.6
C. 6.06
D. 600
E. 12

ans: A

22. If the sound level is increased by 10 db the intensity increases by a factor of:

A. 2
B. 5
C. 10
D. 20
E. 100

ans: C

23. The sound level at a point P is 14 db below the sound level at a point 1.0 m from a point source. The distance from the source to point P is:

A. 4.0 cm
B. 20 2m
C. 2.0 m
D. 5.0 m
E. 25 m

ans: D

24. To raise the pitch of a certain piano string, the piano tuner:

A. loosens the string
B. tightens the string
C. shortens the string
D. lengthens the string
E. removes some mass

ans: B

25. A piano wire has length L and mass M. If its fundamental frequency is f, its tension is:

A. $2Lf/m$
B. $4MLf$
C. $2Mf^2/L$
D. $4f^2L^3/M$
E. $4LMf^2$

ans: E

26. If the length of a piano wire (of given density) is increased by 5%, what approximate change in tension is necessary to keep its fundamental frequency unchanged?

A. Decrease of 10%
B. Decrease of 5%
C. Increase of 5%
D. Increase of 10%
E. Increase of 20%

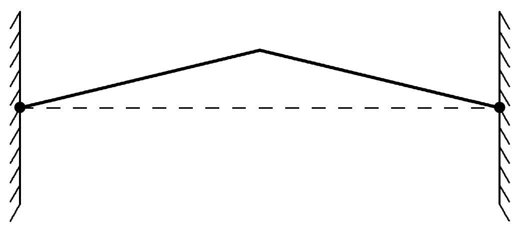
ans: C

27. A piano wire has a length of 81 cm and a mass of 2.0 g. If its fundamental frequency is to be 394 Hz, its tension must be:

A. 0.32 N
B. 63 N
C. 130 N
D. 250 N
E. none of these

ans: B

28. A stretched wire of length 1.0 m is clamped at both ends. It is plucked at its center as shown. The three longest wavelengths in the wire are (in meters):



A. 4, 2, 1
B. 2, 1, 0.5
C. 2, 0.67, 0.4
D. 1, 0.5, 0.33
E. 1, 0.67, 0.5

ans: C

29. Two identical strings, A and B, have nearly the same tension. When they both vibrate in their fundamental resonant modes, there is a beat frequency of 3 Hz. When string B is tightened slightly, to increase the tension, the beat frequency becomes 6 Hz. This means:

A. that before tightening A had a higher frequency than B, but after tightening, B has a higher frequency than A
B. that before tightening B had a higher frequency than A, but after tightening, A has a higher frequency than B
C. that before and after tightening A has a higher frequency than B
D. that before and after tightening B has a higher frequency than A
E. none of the above

ans: D

30. Two pipes are each open at one end and closed at the other. Pipe A has length L and pipe B has length $2L$. Which harmonic of pipe B matches in frequency the fundamental of pipe A?

A. The fundamental
B. The second
C. The third
D. The fourth
E. There are none

ans: E

31. A column of argon is open at one end and closed at the other. The shortest length of such a column that will resonate with a 200 Hz tuning fork is 42.5 cm. The speed of sound in argon must be:

A. 85.0 m/s
B. 170 m/s
C. 340 m/s
D. 470 m/s
E. 940 m/s

ans: C

32. A tuning fork produces sound waves of wavelength λ in air. This sound is used to cause resonance in an air column, closed at one end and open at the other. The length of this column CANNOT be:

A. $\lambda/4$
B. $2\lambda/4$
C. $3\lambda/4$
D. $5\lambda/4$
E. $7\lambda/4$

ans: B

33. A 1024 Hz tuning fork is used to obtain a series of resonance levels in a gas column of variable length, with one end closed and the other open. The length of the column changes by 20 cm from resonance to resonance. From this data, the speed of sound in this gas is:

A. 20 cm/s
B. 51 cm/s
C. 102 cm/s
D. 205 m/s
E. 410 m/s

ans: E

34. A vibrating tuning fork is held over a water column with one end closed and the other open. As the water level is allowed to fall, a loud sound is heard for water levels separated by 17 cm. If the speed of sound in air is 340 m/s, the frequency of the tuning fork is:

A. 500 Hz
B. 1000 Hz
C. 2000 Hz
D. 5780 Hz
E. 578,000 Hz

ans: B

35. An organ pipe with one end open and the other closed is operating at one of its resonant frequencies. The open and closed ends are respectively:

A. pressure node, pressure node
B. pressure node, displacement node
C. displacement antinode, pressure node
D. displacement node, displacement node
E. pressure antinode, pressure node

ans: B

36. An organ pipe with one end closed and the other open has length L. Its fundamental frequency is proportional to:

A. L
B. $1/L$
C. $1/L^2$
D. L^2
E. $\sqrt{L}$

ans: B

37. Five organ pipes are described below. Which one has the highest frequency fundamental?

A. A 2.3-m pipe with one end open and the other closed
B. A 3.3-m pipe with one end open and the other closed
C. A 1.6-m pipe with both ends open
D. A 3.0-m pipe with both ends open
E. A pipe in which the displacement nodes are 5 m apart

ans: C

38. If the speed of sound is 340 m/s, the length of the shortest closed pipe that resonates at 218 Hz is:

A. 23 cm
B. 17 cm
C. 39 cm
D. 78 cm
E. 1.56 cm

ans: C

39. The lowest tone produced by a certain organ comes from a 3.0-m pipe with both ends open. If the speed of sound is 340 m/s, the frequency of this tone is approximately:

A. 7 Hz
B. 14 Hz
C. 28 Hz
D. 57 Hz
E. 70 Hz

ans: D

40. The speed of sound in air is 340 m/s. The length of the shortest pipe, closed at one end, that will respond to a 512 Hz tuning fork is approximately:

A. 4.2 cm
B. 9.4 cm
C. 17 cm
D. 33 cm
E. 66 cm

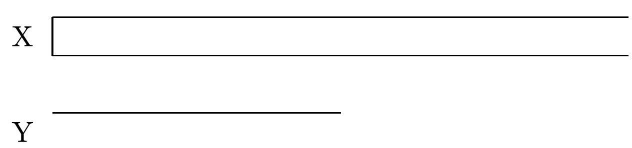
ans: C

41. If the speed of sound is 340 m/s, the two lowest frequencies of an 0.5-m organ pipe, closed at one end, are approximately:

A. 170 and 340 Hz
B. 170 and 510 Hz
C. 340 and 680 Hz
D. 340 and 1020 Hz
E. 57 and 170 Hz

ans: B

42. Organ pipe Y (open at both ends) is half as long as organ pipe X (open at one end) as shown. The ratio of their fundamental frequencies f_X:f_Y is:



A. 1:1
B. 1:2
C. 2:1
D. 1:4
E. 4:1

ans: A

43. A 200-cm organ pipe with one end open is in resonance with a sound wave of wavelength 270 cm. The pipe is operating in its:

A. fundamental frequency
B. second harmonic
C. third harmonic
D. fourth harmonic
E. fifth harmonic

ans: B

44. An organ pipe with both ends open is 0.85 m long. Assuming that the speed of sound is 340 m/s, the frequency of the third harmonic of this pipe is:

A. 200 Hz
B. 300 Hz
C. 400 Hz
D. 600 Hz
E. none of these

ans: D

45. The "A" on a trumpet and a clarinet have the same pitch, but the two are clearly distinguishable. Which property is most important in enabling one to distinguish between these two instruments?

A. Intensity
B. Fundamental frequency
C. Displacement amplitude
D. Pressure amplitude
E. Harmonic content

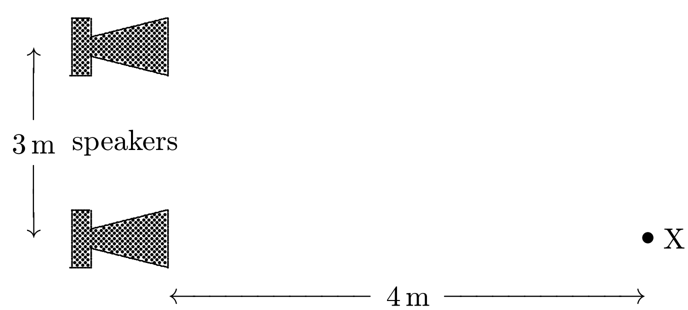
ans: E

46. The valves of a trumpet and the slide of a trombone are for the purpose of:

A. playing short (staccato) notes
B. tuning the instruments
C. changing the harmonic content
D. changing the length of the air column
E. producing gradations in loudness

ans: D

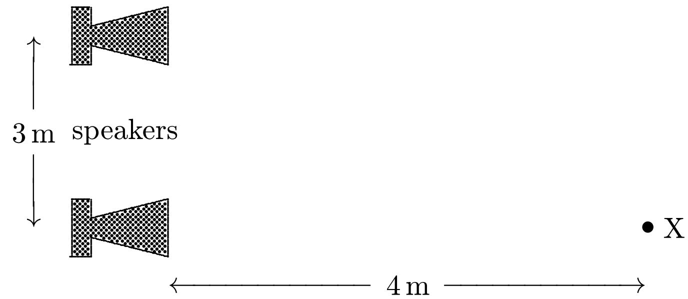
47. Two small identical speakers are connected (in phase) to the same source. The speakers are 3 m apart and at ear level. An observer stands at X, 4 m in front of one speaker as shown. If the amplitudes are not changed, the sound he hears will be most intense if the wavelength is:



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

ans: A

48. Two small identical speakers are connected (in phase) to the same source. The speakers are 3 m apart and at ear level. An observer stands at X, 4 m in front of one speaker as shown. The sound she hears will be most intense if the wavelength is:



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

ans: E

49. The rise in pitch of an approaching siren is an apparent increase in its:
A. speed
B. amplitude
C. frequency
D. wavelength
E. number of harmonics

ans: C

50. The diagram shows four situations in which a source of sound S with variable frequency and a detector D are either moving or stationary. The arrows indicate the directions of motion. The speeds are all the same. Detector 3 is stationary. The frequency detected is the same. Rank the situations according to the frequency of the source, lowest to highest.

A. 1, 2, 3, 4
B. 4, 3, 2, 1
C. 1, 3, 4, 2
D. 2, 1, 2, 3
E. None of the above

ans: B

51. A stationary source generates 5.0 Hz water waves whose speed is 2.0 m/s. A boat is approaching the source at 10 m/s. The frequency of these waves, as observed by a person in the boat, is:

A. 5.0 Hz
B. 15 Hz
C. 20 Hz
D. 25 Hz
E. 30 Hz

ans: E

52. A stationary source S generates circular outgoing waves on a lake. The wave speed is 5.0 m/s and the crest-to-crest distance is 2.0 m. A person in a motor boat heads directly toward S at 3.0 m/s. To this person, the frequency of these waves is:

A. 1.0 Hz
B. 1.5 Hz
C. 2.0 Hz
D. 4.0 Hz
E. 8.0 Hz

ans: D

53. A stationary source emits a sound wave of frequency f. If it were possible for a man to travel toward the source at the speed of sound, he would observe the emitted sound to have a frequency of:

A. zero
B. $f/2$
C. $2f/3$
D. $2f$
E. infinity

ans: D

54. A source emits sound with a frequency of 1000 Hz. It and an observer are moving in the same direction with the same speed, 100 m/s. If the speed of sound is 340 m/s, the observer hears sound with a frequency of:

A. 294 Hz
B. 545 Hz
C. 1000 Hz
D. 1830 Hz
E. 3400 Hz

ans: C

55. A source emits sound with a frequency of 1000 Hz. It and an observer are moving toward each other, each with a speed of 100 m/s. If the speed of sound is 340 m/s, the observer hears sound with a frequency of:

A. 294 Hz
B. 545 Hz
C. 1000 Hz
D. 1830 Hz
E. 3400 Hz

ans: D

56. A source emits sound with a frequency of 1000 Hz. It is moving at 20 m/s toward a stationary reflecting wall. If the speed of sound is 340 m/s an observer at rest directly behind the source hears a beat frequency of:

A. 11 Hz
B. 86 Hz
C. 97 Hz
D. 118 Hz
E. 183 Hz

ans: D

57. In each of the following two situations a source emits sound with a frequency of 1000 Hz. In situation I the source is moving at 100 m/s toward an observer at rest. In situation II the observer is moving at 100 m/s toward the source, which is stationary. The speed of sound is 340 m/s. The frequencies heard by the observers in the two situations are:

A. I: 1417 Hz; II: 1294 Hz
B. I: 1417 Hz; II: 1417 Hz
C. I: 1294 Hz; II: 1294 Hz
D. I: 773 Hz; II: 706 Hz
E. I: 773 Hz; II: 773 Hz

ans: A

58. The Doppler shift formula for the frequency detected is

$$f = f' \frac{v \pm v_D}{v \mp v_S} \,,$$

where f' is the frequency emitted, v is the speed of sound, v_D is the speed of the detector, and v_S is the speed of the source. Suppose the source is traveling at 5 m/s away from the detector, the detector is traveling at 7 m/s toward the source, and there is a 3-m/s wind blowing from the source toward the detector. The values that should be substituted into the Doppler shift equation are:

A. $v_D = 7\,\text{m/s}$ and $v_S = 5\,\text{m/s}$
B. $v_D = 10\,\text{m/s}$ and $v_S = 8\,\text{m/s}$
C. $v_D = 4\,\text{m/s}$ and $v_S = 2\,\text{m/s}$
D. $v_D = 10\,\text{m/s}$ and $v_S = 2\,\text{m/s}$
E. $v_D = 4\,\text{m/s}$ and $v_S = 8\,\text{m/s}$

ans: B

59. A plane produces a sonic boom only when:

A. it emits sound waves of very long wavelength
B. it emits sound waves of high frequency
C. it flys at high altitudes
D. it flys on a curved path
E. it flys faster than the speed of sound

ans: E

60. If the speed of sound is 340 m/s a plane flying at 400 m/s creates a conical shock wave with an apex half angle of:

A. 0 (no shock wave)
B. 32°
C. 40°
D. 50°
E. 58°

ans: E

61. The speed of sound is 340 m/s. A plane flys horizontally at an altitude of 10,000 m and a speed of 400 m/s. When an observer on the ground hears the sonic boom the horizontal distance from the point on its path directly above the observer to the plane is:

A. 5800 m
B. 6200 m
C. 8400 m
D. 12,000 m
E. 16,000 m

ans: B

Chapter 19: THE KINETIC THEORY OF GASES

1. Evidence that a gas consists mostly of empty space is the fact that:
   A. the density of a gas becomes much greater when it is liquefied
   B. gases exert pressure on the walls of their containers
   C. gases are transparent
   D. heating a gas increases the molecular motion
   E. nature abhors a vacuum
   ans: A

2. Air enters a hot-air furnace at 7° C and leaves at 77° C. If the pressure does not change each entering cubic meter of air expands to:
   A. $0.80\,\mathrm{m}^3$
   B. $1.25\,\mathrm{m}^3$
   C. $1.9\,\mathrm{m}^3$
   D. $7.0\,\mathrm{m}^3$
   E. $11\,\mathrm{m}^3$
   ans: B

3. $273\,\mathrm{cm}^3$ of an ideal gas is at 0° C. It is heated at constant pressure to 10° C. It will now occupy:
   A. $263\,\mathrm{cm}^3$
   B. $273\,\mathrm{cm}^3$
   C. $283\,\mathrm{cm}^3$
   D. $278\,\mathrm{cm}^3$
   E. $293\,\mathrm{cm}^3$
   ans: C

4. Two identical rooms in a house are connected by an open doorway. The temperatures in the two rooms are maintained at different values. Which room contains more air?
   A. the room with higher temperature
   B. the room with lower temperature
   C. the room with higher pressure
   D. neither because both have the same pressure
   E. neither because both have the same volume
   ans: B

5. It is known that 28 g of a certain ideal gas occupy 22.4 liters at standard conditions (0° C, 1 atm). The volume occupied by 42 g of this gas at standard conditions is:
   A. 14.9 liters
   B. 22.4 liters
   C. 33.6 liters
   D. 42 liters
   E. more data are needed
   ans: C

6. An automobile tire is pumped up to a gauge pressure of 2.0×10^5 Pa when the temperature is 27° C. What is its gauge pressure after the car has been running on a hot day so that the tire temperature is 77° C? Assume that the volume remains fixed and take atmospheric pressure to be 1.013×10^5 Pa.
   A. 1.6×10^5 Pa
   B. 2.6×10^5 Pa
   C. 3.6×10^5 Pa
   D. 5.9×10^5 Pa
   E. 7.9×10^5 Pa

   ans: A

7. A sample of an ideal gas is compressed by a piston from $10\,\mathrm{m}^3$ to $5\,\mathrm{m}^3$ and simultaneously cooled from 273° C to 0° C. As a result there is:
   A. an increase in pressure
   B. a decrease in pressure
   C. a decrease in density
   D. no change in density
   E. an increase in density

   ans: E

8. A 2-m^3 weather balloon is loosely filled with helium at 1 atm (76 cm Hg) and at 27° C. At an elevation of 20,000 ft, the atmospheric pressure is down to 38 cm Hg and the helium has expanded, being under no constraint from the confining bag. If the temperature at this elevation is -48° C, the gas volume (in m^3) is:
   A. 3
   B. 4
   C. 2
   D. 2.5
   E. 5.3

   ans: A

9. Oxygen (molar mass = 32 g) occupies a volume of 12 liters when its temperature is 20° C and its pressure is 1 atm. Using $R = 0.082\,\mathrm{liter \cdot atm/mol \cdot K}$, calculate the mass of the oxygen:
   A. 6.4 g
   B. 10. g7
   C. 16 g
   D. 32 g
   E. 64 g

   ans: C

10. An ideal gas occupies 12 liters at 293 K and 1 atm (76 cm Hg). Its temperature is now raised to 373 K and its pressure increased to 215 cm Hg. The new volume is:
   A. 0.2 liters
   B. 5.4 liters
   C. 13.6 liters
   D. 20.8 liters
   E. none of these

   ans: B

11. Use $R = 8.2 \times 10^{-5}\,\mathrm{m^3 \cdot atm/mol \cdot K}$ and $N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$. The approximate number of air molecules in a $1\,\mathrm{m^3}$ volume at room temperature (300 K and atmospheric pressure is:

A. 41
B. 450
C. 2.5×10^{25}
D. 2.7×10^{26}
E. 5.4×10^{26}

ans: C

12. An air bubble doubles in volume as it rises from the bottom of a lake ($1000\,\mathrm{kg/m^3}$). Ignoring any temperature changes, the depth of the lake is:

A. 21 m
B. 0.76 m
C. 4.9 m
D. 10 m
E. 0.99 m

ans: D

13. An isothermal process for an ideal gas is represented on a p-V diagram by:

A. a horizontal line
B. a vertical line
C. a portion of an ellipse
D. a portion of a parabola
E. a portion of a hyperbola

ans: E

14. An ideal gas undergoes an isothermal process starting with a pressure of 2×10^5 Pa and a volume of $6\,\mathrm{cm^3}$. Which of the following might be the pressure and volume of the final state?

A. 1×10^5 Pa and $10\,\mathrm{cm^3}$
B. 3×10^5 Pa and $6\,\mathrm{cm^3}$
C. 4×10^5 Pa and $4\,\mathrm{cm^3}$
D. 6×10^5 Pa and $2\,\mathrm{cm^3}$
E. 8×10^5 Pa and $2\,\mathrm{cm^3}$

ans: D

15. The pressures p and volumes V of five ideal gases, with the same number of molecules, are given below. Which has the highest temperature?

A. $p = 1 \times 10^5$ Pa and $V = 10\,\mathrm{cm^3}$
B. $p = 3 \times 10^5$ Pa and $V = 6\,\mathrm{cm^3}$
C. $p = 4 \times 10^5$ Pa and $V = 4\,\mathrm{cm^3}$
D. $p = 6 \times 10^5$ Pa and $V = 2\,\mathrm{cm^3}$
E. $p = 8 \times 10^5$ Pa and $V = 2\,\mathrm{cm^3}$

ans: B

16. During a slow adiabatic expansion of a gas:

A. the pressure remains constant
B. energy is added as heat
C. work is done on the gas
D. no energy enters or leaves as heat
E. the temperature is constant

ans: D

17. An adiabatic process for an ideal gas is represented on a p-V diagram by:

A. a horizontal line
B. a vertical line
C. a hyperbola
D. a circle
E. none of these

ans: E

18. A real gas undergoes a process that can be represented as a curve on a p-V diagram. The work done by the gas during this process is:

A. pV
B. $p(V_2 - V_1)$
C. $(p_2 - p_1)V$
D. $\int p\,dV$
E. $V\,dp$

ans: D

19. A real gas is changed slowly from state 1 to state 2. During this process no work is done on or by the gas. This process must be:

A. isothermal
B. adiabatic
C. isovolumic
D. isobaric
E. a closed cycle with state 1 coinciding with state 2

ans: C

20. A given mass of gas is enclosed in a suitable container so that it may be maintained at constant volume. Under these conditions, there can be no change in what property of the gas?

A. Pressure
B. Density
C. Molecular kinetic energy
D. Internal energy
E. Temperature

ans: B

21. A quantity of an ideal gas is compressed to half its initial volume. The process may be adiabatic, isothermal, or isobaric. Rank those three processes in order of the work required of an external agent, least to greatest.

A. adiabatic, isothermal, isobaric
B. adiabatic, isobaric, isothermal
C. isothermal, adiabatic, isobaric
D. isobaric, adiabatic, isothermal
E. isobaric, isothermal, adiabatic

ans: E

22. During a reversible adiabatic expansion of an ideal gas, which of the following is NOT true?

A. $pV^\gamma = \text{constant}$
B. $pV = nRT$
C. $TV^{\gamma-1} = \text{constant}$
D. $|W| = \int p\,dV$
E. $pV = \text{constant}$

ans: E

23. In order that a single process be both isothermal and isobaric:

A. one must use an ideal gas
B. such a process is impossible
C. a change of phase is essential
D. one may use any real gas such as N_2
E. one must use a solid

ans: C

24. Over 1 cycle of a cyclic process in which a system does net work on its environment:

A. the change in the pressure of the system cannot be zero
B. the change in the volume of the system cannot be zero
C. the change in the temperature of the system cannot be zero
D. the change in the internal energy of the system cannot be zero
E. none of the above

ans: E

25. Evidence that molecules of a gas are in constant motion is:

A. winds exert pressure
B. two gases interdiffuse quickly
C. warm air rises
D. energy as heat is needed to vaporize a liquid
E. gases are easily compressed

ans: B

26. According to the kinetic theory of gases, the pressure of a gas is due to:
   A. change of kinetic energy of molecules as they strike the wall
   B. change of momentum of molecules as the strike the wall
   C. average kinetic energy of the molecules
   D. force of repulsion between the molecules
   E. rms speed of the molecules

   ans: B

27. The force on the walls of a vessel of a contained gas is due to:
   A. the repulsive force between gas molecules
   B. a slight loss in the speed of a gas molecule during a collision with the wall
   C. a change in momentum of a gas molecule during a collision with the wall
   D. elastic collisions between gas molecules
   E. inelastic collisions between gas molecules

   ans: C

28. A gas is confined to a cylindrical container of radius 1 cm and length 1 m. The pressure exerted on an end face, compared with the pressure exerted on the long curved face, is:
   A. smaller because its area is smaller
   B. smaller because most molecules cannot traverse the length of the cylinder without undergoing collisions
   C. larger because the face is flat
   D. larger because the molecules have a greater distance in which to accelerate before they strike the face
   E. none of these

   ans: E

29. Air is pumped into a bicycle tire at constant temperature. The pressure increases because:
   A. more molecules strike the tire wall per second
   B. the molecules are larger
   C. the molecules are farther apart
   D. each molecule is moving faster
   E. each molecule has more kinetic energy

   ans: A

30. The temperature of a gas is most closely related to:
   A. the kinetic energy of translation of its molecules
   B. its total molecular kinetic energy
   C. the sizes of its molecules
   D. the potential energy of its molecules
   E. the total energy of its molecules

   ans: A

31. The temperature of low pressure hydrogen is reduced from 100° C to 20° C. The rms speed of its molecules decreases by approximately:

A. 80%
B. 89%
C. 46%
D. 21%
E. 11%

ans: E

32. The mass of an oxygen molecule is 16 times that of a hydrogen molecule. At room temperature, the ratio of the rms speed of an oxygen molecule to that of a hydrogen molecule is:

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

ans: D

33. The rms speed of an oxygen molecule at 0° C is 460 m/s. If the molar mass of oxygen is 32 g and that of helium is 4 g, then the rms speed of a helium molecule at 0° C is:

A. 230 m/s
B. 326 m/s
C. 650 m/s
D. 920 m/s
E. 1300 m/s

ans: E

34. A sample of argon gas (molar mass 40 g) is at four times the absolute temperature of a sample of hydrogen gas (molar mass 2 g). The ratio of the rms speed of the argon molecules to that of the hydrogen is:

A. 1
B. 5
C. 1/5
D. $\sqrt{5}$
E. $1/\sqrt{5}$

ans: D

35. If the molecules in a tank of hydrogen have the same rms speed as the molecules in a tank of oxygen, we may be sure that:

A. the pressures are the same
B. the hydrogen is at the higher temperature
C. the hydrogen is at the greater pressure
D. the temperatures are the same
E. the oxygen is at the higher temperature

ans: E

36. The principle of equipartition of energy states that the internal energy of a gas is shared equally:

A. among the molecules
B. between kinetic and potential energy
C. among the relevant degrees of freedom
D. between translational and vibrational kinetic energy
E. between temperature and pressure

ans: C

37. The number of degrees of freedom of a rigid diatomic molecule is:

A. 2
B. 3
C. 4
D. 5
E. 6

ans: D

38. The number of degrees of freedom of a triatomic molecule is:

A. 1
B. 3
C. 6
D. 8
E. 9

ans: E

39. Five molecules have speeds of 2.8, 3.2, 5.8, 7.3, and 7.4 m/s. Their root-mean-square speed is closest to:

A. 5.3 m/s
B. 5.7 m/s
C. 7.3 m/s
D. 28 m/s
E. 32 m/s

ans: B

40. The speeds of 25 molecules are distributed as follows: 5 in the range from 2 to 3 m/s, 10 in the range from 3 to 4 m/s, 5 in the range from 4 to 5 m/s, 3 in the range from 5 to 6 m/s, 1 in the range from 6 to 7 m/s, and 1 in the range from 7 to 8 m/s. Their average speed is about:

A. 2 m/s
B. 3 m/s
C. 4 m/s
D. 5 m/s
E. 6 m/s

ans: C

41. In a system of N gas molecules, the individual speeds are v_1, v_2, ..., v_N. The rms speed of these molecules is:

A. $\frac{1}{N}\sqrt{v_1 + v_2 + \ldots + v_N}$
B. $\frac{1}{N}\sqrt{v_1^2 + v_2^2 + \ldots + v_N^2}$
C. $\sqrt{(v_1^2 + v_2^2 + \ldots + v_N^2)/N}$
D. $\sqrt{[(v_1 + v_2 + \ldots + v_N)/N]^2}$
E. $\sqrt{(v_1 + v_2 + \ldots + v_N)^2/N}$

ans: C

42. A system consists of N gas molecules, each with mass m. Their rms speed is $v_{\rm rms}$. Their total translational kinetic energy is:

A. $(1/2)m(Nv_{\rm rms})^2$
B. $(1/2)N(mv_{\rm rms})^2$
C. $(1/2)mv_{\rm rms}^2$
D. $(1/2)Nmv_{\rm rms}^2$
E. $N\left[(1/2)mv_{\rm rms}\right]^2$

ans: D

43. The average speeds v and molecular diameters d of five ideal gases are given below. The number of molecules per unit volume is the same for all of them. For which is the collision rate the greatest?

A. $v = v_0$ and $d = d_0$
B. $v = 2v_0$ and $d = d_0/2$
C. $v = 3v_0$ and $d = d_0$
D. $v = v_0$ and $d = 2d_0$
E. $v = 4v_0$ and $d = d_0/2$

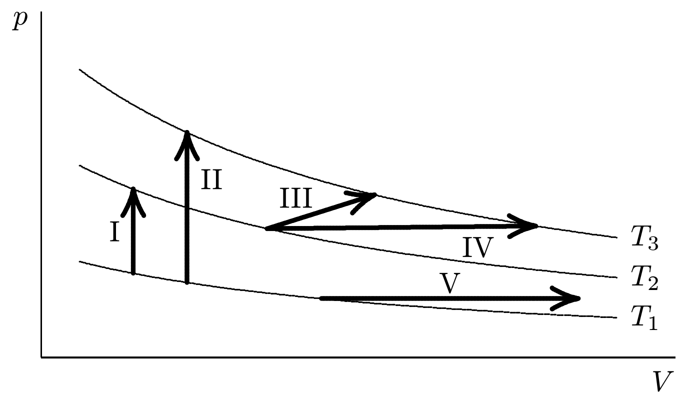
ans: D

44. The internal energy of an ideal gas depends on:

A. the temperature only
B. the pressure only
C. the volume only
D. the temperature and pressure only
E. temperature, pressure, and volume

ans: A

45. The diagram shows three isotherms for an ideal gas, with $T_3 - T_2$ the same as $T_2 - T_1$. It also shows five thermodynamic processes carried out on the gas. Rank the processes in order of the change in the internal energy of th gas, least to greatest.



A. I, II, III, IV, V
B. V, then I, III, and IV tied, then II
C. V, I, then III and IV tied, then II
D. IV, V, III, I, II
E. II, I, then III, IV, and V tied

ans: B

46. An ideal gas of N monatomic molecules is in thermal equilibrium with an ideal gas of the same number of diatomic molecules and equilibrium is maintained as the temperature is increased. The ratio of the changes in the internal energies $\Delta E_{\text{dia}}/\Delta E_{\text{mon}}$ is:

A. 1/2
B. 3/5
C. 1
D. 5/3
E. 2

ans: D

47. Two ideal gases, each consisting of N monatomic molecules, are in thermal equilibrium with each other and equilibrium is maintained as the temperature is increased. A molecule of the first gas has mass m and a molecule of the second has mass $4m$. The ratio of the changes in the internal energies $\Delta E_{4m}/\Delta E_m$ is:

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

ans: C

48. Three gases, one consisting of monatomic molecules, one consisting of diatomic molecules, and one consisting of polyatomic molecules, are in thermal equilibrium with each other and remain in thermal equilibrium as the temperature is raised. All have the same number of molecules. The gases with the least and greatest change in internal energy are respectively:

A. polyatomic, monatomic
B. monatomic, polyatomic
C. diatomic, monatomic
D. polyatomic, diatomic
E. monatomic, diatomic

ans: B

49. An ideal gas of N diatomic molecules has temperature T. If the number of molecules is doubled without changing the temperature, the internal energy increases by:

A. 0
B. $(1/2)NkT$
C. $(3/2)NkT$
D. $(5/2)NkT$
E. $3NkT$

ans: D

50. Both the pressure and volume of an ideal gas of diatomic molecules are doubled. The ratio of the new internal energy to the old, both measured relative to the internal energy at $0\,\mathrm{K}$, is

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

ans: E

51. The pressure of an ideal gas of diatomic molecules is doubled by halving the volume. The ratio of the new internal energy to the old, both measured relative to the internal energy at $0\,\mathrm{K}$, is:

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

ans: C

52. When work W is done on an ideal gas of N diatomic molecules in thermal isolation the temperature increases by:

A. $W/2Nk$
B. $W/3Nk$
C. $2W/3Nk$
D. $2W/5Nk$
E. W/Nk

ans: D

53. When work W is done on an ideal gas of diatomic molecules in thermal isolation the increase in the total rotational energy of the molecules is:

A. 0
B. $W/3$
C. $2W/3$
D. $2W/5$
E. W

ans: D

54. When work W is done on an ideal gas of diatomic molecules in thermal isolation the increase in the total translational kinetic energy of the molecules is:

A. 0
B. $2W/3$
C. $2W/5$
D. $3W/5$
E. W

ans: D

55. The pressure of an ideal gas is doubled in an isothermal process. The root-mean-square speed of the molecules:

A. does not change
B. increases by a factor of $\sqrt{2}$
C. decreases by a factor of $1/\sqrt{2}$
D. increases by a factor of 2
E. decreases by a factor of 1/2

ans: A

56. The Maxwellian speed distribution provides a direct explanation of:

A. thermal expansion
B. the ideal gas law
C. heat
D. evaporation
E. boiling

ans: D

57. For a gas at thermal equilibrium the average speed v, the most probable speed v_p, and the root-mean-square speed $v_{\rm rms}$ are in the order:

A. $v_p < v_{\rm rms} < v$
B. $v_{\rm rms} < v_p < v$
C. $v < v_{\rm rms} < v_p$
D. $v_p < v < v_{\rm rms}$
E. $v < v_p < v_{\rm rms}$

ans: D

58. The average speed of air molecules at room temperature is about:

A. zero
B. 2 m/s (walking speed)
C. 30 m/s (fast car)
D. 500 m/s (supersonic airplane)
E. 3×10^8 m/s (speed of light)

ans: D

59. The root-mean-square sped of molecules in a gas is:

A. the most probable speed
B. that speed such that half the molecules are moving faster than $v_{\rm rms}$ and the other half are moving slower
C. the average speed of the molecules
D. the square root of the square of the average speed
E. none of the above

ans: E

60. According to the Maxwellian speed distribution, as the temperature increases the number of molecules with speeds within a small interval near the most probable speed:

A. increases
B. decreases
C. increases at high temperatures and decreases at low
D. decreases at high temperatures and increases at low
E. stays the same

ans: B

61. According to the Maxwellian speed distribution, as the temperature increases the most probable speed:

A. increases
B. decreases
C. increases at high temperatures and decreases at low
D. decreases at high temperatures and increases at low
E. stays the same

ans: A

62. According to the Maxwellian speed distribution, as the temperature increases the average speed:

A. increases
B. decreases
C. increases at high temperatures and decreases at low
D. decreases at high temperatures and increases at low
E. stays the same

ans: A

63. As the pressure in an ideal gas is increased isothermally the average molecular speed:

A. increases
B. decreases
C. increases at high temperature, decreases at low
D. decreases at high temperature, increases at low
E. stays the same

ans: E

64. As the volume of an ideal gas is increased at constant pressure the average molecular speed:

A. increases
B. decreases
C. increases at high temperature, decreases at low
D. decreases at high temperature, increases at low
E. stays the same

ans: A

65. Two ideal monatomic gases are in thermal equilibrium with each other. Gas A is composed of molecules with mass m while gas B is composed of molecules with mass $4m$. The ratio of the average molecular speeds v_A/v_B is:

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

ans: D

66. Ideal monatomic gas A is composed of molecules with mass m while ideal monatomic gas B is composed of molecules with mass $4m$. The average molecular speeds are the same if the ratio of the temperatures T_A/T_B is:

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

ans: A

67. Two monatomic ideal gases are in thermal equilibrium with each other. Gas A is composed of molecules with mass m while gas B is composed of molecules with mass $4m$. The ratio of the average translational kinetic energies K_A/K_B is:

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

ans: C

68. Ideal monatomic gas A is composed of molecules with mass m while ideal monatomic gas B is composed of molecules with mass $4m$. The average translational kinetic energies are the same if the ratio of the temperatures T_A/T_B is:

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

ans: C

69. Which of the following change when the pressure of an ideal gas is changed isothermally?

A. Mean free path
B. Root-mean-square molecular speed
C. Internal energy
D. Most probable kinetic energy
E. Average speed

ans: A

70. When an ideal gas undergoes a slow isothermal expansion:

A. the work done by the gas is the same as the energy absorbed as heat
B. the work done by the environment is the same as the energy absorbed as heat
C. the increase in internal energy is the same as the energy absorbed as heat
D. the increase in internal energy is the same as the work done by the gas
E. the increase in internal energy is the same as the work done by the environment

ans: A

71. The pressure of an ideal gas is doubled during a process in which the energy given up as heat by the gas equals the work done on the gas. As a result, the volume is:

A. doubled
B. halved
C. unchanged
D. need more information to answer
E. nonsense; the process is impossible

ans: B

72. The energy absorbed as heat by an ideal gas for an isothermal process equals:

A. the work done by the gas
B. the work done on the gas
C. the change in the internal energy of the gas
D. the negative of the change in internal energy of the gas
E. zero since the process is isothermal

ans: A

73. An ideal gas has molar specific heat C_p at constant pressure. When the temperature of n moles is increased by ΔT the increase in the internal energy is:

A. $nC_p\,\Delta T$
B. $n(C_p + R)\,\Delta T$
C. $n(C_p - R)\,\Delta T$
D. $n(2C_p + R)\,\Delta T$
E. $n(2C_p - R)\,\Delta T$

ans: C

74. The temperature of n moles of an ideal monatomic gas is increased by ΔT at constant pressure. The energy Q absorbed as heat, change ΔE_{int} in internal energy, and work W done by the environment are given by:

A. $Q = (5/2)nR\,\Delta T$, $\Delta E_{\text{int}} = 0$, $W = -nR\,\Delta T$
B. $Q = (3/2)nR\,\Delta T$, $\Delta E_{\text{int}} = (5/2)nR\,\Delta T$, $W = -(3/2)nR\,\Delta T$
C. $Q = (5/2)nR\,\Delta T$, $\Delta E_{\text{int}} = (5/2)nR\,\Delta T$, $W = 0$
D. $Q = (3/2)nR\,\Delta T$, $\Delta E_{\text{int}} = 0$, $W = -nR\,\Delta T$
E. $Q = (5/2)nR\,\Delta T$, $\Delta E_{\text{int}} = (3/2)nR\,\Delta T$, $W = -nR\,\Delta T$

ans: E

75. The temperature of n moles of an ideal monatomic gas is increased by ΔT at constant volume. The energy Q absorbed as heat, change ΔE_{int} in internal energy, and work W done by the environment are given by:

A. $Q = (5/2)nR\,\Delta T$, $\Delta E_{\text{int}} = 0$, $W = 0$
B. $Q = (3/2)nR\,\Delta T$, $\Delta E_{\text{int}} = (3/2)nR\,\Delta T$, $W = 0$
C. $Q = (3/2)nR\,\Delta T$, $\Delta E_{\text{int}} = (1/2)nR\,\Delta T$, $W = -nR\,\Delta t$
D. $Q = (5/2)nR\,\Delta T$, $\Delta E_{\text{int}} = (3/2)nR\,\Delta T$, $W = -nR\,\Delta T$
E. $Q = (3/2)nR\,\Delta T$, $\Delta E_{\text{int}} = 0$, $W = -(3/2)nR\,\Delta T$

ans: B

76. The heat capacity at constant volume of an ideal gas depends on:

A. the temperature
B. the pressure
C. the volume
D. the number of molecules
E. none of the above

ans: D

77. The specific heat at constant volume of an ideal gas depends on:

A. the temperature
B. the pressure
C. the volume
D. the number of molecules
E. none of the above

ans: E

78. The difference between the molar specific heat at constant pressure and the molar specific heat at constant volume for an ideal gas is:

A. the Boltzmann constant k
B. the universal gas constant R
C. the Avogadro constant N_A
D. kT
E. RT

ans: B

79. An ideal monatomic gas has a molar specific heat C_v at constant volume of:

A. R
B. $3R/2$
C. $5R/2$
D. $7R/2$
E. $9R/2$

ans: B

80. The specific heat C_v at constant volume of a monatomic gas at low pressure is proportional to T^n where the exponent n is:

A. -1
B. 0
C. 1
D. 1/2
E. 2

ans: B

81. An ideal diatomic gas has a molar specific heat at constant pressure C_p of:

A. R
B. $3R/2$
C. $5R/2$
D. $7R/2$
E. $9R/2$

ans: D

82. The specific heat of a polyatomic gas is greater than the specific heat of a monatomic gas because:

A. the polyatomic gas does more positive work when energy is absorbed as heat
B. the monatomic gas does more positive work when energy is absorbed as heat
C. the energy absorbed by the polyatomic gas is split among more degrees of freedom
D. the pressure is greater in the polyatomic gas
E. a monatomic gas cannot hold as much heat

ans: C

83. The ratio of the specific heat of a gas at constant volume to its specific heat at constant pressure is:

A. 1
B. less than 1
C. more than 1
D. has units of pressure/volume
E. has units of volume/pressure

ans: B

84. The ratio of the specific heat of an ideal gas at constant volume to its specific heat at constant pressure is:

A. R
B. $1/R$
C. dependent on the temperature
D. dependent on the pressure
E. different for monatomic, diatomic, and polyatomic gases

ans: E

85. Consider the ratios of the heat capacities $\gamma = C_p/C_v$ for the three types of ideal gases: monatomic, diatomic, and polyatomic.

A. γ is the greatest for monatomic gases
B. γ is the greatest for polyatomic gases
C. γ is the same only for diatomic and polyatomic gases
D. γ is the same only for monatomic and diatomic gases
E. γ is the same for all three

ans: A

86. $TV^{\gamma-1}$ is constant for an ideal gas undergoing an adiabatic process, where γ is the ratio of heat capacities C_p/C_v. This is a direct consequence of:

A. the zeroth law of thermodynamics alone
B. the zeroth law and the ideal gas equation of state
C. the first law of thermodynamics alone
D. the ideal gas equation of state alone
E. the first law and the equation of state

ans: E

87. Monatomic, diatomic, and polyatomic ideal gases each undergo slow adiabatic expansions from the same initial volume and the same initial pressure to the same final volume. The magnitude of the work done by the environment on the gas:

A. is greatest for the polyatomic gas
B. is greatest for the diatomic gas
C. is greatest for the monatomic gas
D. is the same only for the diatomic and polyatomic gases
E. is the same for all three gases

ans: A

88. The mean free path of a gas molecule is:

A. the shortest dimension of the containing vessel
B. the cube root of the volume of the containing vessel
C. approximately the diameter of a molecule
D. average distance between adjacent molecules
E. average distance a molecule travels between intermolecular collisions

ans: E

89. The mean free path of molecules in a gas is:

A. the average distance a molecule travels before escaping
B. the average distance a molecule travels between collisions
C. the greatest distance a molecule travels between collisions
D. the shortest distance a molecule travels between collisions
E. the average distance a molecule travels before splitting apart

ans: B

90. The mean free path of air molecules at room temperature and atmospheric pressure is about:

A. 10^{-3} m
B. 10^{-5} m
C. 10^{-7} m
D. 10^{-9} m
E. 10^{-11} m

ans: C

91. The mean free path of molecules in a gas is proportional to:

A. the molecular cross-sectional area
B. the reciprocal of the molecular cross-sectional area
C. the root-mean-square molecular speed
D. the square of the average molecular speed
E. the molar mass

ans: B

92. The mean free path of molecules in a gas is proportional to:

A. the molecular diameter
B. the reciprocal of the molecular diameter
C. the molecular concentration
D. the reciprocal of the molecular concentration
E. the average molecular speed

ans: D

93. In a certain gas the molecules are 5.0×10^{-9} m apart on average, have a mean free path of 5.0×10^{-6} m, and have an average speed of 500 m/s. The rate at which a molecule has collisions with other molecules is about:

A. $10^{-11}\,\mathrm{s}^{-1}$
B. $10^{-8}\,\mathrm{s}^{-1}$
C. $1\,\mathrm{s}^{-1}$
D. $10^{8}\,\mathrm{s}^{-1}$
E. $10^{11}\,\mathrm{s}^{-1}$

ans: D

94. If the temperature T of an ideal gas is increased at constant pressure the mean free path:

A. decreases in proportion to $1/T$
B. decreases in proportion to $1/T^2$
C. increases in proportion to T
D. increases in proportion to T^2
E. does not change

ans: C

95. A certain ideal gas has a temperature 300 K and a pressure 5.0×10^4 Pa. The molecules have a mean free path of 4.0×10^{-7} m. If the temperature is raised to 350 K and the pressure is reduced to 1.0×10^4 Pa the mean free path is then:

A. 6.9×10^{-8} m
B. 9.3×10^{-8} m
C. 3.3×10^{-7} m
D. 1.7×10^{-6} m
E. 2.3×10^{-6} m

ans: E

Chapter 13: GRAVITATION

1. In the formula $F = Gm_1m_2/r^2$, the quantity G:
   A. depends on the local value of g
   B. is used only when Earth is one of the two masses
   C. is greatest at the surface of Earth
   D. is a universal constant of nature
   E. is related to the Sun in the same way that g is related to Earth
   ans: D

2. The magnitude of the acceleration of a planet in orbit around the Sun is proportional to:
   A. the mass of the planet
   B. the mass of the Sun
   C. the distance between the planet and the Sun
   D. the reciprocal of the distance between the planet and the Sun
   E. the product of the mass of the planet and the mass of the Sun
   ans: B

3. Suitable units for the gravitational constant G are:
   A. $\text{kg}\cdot\text{m/s}^2$
   B. m/s^2
   C. $\text{N}\cdot\text{s/m}$
   D. $\text{kg}\cdot\text{m/s}$
   E. $\text{m}^3/(\text{kg}\cdot\text{s}^2)$
   ans: E

4. The gravitational constant G has the derived units:
   A. $\text{N}\cdot\text{m}$
   B. $\text{N}\cdot\text{m/kg}$
   C. $\text{N}\cdot\text{kg/m}$
   D. $\text{N}\cdot\text{m}^2/\text{kg}^2$
   E. $\text{N}\cdot\text{kg}^2/\text{m}^2$
   ans: D

5. Earth exerts a gravitational force on the Moon, keeping it in its orbit. The reaction to this force, in the sense of Newton's third law, is:
   A. the centripetal force on the Moon
   B. the nearly circular orbit of the Moon
   C. the gravitational force on Earth by the Moon
   D. the tides due to the Moon
   E. the apple hitting Newton on the head.
   ans: C

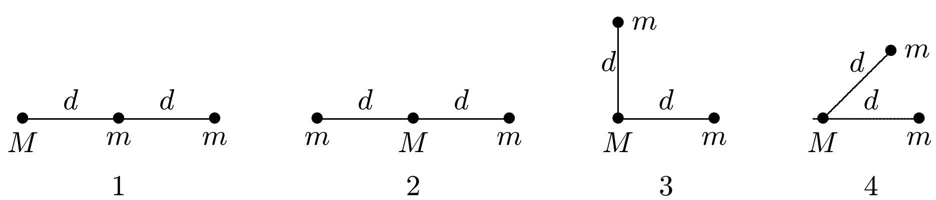
6. A particle might be placed
   1. inside a uniform spherical shell of mass M, but not at the center
   2. inside a uniform spherical shell of mass M, at the center
   3. outside a uniform spherical shell of mass M, a distance r from the center
   4. outside a uniform solid sphere of mass M, a distance $2r$ from the center

   Rank these situations according to the magnitude of the gravitational force on the particle, least to greatest.

   A. All tie
   B. 1, 2, 3, 4
   C. 1 and 2 tie, then 3 and 4 tie
   D. 1 and 2 tie, then 3, then 4
   E. 1 and 2 tie, then 4, then 3

   ans: D

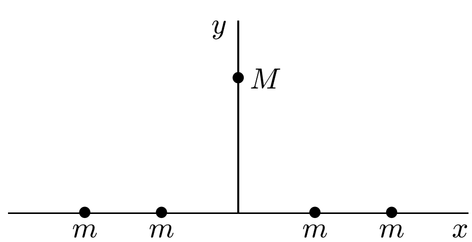
7. Three particles, two with mass m and one with mass M, might be arranged in any of the four configurations known below. Rank the configurations according to the magnitude of the gravitational force on M, least to greatest.



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

   ans: B

8. Four particles, each with mass m are arranged symmetrically about the origin on the x axis. A fifth particle, with mass M, is on the y axis. The direction of the gravitational force on M is:



   A. $\uparrow$
   B. $\downarrow$
   C. $\leftarrow$
   D. $\rightarrow$
   E. none of these directions

   ans: B

9. Let F_1 be the magnitude of the gravitational force exerted on the Sun by Earth and F_2 be the magnitude of the force exerted on Earth by the Sun. Then:
   A. F_1 is much greater than F_2
   B. F_1 is slightly greater than F_2
   C. F_1 is equal to F_2
   D. F_1 is slightly less than F_2
   E. F_1 is much less than F_2

   ans: C

10. Let M denote the mass of Earth and let R denote its radius. The ratio g/G at Earth's surface is:
   A. R^2/M
   B. M/R^2
   C. MR^2
   D. M/R
   E. R/M

   ans: B

11. Venus has a mass of about 0.0558 times the mass of Earth and a diameter of about 0.381 times the diameter of Earth. The acceleration of a body falling near the surface of Venus is about:
   A. $0.21\,\mathrm{m/s^2}$
   B. $1.4\,\mathrm{m/s^2}$
   C. $2.8\,\mathrm{m/s^2}$
   D. $3.8\,\mathrm{m/s^2}$
   E. $25\,\mathrm{m/s^2}$

   ans: D

12. The approximate value of g at an altitude above Earth equal to one Earth diameter is:
   A. $9.8\,\mathrm{m/s^2}$
   B. $4.9\,\mathrm{m/s^2}$
   C. $2.5\,\mathrm{m/s^2}$
   D. $1.9\,\mathrm{m/s^2}$
   E. $1.1\,\mathrm{m/s^2}$

   ans: E

13. A rocket ship is coasting toward a planet. Its captain wishes to know the value of g at the surface of the planet. This may be inferred by:
   A. measuring the apparent weight of one of the crew
   B. measuring the apparent weight of an object of known mass in the ship
   C. measuring the diameter of the planet
   D. measuring the density of the planet
   E. observing the ship's acceleration and correcting for the distance from the center of the planet.

   ans: E

14. To measure the mass of a planet with the same radius as Earth, an astronaut drops an object from rest (relative to the planet) from an altitude of one radius above the surface. When the object hits its speed is 4 times what it would be if the same experiment were carried out for Earth. In units of Earth masses, the mass of the planet is:

A. 2
B. 4
C. 8
D. 16
E. 32

ans: D

15. Suppose you have a pendulum clock that keeps correct time on Earth (acceleration due to gravity $= 9.8\,\mathrm{m/s^2}$). Without changing the clock, you take it to the Moon (acceleration due to gravity $= 1.6\,\mathrm{m/s^2}$). For every hour interval (on Earth) the Moon clock will record:

A. $(9.8/1.6)\,\mathrm{h}$
B. $1\,\mathrm{h}$
C. $\sqrt{9.8/1.6}\,\mathrm{h}$
D. $(1.6/9.8)\,\mathrm{h}$
E. $\sqrt{1.6/9.8}\,\mathrm{h}$

ans: E

16. The mass of an object:

A. is slightly different at different locations on Earth
B. is a vector
C. is independent of the acceleration due to gravity
D. is the same for all objects of the same size and shape
E. can be measured directly and accurately on a spring scale

ans: C

17. An astronaut on the Moon simultaneously drops a feather and a hammer. The fact that they land together shows that:

A. no gravity forces act on a body in a vacuum
B. the acceleration due to gravity on the Moon is less than on Earth
C. in the absence of air resistance all bodies at a given location fall with the same acceleration
D. the feather has a greater weight on the Moon than on Earth
E. $G = 0$ on the Moon

ans: C

18. The mass of a hypothetical planet is 1/100 that of Earth and its radius is 1/4 that of Earth. If a person weighs 600 N on Earth, what would he weigh on this planet?

A. 24 N
B. 48 N
C. 96 N
D. 192 N
E. 600 N

ans: C

19. An object at the surface of Earth (at a distance R from the center of Earth) weighs 90 N. Its weight at a distance $3R$ from the center of Earth is:

A. 10 N
B. 30 N
C. 90 N
D. 270 N
E. 810 N

ans: A

20. An object is raised from the surface of Earth to a height of two Earth radii above Earth. Then:

A. its mass increases and its weight remains constant
B. both its mass and weight remain constant
C. its mass remains constant and its weight decreases
D. both its mass and its weight decrease
E. its mass remains constant and its weight increases

ans: C

21. A spring scale, calibrated in newtons, is used to weigh sugar. If it were possible to weigh sugar at the following locations, where will the buyer get the most sugar to a newton?

A. At the north pole
B. At the equator
C. At the center of Earth
D. On the Moon
E. On Jupiter

ans: C

22. Of the following where would the weight of an object be the least?

A. 2000 miles above Earth's surface
B. At the north pole
C. At the equator
D. At the center of Earth
E. At the south pole

ans: D

23. If Earth were to rotate only 100 times per year about its axis:

A. airplanes flying west to east would make better time
B. we would fly off Earth's surface
C. our apparent weight would slightly increase
D. Earth's atmosphere would float into outer space
E. our apparent weight would slightly decrease

ans: C

24. An astronaut in an orbiting spacecraft feels "weightless" because she:
    A. is beyond the range of gravity
    B. is pulled outward by centrifugal force
    C. has no acceleration
    D. has the same acceleration as the spacecraft
    E. is outside Earth's atmosphere

    ans: D

25. Each of the four corners of a square with edge a is occupied by a point mass m. There is a fifth mass, also m, at the center of the square. To remove the mass from the center to a point far away the work that must be done by an external agent is given by:
    A. $4Gm^2/a$
    B. $-4Gm^2/a$
    C. $4\sqrt{2}Gm^2/a$
    D. $-4\sqrt{2}Gm^2/a$
    E. $4Gm^2/a^2$

    ans: C

26. Two particles, each of mass m, are a distance d apart. To bring a third particle, with mass $2m$, from far away to a resting point midway between the two particles the work done by an external agent is given by:
    A. $4Gm^2/d$
    B. $-4Gm^2/d$
    C. $8Gm^2/d^2$
    D. $-8Gm^2/d^2$
    E. zero

    ans: D

27. The escape speed at the surface of Earth is approximately 8 km/s. What is the mass, in units of Earth's mass, of a planet with twice the radius of Earth for which the escape speed is twice that for Earth?
    A. 2
    B. 4
    C. 8
    D. 1/2
    E. 1/4

    ans: C

28. Neglecting air resistance, a 1.0-kg projectile has an escape velocity of about 11 km/s at the surface of Earth. The corresponding escape velocity for a 2.0 kg projectile is:
    A. 3.5 km/s
    B. 5.5 km/s
    C. 7.1 km/s
    D. 10 km/s
    E. 11 km/s

    ans: E

29. Neglecting air resistance, the escape speed from a certain planet for an empty space vehicle is 1.12×10^4 m/s. What is the corresponding escape speed for the fully loaded vehicle, which has triple the mass of the empty one?

A. 3.73×10^3 m/s
B. 1.12×10^4 m/s
C. 3.36×10^4 m/s
D. 9.98×10^4 m/s
E. 1.40×10^{12} m/s

ans: B

30. An object is dropped from an altitude of one Earth radius above Earth's surface. If M is the mass of Earth and R is its radius the speed of the object just before it hits Earth is given by:

A. $\sqrt{GM/R}$
B. $\sqrt{GM/2R}$
C. $\sqrt{2GM/R}$
D. $\sqrt{GM/R^2}$
E. $\sqrt{GM/2R^2}$

ans: A

31. A projectile is fired straight upward from Earth's surface with a speed that is half the escape speed. If R is the radius of Earth, the highest altitude reached, measured from the surface, is:

A. $R/4$
B. $R/3$
C. $R/2$
D. R
E. $2R$

ans: B

32. The mass density of a certain planet has spherical symmetry but varies in such a way that the mass inside every spherical surface with center at the center of the planet is proportional to the radius of the surface. If r is the distance from the center of the planet to a point mass inside the planet, the gravitational force on the mass is:

A. not dependent on r
B. proportional to r^2
C. proportional to r
D. proportional to $1/r$
E. proportional to $1/r^2$

ans: D

33. A spherical shell has inner radius R_1, outer radius R_2, and mass M, distributed uniformly throughout the shell. The magnitude of the gravitational force exerted on the shell by a point mass particle of m, located a distance d from the center, inside the inner radius, is:

A. 0
B. GMm/R_1^2
C. GMm/d^2
D. $GMm/(R_2^2 - d^2)$
E. $GMm/(R_1 - d)^2$

ans: A

34. A spherical shell has inner radius R_1, outer radius R_2, and mass M, distributed uniformly throughout the shell. The magnitude of the gravitational force exerted on the shell by a point mass m, located a distance d from the center, outside the outer radius, is:

A. 0
B. GMm/R_1^2
C. GMm/d^2
D. $GMm/(R_2^2 - d^2)$
E. $GMm/(R_1 - d)^2$

ans: C

35. A spherical shell has inner radius R_1, outer radius R_2, and mass M, distributed uniformly throughout the shell. The magnitude of the gravitational force exerted on the shell by a point particle of mass m located a distance d from the center, outside the inner radius and inside the outer radius, is:

A. 0
B. GMm/d^2
C. $GMm/(R_2^3 - d^3)$
D. $GMm(d^3 - R_1^3)/d^2(R_2^3 - R_1^3)$
E. $GMm/(d^3 - R_1^3)$

ans: D

36. An artificial satellite of Earth releases a bomb. Neglecting air resistance, the bomb will:

A. strike Earth under the satellite at the instant of release
B. strike Earth under the satellite at the instant of impact
C. strike Earth ahead of the satellite at the instant of impact
D. strike Earth behind the satellite at the instant of impact
E. never strike Earth

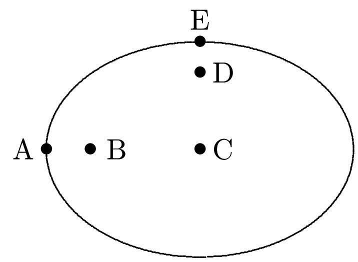
ans: E

37. An astronaut finishes some work on the outside of his satellite, which is in circular orbit around Earth. He leaves his wrench outside the satellite. The wrench will:

A. fall directly down to Earth
B. continue in orbit at reduced speed
C. continue in orbit with the satellite
D. fly off tangentially into space
E. spiral down to Earth

ans: C

38. The elliptical orbit of a planet around the Sun is shown on the diagram. Which of the following statements is true?



A. the eccentricity of the orbit is less than zero
B. the eccentricity of the orbit is greater than 1
C. the sun might be at point C
D. the sun might be at point D
E. the sun might be at point B

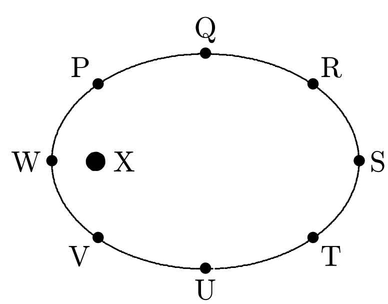
ans: E

39. Consider the statement: "Earth moves in a stable orbit around the Sun and is therefore in equilibrium". The statement is:

A. false, because no moving body can be in equilibrium
B. true, because Earth does not fall into or fly away from the Sun
C. false, because Earth is rotating on its axis and no rotating body can be in equilibrium
D. false, because Earth has a considerable acceleration
E. true, because if it were not in equilibrium then buildings and structures would not be stable

ans: D

40. A planet travels in an elliptical orbit about a star X as shown. The magnitude of the acceleration of the planet is:



A. greatest at point Q
B. greatest at point S
C. greatest at point U
D. greatest at point W
E. the same at all points

ans: D

41. In planetary motion the line from the star to the planet sweeps out equal areas in equal times. This is a direct consequence of:

A. the conservation of energy
B. the conservation of momentum
C. the conservation of angular momentum
D. the conservation of mass
E. none of the above

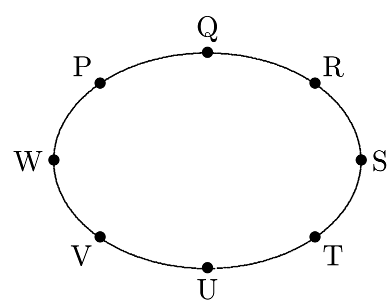
ans: C

42. The speed of a comet in an elliptical orbit about the Sun:

A. decreases while it is receding from the Sun
B. is constant
C. is greatest when farthest from the Sun
D. varies sinusoidally with time
E. equals $L/(mr)$, where L is its angular momentum, m is its mass, and r is its distance from the Sun

ans: A

43. A planet travels in an elliptical orbit about a star as shown. At what pair of points is the speed of the planet the same?



A. W and S
B. P and T
C. P and R
D. Q and U
E. V and R

ans: D

44. Planet 1 and planet 2 are both in circular orbits around the same central star. The orbit of planet 2 has a radius that is much larger than the radius of the orbit of planet 1. This means that:

A. the period of planet 1 is greater than the period of planet 2 and the speed of planet 1 is greater than the speed of planet 2
B. the period of planet 1 is greater than the period of planet 2 and the speed of planet 1 is less than the speed of planet 2
C. the period of planet 1 is less than the period of planet 2 and the speed of planet 1 is less than the speed of planet 2
D. the period of planet 1 is less than the period of planet 2 and the speed of planet 1 is greater than the speed of planet 2
E. the planets have the same speed and the same period

ans: D

45. For a planet in orbit around a star the perihelion distance is r_p ad its speed at perihelion is v_p. The aphelion distance is r_a and its speed at aphelion is v_a. Which of the following is true?

A. $v_a = v_p$
B. $v_a/r_a = v_p/r_p$
C. $v_a r_a = v_p r_p$
D. $v_a/r_a^2 = v_p/r_p^2$
E. $v_a r_a^2 = v_p r_p^2$

ans: C

46. A planet is in circular orbit around the Sun. Its distance from the Sun is four times the average distance of Earth from the Sun. The period of this planet, in Earth years, is:

A. 4
B. 8
C. 16
D. 64
E. 2.52

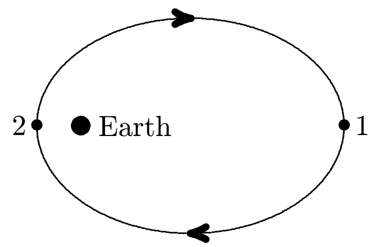
ans: B

47. Two planets are orbiting a star in a distant galaxy. The first has a semimajor axis of 150×10^6 km, an eccentricity of 0.20, and a period of 1.0 Earth years. The second has a semimajor axis of 250×10^6 km, an eccentricity of 0.30, and a period of:

A. 0.46 Earth years
B. 0.57 Earth years
C. 1.4 Earth years
D. 1.8 Earth years
E. 2.2 Earth years

ans: E

48. A small satellite is in elliptical orbit around Earth as shown. If L denotes the magnitude of its angular momentum and K denotes kinetic energy:



A. $L_2 > L_1$ and $K_2 > K_1$
B. $L_2 > L_1$ and $K_2 = K_1$
C. $L_2 = L_1$ and $K_2 = K_1$
D. $L_2 < L_1$ and $K_2 = K_1$
E. $L_2 = L_1$ and $K_2 > K_1$

ans: E

49. Assume that Earth is in circular orbit around the Sun with kinetic energy K and potential energy U, taken to be zero for infinite separation. Then, the relationship between K and U:

A. is $K = U$
B. is $K = -U$
C. is $K = U/2$
D. is $K = -U/2$
E. depends on the radius of the orbit

ans: D

50. An artificial Earth satellite is moved from a circular orbit with radius R to a circular orbit with radius $2R$. During this move:

A. the gravitational force does positive work, the kinetic energy of the satellite increases, and the potential energy of the Earth-satellite system increases
B. the gravitational force does positive work, the kinetic energy of the satellite increases, and the potential energy of the Earth-satellite system decreases
C. the gravitational force does positive work, the kinetic energy of the satellite decreases, and the potential energy of the Earth-satellite system increases
D. the gravitational force does negative work, the kinetic energy of the satellite increases, and the potential energy of the Earth-satellite system decreases
E. the gravitational force does negative work, the kinetic energy of the satellite decreases, and the potential energy of the Earth-satellite system increases

ans: E

51. An artificial satellite of Earth nears the end of its life due to air resistance. While still in orbit:

A. it moves faster as the orbit lowers
B. it moves slower as the orbit lowers
C. it slowly spirals away from Earth
D. it moves slower in the same orbit but with a decreasing period
E. it moves faster in the same orbit but with an increasing period

ans: A

52. A spaceship is returning to Earth with its engine turned off. Consider only the gravitational field of Earth and let M be the mass of Earth, m be the mass of the spaceship, and R be the distance from the center of Earth. In moving from position 1 to position 2 the kinetic energy of the spaceship increases by:

A. $GMm\left[\frac{1}{R_2^2}-\frac{1}{R_1^2}\right]GMm/R_2$
B. $GMm\left[\frac{1}{R_1^2}+\frac{1}{R_2^2}\right]$
C. $GMm\frac{R_1-R_2}{R_1^2}$
D. $GMm\frac{R_1-R_2}{R_1R_2}$
E. $GMm\frac{R_1-R_2}{R_1^2R_2^2}$

ans: D

53. Given the perihelion distance, aphelion distance, and speed at perihelion of a planet, which of the following CANNOT be calculated?

A. The mass of the star
B. The mass of the planet
C. The speed of the planet at aphelion
D. The period of orbit
E. The semimajor axis of the orbit

ans: B

54. The orbit of a certain satellite has a semimajor axis of 1.5×10^7 m and an eccentricity of 0.20. Its perigee (minimum distance) and apogee (maximum distance) are respectively:

A. 1.2×10^7 m, 1.8×10^7 m
B. 3.0×10^6 m, 1.2×10^7 m
C. 9.6×10^6 m, 1.0×10^7 m
D. 1.0×10^7 m, 1.2×10^7 m
E. 9.6×10^6 m, 1.8×10^7 m

ans: A

55. A planet in another solar system orbits a star with a mass of 4.0×10^{30} kg. At one point in its orbit it is 250×10^6 km from the star and is moving at 35 km/s. Take the universal gravitational constant to be $6.67\times10^{-11}\,\mathrm{m^2/s^2\cdot kg}$ and calculate the semimajor axis of the planet's orbit. The result is:

A. 79×10^6 km
B. 160×10^6 km
C. 290×10^6 km
D. 320×10^6 km
E. 590×10^6 km

ans: C

Chapter 14: FLUIDS

1. All fluids are:
   A. gases
   B. liquids
   C. gases or liquids
   D. non-metallic
   E. transparent
   ans: C

2. Gases may be distinguished from other forms of matter by their:
   A. lack of color
   B. small atomic weights
   C. inability to form free surfaces
   D. ability to flow
   E. ability to exert a buoyant force
   ans: C

3. 1 Pa is:
   A. $1\,\mathrm{N/m}$
   B. $1\,\mathrm{m/N}$
   C. $1\,\mathrm{kg/m\cdot s}$
   D. $1\,\mathrm{kg/m\cdot s^2}$
   E. $1\,\mathrm{N/m\cdot s}$
   ans: D

4. Mercury is a convenient liquid to use in a barometer because:
   A. it is a metal
   B. it has a high boiling point
   C. it expands little with temperature
   D. it has a high density
   E. it looks silvery
   ans: D

5. To obtain the absolute pressure from the gauge pressure:
   A. subtract atmospheric pressure
   B. add atmospheric pressure
   C. subtract 273
   D. add 273
   E. convert to $\mathrm{N/m^2}$
   ans: B

6. Barometers and open-tube manometers are two instruments that are used to measure pressure.
   A. Both measure gauge pressure
   B. Both measure absolute pressure
   C. Barometers measure gauge pressure and manometers measure absolute pressure
   D. Barometers measure absolute pressure and manometers measure gauge pressure
   E. Both measure an average of the absolute and gauge pressures

   ans: D

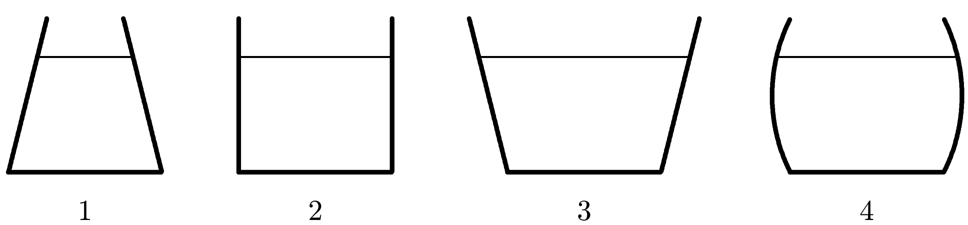
7. To measure moderately low pressures oil with a density of $8.5 \times 10^2\,\mathrm{kg/m^3}$ is used in place of mercury in a barometer. A change in the height of the oil column of 1.0 mm indicates a change in pressure of about:
   A. $1.2 \times 10^{-7}\,\mathrm{Pa}$
   B. $1.2 \times 10^{-5}\,\mathrm{Pa}$
   C. 0.85 Pa
   D. 1.2 Pa
   E. 8.3 Pa

   ans: E

8. The pressure exerted on the ground by a man is greatest when:
   A. he stands with both feet flat on the ground
   B. he stands flat on one foot
   C. he stands on the toes of one foot
   D. he lies down on the ground
   E. all of the above yield the same pressure

   ans: C

9. The vessels shown below all contain water to the same height. Rank them according to the pressure exerted by the water on the vessel bottoms, least to greatest.



   A. 1, 2, 3, 4
   B. 3, 4, 2, 1
   C. 4, 3, 2, 1
   D. 2, 3, 4, 1
   E. All pressures are the same

   ans: E

10. In a stationary homogeneous liquid:
    A. pressure is the same at all points
    B. pressure depends on the direction
    C. pressure is independent of any atmospheric pressure on the upper surface of the liquid
    D. pressure is the same at all points at the same level
    E. none of the above

    ans: D

11. Which of the following five statements, concerning the upper surface pressure of a liquid, is FALSE?
    A. It is independent of the surface area
    B. It is the same for all points on that surface
    C. It would not increase if the liquid depth were increased
    D. It would increase if the liquid density were increased
    E. It would increase if the atmospheric pressure increased

    ans: D

12. Several cans of different sizes and shapes are all filled with the same liquid to the same depth. Then:
    A. the weight of the liquid is the same for all cans
    B. the force of the liquid on the bottom of each can is the same
    C. the least pressure is at the bottom of the can with the largest bottom area
    D. the greatest pressure is at the bottom of the can with the largest bottom area
    E. the pressure on the bottom of each can is the same

    ans: E

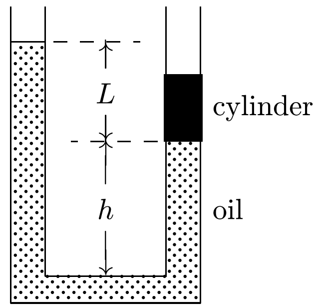
13. An airtight box, having a lid of area $80\,\text{cm}^2$, is partially evacuated. Atmospheric pressure is 1.01×10^5 Pa. A force of 600 N is required to pull the lid off the box. The pressure in the box was:
    A. 2.60×10^4 Pa
    B. 6.35×10^4 Pa
    C. 7.50×10^4 Pa
    D. 1.38×10^5 Pa
    E. 1.76×10^5 Pa

    ans: A

14. A closed hemispherical shell of radius R is filled with fluid at uniform pressure p. The net force of the fluid on the curved portion of the shell is given by:
    A. $2\pi R^2 p$
    B. $\pi R^2 p$
    C. $4\pi R^2 p$
    D. $(4/3)\pi R^2 p$
    E. $(4/3)\pi R^3 p$

    ans: B

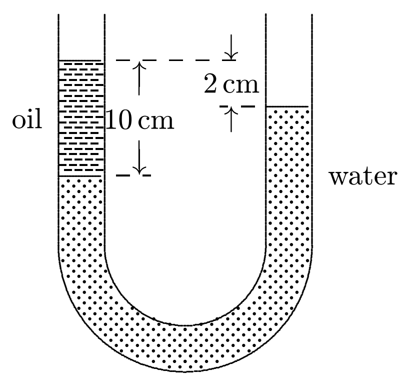
15. The diagram shows a U-tube with cross-sectional area A and partially filled with oil of density ρ. A solid cylinder, which fits the tube tightly but can slide without friction, is placed in the right arm. The system is in equilibrium. The weight of the cylinder is:



A. $AL\rho g$
B. $L^3\rho g$
C. $A\rho(L+h)g$
D. $A\rho(L-h)g$
E. none of these

ans: A

16. The density of water is $1.0\,\mathrm{g/cm^3}$. The density of the oil in the left column of the U-tube shown below is:



A. $0.20\,\mathrm{g/cm^3}$
B. $0.80\,\mathrm{g/cm^3}$
C. $1.0\,\mathrm{g/cm^3}$
D. $1.3\,\mathrm{g/cm^3}$
E. $5.0\,\mathrm{g/cm^3}$

ans: B

17. A uniform U-tube is partially filled with water. Oil, of density $0.75\,\mathrm{g/cm^3}$, is poured into the right arm until the water level in the left arm rises 3 cm. The length of the oil column is then:
   A. 2.25 cm
   B. 8 cm
   C. 6 cm
   D. 4 cm
   E. need to know the cross-sectional area of the U-tube

   ans: B

18. A long U-tube contains mercury (density $= 14 \times 10^3\,\mathrm{kg/m^3}$). When 10 cm of water (density $= 1.0 \times 10^3\,\mathrm{kg/m^3}$) is poured into the left arm, the mercury in the right arm rises above its original level by:
   A. 0.36 cm
   B. 0.72 cm
   C. 14 cm
   D. 35 cm
   E. 70 cm

   ans: A

19. A bucket of water is pushed from left to right with increasing speed across a horizontal surface. Consider the pressure at two points at the same level in the water.
   A. It is the same
   B. It is higher at the point on the left
   C. It is higher at the point on the right
   D. At first it is higher at the point on the left but as the bucket speeds up it is lower there
   E. At first it is higher at the point on the right but as the bucket speeds up it is lower there

   ans: B

20. A bucket resting on the floor of an elevator contains an incompressible fluid of density ρ. When the elevator has an upward acceleration of magnitude a the pressure difference between two points in a fluid separated by a vertical distance Δh, is given by:
   A. $\rho a \Delta h$
   B. $\rho g \Delta h$
   C. $\rho(g + a)\Delta h$
   D. $\rho(g - a)\Delta h$
   E. $\rho g a \Delta h$

   ans: C

21. A bucket resting on the floor of an elevator contains an incompressible fluid of density ρ. When the elevator has a downward acceleration of magnitude a the pressure difference between two points in a fluid, separated by a vertical distance Δh, is given by:
   A. $\rho a \Delta h$
   B. $\rho g \Delta h$
   C. $\rho(g + a)\Delta h$
   D. $\rho(g - a)\Delta h$
   E. $\rho g a \Delta h$

   ans: D

22. “An object completely submerged in a fluid displaces its own volume of fluid”. This is:

A. Pascal’s paradox
B. Archimedes’ principle
C. Pascal’s principle
D. true, but none of the above
E. false

ans: D

23. A certain object floats in fluids of density

1. $0.9\rho_0$
2. ρ_0
3. $1.1\rho_0$

Which of the following statements is true?

A. the buoyant force of fluid i is greater than the buoyant forces of the other two fluids
B. the buoyant force of fluid 3 is greater than the buoyant forces of the other two fluids
C. the three fluids exert the same buoyant force
D. the object displace the same volume of all three fluids
E. none of these are true

ans: C

24. A certain object floats in fluids of density

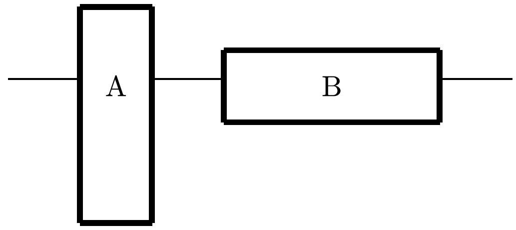
1. $0.9\rho_0$
2. ρ_0
3. $1.1\rho_0$

Rank these fluids according to the volume displaced by the object, least to greatest.

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

ans: B

25. Two identical blocks of ice float in water as shown. Then:



A. block A displaces a greater volume of water since the pressure acts on a smaller bottom area
B. block B displaces a greater volume of water since the pressure is less on its bottom
C. the two blocks displace equal volumes of water since they have the same weight
D. block A displaces a greater volume of water since its submerged end is lower in the water
E. block B displaces a greater volume of water since its submerged end has a greater area

ans: C

26. A block of ice at 0° C is floating on the surface of ice water in a beaker. The surface of the water just comes to the top of the beaker. When the ice melts the water level will:

A. rise and overflow will occur
B. remain the same
C. fall
D. depend on the initial ratio of water to ice
E. depend on the shape of the block of ice

ans: B

27. A block of ice at 0° C containing a piece of cork is floating on the surface of ice water in a beaker. When the ice has melted the water level:

A. is higher
B. is lower
C. is the same
D. depends on the initial ratio of water to ice
E. depends on the shape of the ice block

ans: C

28. A pirate chest rests at the bottom of an ocean. If the water is still, the net force it exerts on the chest:

A. is upward
B. is downward
C. is zero
D. depends on the mass of the chest
E. depends on the contents of the chest

ans: B

29. A small steel ball floats in a half-full container of mercury. When water is added:
  A. the ball will float on the water
  B. the ball will rise slightly
  C. the mercury will float on the water
  D. the ball will sink to the bottom of the container
  E. the ball will lower slightly more into the mercury

  ans: B

30. A cork floats on the surface of an incompressible liquid in a container exposed to atmospheric pressure. The container is then sealed and the air above the liquid is evacuated. The cork:
  A. sinks slightly
  B. rises slightly
  C. floats at the same height
  D. bobs up and down about its old position
  E. behaves erratically

  ans: C

31. An object hangs from a spring balance. The balance indicates 30 N in air and 20 N when the object is submerged in water. What does the balance indicate when the object is submersed in a liquid with a density that is half that of water?
  A. 20 N
  B. 25 N
  C. 30 N
  D. 35 N
  E. 40 N

  ans: B

32. A fir wood board floats in fresh water with 60% of its volume under water. The density of the wood in g/cm^3 is:
  A. 0.4
  B. 0.5
  C. 0.6
  D. less than 0.4
  E. more than 0.6

  ans: C

33. A boat floating in fresh water displaces 16, 000 N of water. How many newtons of saltwater would it displace if it floats in saltwater of specific gravity 1.17?
  A. 14, 500
  B. 17, 600
  C. 16, 000
  D. 284
  E. 234

  ans: C

34. A rock, which weighs 1400 N in air, has an apparent weight of 900 N when submerged in fresh water (998 kg/m^3). The volume of the rock is:

A. $0.14\,\text{m}^3$
B. $0.60\,\text{m}^3$
C. $0.90\,\text{m}^3$
D. $5.1 \times 10^{-2}\,\text{m}^3$
E. $9.2 \times 10^{-2}\,\text{m}^3$

ans: D

35. A loaded ship passes from a lake (fresh water) to the ocean (saltwater). Saltwater is more dense than fresh water and as a result the ship will:

A. ride higher in the water
B. settle lower in the water
C. ride at the same level in the water
D. experience an increase in buoyant force
E. experience a decrease in buoyant force

ans: A

36. The dimensions of a wooden raft (density = $150\,\text{kg/m}^3$) are $3.0\,\text{m} \times 3.0\,\text{m} \times 1.0\,\text{m}$. What maximum load can it carry in seawater (density = $1020\,\text{kg/m}^3$)?

A. 1350 kg
B. 7800 kg
C. 9200 kg
D. 19,500 kg
E. 24,300 kg

ans: B

37. A tin can has a volume of $1000\,\text{cm}^3$ and a mass of 100 g. Approximately what mass of lead shot can it carry without sinking in water?

A. 900 g
B. 100 g
C. 1000 g
D. 1100 g
E. 980 g

ans: A

38. A block of wood weighs 160 N and has a specific gravity of 0.60. To sink it in fresh water requires an additional downward force of:

A. 54 N
B. 64 N
C. 96 N
D. 110 N
E. 240 N

ans: D

39. A student standardizes the concentration of a saltwater solution by slowly adding salt until an egg will just float. The procedure is based on the assumption that:

A. all eggs have the same volume
B. all eggs have the same weight
C. all eggs have the same density
D. all eggs have the same shape
E. the salt tends to neutralize the cholesterol in the egg

ans: C

40. A solid has a volume of $8\,\mathrm{cm}^3$. When weighed on a spring scale calibrated in grams, the scale indicates $20\,\mathrm{g}$. What does the scale indicate if the object is weighed while immersed in a liquid of density $2\,\mathrm{g/cm}^3$?

A. $4\,\mathrm{g}$
B. $10\,\mathrm{g}$
C. $12\,\mathrm{g}$
D. $16\,\mathrm{g}$
E. Zero, since the object will float

ans: A

41. A 210-g object apparently loses $30\,\mathrm{g}$ when suspended in a liquid of density $2.0\,\mathrm{g/cm}^3$. The density of the object is:

A. $7.0\,\mathrm{g/cm}^3$
B. $3.5\,\mathrm{g/cm}^3$
C. $1.4\,\mathrm{g/cm}^3$
D. $14\,\mathrm{g/cm}^3$
E. none of these

ans: D

42. A steel ax and an aluminum piston have the same apparent weight in water. When they are weighed in air:

A. they weigh the same
B. the ax is heavier
C. the piston is heavier
D. both weigh less than they did in water
E. depends on their shapes

ans: C

43. The apparent weight of a steel sphere immersed in various liquids is measured using a spring scale. The greatest reading is obtained for that liquid:

A. having the smallest density
B. having the largest density
C. subject to the greatest atmospheric pressure
D. having the greatest volume
E. in which the sphere was submerged deepest

ans: A

44. A 0.50-N metal sinker appears (as measured using a spring scale) to have a weight of 0.45 N when submerged in water. The specific gravity of the metal is:

A. 6
B. 8
C. 9
D. 10
E. 12

ans: D

45. An object floats on the surface of a fluid. For purposes of calculating the torque on it, the buoyant force is taken to act at:

A. the center of the bottom surface of the object
B. the center of gravity of the object
C. the center of gravity of the fluid that the object replaced
D. the geometric center of the object
E. none of the above

ans: C

46. A blast of wind tips a sailboat in the clockwise direction when viewed from the stern. When the wind ceases the boat rotates back toward the upright position if, when it is tilted, the center of buoyancy:

A. is above the center of gravity
B. is below the center of gravity
C. is to the right of the center of gravity
D. is to the left of the center of gravity
E. coincides with the center of gravity

ans: C

47. A cork floats in water in a bucket resting on the floor of an elevator. The elevator then accelerates upward. During the acceleration:

A. the cork is immersed more
B. the cork is immersed less
C. the cork is immersed the same amount
D. at first the cork is immersed less but as the elevator speeds up it is immersed more
E. at first the cork is immersed more but as the elevator speeds up it is immersed less

ans: C

48. Two balls have the same shape and size but one is denser than the other. If frictional forces are negligible when they are dropped in air, which has the greater acceleration?

A. The heavier ball
B. The lighter ball
C. They have the same acceleration
D. The heavier ball if atmospheric pressure is high, they lighter ball if it is low
E. The lighter ball if atmospheric pressure is high, the heavier ball if it is low

ans: A

49. The principle of fluid pressure that is used in hydraulic brakes or lifts is that:

A. pressure is the same at all levels in a fluid
B. increases of pressure are transmitted equally to all parts of a fluid
C. the pressure at a point in a fluid is due to the weight of the fluid above it
D. increases of pressure can only be transmitted through fluids
E. the pressure at a given depth is proportional to the depth in the fluid

ans: B

50. Which of the following statements about Pascal's principle is true?

A. It is valid only for incompressible fluids
B. It explains why light objects float
C. It explains why the pressure is greater at the bottom of a lake than at the surface
D. It is valid only for objects that are less dense than water
E. None of the above are true

ans: E

51. The hydraulic automobile jack illustrates:

A. Archimedes' principle
B. Pascal's principle
C. Hooke's law
D. Newton's third law
E. Newton's second law

ans: B

52. One piston in a hydraulic lift has an area that is twice the area of the other. When the pressure at the smaller piston is increased by Δp the pressure at the larger piston:

A. increases by $2\Delta p$
B. increases by $\Delta p/2$
C. increases by Δp
D. increases by $4\Delta p$
E. does not change

ans: C

53. A hydraulic press has one piston of diameter 2.0 cm and the other piston of diameter 8.0 cm. What force must be applied to the smaller piston to obtain a force of 1600 N at the larger piston?

A. 6.25 N
B. 25 N
C. 100 N
D. 400 N
E. 1600 N

ans: C

54. The two arms of a U-tube are not identical, one having twice the diameter of the other. A cork in the narrow arm requires a force of 16 N to remove it. The tube is filled with water and the wide arm is fitted with a piston. The minimum force that must be applied to the piston to push the cork out is:

A. 4 N
B. 8 N
C. 16 N
D. 32 N
E. 64 N

ans: E

55. A U-tube has dissimilar arms, one having twice the diameter of the other. It contains an incompressible fluid and is fitted with a sliding piston in each arm, with each piston in contact with the fluid. When the piston in the narrow arm is pushed down a distance d, the piston in the wide arm rises a distance:

A. d
B. $2d$
C. $d/2$
D. $4d$
E. $d/4$

ans: E

56. A U-tube has dissimilar arms, one having twice the diameter of the other. It contains an incompressible fluid and is fitted with a sliding piston in each arm, with each piston in contact with the fluid. When an applied force does work W in pushing the piston in the narrow arm down, the fluid does work ______ on the piston in the wide arm.

A. W
B. $2W$
C. $W/2$
D. $4W$
E. $W/4$

ans: A

57. A fluid is undergoing "incompressible" flow. This means that:

A. the pressure at a given point cannot change with time
B. the velocity at a given point cannot change with time
C. the velocity must be the same everywhere
D. the pressure must be the same everywhere
E. the density cannot change with time or location

ans: E

58. A fluid is undergoing steady flow. Therefore:

A. the velocity of any given molecule of fluid does not change
B. the pressure does not vary from point to point
C. the velocity at any given point does not vary with time
D. the density does not vary from point to point
E. the flow is not uphill or downhill

ans: C

59. If p is a pressure and ρ is a density then p/ρ has units of:

A. m^2
B. m^2/s^2
C. N/m^2
D. kg/m^2
E. m^3/kg

ans: B

60. One end of a cylindrical pipe has a radius of 1.5 cm. Water (density $= 1.0 \times 10^3\,kg/m^3$) streams steadily out at 7.0 m/s. The rate at which mass is leaving the pipe is:

A. 2.5 kg/s
B. 4.9 kg/s
C. 7.0 kg/s
D. 48 kg/s
E. 7.0×10^3 kg/s

ans: B

61. One end of a cylindrical pipe has a radius of 1.5 cm. Water (density $= 1.0 \times 10^3\,kg/m^3$) streams steadily out at 7.0 m/s. The volume flow rate is:

A. $4.9 \times 10^{-3}\,m^3/s$
B. $2.5\,m^3/s$
C. $4.9\,m^3/s$
D. $7.0\,m^3/s$
E. $48\,m^3/s$

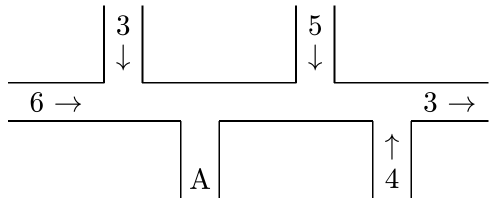
ans: A

62. The equation of continuity for fluid flow can be derived from the conservation of:

A. energy
B. mass
C. angular momentum
D. volume
E. pressure

ans: B

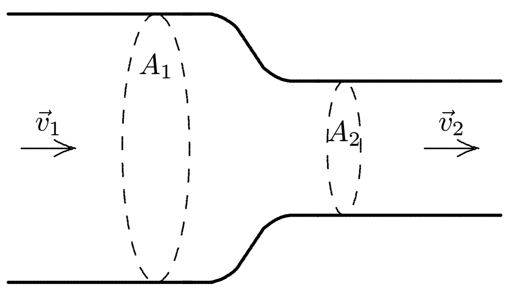
63. The diagram shows a pipe of uniform cross section in which water is flowing. The directions of flow and the volume flow rates (in cm^3/s) are shown for various portions of the pipe. The direction of flow and the volume flow rate in the portion marked A are:



A. $\downarrow$ and $3\,\text{cm}^3/\text{s}$
B. $\uparrow$ and $7\,\text{cm}^3/\text{s}$
C. $\downarrow$ and $9\,\text{cm}^3/\text{s}$
D. $\uparrow$ and $11\,\text{cm}^3/\text{s}$
E. $\downarrow$ and $15\,\text{cm}^3/\text{s}$

ans: E

64. An incompressible liquid flows along the pipe as shown. The ratio of the speeds v_2/v_1 is:



A. A_1/A_2
B. A_2/A_1
C. $\sqrt{A_1/A_2}$
D. $\sqrt{A_2/A_1}$
E. v_1/v_2

ans: A

65. Water flows through a cylindrical pipe of varying cross section. The velocity is 3.0 m/s at a point where the pipe diameter is 1.0 cm. At a point where the pipe diameter is 3.0 cm, the velocity is:

A. 9 m/s
B. 3 m/s
C. 1 m/s
D. 0.33 m/s
E. 0.11 m/s

ans: D

66. A constriction in a pipe reduces its diameter from 4.0 cm to 2.0 cm. Where the pipe is narrow the water speed is 8.0 m/s. Where it is wide the water speed is:

A. 2.0 m/s
B. 4.0 m/s
C. 8.0 m/s
D. 16 m/s
E. 32 m/s

ans: C

67. Water flows from a 6.0-cm diameter pipe into an 8.0-cm diameter pipe. The speed in the 6.0-cm pipe is 5.0 m/s. The speed in the 8.0-cm pipe is:

A. 2.8 m/s
B. 3.7 m/s
C. 6.6 m/s
D. 8.8 m/s
E. 9.9 m/s

ans: A

68. A lawn sprinkler is made of a 1.0-cm diameter garden hose with one end closed and 25 holes, each with a diameter of 0.050 cm, cut near the closed end. If water flows at 2.0 m/s in the hose, the speed of the water leaving a hole is:

A. 2.0 m/s
B. 32 m/s
C. 40 m/s
D. 600 m/s
E. 800 m/s

ans: B

69. Bernoulli's equation can be derived from the conservation of:

A. energy
B. mass
C. angular momentum
D. volume
E. pressure

ans: A

70. Which of the following assumptions is NOT made in the derivation of Bernoulli's equation?

A. Assume streamline flow
B. Neglect viscosity
C. Neglect friction
D. Neglect gravity
E. Neglect turbulence

ans: D

71. The quantity y appearing in Bernoulli's equation MUST be measured:

A. upward from the center of Earth
B. upward from the surface of Earth
C. upward from the lowest point in the flow
D. downward from the highest point in the flow
E. upward from any convenient level

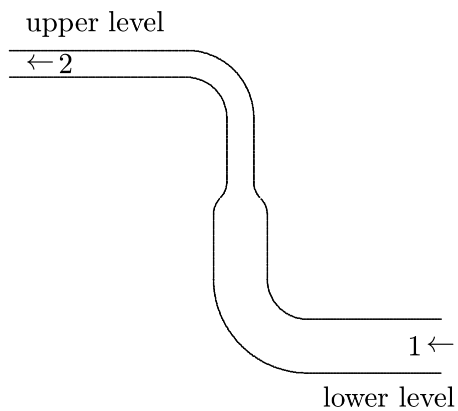
ans: E

72. Water flows through a constriction in a horizontal pipe. As it enters the constriction, the water's:

A. speed increases and pressure decreases
B. speed increases and pressure remains constant
C. speed increases and pressure increases
D. speed decreases and pressure increases
E. speed decreases and pressure decreases

ans: A

73. Water is pumped through the hose shown below, from a lower level to an upper level. Compared to the water at point 1, the water at point 2:



A. has greater speed and greater pressure
B. has greater speed and less pressure
C. has less speed and less pressure
D. has less speed and greater pressure
E. has greater speed and the same pressure

ans: B

74. A non-viscous incompressible liquid is flowing through a horizontal pipe of constant cross section. Bernoulli's equation and the equation of continuity predict that the drop in pressure along the pipe:

A. is zero
B. depends on the length of the pipe
C. depends on the fluid velocity
D. depends on the cross-sectional area of the pipe
E. depends on the height of the pipe

ans: A

75. A non-viscous incompressible fluid is pumped steadily into the narrow end of a long tapered pipe and emerges from the wide end. The pressure at the input is greater than at the output. A possible explanation is:

A. the fluid speed increases from input to output
B. the fluid speed is the same at the two ends
C. the fluid is flowing uphill
D. the fluid is flowing downhill
E. the fluid is flowing horizontally

ans: C

76. Water is pumped into one end of a long pipe at the rate of 40 L/min. It emerges at the other end at 24 L/min. A possible reason for this decrease in flow is:

A. the water is being pumped uphill
B. the water is being pumped downhill
C. the diameter of the pipe is not the same at the two ends
D. friction in the pipe
E. a leak in the pipe

ans: E

77. Consider a pipe containing a fluid, with the fluid being at rest. To apply Bernoulli's equation to this situation:

A. set v equal to zero because there is no motion
B. set g equal to zero because there is no acceleration
C. set v and g both equal to zero
D. set p equal to the atmospheric pressure
E. cannot be done, Bernoulli's equation applies only to fluids in motion

ans: A

78. Water (density $= 1.0 \times 10^3\,\mathrm{kg/m^3}$) flows through a horizontal tapered pipe. At the wide end its speed is 4.0 m/s. The difference in pressure between the two ends is 4.5×10^3 Pa. The speed of the water at the narrow end is:

A. 2.6 m/s
B. 3.4 m/s
C. 4.0 m/s
D. 4.5 m/s
E. 5.0 m/s

ans: E

79. Water is streaming downward from a faucet opening with an area of $3.0 \times 10^{-5}\,m^2$. It leaves the faucet with a speed of 5.0 m/s. The cross-sectional area of the stream 0.50 m below the faucet is:

A. $1.5 \times 10^{-5}\,m^2$
B. $2.0 \times 10^{-5}\,m^2$
C. $2.5 \times 10^{-5}\,m^2$
D. $3.0 \times 10^{-5}\,m^2$
E. $3.5 \times 10^{-5}\,m^2$

ans: C

80. A large water tank, open at the top, has a small hole in the bottom. When the water level is 30 m above the bottom of the tank, the speed of the water leaking from the hole:

A. is 2.5 m/s
B. is 24 m/s
C. is 44 m/s
D. cannot be calculated unless the area of the hole is given
E. cannot be calculated unless the areas of the hole and tank are given

ans: B

81. A large tank filled with water has two holes in the bottom, one with twice the radius of the other. In steady flow the speed of water leaving the larger hole is ____ the speed of the water leaving the smaller.

A. twice
B. four times
C. half
D. one-fourth
E. the same as

ans: E

82. A non-viscous incompressible fluid is pumped steadily up a vertical pipe with uniform cross section. The difference in pressure between points at the top and bottom:

A. is the same as it would be if the fluid were motionless
B. is greater at higher flow rates than at lower flow rates
C. is less at higher flow rates than at lower flow rates
D. does not depend on the density of the fluid
E. is zero

ans: A

Chapter 7: KINETIC ENERGY AND WORK

1. Which of the following is NOT a correct unit for work?

   A. erg
   B. ft·lb
   C. watt
   D. newton·meter
   E. joule

   ans: C

2. Which of the following groups does NOT contain a scalar quantity?

   A. velocity, force, power
   B. displacement, acceleration, force
   C. acceleration, speed, work
   D. energy, work, distance
   E. pressure, weight, time

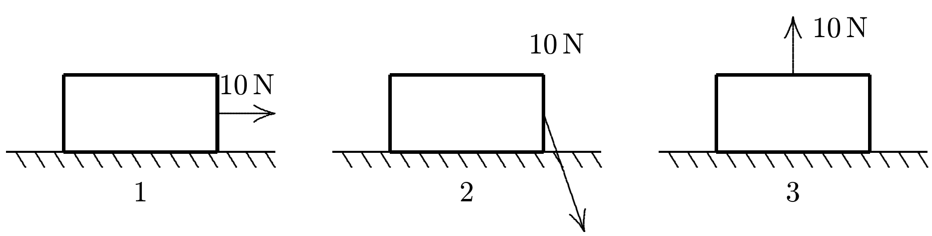
   ans: B

3. A boy holds a 40-N weight at arm's length for 10 s. His arm is 1.5 m above the ground. The work done by the force of the boy on the weight while he is holding it is:

   A. 0
   B. 6.1 J
   C. 40 J
   D. 60 J
   E. 90 J

   ans: A

4. A crate moves 10 m to the right on a horizontal surface as a woman pulls on it with a 10-N force. Rank the situations shown below according to the work done by her force, least to greatest.



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

   ans: E

5. An object moves in a circle at constant speed. The work done by the centripetal force is zero because:
   A. the displacement for each revolution is zero
   B. the average force for each revolution is zero
   C. there is no friction
   D. the magnitude of the acceleration is zero
   E. the centripetal force is perpendicular to the velocity

   ans: E

6. An object of mass 1 g is whirled in a horizontal circle of radius 0.5 m at a constant speed of 2 m/s. The work done on the object during one revolution is:
   A. 0
   B. 1 J
   C. 2 J
   D. 4 J
   E. 16 J

   ans: A

7. The work done by gravity during the descent of a projectile:
   A. is positive
   B. is negative
   C. is zero
   D. depends for its sign on the direction of the y axis
   E. depends for its sign on the direction of both the x and y axes

   ans: A

8. A baseball is hit high into the upper bleachers of left field. Over its entire flight the work done by gravity and the work done by air resistance, respectively, are:
   A. positive; positive
   B. positive; negative
   C. negative; positive
   D. negative; negative
   E. unknown since vital information is lacking

   ans: D

9. A line drive to the shortstop is caught at the same height as it was originally hit. Over its entire flight the work done by gravity and the work done by air resistance, respectively, are:
   A. zero; positive
   B. zero; negative
   C. positive; negative
   D. negative; positive
   E. negative; negative

   ans: B

10. A 2-kg object is moving at 3 m/s. A 4-N force is applied in the direction of motion and then removed after the object has traveled an additional 5 m. The work done by this force is:

A. 12 J
B. 15 J
C. 18 J
D. 20 J
E. 38 J

ans: D

11. A sledge (including load) weighs 5000 N. It is pulled on level snow by a dog team exerting a horizontal force on it. The coefficient of kinetic friction between sledge and snow is 0.05. How much work is done by the dog team pulling the sledge 1000 m at constant speed?

A. 2.5×10^4 J
B. 2.5×10^5 J
C. 5.0×10^5 J
D. 2.5×10^6 J
E. 5.0×10^6 J

ans: B

12. Camping equipment weighing 6000 N is pulled across a frozen lake by means of a horizontal rope. The coefficient of kinetic friction is 0.05. The work done by the campers in pulling the equipment 1000 m at constant velocity is:

A. 3.1×10^4 J
B. 1.5×10^5 J
C. 3.0×10^5 J
D. 2.9×10^6 J
E. 6.0×10^6 J

ans: C

13. Camping equipment weighing 6000 N is pulled across a frozen lake by means of a horizontal rope. The coefficient of kinetic friction is 0.05. How much work is done by the campers in pulling the equipment 1000 m if its speed is increasing at the constant rate of $0.20\,\mathrm{m/s^2}$?

A. -1.2×10^6 J
B. 1.8×10^5 J
C. 3.0×10^5 J
D. 4.2×10^5 J
E. 1.2×10^6 J

ans: D

14. A 1-kg block is lifted vertically 1 m by a boy. The work done by the boy is about:

A. 1 ft · lb
B. 1 J
C. 10 J
D. 0.1 J
E. zero

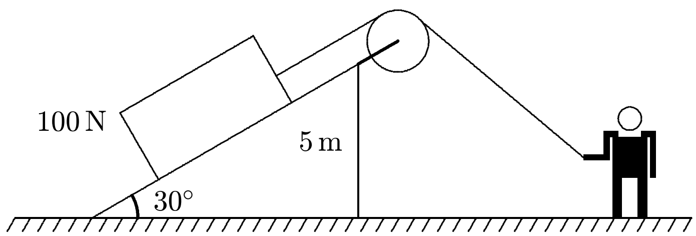
ans: C

15. A 0.50-kg object moves in a horizontal circular track with a radius of 2.5 m. An external force of 3.0 N, always tangent to the track, causes the object to speed up as it goes around. The work done by the external force as the mass makes one revolution is:

A. 24 J
B. 47 J
C. 59 J
D. 94 J
E. 120 J

ans: B

16. A man pulls a 100-N crate up a frictionless 30° slope 5 m high, as shown. Assuming that the crate moves at constant speed, the work done by the man is:



A. −500 J
B. −250 J
C. 0
D. 250 J
E. 500 J

ans: E

17. A man pushes an 80-N crate a distance of 5.0 m upward along a frictionless slope that makes an angle of 30° with the horizontal. His force is parallel to the slope. If the speed of the crate decreases at a rate of $1.5\,\mathrm{m/s^2}$, then the work done by the man is:

A. −200 J
B. 61 J
C. 140 J
D. 200 J
E. 260 J

ans: C

18. A man pushes an 80-N crate a distance of 5.0 m upward along a frictionless slope that makes an angle of 30° with the horizontal. The force he exerts is parallel to the slope. If the speed of the crate is constant, then the work done by the man is:

A. −200 J
B. 61 J
C. 140 J
D. 200 J
E. 260 J

ans: D

19. An 80-N crate slides with constant speed a distance of 5.0 m downward along a rough slope that makes an angle of 30° with the horizontal. The work done by the force of gravity is:

A. −400 J
B. −200 J
C. −69 J
D. 200 J
E. 400 J

ans: D

20. A man pulls a sled along a rough horizontal surface by applying a constant force $\vec{F}$ at an angle θ above the horizontal. In pulling the sled a horizontal distance d, the work done by the man is:

A. Fd
B. $Fd\cos\theta$
C. $Fd\sin\theta$
D. $Fd/\cos\theta$
E. $Fd/\sin\theta$

ans: B

21. A man wishes to pull a crate 15 m across a rough floor by exerting a force of 100 N. The coefficient of kinetic friction is 0.25. For the man to do the least work, the angle between the force and the horizontal should be:

A. 0
B. 14°
C. 43°
D. 66°
E. 76°

ans: A

22. A particle moves 5 m in the positive x direction while being acted upon by a constant force $\vec{F} = (4\,\text{N})\hat{\text{i}} + (2\,\text{N})\hat{\text{j}} - (4\,\text{N})\hat{\text{k}}$. The work done on the particle by this force is:

A. 20 J
B. 10 J
C. −20 J
D. 30 J
E. is impossible to calculate without knowing other forces

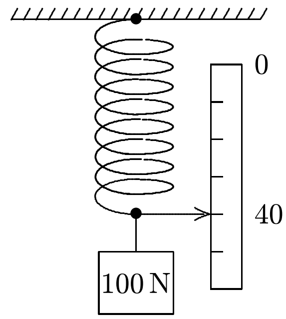
ans: A

23. A block is attached to the end of an ideal spring and moved from coordinate x_i to coordinate x_f. The relaxed position is at $x = 0$. The work done by spring is positive if:

A. $x_i = 2\,\text{cm}$ and $x_f = 4\,\text{cm}$
B. $x_i = -2\,\text{cm}$ and $x_f = 4\,\text{cm}$
C. $x_i = -2\,\text{cm}$ and $x_f = -4\,\text{cm}$
D. $x_i = 2\,\text{cm}$ and $x_f = -4\,\text{cm}$
E. $x_i = -4\,\text{cm}$ and $x_f = -2\,\text{cm}$

ans: E

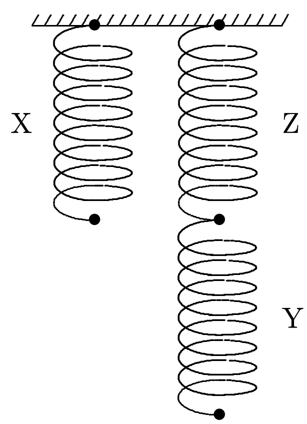
24. An ideal spring, with a pointer attached to its end, hangs next to a scale. With a 100-N weight attached, the pointer indicates "40" on the scale as shown. Using a 200-N weight instead results in "60" on the scale. Using an unknown weight X instead results in "30" on the scale. The weight of X is:



A. 10 N
B. 20 N
C. 30 N
D. 40 N
E. 50 N

ans: E

25. Three identical ideal springs (X,Y,Z) are arranged as shown. When a 4.0-kg mass is hung on X, the mass descends 3.0 cm. When a 6.0-kg mass is hung on Y, the mass descends:



A. 2.0 cm
B. 4.0 cm
C. 4.5 cm
D. 6.0 cm
E. 9.0 cm

ans: E

26. When a certain rubber band is stretched a distance x, it exerts a restoring force of magnitude $F = Ax$, where A is a constant. The work done by a person in stretching this rubber band from $x = 0$ to $x = L$, beginning and ending at rest, is:

A. AL^2
B. $A + 2L$
C. $A + 2L^2$
D. A/L
E. $AL^2/2$

ans: E

27. When a certain rubber band is stretched a distance x, it exerts a restoring force of magnitude $F = ax + bx^2$, where a and b are constants. The work done in stretching this rubber band from $x = 0$ to $x = L$ is:

A. $aL^2 + bLx^3$
B. $aL + 2bL^2$
C. $a + 2bL$
D. bL
E. $aL^2/2 + bL^3/3$

ans: E

28. An ideal spring is hung vertically from the ceiling. When a 2.0-kg mass hangs at rest from it the spring is extended 6.0 cm from its relaxed length. A downward external force is now applied to the mass to extend the spring an additional 10 cm. While the spring is being extended by the force, the work done by the spring is:

A. -3.6 J
B. -3.3 J
C. -3.4×10^{-5} J
D. 3.3 J
E. 3.6 J

ans: A

29. An ideal spring is hung vertically from the ceiling. When a 2.0-kg block hangs at rest from it the spring is extended 6.0 cm from its relaxed length. A upward external force is then applied to the block to move it upward a distance of 16 cm. While the block is moving upward the work done by the spring is:

A. -1.0 J
B. -0.52 J
C. -0.26 J
D. 0.52 J
E. 1.0 J

ans: A

30. Which of the following bodies has the largest kinetic energy?

A. Mass $3M$ and speed V
B. Mass $3M$ and speed $2V$
C. Mass $2M$ and speed $3V$
D. Mass M and speed $4V$
E. All four of the above have the same kinetic energy

ans: C

31. Two trailers, X with mass 500 kg and Y with mass 2000 kg, are being pulled at the same speed. The ratio of the kinetic energy of Y to that of X is:

A. 1:1
B. 2:1
C. 4:1
D. 9:1
E. 1500:1

ans: C

32. A 8000-N car is traveling at 12 m/s along a horizontal road when the brakes are applied. The car skids to a stop in 4.0 s. How much kinetic energy does the car lose in this time?

A. 4.8×10^4 J
B. 5.9×10^4 J
C. 1.2×10^5 J
D. 5.8×10^5 J
E. 4.8×10^6 J

ans: B

33. The velocity of a particle moving along the x axis changes from v_i to v_f. For which values of v_i and v_f is the total work done on the particle positive?

A. $v_i = 5\,\text{m/s}$, $v_f = 2\,\text{m/s}$
B. $v_i = 5\,\text{m/s}$, $v_f = -2\,\text{m/s}$
C. $v_i = -5\,\text{m/s}$, $v_f = -2\,\text{m/s}$
D. $v_i = -5\,\text{m/s}$, $v_f = 2\,\text{m/s}$
E. $v_i = 2\,\text{m/s}$, $v_f = -5\,\text{m/s}$

ans: E

34. An object is constrained by a cord to move in a circular path of radius 0.5 m on a horizontal frictionless surface. The cord will break if its tension exceeds 16 N. The maximum kinetic energy the object can have is:

A. 4 J
B. 8 J
C. 16 J
D. 32 J
E. 64 J

ans: A

35. The weight of an object on the moon is one-sixth of its weight on Earth. The ratio of the kinetic energy of a body on Earth moving with speed V to that of the same body moving with speed V on the moon is:

A. 6:1
B. 36:1
C. 1:1
D. 1:6
E. 1:36

ans: C

36. Which of the following is the correct combination of dimensions for energy?

A. MLT
B. LT^2/m
C. ML^2/T^2
D. M^2L^3T
E. ML/T^2

ans: C

37. The amount of work required to stop a moving object is equal to:

A. the velocity of the object
B. the kinetic energy of the object
C. the mass of the object times its acceleration
D. the mass of the object times its velocity
E. the square of the velocity of the object

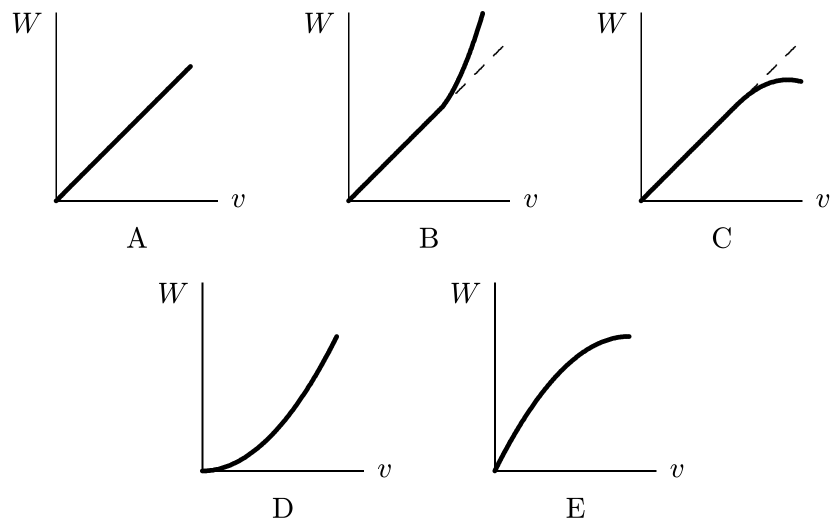
ans: B

38. A 5.0-kg cart is moving horizontally at 6.0 m/s. In order to change its speed to 10.0 m/s, the net work done on the cart must be:

A. 40 J
B. 90 J
C. 160 J
D. 400 J
E. 550 J

ans: C

39. A crate is initially at rest on a horizontal frictionless table. A constant horizontal force F is applied. Which of the following five graphs is a correct plot of work W as a function of the crate's speed v?



ans: D

40. An 8-N block slides down an incline. It has an initial speed of 7 m/s. The work done by the resultant force on this block is:

A. 3 J
B. 6 J
C. 56 J
D. impossible to calculate without more information
E. none of these

ans: D

41. A 4-kg cart starts up an incline with a speed of 3 m/s and comes to rest 2 m up the incline. The total work done on the car is:

A. 6 J
B. 8 J
C. 12 J
D. 18 J
E. impossible to calculate without more information

ans: D

42. Two objects with masses of m_1 and m_2 have the same kinetic energy and are both moving to the right. The same constant force $\vec{F}$ is applied to the left to both masses. If $m_1 = 4m_2$, the ratio of the stopping distance of m_1 to that of m_2 is:

A. 1:4
B. 4:1
C. 1:2
D. 2:1
E. 1:1

ans: E

43. A Boston Red Sox baseball player catches a ball of mass m that is moving toward him with speed v. While bringing the ball to rest, his hand moves back a distance d. Assuming constant deceleration, the horizontal force exerted on the ball by his hand is:

A. mv/d
B. mvd
C. mv^2/d
D. $2mv/d$
E. $mv^2/(2d)$

ans: E

44. A 0.50-kg object moves on a horizontal circular track with a radius of 2.5 m. An external force of 3.0 N, always tangent to the track, causes the object to speed up as it goes around. If it starts from rest its speed at the end of one revolution is:

A. 9.8 m/s
B. 14 m/s
C. 15 m/s
D. 19 m/s
E. 21 m/s

ans: B

45. A 0.50-kg object moves on a horizontal frictionless circular track with a radius of 2.5 m. An external force of 3.0 N, always tangent to the track, causes the object to speed up as it goes around. If it starts from rest, then at the end of one revolution the radial component of the force of the track on it is:

A. 19 N
B. 38 N
C. 47 N
D. 75 N
E. 96 N

ans: B

46. A 2-kg block is attached to a horizonal ideal spring with a spring constant of 200 N/m. When the spring has its equilibrium length the block is given a speed of 5 m/s. What is the maximum elongation of the spring?

A. 0
B. 0.05 m
C. 5 m
D. 10 m
E. 100 m

ans: C

47. At time $t = 0$ a particle starts moving along the x axis. If its kinetic energy increases uniformly with t the net force acting on it must be:

A. constant
B. proportional to t
C. inversely proportional to t
D. proportional to $\sqrt{t}$
E. proportional to $1/\sqrt{t}$

ans: E

48. At time $t = 0$ a 2-kg particle has a velocity of $(4\,\mathrm{m/s})\,\hat{\mathrm{i}} - (3\,\mathrm{m/s})\,\hat{\mathrm{j}}$. At $t = 3\,\mathrm{s}$ its velocity is $(2\,\mathrm{m/s})\,\hat{\mathrm{i}} + (3\,\mathrm{m/s})\,\hat{\mathrm{j}}$. During this time the work done on it was:

A. $4\,\mathrm{J}$
B. $-4\,\mathrm{J}$
C. $-12\,\mathrm{J}$
D. $-40\,\mathrm{J}$
E. $(4\,\mathrm{J})\hat{\mathrm{i}} + (36\,\mathrm{J})\hat{\mathrm{j}}$

ans: C

49. A particle starts from rest at time $t = 0$ and moves along the x axis. If the net force on it is proportional to t, its kinetic energy is proportional to:

A. t
B. t^2
C. t^4
D. $1/t^2$
E. none of the above

ans: C

50. A 1.5-kg crate falls from a height of 2.0 m onto an industrial spring scale with a spring constant of $1.5 \times 10^5\,\mathrm{N/m}$. At its greatest compression the reading on the scale is:

A. 15 N
B. 30 N
C. $1.5 \times 10^3\,\mathrm{N}$
D. $2.1 \times 10^3\,\mathrm{N}$
E. $3.0 \times 10^3\,\mathrm{N}$

ans: E

51. A particle moving along the x axis is acted upon by a single force $F = F_0 e^{-kx}$, where F_0 and k are constants. The particle is released from rest at $x = 0$. It will attain a maximum kinetic energy of:

A. F_0/k
B. F_0/e^k
C. kF_0
D. $1/2(kF_0)^2$
E. ke^kF_0

ans: A

52. The mechanical advantage of any machine is:

A. the efficiency of the machine
B. the work done by the machine
C. the ratio of the work done by the machine to the work expended on it
D. the ratio of the force exerted by the machine to the force applied to it
E. the ratio of the force applied to the machine to the force exerted by it

ans: D

53. In raising an object to a given height by means of an inclined plane, as compared with raising the object vertically, there is a reduction in:

A. work required
B. distance pushed
C. friction
D. force required
E. value of the acceleration due to gravity

ans: D

54. A watt is:

A. $\mathrm{kg \cdot m/s^3}$
B. $\mathrm{kg \cdot m^2/s}$
C. $\mathrm{kg \cdot m^2/s^3}$
D. $\mathrm{kg \cdot m/s}$
E. $\mathrm{kg \cdot m^2/s^2}$

ans: C

55. Power has the dimensions of:

A. $\mathrm{ML^2/T^2}$
B. $\mathrm{MT/L^2}$
C. $\mathrm{ML/T^2}$
D. $\mathrm{ML^2/T^3}$
E. none of these

ans: D

56. Which of the following five units represents a quantity that is NOT the same as the other four?

A. joule
B. erg
C. watt
D. foot·pound
E. newton·meter

ans: C

57. Which of the following five quantities is NOT an expression for energy? Here m is a mass, g is the acceleration due to gravity, h and d are distances, F is a force, v is a speed, a is an acceleration, P is power, and t is time.

A. mgh
B. Fd
C. $1/2mv^2$
D. ma
E. Pt

ans: D

58. A watt·second is a unit of:

A. force
B. power
C. displacement
D. speed
E. energy

ans: E

59. A watt per hour is a unit of:

A. energy
B. power
C. force
D. acceleration
E. none of these

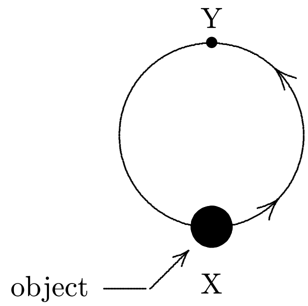
ans: E

60. A kilowatt·hour is a unit of:

A. power
B. energy/time
C. work
D. power/time
E. force/distance

ans: C

61. A man moves the 10-g object shown in a vertical plane from position X to position Y along a circular track of radius 20 m. The process takes 0.75 min. The work done by the man is about:



A. 1 J
B. 2 J
C. 4 J
D. 6 J
E. 12 J

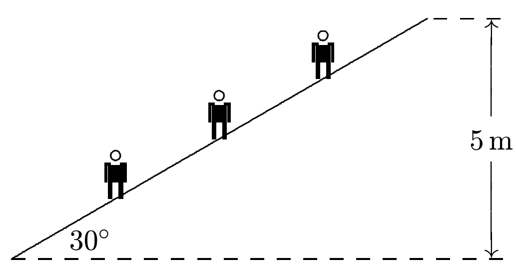
ans: C

62. A woman lifts a barbell 2.0 m in 5.0 s. If she lifts it the same distance in 10 s, the work done by her is:

A. four times as great
B. two times as great
C. the same
D. half as great
E. one-fourth as great

ans: C

63. An escalator is used to move 20 people (60 kg each) per minute from the first floor of a department store to the second floor, 5 m above. Neglecting friction, the power required is approximately:



A. 100 W
B. 200 W
C. 1000 W
D. 2000 W
E. 60, 000 W

ans: C

64. A person holds an 80-N weight 2 m above the floor for 30 seconds. The power required to do this is:

A. 80 W
B. 40 W
C. 20 W
D. 10 W
E. none of these

ans: E

65. A 50-N force is the only force on a 2-kg object that starts from rest. When the force has been acting for 2 s the rate at which it is doing work is:

A. 75 W
B. 100 W
C. 1000 W
D. 2500 W
E. 5000 W

ans: D

66. A 50-N force is the only force a 2-kg crate that starts from rest. At the instant the object has gone 2 m the rate at which the force is doing work is:

A. 2.5 W
B. 25 W
C. 75 W
D. 100 W
E. 500 W

ans: E

67. A particle starts from rest and is acted on by a net force that does work at a rate that is proportional to the time t. The speed of the particle is proportional to:

A. $\sqrt{t}$
B. t
C. t^2
D. $1/\sqrt{t}$
E. $1/t$

ans: A

Chapter 21: ELECTRIC CHARGE

1. A coulomb is the same as:
   A. an ampere/second
   B. half an ampere·second^2
   C. an ampere/meter^2
   D. an ampere·second
   E. a newton·meter^2
   ans: D

2. A kiloampere·hour is a unit of:
   A. current
   B. charge per time
   C. power
   D. charge
   E. energy
   ans: D

3. The magnitude of the charge on an electron is approximately:
   A. 10^{23} C
   B. 10^{-23} C
   C. 10^{19} C
   D. 10^{-19} C
   E. 10^{9} C
   ans: D

4. The total negative charge on the electrons in 1 mol of helium (atomic number 2, molar mass 4) is:
   A. 4.8×10^4 C
   B. 9.6×10^4 C
   C. 1.9×10^5 C
   D. 3.8×10^5 C
   E. 7.7×10^5 C
   ans: C

5. The total negative charge on the electrons in 1 kg of helium (atomic number 2, molar mass 4) is:
   A. 48 C
   B. 2.4×10^7 C
   C. 4.8×10^7 C
   D. 9.6×10^8 C
   E. 1.9×10^8 C
   ans: C

6. A wire carries a steady current of 2 A. The charge that passes a cross section in 2 s is:
   A. 3.2×10^{-19} C
   B. 6.4×10^{-19} C
   C. 1 C
   D. 2 C
   E. 4 C

   ans: E

7. A wire contains a steady current of 2 A. The number of electrons that pass a cross section in 2 s is:
   A. 2
   B. 4
   C. 6.3×10^{18}
   D. 1.3×10^{19}
   E. 2.5×10^{19}

   ans: E

8. The charge on a glass rod that has been rubbed with silk is called positive:
   A. by arbitrary convention
   B. so that the proton charge will be positive
   C. to conform to the conventions adopted for G and m in Newton's law of gravitation
   D. because like charges repel
   E. because glass is an insulator

   ans: A

9. To make an uncharged object have a negative charge we must:
   A. add some atoms
   B. remove some atoms
   C. add some electrons
   D. remove some electrons
   E. write down a negative sign

   ans: C

10. To make an uncharged object have a positive charge:
   A. remove some neutrons
   B. add some neutrons
   C. add some electrons
   D. remove some electrons
   E. heat it to cause a change of phase

   ans: D

11. When a hard rubber rod is given a negative charge by rubbing it with wool:

A. positive charges are transferred from rod to wool
B. negative charges are transferred from rod to wool
C. positive charges are transferred from wool to rod
D. negative charges are transferred from wool to rod
E. negative charges are created and stored on the rod

ans: D

12. An electrical insulator is a material:

A. containing no electrons
B. through which electrons do not flow easily
C. that has more electrons than protons on its surface
D. cannot be a pure chemical element
E. must be a crystal

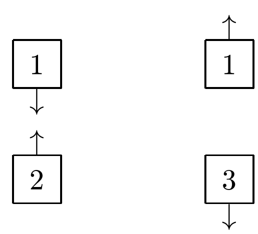
ans: B

13. A conductor is distinguished from an insulator with the same number of atoms by the number of:

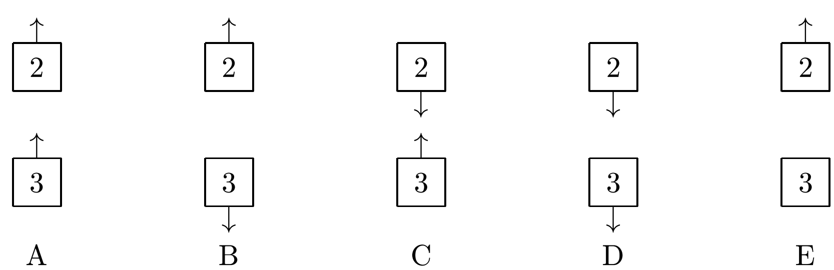
A. nearly free atoms
B. electrons
C. nearly free electrons
D. protons
E. molecules

ans: C

14. The diagram shows two pairs of heavily charged plastic cubes. Cubes 1 and 2 attract each other and cubes 1 and 3 repel each other.

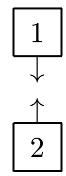


Which of the following illustrates the forces of cube 2 on cube 3 and cube 3 on cube 2?

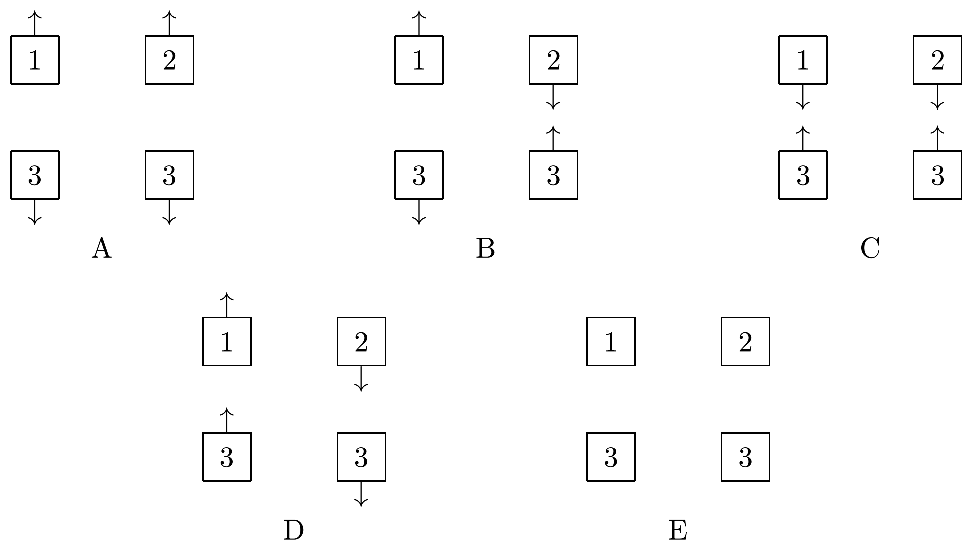


ans: C

15. The diagram shows a pair of heavily charged plastic cubes that attract each other.



Cube 3 is a conductor and is uncharged. Which of the following illustrates the forces between cubes 1 and 3 and between cubes 2 and 3?



ans: C

16. A neutral metal ball is suspended by a string. A positively charged insulating rod is placed near the ball, which is observed to be attracted to the rod. This is because:

A. the ball becomes positively charged by induction
B. the ball becomes negatively charged by induction
C. the number of electrons in the ball is more than the number in the rod
D. the string is not a perfect insulator
E. there is a rearrangement of the electrons in the ball

ans: E

17. A positively charged insulating rod is brought close to an object that is suspended by a string. If the object is attracted toward the rod we can conclude:

A. the object is positively charged
B. the object is negatively charged
C. the object is an insulator
D. the object is a conductor
E. none of the above

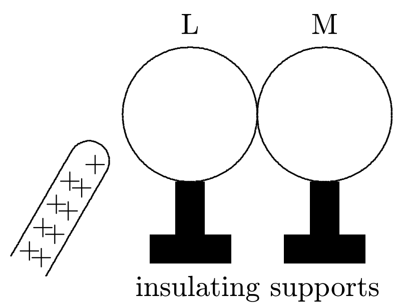
ans: E

18. A positively charged insulating rod is brought close to an object that is suspended by a string. If the object is repelled away from the rod we can conclude:

A. the object is positively charged
B. the object is negatively charged
C. the object is an insulator
D. the object is a conductor
E. none of the above

ans: A

19. Two uncharged metal spheres, L and M, are in contact. A negatively charged rod is brought close to L, but not touching it, as shown. The two spheres are slightly separated and the rod is then withdrawn. As a result:



A. both spheres are neutral
B. both spheres are positive
C. both spheres are negative
D. L is negative and M is positive
E. L is positive and M is negative

ans: D

20. A positively charged metal sphere A is brought into contact with an uncharged metal sphere B. As a result:

A. both spheres are positively charged
B. A is positively charged and B is neutral
C. A is positively charged and B is negatively charged
D. A is neutral and B is positively charged
E. A is neutral and B is negatively charged

ans: A

21. The leaves of a positively charged electroscope diverge more when an object is brought near the knob of the electroscope. The object must be:

A. a conductor
B. an insulator
C. positively charged
D. negatively charged
E. uncharged

ans: C

22. A negatively charged rubber rod is brought near the knob of a positively charged electroscope. The result is that:

A. the electroscope leaves will move farther apart
B. the rod will lose its charge
C. the electroscope leaves will tend to collapse
D. the electroscope will become discharged
E. nothing noticeable will happen

ans: C

23. An electroscope is charged by induction using a glass rod that has been made positive by rubbing it with silk. The electroscope leaves:

A. gain electrons
B. gain protons
C. lose electrons
D. lose protons
E. gain an equal number of protons and electrons

ans: A

24. Consider the following procedural steps:

1. ground an electroscope
2. remove the ground from the electroscope
3. touch a charged rod to the electroscope
4. bring a charged rod near, but not touching, the electroscope
5. remove the charged rod

To charge an electroscope by induction, use the sequence:

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

ans: B

25. A charged insulator can be discharged by passing it just above a flame. This is because the flame:

A. warms it
B. dries it
C. contains carbon dioxide
D. contains ions
E. contains more rapidly moving atoms

ans: D

26. A small object has charge Q. Charge q is removed from it and placed on a second small object. The two objects are placed 1 m apart. For the force that each object exerts on the other to be a maximum. q should be:

A. $2Q$
B. Q
C. $Q/2$
D. $Q/4$
E. 0

ans: C

27. Two small charged objects attract each other with a force F when separated by a distance d. If the charge on each object is reduced to one-fourth of its original value and the distance between them is reduced to $d/2$ the force becomes:

A. $F/16$
B. $F/8$
C. $F/4$
D. $F/2$
E. F

ans: C

28. Two identical conducting spheres A and B carry equal charge. They are separated by a distance much larger than their diameters. A third identical conducting sphere C is uncharged. Sphere C is first touched to A, then to B, and finally removed. As a result, the electrostatic force between A and B, which was originally F, becomes:

A. $F/2$
B. $F/4$
C. $3F/8$
D. $F/16$
E. 0

ans: C

29. Two particles, X and Y, are 4 m apart. X has a charge of $2Q$ and Y has a charge of Q. The force of X on Y:

A. has twice the magnitude of the force of Y on X
B. has half the magnitude of the force of Y on X
C. has four times the magnitude of the force of Y on X
D. has one-fourth the magnitude of the force of Y on X
E. has the same magnitude as the force of Y on X

ans: E

30. The units of $1/4\pi\epsilon_0$ are:

A. $\mathrm{N^2C^2}$
B. $\mathrm{N \cdot m/C}$
C. $\mathrm{N^2 \cdot m^2/C^2}$
D. $\mathrm{N \cdot m^2/C^2}$
E. $\mathrm{m^2/C^2}$

ans: D

31. A 5.0-C charge is 10 m from a −2.0-C charge. The electrostatic force on the positive charge is:

A. 9.0×10^8 N toward the negative charge
B. 9.0×10^8 N away from the negative charge
C. 9.0×10^9 N toward the negative charge
D. 9.0×10^9 N away from the negative charge
E. none of these

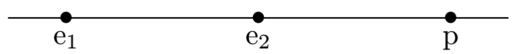
ans: A

32. Two identical charges, 2.0 m apart, exert forces of magnitude 4.0 N on each other. The value of either charge is:

A. 1.8×10^{-9} C
B. 2.1×10^{-5} C
C. 4.2×10^{-5} C
D. 1.9×10^{5} C
E. 3.8×10^{5} C

ans: C

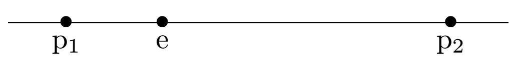
33. Two electrons (e_1 and e_2) and a proton (p) lie on a straight line, as shown. The directions of the force of e_2 on e_1, the force of p on e_1, and the total force on e_1, respectively, are:



A. $\longrightarrow, \longleftarrow, \longrightarrow$
B. $\longleftarrow, \longrightarrow, \longrightarrow$
C. $\longrightarrow, \longleftarrow, \longleftarrow$
D. $\longleftarrow, \longrightarrow, \longleftarrow$
E. $\longleftarrow, \longleftarrow, \longleftarrow$

ans: D

34. Two protons (p_1 and p_2) and an electron (e) lie on a straight line, as shown. The directions of the force of p_1 on e, the force of p_2 on e, and the total force on e, respectively, are:



A. $\longrightarrow, \longleftarrow, \longrightarrow$
B. $\longleftarrow, \longrightarrow, \longrightarrow$
C. $\longrightarrow, \longleftarrow, \longleftarrow$
D. $\longleftarrow, \longrightarrow, \longleftarrow$
E. $\longleftarrow, \longleftarrow, \longleftarrow$

ans: D

35. Two particles have charges Q and $-Q$ (equal magnitude and opposite sign). For a net force of zero to be exerted on a third charge it must be placed:

A. midway between Q and $-Q$
B. on the perpendicular bisector of the line joining Q and $-Q$, but not on that line itself
C. on the line joining Q and $-Q$, to the side of Q opposite $-Q$
D. on the line joining Q and $-Q$, to the side of $-Q$ opposite Q
E. at none of these places (there is no place)

ans: E

36. Particles 1, with charge q_1, and 2, with charge q_2, are on the x axis, with particle 1 at $x = a$ and particle 2 at $x = -2a$. For the net force on a third charged particle, at the origin, to be zero, q_1 and q_2 must be related by $q_2 =$:

A. $2q_1$
B. $4q_1$
C. $-2q_1$
D. $-4q_1$
E. $-q_1/4$

ans: B

37. Two particles A and B have identical charge Q. For a net force of zero to be exerted on a third charged particle it must be placed:

A. midway between A and B
B. on the perpendicular bisector of the line joining A and B but away from the line
C. on the line joining A and B, not between the particles
D. on the line joining A and B, closer to one of them than the other
E. at none of these places (there is no place)

ans: A

38. A particle with charge 2-μC is placed at the origin, an identical particle, with the same charge, is placed 2 m from the origin on the x axis, and a third identical particle, with the same charge, is placed 2 m from the origin on the y axis. The magnitude of the force on the particle at the origin is:

A. 9.0×10^{-3} N
B. 6.4×10^{-3} N
C. 1.3×10^{-2} N
D. 1.8×10^{-2} N
E. 3.6×10^{-2} N

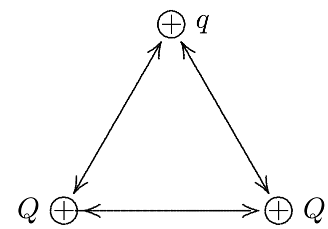
ans: C

39. Charge Q is spread uniformly along the circumference of a circle of radius R. A point particle with charge q is placed at the center of this circle. The total force exerted on the particle can be calculated by Coulomb's law:

A. just use R for the distance
B. just use $2R$ for the distance
C. just use $2\pi R$ for the distance
D. the result of the calculation is zero
E. none of the above

ans: D

40. Two particles, each with charge Q, and a third particle, with charge q, are placed at the vertices of an equilateral triangle as shown. The total force on the particle with charge q is:



A. parallel to the left side of the triangle
B. parallel to the right side of the triangle
C. parallel to the bottom side of the triangle
D. perpendicular to the bottom side of the triangle
E. perpendicular to the left side of the triangle

ans: D

41. A particle with charge Q is on the y axis a distance a from the origin and a particle with charge q is on the x axis a distance d from the origin. The value of d for which the x component of the force on the second particle is the greatest is:

A. 0
B. a
C. $\sqrt{2}a$
D. $a/2$
E. $a/\sqrt{2}$

ans: E

42. In the Rutherford model of the hydrogen atom, a proton (mass M, charge Q) is the nucleus and an electron (mass m, charge q) moves around the proton in a circle of radius r. Let k denote the Coulomb force constant $(1/4\pi\epsilon_0)$ and G the universal gravitational constant. The ratio of the electrostatic force to the gravitational force between electron and proton is:

A. $kQq/GMmr^2$
B. GQq/kMm
C. kMm/GQq
D. GMm/kQq
E. kQq/GMm

ans: E

43. A particle with a charge of 5×10^{-6} C and a mass of 20 g moves uniformly with a speed of 7 m/s in a circular orbit around a stationary particle with a charge of -5×10^{-6} C. The radius of the orbit is:

A. 0
B. 0.23 m
C. 0.62 m
D. 1.6
E. 4.4 m

ans: B

44. Charge is distributed uniformly on the surface of a spherical balloon (an insulator). A point particle with charge q is inside. The electrical force on the particle is greatest when:

A. it is near the inside surface of the balloon
B. it is at the center of the balloon
C. it is halfway between the balloon center and the inside surface
D. it is anywhere inside (the force is same everywhere and is not zero)
E. it is anywhere inside (the force is zero everywhere)

ans: E

45. Charge is distributed on the surface of a spherical conducting shell. A point particle with charge q is inside. If polarization effects are negligible the electrical force on the particle is greatest when:

A. it is near the inside surface of the balloon
B. it is at the center of the balloon
C. it is halfway between the balloon center and the inside surface
D. it is anywhere inside (the force is same everywhere and is not zero)
E. it is anywhere inside (the force is zero everywhere)

ans: A

Chapter 1: MEASUREMENT

1. The SI standard of time is based on:
   A. the daily rotation of the earth
   B. the frequency of light emitted by Kr^{86}
   C. the yearly revolution of the earth about the sun
   D. a precision pendulum clock
   E. none of these

   Ans: E

2. A nanosecond is:
   A. 10^{9} s
   B. 10^{-9} s
   C. 10^{-10} s
   D. 10^{-10} s
   E. 10^{-12}

   Ans: B

3. The SI standard of length is based on:
   A. the distance from the north pole to the equator along a meridian passing through Paris
   B. wavelength of light emitted by Hg^{198}
   C. wavelength of light emitted by Kr^{86}
   D. a precision meter stick in Paris
   E. the speed of light

   Ans: E

4. In 1866, the U. S. Congress defined the U. S. yard as exactly 3600/3937 international meter. This was done primarily because:
   A. length can be measured more accurately in meters than in yards
   B. the meter is more stable than the yard
   C. this definition relates the common U. S. length units to a more widely used system
   D. there are more wavelengths in a yard than in a meter
   E. the members of this Congress were exceptionally intelligent

   Ans: C

5. Which of the following is closest to a yard in length?
   A. 0.01 m
   B. 0.1 m
   C. 1 m
   D. 100 m
   E. 1000 m

   Ans: C

6. There is no SI base unit for area because:
   A. an area has no thickness; hence no physical standard can be built
   B. we live in a three (not a two) dimensional world
   C. it is impossible to express square feet in terms of meters
   D. area can be expressed in terms of square meters
   E. area is not an important physical quantity

   Ans: D

7. The SI base unit for mass is:
   A. gram
   B. pound
   C. kilogram
   D. ounce
   E. kilopound

   Ans: C

8. A gram is:
   A. 10^{-6} kg
   B. 10^{-3} kg
   C. 1 kg
   D. 10^{3} kg
   E. 10^{6} kg

   Ans: B

9. Which of the following weighs about a pound?
   A. 0.05 kg
   B. 0.5 kg
   C. 5 kg
   D. 50 kg
   E. 500 kg

   Ans: D

10. $(5.0 \times 10^4) \times (3.0 \times 10^6) =$
   A. 1.5×10^9
   B. 1.5×10^{10}
   C. 1.5×10^{11}
   D. 1.5×10^{12}
   E. 1.5×10^{13}

   Ans: C

11. $(5.0 \times 10^4) \times (3.0 \times 10^{-6}) =$
   A. 1.5×10^{-3}
   B. 1.5×10^{-1}
   C. 1.5×10^{1}
   D. 1.5×10^{3}
   E. 1.5×10^{5}

   Ans: B

12. $5.0 \times 10^5 + 3.0 \times 10^6 =$
  A. 8.0×10^5
  B. 8.0×10^6
  C. 5.3×10^5
  D. 3.5×10^5
  E. 3.5×10^6
  Ans: E

13. $(7.0 \times 10^6)/(2.0 \times 10^{-6}) =$
  A. 3.5×10^{-12}
  B. 3.5×10^{-6}
  C. 3.5
  D. 3.5×10^6
  E. 3.5×10^{12}
  Ans: E

14. The number of significant figures in 0.00150 is:
  A. 2
  B. 3
  C. 4
  D. 5
  E. 6
  Ans: B

15. The number of significant figures in 15.0 is:
  A. 1
  B. 2
  C. 3
  D. 4
  E. 5
  Ans: C

16. $3.2 \times 2.7 =$
  A. 9
  B. 8
  C. 8.6
  D. 8.64
  E. 8.640
  Ans: C

17. $1.513 + 27.3 =$

A. 29
B. 28.8
C. 28.9
D. 28.81
E. 28.813

( )Ans: B

18. 1 mi is equivalent to 1609 m so 55 mph is:

A. 15 m/s
B. 25 m/s
C. 66 m/s
D. 88 m/s
E. 1500 m/s

Ans: B

19. A sphere with a radius of 1.7 cm has a volume of:

A. 2.1×10^{-5} m^3
B. 9.1×10^{-4} m^3
C. 3.6×10^{-3} m^3
D. 0.11 m^3
E. 21 m^3

Ans: A

20. A sphere with a radius of 1.7 cm has a surface area of:

A. 2.1×10^{-5} m^2
B. 9.1×10^{-4} m^2
C. 3.6×10^{-3} m^2
D. 0.11 m^2
E. 36 m^2

Ans: C

21. A right circular cylinder with a radius of 2.3 cm and a height of 1.4 m has a volume of:

A. 0.20 m^3
B. 0.14 m^3
C. 9.3×10^{-3} m^3
D. 2.3×10^{-3} m^3
E. 7.4×10^{-4} m^3

Ans: D

22. A right circular cylinder with a radius of 2.3 cm and a height of 1.4 cm has a total surface area of:

A. 1.7×10^{-3} m^2
B. 3.2×10^{-3} m^2
C. 2.0×10^{-3} m^3
D. 5.3×10^{-3} m^2
E. 7.4×10^{-3} m^2

Ans: D

23. A cubic box with an edge of exactly 1 cm has a volume of:
   A. 10^{-9} m^3
   B. 10^{-6} m^3
   C. 10^{-3} m^3
   D. 10^{3} m^3
   E. 10^{6} m^3

   Ans: B

24. A square with an edge of exactly 1 cm has an area of:
   A. 10^{-6} m^2
   B. 10^{-4} m^2
   C. 10^{2} m^2
   D. 10^{4} m^2
   E. 10^{6} m^2

   Ans: B

25. 1 m is equivalent to 3.281 ft. A cube with an edge of 1.5 ft has a volume of:
   A. 1.2×10^{2} m^3
   B. 9.6×10^{-2} m^3
   C. 10.5 m^3
   D. 9.5×10^{-2} m^3
   E. 0.21 m^3

   Ans: B

26. During a short interval of time the speed v in m/s of an automobile is given by $v = at^2 + bt^3$, where the time t is in seconds. The units of a and b are respectively:
   A. $\mathrm{m \cdot s^2; m \cdot s^4}$
   B. $\mathrm{s^3/m; s^4/m}$
   C. $\mathrm{m/s^2; m/s^3}$
   D. $\mathrm{m/s^3; m/s^4}$
   E. $\mathrm{m/s^4; m/s^5}$

   Ans: D

27. Suppose $A = BC$, where A has the dimension L/M and C has the dimension L/T. Then B has the dimension:
   A. T/M
   B. $\mathrm{L^2/TM}$
   C. $\mathrm{TM/L^2}$
   D. $\mathrm{L^2T/M}$
   E. $\mathrm{M/L^2T}$

   Ans: A

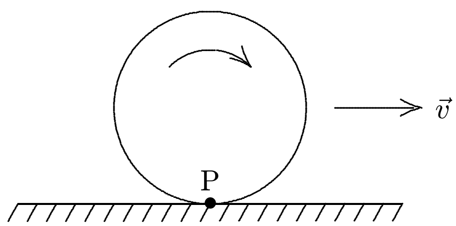
28. Suppose $A = B^n C^m$, where A has dimensions LT, B has dimensions L^2T^{-1}, and C has dimensions LT^2. Then the exponents n and m have the values:

A. 2/3; 1/3
B. 2; 3
C. 4/5; −1/5
D. 1/5; 3/5
E. 1/2; 1/2

Ans: D

Chapter 11: ROLLING, TORQUE, AND ANGULAR MOMENTUM

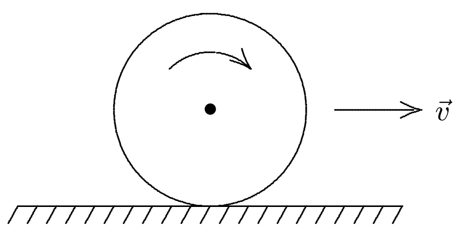
1. A wheel rolls without sliding along a horizontal road as shown. The velocity of the center of the wheel is represented by $\longrightarrow$. Point P is painted on the rim of the wheel. The instantaneous velocity of point P is:



A. $\rightarrow$
B. $\leftarrow$
C. $\uparrow$
D. $\nearrow$
E. zero

ans: E

2. A wheel of radius 0.5 m rolls without sliding on a horizontal surface as shown. Starting from rest, the wheel moves with constant angular acceleration $6\,\mathrm{rad/s^2}$. The distance traveled by the center of the wheel from $t = 0$ to $t = 3\,\mathrm{s}$ is:



A. zero
B. 27 m
C. 13.5 m
D. 18 m
E. none of these

ans: C

3. Two wheels roll side-by-side without sliding, at the same speed. The radius of wheel 2 is twice the radius of wheel 1. The angular velocity of wheel 2 is:

A. twice the angular velocity of wheel 1
B. the same as the angular velocity of wheel 1
C. half the angular velocity of wheel 1
D. more than twice the angular velocity of wheel 1
E. less than half the angular velocity of wheel 1

ans: C

4. A forward force on the axle accelerates a rolling wheel on a horizontal surface. If the wheel does not slide the frictional force of the surface on the wheel is:

A. zero
B. in the forward direction
C. in the backward direction
D. in the upward direction
E. in the downward direction

ans: D

5. When the speed of a rear-drive car is increasing on a horizontal road the direction of the frictional force on the tires is:

A. forward for all tires
B. backward for all tires
C. forward for the front tires and backward for the rear tires
D. backward for the front tires and forward for the rear tires
E. zero

ans: D

6. A solid wheel with mass M, radius R, and rotational inertia $MR^2/2$, rolls without sliding on a horizontal surface. A horizontal force F is applied to the axle and the center of mass has an acceleration a. The magnitudes of the applied force F and the frictional force f of the surface, respectively, are:

A. $F = Ma,\ f = 0$
B. $F = Ma,\ f = Ma/2$
C. $F = 2Ma,\ f = Ma$
D. $F = 2Ma,\ f = Ma/2$
E. $F = 3Ma/2,\ f = Ma/2$

ans: E

7. The coefficient of static friction between a certain cylinder and a horizontal floor is 0.40. If the rotational inertia of the cylinder about its symmetry axis is given by $I = (1/2)MR^2$, then the magnitude of the maximum acceleration the cylinder can have without sliding is:

A. $0.1g$
B. $0.2g$
C. $0.4g$
D. $0.8g$
E. g

ans: D

8. A thin-walled hollow tube rolls without sliding along the floor. The ratio of its translational kinetic energy to its rotational kinetic energy (about an axis through its center of mass) is:

A. 1
B. 2
C. 3
D. 1/2
E. 1/3

ans: A

9. A sphere and a cylinder of equal mass and radius are simultaneously released from rest on the same inclined plane and roll without sliding down the incline. Then:
   A. the sphere reaches the bottom first because it has the greater inertia
   B. the cylinder reaches the bottom first because it picks up more rotational energy
   C. the sphere reaches the bottom first because it picks up more rotational energy
   D. they reach the bottom together
   E. none of the above are true

   ans: E

10. A hoop, a uniform disk, and a uniform sphere, all with the same mass and outer radius, start with the same speed and roll without sliding up identical inclines. Rank the objects according to how high they go, least to greatest.
    A. hoop, disk, sphere
    B. disk, hoop, sphere
    C. sphere, hoop, disk
    D. sphere, disk, hoop
    E. hoop, sphere, disk

    ans: A

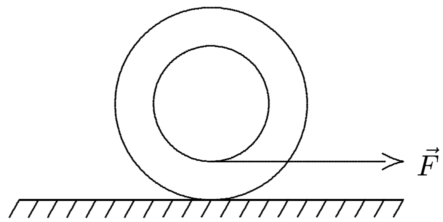
11. A hoop rolls with constant velocity and without sliding along level ground. Its rotational kinetic energy is:
    A. half its translational kinetic energy
    B. the same as its translational kinetic energy
    C. twice its translational kinetic energy
    D. four times its translational kinetic energy
    E. one-third its translational kinetic energy

    ans: B

12. Two identical disks, with rotational inertia I $(= \frac{1}{2}MR^2)$, roll without sliding across a horizontal floor with the same speed and then up inclines. Disk A rolls up its incline without sliding. On the other hand, disk B rolls up a frictionless incline. Otherwise the inclines are identical. Disk A reaches a height 12 cm above the floor before rolling down again. Disk B reaches a height above the floor of:
    A. 24 cm
    B. 18 cm
    C. 12 cm
    D. 8 cm
    E. 6 cm

    ans: D

13. A yo-yo, arranged as shown, rests on a frictionless surface. When a force $\vec{F}$ is applied to the string as shown, the yo-yo:



A. moves to the left and rotates counterclockwise
B. moves to the right and rotates counterclockwise
C. moves to the left and rotates clockwise
D. moves to the right and rotates clockwise
E. moves to the right and does not rotate

ans: B

14. When we apply the energy conservation principle to a cylinder rolling down an incline without sliding, we exclude the work done by friction because:

A. there is no friction present
B. the angular velocity of the center of mass about the point of contact is zero
C. the coefficient of kinetic friction is zero
D. the linear velocity of the point of contact (relative to the inclined surface) is zero
E. the coefficient of static and kinetic friction are equal

ans: D

15. Two uniform cylinders have different masses and different rotational inertias. They simultaneously start from rest at the top of an inclined plane and roll without sliding down the plane. The cylinder that gets to the bottom first is:

A. the one with the larger mass
B. the one with the smaller mass
C. the one with the larger rotational inertia
D. the one with the smaller rotational inertia
E. neither (they arrive together)

ans: E

16. A 5.0-kg ball rolls without sliding from rest down an inclined plane. A 4.0-kg block, mounted on roller bearings totaling 100 g, rolls from rest down the same plane. At the bottom, the block has:

A. greater speed than the ball
B. less speed than the ball
C. the same speed as the ball
D. greater or less speed than the ball,depending on the angle of inclination
E. greater or less speed than the ball, depending on the radius of the ball

ans: A

17. A cylinder of radius $R = 6.0\,\text{cm}$ is on a rough horizontal surface. The coefficient of kinetic friction between the cylinder and the surface is 0.30 and the rotational inertia for rotation about the axis is given by $MR^2/2$, where M is its mass. Initially it is not rotating but its center of mass has a speed of 7.0 m/s. After 2.0 s the speed of its center of mass and its angular velocity about its center of mass, respectively, are:

A. 1.1 m/s, 0
B. 1.1 m/s, 19 rad/s
C. 1.1 m/s, 98 rad/s
D. 1.1 m/s, 200 rad/s
E. 5.9 m/s, 98 rad/s

ans: D

18. The fundamental dimensions of angular momentum are:

A. mass·length·time^{-1}
B. mass·length^{-2}·time^{-2}
C. mass^2·time^{-1}
D. mass·length^2·time^{-2}
E. none of these

ans: E

19. Possible units of angular momentum are:

A. kg·m/s
B. kg·m^2/s^2
C. kg·m/s^2
D. kg·m^2/s
E. none of these

ans: D

20. The unit kg·m^2/s can be used for:

A. angular momentum
B. rotational kinetic energy
C. rotational inertia
D. torque
E. power

ans: A

21. The newton·second is a unit of:

A. work
B. angular momentum
C. power
D. linear momentum
E. none of these

ans: D

22. A 2.0-kg block travels around a 0.50-m radius circle with an angular velocity of 12 rad/s. The magnitude of its angular momentum about the center of the circle is:

A. $6.0\,\text{kg}\cdot\text{m}^2/\text{s}$
B. $12\,\text{kg}\cdot\text{m}^2/\text{s}$
C. $48\,\text{kg}/\text{m}^2\cdot\text{s}$
D. $72\,\text{kg}\cdot\text{m}^2/\text{s}^2$
E. $576\,\text{kg}/\text{m}^2\cdot\text{s}^2$

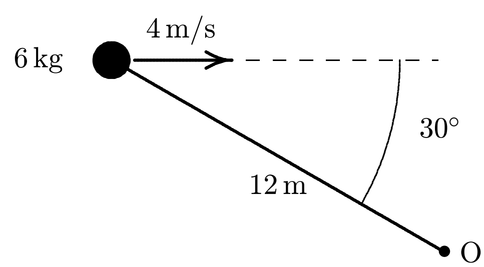
ans: A

23. The angular momentum vector of Earth about its rotation axis, due to its daily rotation, is directed:

A. tangent to the equator toward the east
B. tangent to the equator toward the west
C. north
D. south
E. toward the Sun

ans: C

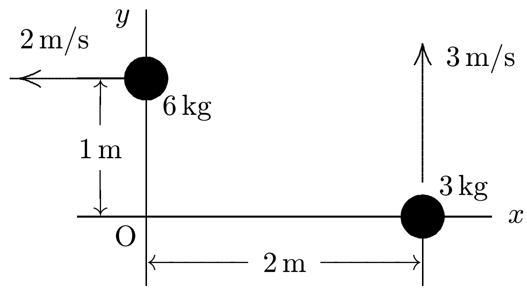
24. A 6.0-kg particle moves to the right at 4.0 m/s as shown. The magnitude of its angular momentum about the point O is:



A. zero
B. $288\,\text{kg}\cdot\text{m}^2/\text{s}$
C. $144\,\text{kg}\cdot\text{m}^2/\text{s}$
D. $24\,\text{kg}\cdot\text{m}^2/\text{s}$
E. $249\,\text{kg}\cdot\text{m}^2/\text{s}$

ans: C

25. Two objects are moving in the x, y plane as shown. The magnitude of their total angular momentum (about the origin O) is:



A. zero
B. $6\,\text{kg}\cdot\text{m}^2/\text{s}$
C. $12\,\text{kg}\cdot\text{m}^2/\text{s}$
D. $30\,\text{kg}\cdot\text{m}^2/\text{s}$
E. $78\,\text{kg}\cdot\text{m}^2/\text{s}$

ans: D

26. A 2.0-kg block starts from rest on the positive x axis 3.0 m from the origin and thereafter has an acceleration given by $\vec{a} = (4.0\,\text{m/s}^2)\,\hat{\text{i}} - (3.0\,\text{m/s}^2)\,\hat{\text{j}}$. At the end of 2.0 s its angular momentum about the origin is:

A. 0
B. $(-36\,\text{kg}\cdot\text{m}^2/\text{s})\,\hat{\text{k}}$
C. $(+48\,\text{kg}\cdot\text{m}^2/\text{s})\,\hat{\text{k}}$
D. $(-96\,\text{kg}\cdot\text{m}^2/\text{s})\,\hat{\text{k}}$
E. $(+96\,\text{kg}\cdot\text{m}^2/\text{s})\,\hat{\text{k}}$

ans: B

27. A 15-g paper clip is attached to the rim of a phonograph record with a radius of 30 cm, spinning at 3.5 rad/s. The magnitude of its angular momentum is:

A. $1.4\times10^{-3}\,\text{kg}\cdot\text{m}^2/\text{s}$
B. $4.7\times10^{-3}\,\text{kg}\cdot\text{m}^2/\text{s}$
C. $1.6\times10^{-2}\,\text{kg}\cdot\text{m}^2/\text{s}$
D. $3.2\times10^{-1}\,\text{kg}\cdot\text{m}^2/\text{s}$
E. $1.1\,\text{kg}\cdot\text{m}^2/\text{s}$

ans: B

28. As a 2.0-kg block travels around a 0.50-m radius circle it has an angular speed of 12 rad/s. The circle is parallel to the xy plane and is centered on the z axis, 0.75 m from the origin. The magnitude of its angular momentum around the origin is:

A. $6.0\,\text{kg}\cdot\text{m}^2/\text{s}$
B. $9.0\,\text{kg}\cdot\text{m}^2/\text{s}$
C. $11\,\text{kg}\cdot\text{m}^2/\text{s}$
D. $14\,\text{kg}\cdot\text{m}^2/\text{s}$
E. $20\,\text{kg}\cdot\text{m}^2/\text{s}$

ans: C

29. As a 2.0-kg block travels around a 0.50-m radius circle it has an angular speed of 12 rad/s. The circle is parallel to the xy plane and is centered on the z axis, a distance of 0.75 m from the origin. The z component of the angular momentum around the origin is:

A. $6.0\,\text{kg}\cdot\text{m}^2/\text{s}$
B. $9.0\,\text{kg}\cdot\text{m}^2/\text{s}$
C. $11\,\text{kg}\cdot\text{m}^2/\text{s}$
D. $14\,\text{kg}\cdot\text{m}^2/\text{s}$
E. $20\,\text{kg}\cdot\text{m}^2/\text{s}$

ans: A

30. As a 2.0-kg block travels around a 0.50-m radius circle it has an angular speed of 12 rad/s. The circle is parallel to the xy plane and is centered on the z axis, 0.75 m from the origin. The component in the xy plane of the angular momentum around the origin has a magnitude of:

A. 0
B. $6.0\,\text{kg}\cdot\text{m}^2/\text{s}$
C. $9.0\,\text{kg}\cdot\text{m}^2/\text{s}$
D. $11\,\text{kg}\cdot\text{m}^2/\text{s}$
E. $14\,\text{kg}\cdot\text{m}^2/\text{s}$

ans: C

31. A uniform disk has radius R and mass M. When it is spinning with angular velocity ω about an axis through its center and perpendicular to its face its angular momentum is $I\omega$. When it is spinning with the same angular velocity about a parallel axis a distance h away its angular momentum is:

A. $I\omega$
B. $(I + Mh^2)\omega$
C. $I - Mh^2)\omega$
D. $(I + MR^2)\omega$
E. $(I - MR^2)\omega$

ans: B

32. A pulley with radius R and rotational inertia I is free to rotate on a horizontal fixed axis through its center. A string passes over the pulley. A block of mass m_1 is attached to one end and a block of mass m_2 is attached to the other. At one time the block with mass m_1 is moving downward with speed v. If the string does not slip on the pulley, the magnitude of the total angular momentum, about the pulley center, of the blocks and pulley, considered as a system, is given by:

A. $(m_1 - m_2)vR + Iv/R$
B. $(m_1 + m_2)vR + Iv/R$
C. $(m_1 - m_2)vR + Iv/R^2$
D. $(m_1 + m_2)vR + Iv/R^2$
E. none of the above

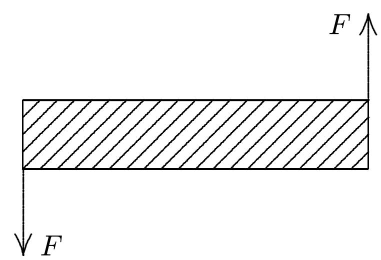
ans: B

33. A single force acts on a particle situated on the positive x axis. The torque about the origin is in the negative z direction. The force might be:

A. in the positive y direction
B. in the negative y direction
C. in the positive x direction
D. in the negative x direction
E. in the positive z direction

ans: B

34. A rod rests on frictionless ice. Forces that are equal in magnitude and opposite in direction are then simultaneously applied to its ends as shown. The quantity that vanishes is its:



A. angular momentum
B. angular acceleration
C. total linear momentum
D. kinetic energy
E. rotational inertia

ans: C

35. A 2.0-kg stone is tied to a 0.50-m long string and swung around a circle at a constant angular velocity of 12 rad/s. The net torque on the stone about the center of the circle is:

A. 0
B. $6.0\,\mathrm{N\cdot m}$
C. $12\,\mathrm{N\cdot m}$
D. $72\,\mathrm{N\cdot m}$
E. $140\,\mathrm{N\cdot m}$

ans: A

36. A 2.0-kg stone is tied to a 0.50-m long string and swung around a circle at a constant angular velocity of 12 rad/s. The circle is parallel to the xy plane and is centered on the z axis, 0.75 m from the origin. The magnitude of the torque about the origin is:

A. 0
B. $6.0\,\mathrm{N\cdot m}$
C. $14\,\mathrm{N\cdot m}$
D. $72\,\mathrm{N\cdot m}$
E. $108\,\mathrm{N\cdot m}$

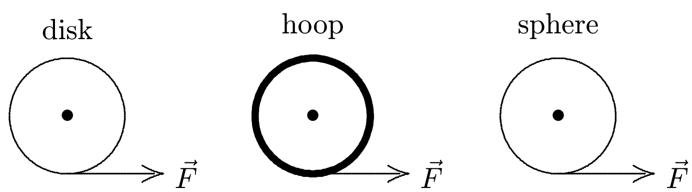
ans: E

37. A 2.0-kg block starts from rest on the positive x axis 3.0 m from the origin and thereafter has an acceleration given by $\vec{a} = (4.0\,\mathrm{m/s^2})\,\hat{\mathrm{i}} - (3.0\,\mathrm{m/s^2})\,\hat{\mathrm{j}}$. The torque, relative to the origin, acting on it at the end of 2.0 s is:

A. 0
B. $(-18\,\mathrm{N\cdot m})\,\hat{\mathrm{k}}$
C. $(+24\,\mathrm{N\cdot m})\,\hat{\mathrm{k}}$
D. $(-144\,\mathrm{N\cdot m})\,\hat{\mathrm{k}}$
E. $(+144\,\mathrm{N\cdot m})\,\hat{\mathrm{k}}$

ans: B

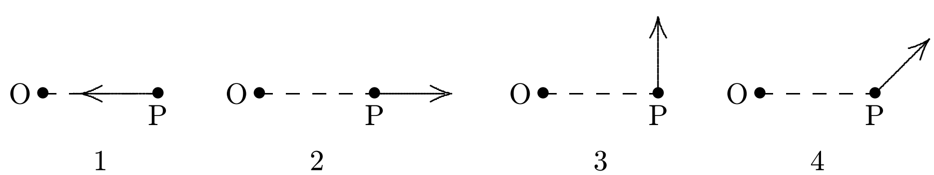
38. A uniform disk, a thin hoop, and a uniform sphere, all with the same mass and same outer radius, are each free to rotate about a fixed axis through its center. Assume the hoop is connected to the rotation axis by light spokes. With the objects starting from rest, identical forces are simultaneously applied to the rims, as shown. Rank the objects according to their angular momenta after a given time t, least to greatest.



A. all tie
B. disk, hoop, sphere
C. hoop, disk, sphere
D. hoop, sphere, disk
E. hoop, disk, sphere

ans: A

39. A single force acts on a particle P. Rank each of the orientations of the force shown below according to the magnitude of the time rate of change of the particle's angular momentum about the point O, least to greatest.



A. 1, 2, 3, 4
B. 1 and 2 tie, then 3, 4
C. 1 and 2 tie, then 4, 3
D. 1 and 2 tie, then 3 and 4 tie
E. All are the same

ans: C

40. A pulley with radius R is free to rotate on a horizontal fixed axis through its center. A string passes over the pulley. Mass m_1 is attached to one end and mass m_2 is attached to the other. The portion of the string attached to m_1 has tension T_1 and the portion attached to m_2 has tension T_2. The magnitude of the total external torque, about the pulley center, acting on the masses and pulley, considered as a system, is given by:

A. $|m_1 - m_2|gR$
B. $(m_1 + m_2)gR$
C. $|m_1 - m_2|gR + (T_1 + T_2)R$
D. $(m_1 + m_2)gR + (T_1 - T_2)R$
E. $|m_1 - m_2|gR + (T_2 - T_1)R$

ans: A

41. An ice skater with rotational inertia I_0 is spinning with angular speed ω_0. She pulls her arms in, thereby increasing her angular speed to $4\omega_0$. Her rotational inertia is then:

A. I_0
B. $I_0/2$
C. $2I_0$
D. $I_0/4$
E. $4I_0$

ans: D

42. A man, with his arms at his sides, is spinning on a light frictionless turntable. When he extends his arms:

A. his angular velocity increases
B. his angular velocity remains the same
C. his rotational inertia decreases
D. his rotational kinetic energy increases
E. his angular momentum remains the same

ans: E

43. A man, holding a weight in each hand, stands at the center of a horizontal frictionless rotating turntable. The effect of the weights is to double the rotational inertia of the system. As he is rotating, the man opens his hands and drops the two weights. They fall outside the turntable. Then:

A. his angular velocity doubles
B. his angular velocity remains about the same
C. his angular velocity is halved
D. the direction of his angular momentum vector changes
E. his rotational kinetic energy increases

ans: B

44. A uniform sphere of radius R rotates about a diameter with an angular momentum of magnitude L. Under the action of internal forces the sphere collapses to a uniform sphere of radius $R/2$. The magnitude of its new angular momentum is:

A. $L/4$
B. $L/2$
C. L
D. $2L$
E. $4L$

ans: C

45. When a man on a frictionless rotating stool extends his arms horizontally, his rotational kinetic energy:

A. must increase
B. must decrease
C. must remain the same
D. may increase or decrease depending on his initial angular velocity
E. may increase or decrease depending on his angular acceleration

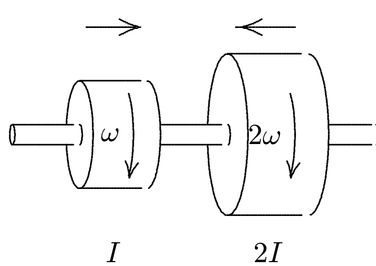
ans: B

46. When a woman on a frictionless rotating turntable extends her arms out horizontally, her angular momentum:

A. must increase
B. must decrease
C. must remain the same
D. may increase or decrease depending on her initial angular velocity
E. tilts away from the vertical

ans: C

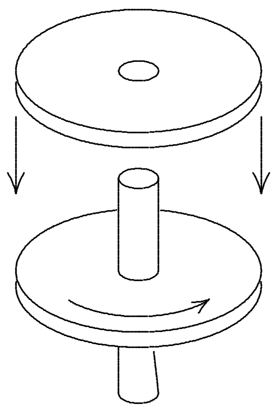
47. Two disks are mounted on low-friction bearings on a common shaft. The first disc has rotational inertia I and is spinning with angular velocity ω. The second disc has rotational inertia $2I$ and is spinning in the same direction as the first disc with angular velocity 2ω as shown. The two disks are slowly forced toward each other along the shaft until they couple and have a final common angular velocity of:



A. $5\omega/3$
B. $\omega\sqrt{3}$
C. $\omega\sqrt{7/3}$
D. ω
E. 3ω

ans: A

48. A wheel with rotational inertia I, mounted on a vertical shaft with negligible rotational inertia, is rotating with angular speed ω_0. A nonrotating wheel with rotational inertia $2I$ is suddenly dropped onto the same shaft as shown. The resultant combination of the two wheels and shaft will rotate at:



A. $\omega_0/2$
B. $2\omega_0$
C. $\omega_0/3$
D. $3\omega_0$
E. $\omega_0/4$

ans: C

49. A phonograph record is dropped onto a freely spinning turntable. Then:

A. neither angular momentum nor mechanical energy is conserved because of the frictional forces between record and turntable
B. the frictional force between record and turntable increases the total angular momentum
C. the frictional force between record and turntable decreases the total angular momentum
D. the total angular momentum remains constant
E. the sum of the angular momentum and rotational kinetic energy remains constant

ans: D

50. A playground merry-go-round has a radius R and a rotational inertia I. When the merry-go-round is at rest, a child with mass m runs with speed v along a line tangent to the rim and jumps on. The angular velocity of the merry-go-round is then:

A. mv/I
B. v/R
C. mRv/I
D. $2mRv/I$
E. $mRv/(mR^2 + I)$

ans: E

51. A playground merry-go-round has a radius of 3.0 m and a rotational inertia of 600 $\mathrm{kg \cdot m^2}$. It is initially spinning at 0.80 rad/s when a 20-kg child crawls from the center to the rim. When the child reaches the rim the angular velocity of the merry-go-round is:

A. 0.62 rad/s
B. 0.73 rad/s
C. 0.80 rad/s
D. 0.89 rad/s
E. 1.1 rad/s

ans: A

52. Two pendulum bobs of unequal mass are suspended from the same fixed point by strings of equal length. The lighter bob is drawn aside and then released so that it collides with the other bob on reaching the vertical position. The collision is elastic. What quantities are conserved in the collision?

A. Both kinetic energy and angular momentum of the system
B. Only kinetic energy
C. Only angular momentum
D. Angular speed of lighter bob
E. None of the above

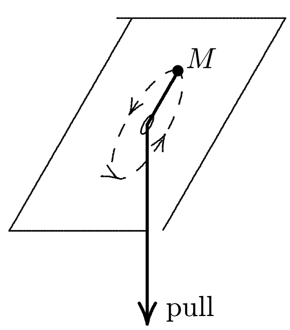
ans: A

53. A particle, held by a string whose other end is attached to a fixed point C, moves in a circle on a horizontal frictionless surface. If the string is cut, the angular momentum of the particle about the point C:

A. increases
B. decreases
C. does not change
D. changes direction but not magnitude
E. none of these

ans: C

54. A block with mass M, on the end of a string, moves in a circle on a horizontal frictionless table as shown. As the string is slowly pulled through a small hole in the table:



A. the angular momentum of the block remains constant
B. the angular momentum of the block decreases
C. the kinetic energy of the block remains constant
D. the kinetic energy of the block decreases
E. none of the above

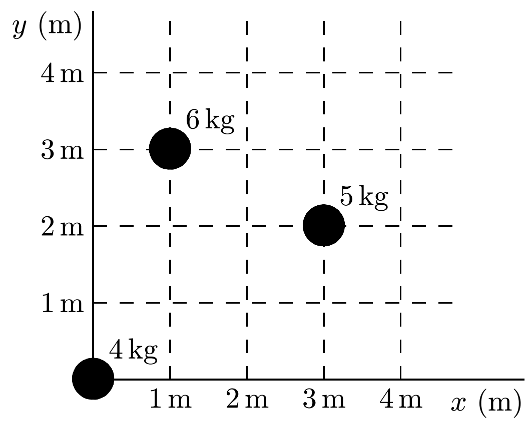
ans: A

Chapter 9: CENTER OF MASS AND LINEAR MOMENTUM

1. Which one of the following statements is true?
   A. the center of mass of an object must lie within the object
   B. all the mass of an object is actually concentrated at its center of mass
   C. the center of mass of an object cannot move if there is zero net force on the object
   D. the center of mass of a cylinder must lie on its axis
   E. none of the above

   ans: E

2. The x and y coordinates of the center of mass of the three-particle system shown below are:



   A. $0, 0$
   B. $1.3\,\text{m}$, $1.7\,\text{m}$
   C. $1.4\,\text{m}$, $1.9\,\text{m}$
   D. $1.9\,\text{m}$, $2.5\,\text{m}$
   E. $1.4\,\text{m}$, $2.5\,\text{m}$

   ans: C

3. The center of mass of a uniform disk of radius R is located:
   A. on the rim
   B. a distance $R/2$ from the center
   C. a distance $R/3$ from the center
   D. a distance $2R/3$ from the center
   E. at the center

   ans: E

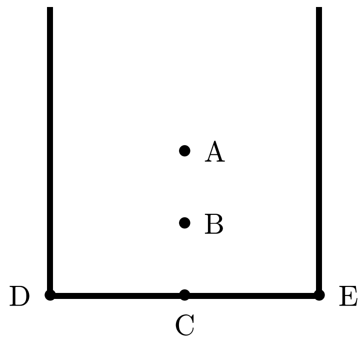
4. The center of mass of the system consisting of Earth, the Sun, and the planet Mars is:
   A. closer to Earth than to either of the other bodies
   B. closer to the Sun than to either of the other bodies
   C. closer to Mars than to either of the other bodies
   D. at the geometric center of the triangle formed by the three bodies
   E. at the center of the line joining Earth and Mars

   ans: B

5. The center of mass of Earth's atmosphere is:
   A. a little less than halfway between Earth's surface and the outer boundary of the atmosphere
   B. near the surface of Earth
   C. near the outer boundary of the atmosphere
   D. near the center of Earth
   E. none of the above

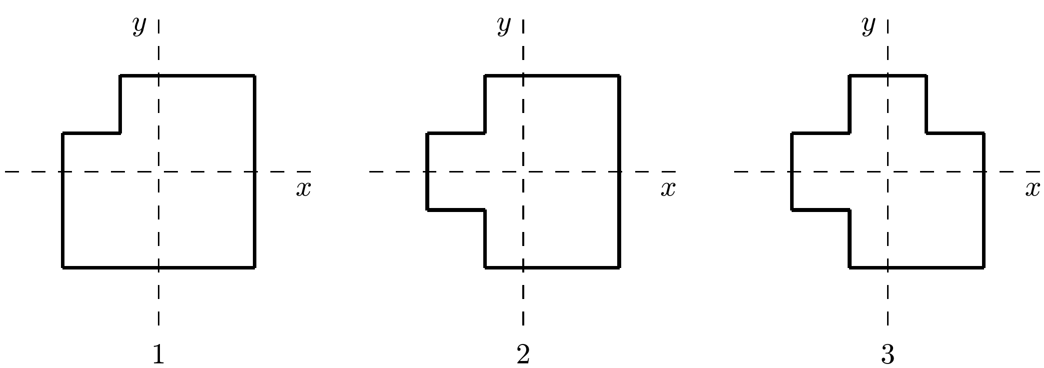
   ans: D

6. A thick uniform wire is bent into the shape of the letter "U" as shown. Which point indicates the location of the center of mass of this wire?



   ans: B

7. A machinist starts with three identical square plates but cuts one corner from one of them, two corners from the second, and three corners from the third. Rank the three plates according to the x coordinate of their centers of mass, from smallest to largest.



   A. 1, 2, 3
   B. 1 and 2 tie, then 3
   C. 1, then 2 and 3 tie
   D. 3, 2, 1
   E. 1 and 3 tie, then 2

   ans: E

8. Block A, with a mass of 4 kg, is moving with a speed of 2.0 m/s while block B, with a mass of 8 kg, is moving in the opposite direction with a speed of 3 m/s. The center of mass of the two block-system is moving with a velocity of:
   A. 1.3 m/s in the same direction as A
   B. 1.3 m/s in the same direction as B
   C. 2.7 m/s in the same direction as A
   D. 1.0 m/s in the same direction as B
   E. 5.0 m/s in the same direction as A

   ans: B

9. At the same instant that a 0.50-kg ball is dropped from 25 m above Earth, a second ball, with a mass of 0.25 kg, is thrown straight upward from Earth's surface with an initial speed of 15 m/s. They move along nearby lines and pass each other without colliding. At the end of 2.0 s the height above Earth's surface of the center of mass of the two-ball system is:
   A. 2.9 m
   B. 4.0 m
   C. 5.0 m
   D. 7.1 m
   E. 10.4 m

   ans: D

10. At the same instant that a 0.50-kg ball is dropped from 25 m above Earth, a second ball, with a mass of 0.25 kg, is thrown straight upward from Earth's surface with an initial speed of 15 m/s. They move along nearby lines and pass without colliding. At the end of 2.0 s the velocity of the center of mass of the two-ball system is:
    A. 11 m/s, down
    B. 11 m/s, up
    C. 15 m/s, down
    D. 15 m/s, up
    E. 20 m/s, down

    ans: C

11. At the same instant that a 0.50-kg ball is dropped from 25 m above Earth, a second ball, with a mass of 0.25 kg, is thrown straight upward from Earth's surface with an initial speed of 15 m/s. They move along nearby lines and pass without colliding. At the end of 2.0 s the magnitude of the acceleration of the center of mass of the two-ball system is:
    A. $0.25g$
    B. $0.50g$
    C. $0.75g$
    D. g
    E. $g/0.75$

    ans: D

12. A light rope passes over a light frictionless pulley attached to the ceiling. An object with a large mass is tied to one end and an object with a smaller mass is tied to the other end. Starting from rest the heavier object moves downward and the lighter object moves upward with the same magnitude acceleration. Which of the following statements is true for the system consisting of the two masses?

    A. The center of mass remains at rest.
    B. The net external force is zero.
    C. The velocity of the center of mass is a constant.
    D. The acceleration of the center of mass is g, downward.
    E. None of the above statements are true.

    ans: E

13. Two 4.0-kg blocks are tied together with a compressed spring between them. They are thrown from the ground with an initial velocity of $35\,\mathrm{m/s}$, 45° above the horizontal. At the highest point of the trajectory they become untied and spring apart. About how far below the highest point is the center of mass of the two-block system 2.0 s later, before either fragment has hit the ground?

    A. 12 m
    B. 20 m
    C. 31 m
    D. Can't tell because the velocities of the fragments are not given.
    E. Can't tell because the coordinates of the highest point are not given.

    ans: B

14. The center of mass of a system of particles has a constant velocity if:

    A. the forces exerted by the particles on each other sum to zero
    B. the external forces acting on particles of the system sum to zero
    C. the velocity of the center of mass is initially zero
    D. the particles are distributed symmetrically around the center of mass
    E. the center of mass is at the geometric center of the system

    ans: B

15. The center of mass of a system of particles remains at the same place if:

    A. it is initially at rest and the external forces sum to zero
    B. it is initially at rest and the internal forces sum to zero
    C. the sum of the external forces is less than the maximum force of static friction
    D. no friction acts internally
    E. none of the above

    ans: A

16. A man sits in the back of a canoe in still water. He then moves to the front of the canoe and sits there. Afterwards the canoe:

    A. is forward of its original position and moving forward
    B. is forward of its original position and moving backward
    C. is rearward of its original position and moving forward
    D. is rearward of its original position and moving backward
    E. is rearward of its original position and not moving

    ans: E

17. A 640-N hunter gets a rope around a 3200-N polar bear. They are stationary, 20 m apart, on frictionless level ice. When the hunter pulls the polar bear to him, the polar bear will move:

A. 1.0 m
B. 3.3 m
C. 10 m
D. 12 m
E. 17 m

ans: B

18. Two boys, with masses of 40 kg and 60 kg, respectively, stand on a horizontal frictionless surface holding the ends of a light 10-m long rod. The boys pull themselves together along the rod. When they meet the 60-kg boy will have moved what distance?

A. 4 m
B. 5 m
C. 6 m
D. 10 m
E. need to know the forces they exert

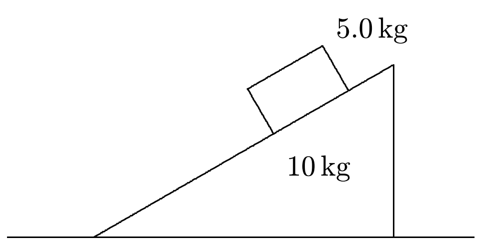
ans: A

19. The center of mass of a system of particles obeys an equation similar to Newton's second law $\vec{F} = m\vec{a}_{\text{com}}$, where:

A. $\vec{F}$ is the net internal force and m is the total mass of the system
B. $\vec{F}$ is the net internal force and m is the mass acting on the system
C. $\vec{F}$ is the net external force and m is the total mass of the system
D. $\vec{F}$ is the force of gravity and m is the mass of Earth
E. $\vec{F}$ is the force of gravity and m is the total mass of the system

ans: C

20. A large wedge with a mass of 10 kg rests on a horizontal frictionless surface, as shown. A block with a mass of 5.0 kg starts from rest and slides down the inclined surface of the wedge, which is rough. At one instant the vertical component of the block's velocity is 3.0 m/s and the horizontal component is 6.0 m/s. At that instant the velocity of the wedge is:



A. 3.0 m/s to the left
B. 3.0 m/s to the right
C. 6.0 m/s to the right
D. 6.0 m/s to the left
E. 17 m/s to the right

ans: B

21. A 2.0-kg block is attached to one end of a spring with a spring constant of 100 N/m and a 4.0-kg block is attached to the other end. The blocks are placed on a horizontal frictionless surface and set into motion. At one instant the 2.0-kg block is observed to be traveling to the right with a speed of 0.50 m/s and the 4.0-kg block is observed to be traveling to the left with a speed of 0.30 m/s. Since the only forces on the blocks are the force of gravity, the normal force of the surface, and the force of the spring, we conclude that:

A. the spring is compressed at the time of the observation
B. the spring is not compressed at the time of observation
C. the motion was started with the masses at rest
D. the motion was started with at least one of masses moving
E. the motion was started by compressing the spring

ans: D

22. A 2.0-kg mass is attached to one end of a spring with a spring constant of 100 N/m and a 4.0-kg mass is attached to the other end. The masses are placed on a horizontal frictionless surface and the spring is compressed 10 cm. The spring is then released with the masses at rest and the masses oscillate. When the spring has its equilibrium length for the first time the 2.0-kg mass has a speed of 0.36 m/s. The mechanical energy that has been lost to the instant is:

A. zero
B. 0.31 J
C. 0.61 J
D. 0.81 J
E. 1.2 J

ans: B

23. Momentum may be expressed in:

A. kg/m
B. gram·s
C. N·s
D. kg/(m·s)
E. N/s

ans: C

24. The momentum of an object at a given instant is independent of its:

A. inertia
B. mass
C. speed
D. velocity
E. acceleration

ans: E

25. Two bodies, A and B, have equal kinetic energies. The mass of A is nine times that of B. The ratio of the momentum of A to that of B is:

A. 1:9
B. 1:3
C. 1:1
D. 3:1
E. 9:1

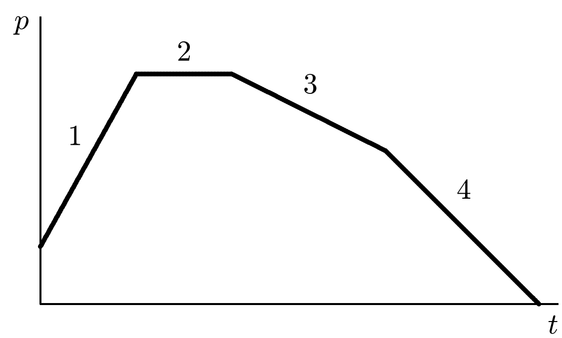
ans: D

26. Two objects, P and Q, have the same momentum. Q has more kinetic energy than P if it:

A. weighs more than P
B. is moving faster than P
C. weighs the same as P
D. is moving slower than P
E. is moving at the same speed as P

ans: B

27. A particle moves along the x axis. Its momentum is graphed below as a function of time. Rank the numbered regions according to the magnitude of the force acting on the particle, least to greatest.



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

ans: B

28. A 1.0-kg ball moving at 2.0 m/s perpendicular to a wall rebounds from the wall at 1.5 m/s. The change in the momentum of the ball is:

A. zero
B. 0.5 N · s away from wall
C. 0.5 N · s toward wall
D. 3.5 N · s away from wall
E. 3.5 N · s toward wall

ans: D

29. If the total momentum of a system is changing:

A. particles of the system must be exerting forces on each other
B. the system must be under the influence of gravity
C. the center of mass must have constant velocity
D. a net external force must be acting on the system
E. none of the above

ans: D

30. When you step on the accelerator to increase the speed of your car, the force that accelerates the car is:

A. the force of your foot on the accelerator
B. the force of friction of the road on the tires
C. the force of the engine on the drive shaft
D. the normal force of the road on the tires
E. none of the above

ans: B

31. A 2.5-kg stone is released from rest and falls toward Earth. After 4.0 s, the magnitude of its momentum is:

A. $98\,\text{kg}\cdot\text{m/s}$
B. $78\,\text{kg}\cdot\text{m/s}$
C. $39\,\text{kg}\cdot\text{m/s}$
D. $24\,\text{kg}\cdot\text{m/s}$
E. zero

ans: A

32. A 64-kg woman stands on frictionless level ice with a 0.10-kg stone at her feet. She kicks the stone with her foot so that she acquires a velocity of 0.0017 m/s in the forward direction. The velocity acquired by the stone is:

A. 1.1 m/s forward
B. 1.1 m/s backward
C. 0.0017 m/s forward
D. 0.0017 m/s backward
E. none of these

ans: B

33. A man is marooned at rest on level frictionless ice. In desperation, he hurls his shoe to the right at 15 m/s. If the man weighs 720 N and the shoe weighs 4.0 N, the man moves to the left with a speed of:

A. 0
B. $2.1\times10^{-2}\,\text{m/s}$
C. $8.3\times10^{-2}\,\text{m/s}$
D. 15 m/s
E. $2.7\times10^{3}\,\text{m/s}$

ans: C

34. Two spacemen are floating together with zero speed in a gravity-free region of space. The mass of spaceman A is 120 kg and that of spaceman B is 90 kg. Spaceman A pushes B away from him with B attaining a final speed of 0.5 m/s. The final recoil speed of A is:

A. zero
B. 0.38 m/s
C. 0.5 m/s
D. 0.67 m/s
E. 1.0 m/s

ans: B

35. A projectile in flight explodes into several fragments. The total momentum of the fragments immediately after this explosion:

A. is the same as the momentum of the projectile immediately before the explosion
B. has been changed into kinetic energy of the fragments
C. is less than the momentum of the projectile immediately before the explosion
D. is more than the momentum of the projectile immediately before the explosion
E. has been changed into radiant energy

ans: A

36. A rifle of mass M is initially at rest but free to recoil. It fires a bullet of mass m and velocity v (relative to the ground). After firing, the velocity of the rifle (relative to the ground) is:

A. $-mv$
B. $-Mv/m$
C. $-mv/M$
D. $-v$
E. mv/M

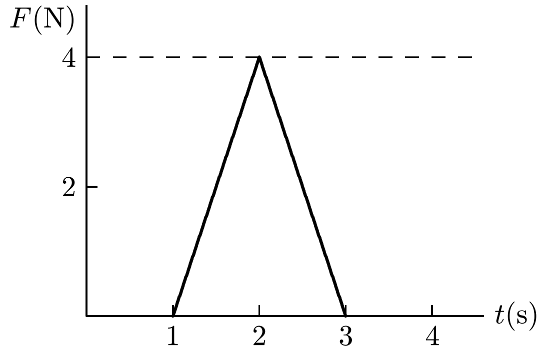
ans: C

37. Bullets from two revolvers are fired with the same velocity. The bullet from gun #1 is twice as heavy as the bullet from gun #2. Gun #1 weighs three times as much as gun #2. The ratio of the momentum imparted to gun #1 to that imparted to gun #2 is:

A. 2:3
B. 3:2
C. 2:1
D. 3:1
E. 6:1

ans: C

38. A 5-kg object can move along the x axis. It is subjected to a force $\vec{F}$ in the positive x direction; a graph of F as a function of time t is shown below. Over the time the force is applied the change in the velocity of the object is:



A. 0.8 m/s
B. 1.1 m/s
C. 1.6 m/s
D. 2.3 m/s
E. 4.0 m/s

ans: A

39. Force:

A. equals the negative integral (with respect to distance) of the potential energy function
B. is the ability to do work
C. is the rate of change of doing work
D. equals the time rate of change of momentum
E. has dimensions of momentum multiplied by time

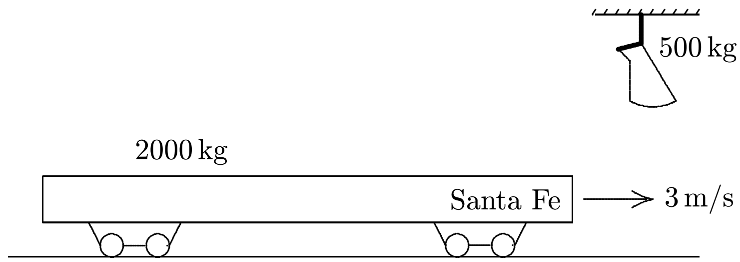
ans: D

40. Cart A, with a mass of 0.20 kg, travels on a horizontal air track at 3.0 m/s and hits cart B, which has a mass of 0.40 kg and is initially traveling away from A at 2.0 m/s. After the collision the center of mass of the two cart system has a speed of:

A. zero
B. 0.33 m/s
C. 2.3 m/s
D. 2.5 m/s
E. 5.0 m/s

ans: B

41. A 500-kg sack of coal is dropped on a 2000-kg railroad flatcar which was initially moving at 3 m/s as shown. After the sack rests on the flatcar, the speed of the flatcar is:



A. 0.6 m/s
B. 1.2 m/s
C. 1.8 m/s
D. 2.4 m/s
E. 3.6 m/s

ans: D

42. A cart loaded with sand slides forward along a horizontal frictionless track. As the cart moves, sand trickles out at a constant rate through a hole in the back of the cart. The acceleration of the cart is:

A. constant and in the forward direction
B. constant and in the backward direction
C. variable and in the forward direction
D. variable and in the backward direction
E. zero

ans: E

43. The thrust of a rocket is:

A. a gravitational force acting on the rocket
B. the force of the exiting fuel gases on the rocket
C. any force that is external to the rocket-fuel system
D. a force that arises from the reduction in mass of the rocket-fuel system
E. none of the above

ans: B:

44. At one instant of time a rocket is traveling in outer space at 2500 m/s and is exhausting fuel at a rate of 100 kg/s. If the speed of the fuel as it leaves the rocket is 1500 m/s, relative to the rocket, the thrust is:

A. 0
B. 1.0×10^5 N
C. 1.5×10^5 N
D. 2.9×10^5 N
E. 2.5×10^5 N

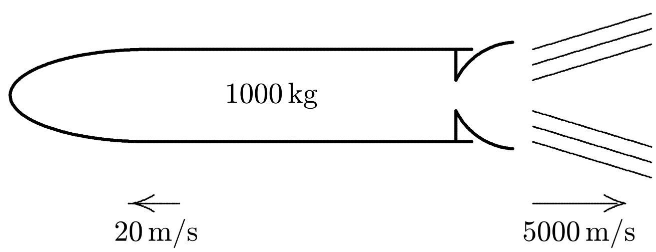
ans: C

45. A rocket exhausts fuel with a velocity of 1500 m/s, relative to the rocket. It starts from rest in outer space with fuel comprising 80 per cent of the total mass. When all the fuel has been exhausted its speed is:

A. 3600 m/s
B. 2400 m/s
C. 1200 m/s
D. 880 m/s
E. 400 m/s

ans: B

46. A 1000-kg space probe is motionless in space. To start moving, its main engine is fired for 5 s during which time it ejects exhaust gases at 5000 m/s. At the end of this process it is moving at 20 m/s. The approximate mass of the ejected gas is:



A. 0.8 kg
B. 4 kg
C. 5 kg
D. 20 kg
E. 25 kg

ans: B

47. The physical quantity "impulse" has the same dimensions as that of:

A. force
B. power
C. energy
D. momentum
E. work

ans: D

48. The law of conservation of momentum applies to a system of colliding objects only if:

A. there is no change in kinetic energy of the system
B. the coefficient of restitution is one
C. the coefficient of restitution is zero
D. the net external impulse is zero
E. the collisions are all elastic

ans: D

49. Sphere X, of mass 2 kg, is moving to the right at 10 m/s. Sphere Y, of mass 4 kg, is moving to the left at 10 m/s. The two spheres collide head-on. The magnitude of the impulse of X on Y is:

A. twice the magnitude of the impulse of Y on X
B. half the magnitude of the impulse of Y on X
C. one-fourth the magnitude of the impulse of Y on X
D. four times the magnitude of the impulse of Y on X
E. the same as the magnitude of the impulse of Y on X

ans: E

50. Two bodies of unequal mass, placed at rest on a frictionless surface, are acted on by equal horizontal forces for equal times. Just after these forces are removed, the body of greater mass will have:

A. the greater speed
B. the greater acceleration
C. the smaller momentum
D. the greater momentum
E. the same momentum as the other body

ans: E

51. A 0.2-kg rubber ball is dropped from the window of a building. It strikes the sidewalk below at 30 m/s and rebounds up at 20 m/s. The impulse on the ball during the collision is:

A. $10\,\mathrm{N\cdot s}$ upward
B. $10\,\mathrm{N\cdot s}$ downward
C. $2.0\,\mathrm{N\cdot s}$ upward
D. $2.0\,\mathrm{N\cdot s}$ downward
E. $9.8\,\mathrm{N\cdot s}$ upward

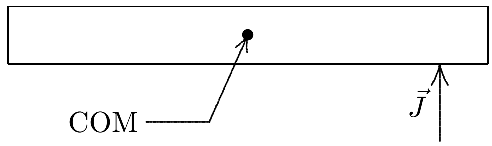
ans: A

52. A 10-kg block of ice is at rest on a frictionless horizontal surface. A 1.0-N force is applied in an easterly direction for 1.0 s. During this time interval, the block:

A. acquires a speed of 1 m/s
B. moves 10 cm
C. acquires a momentum of $1.0\,\mathrm{kg\cdot m/s}$
D. acquires a kinetic energy of 0.1 J
E. none of the above

ans: C

53. A uniform narrow bar, resting on ice, is given a transverse horizontal impulse $\vec{J}$ at one end as shown. The center of mass of the bar COM will then:



A. remain at rest
B. move in a circle
C. move in a straight line
D. move in a parabola
E. move along some other curve

ans: C

54. What magnitude impulse will give a 2.0-kg object a momentum change of magnitude $+\,50\,\mathrm{kg\cdot m/s}$?

A. $+25\,\mathrm{N\cdot s}$
B. $-25\,\mathrm{N\cdot s}$
C. $+50\,\mathrm{N\cdot s}$
D. $-50\,\mathrm{N\cdot s}$
E. $+100\,\mathrm{N\cdot s}$

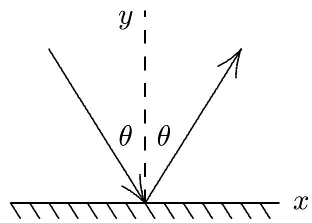
ans: C

55. A student's life was saved in an automobile accident because an airbag expanded in front of his head. If the car had not been equipped with an airbag, the windshield would have stopped the motion of his head in a much shorter time. Compared to the windshield, the airbag:

A. causes a much smaller change in momentum
B. exerts a much smaller impulse
C. causes a much smaller change in kinetic energy
D. exerts a much smaller force
E. does much more work

ans: D

56. A ball hits a wall and rebounds with the same speed, as diagramed below. The changes in the components of the momentum of the ball are:



A. $\Delta p_x > 0$, $\Delta p_y > 0$
B. $\Delta p_x < 0$, $\Delta p_y > 0$
C. $\Delta p_x = 0$, $\Delta p_y > 0$
D. $\Delta p_x = 0$, $\Delta p_y < 0$
E. $\Delta p_x > 0$, $\Delta p_y < 0$

ans: C

57. A golf ball of mass m is hit by a golf club so that the ball leaves the tee with speed v. The club is in contact with the ball for time T. The magnitude of the average force on the club on the ball during the time T is:

A. mvT
B. mv/T
C. $(1/2)mv^2T$
D. $mv^2/(2T)$
E. $mT^2/(2v)$

ans: B

58. A 640-N acrobat falls 5.0 m from rest into a net. The net tosses him back up with the same speed he had just before he hit the net. The magnitude of the average upward force exerted on him by the net during this collision is:

A. 32 N
B. 64 N
C. 320 N
D. 640 N
E. impossible to determine from given data

ans: E

59. Whenever an object strikes a stationary object of equal mass:

A. the two objects cannot stick together
B. the collision must be elastic
C. the first object must stop
D. momentum is not necessarily conserved
E. none of the above

ans: E

60. For a two-body collision involving objects with different masses, a frame of reference which has the same velocity relative to the laboratory as does the center of mass of the two objects is:

A. a frame for which the momentum of the incident object is zero
B. a frame for which the momentum of the target object is zero
C. a frame for which the average momentum of the two objects is zero
D. a frame for which the total momentum of the two objects is zero
E. none of the above

ans: D

61. An inelastic collision is one in which:

A. momentum is not conserved but kinetic energy is conserved
B. total mass is not conserved but momentum is conserved
C. neither kinetic energy nor momentum is conserved
D. momentum is conserved but kinetic energy is not conserved
E. the total impulse is equal to the change in kinetic energy

ans: D

62. A 4.0-N puck is traveling at 3.0 m/s. It strikes a 8.0-N puck, which is stationary. The two pucks stick together. Their common final speed is:

A. 1.0 m/s
B. 1.5 m/s
C. 2.0 m/s
D. 2.3 m/s
E. 3.0 m/s

ans: A

63. A 3.00-g bullet traveling horizontally at 400 m/s hits a 3.00-kg wooden block, which is initially at rest on a smooth horizontal table. The bullet buries itself in the block without passing through. The speed of the block after the collision is:

A. 1.33 m/s
B. 0.40 m/s
C. 12.0 m/s
D. 40.0 m/s
E. 160 m/s

ans: B

64. A 2-kg cart, traveling on a horizontal air track with a speed of 3 m/s, collides with a stationary 4-kg cart. The carts stick together. The impulse exerted by one cart on the other has a magnitude of:

A. 0
B. $4\,\mathrm{N}\cdot\mathrm{s}$
C. $6\,\mathrm{N}\cdot\mathrm{s}$
D. $9\,\mathrm{N}\cdot\mathrm{s}$
E. $12\,\mathrm{N}\cdot\mathrm{s}$

ans: B

65. A 3-g bullet is fired horizontally into a 10-kg block of wood suspended by a rope from the ceiling. The block swings in an arc, rising 3 mm above its lowest position. The velocity of the bullet was:

A. unknown since the heat generated in the collision was not given
B. 8.0×10^2 m/s
C. 24.0 m/s
D. 8.00 m/s
E. 2.4×10^4 m/s

ans: B

66. A 3.0-kg and a 2.0-kg cart approach each other on a horizontal air track. They collide and stick together. After the collision their total kinetic energy is 40 J. The speed of their center of mass is:

A. zero
B. 2.8 m/s
C. 4.0 m/s
D. 5.2 m/s
E. 6.3 m/s

ans: C

67. Blocks A and B are moving toward each other. A has a mass of 2.0 kg and a velocity of 50 m/s, while B has a mass of 4.0 kg and a velocity of -25 m/s. They suffer a completely inelastic collision. The kinetic energy lost during the collision is:

A. 0
B. 1250 J
C. 3750 J
D. 5000 J
E. 5600 J

ans: C

68. For a completely inelastic two-body collision the kinetic energy retained by the objects is the same as:

A. the total kinetic energy before the collision
B. the difference in the kinetic energies of the objects before the collision
C. $\frac{1}{2}Mv_{\text{com}}^2$, where M is the total mass and v_{com} is the velocity of the center of mass
D. the kinetic energy of the more massive body before the collision
E. the kinetic energy of the less massive body before the collision

ans: C

69. A 75-kg man is riding in a 30-kg cart at 2.0 m/s. He jumps off in such a way as to land on the ground with no horizontal velocity. The resulting change in speed of the cart is:

A. zero
B. 2.0 m/s
C. 3.0 m/s
D. 5.0 m/s
E. 7.0 m/s

ans: D

70. An elastic collision is one in which:

A. momentum is not conserved but kinetic energy is conserved
B. total mass is not conserved but momentum is conserved
C. kinetic energy and momentum are both conserved
D. momentum is conserved but kinetic energy is not conserved
E. the total impulse is equal to the change in kinetic energy

ans: C

71. Object A strikes the stationary object B head-on in an elastic collision. The mass of A is fixed, you may choose the mass of B appropriately. Then:

A. for B to have the greatest recoil speed, choose $m_B = m_A$
B. for B to have the greatest recoil momentum, choose $m_B \ll m_A$
C. for B to have the greatest recoil kinetic energy, choose $m_B \ll m_A$
D. for B to have the least recoil speed, choose $m_B = m_A$
E. for B to have the greatest recoil kinetic energy, choose $m_B = m_A$

ans: E

72. Block A, with a mass of 2.0 kg, moves along the x axis with a velocity of 5.0 m/s in the positive x direction. It suffers an elastic collision with block B, initially at rest, and the blocks leave the collision along the x axis. If B is much more massive than A, the speed of A after the collision is:

A. 0
B. +5.0 m/s
C. −5.0 m/s
D. +10 m/s
E. −10 m/s

ans: C

73. A very massive object traveling at 10 m/s strikes a very light object, initially at rest, and the light object moves off in the direction of travel of the heavy object. If the collision is elastic, the speed of the lighter object is:

A. 5.0 m/s
B. 10 m/s
C. 15 m/s
D. 20 m/s
E. Can't tell from the information given.

ans: D

74. Sphere A has mass m and is moving with velocity v. It makes a head-on elastic collision with a stationary sphere B of mass $2m$. After the collision their speeds (v_A and v_B) are:

A. 0, $v/2$
B. $-v/3$, $2v/3$
C. $-v$, v
D. $-2v/3$, $v/3$
E. none of these

ans: B

75. Blocks A and B are moving toward each other along the x axis. A has a mass of 2.0 kg and a velocity of 50 m/s, while B has a mass of 4.0 kg and a velocity of -25 m/s. They suffer an elastic collision and move off along the x axis. The kinetic energy transferred from A to B during the collision is:

A. 0
B. 2500 J
C. 5000 J
D. 7500 J
E. 10000 J

ans: A

76. When a particle suffers a head-on elastic collision with another particle, initially at rest, the greatest fraction of kinetic energy is transferred if:

A. the incident particle is initially traveling very fast
B. the incident particle is traveling very slowly
C. the incident particle is much more massive than the target particle
D. the incident particle is much less massive than the target particle
E. the incident and target particle have the same mass

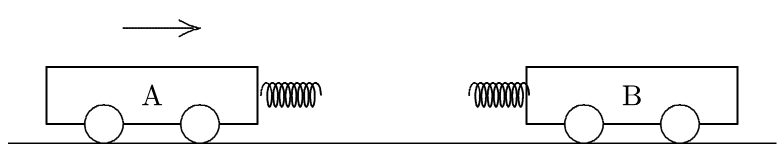
ans: E

77. Two objects, X and Y, are held at rest on a horizontal frictionless surface and a spring is compressed between them. The mass of X is 2/5 times the mass of Y. Immediately after the spring is released, X has a kinetic energy of 50 J and Y has a kinetic energy of:

A. 20 J
B. 8 J
C. 310 J
D. 125 J
E. 50 J

ans: D

78. Two carts (A and B), having spring bumpers, collide as shown. Cart A has a mass of 2 kg and is initially moving to the right. Cart B has a mass of 3 kg and is initially stationary. When the separation between the carts is a minimum:



A. cart B is still at rest
B. cart A has come to rest
C. the carts have the same momentum
D. the carts have the same kinetic energy
E. the kinetic energy of the system is at a minimum

ans: E

79. Two identical carts travel at 1 m/s in opposite directions on a common horizontal surface. They collide head-on and are reported to rebound, each with a speed of 2 m/s. Then:

A. momentum was not conserved; therefore, the report must be false
B. if some other form of energy were changed to kinetic during the collision, the report could be true
C. if the collision were elastic, the report could be true
D. if friction were present, the report could be true
E. if the duration of the collision were long enough, the report could be true

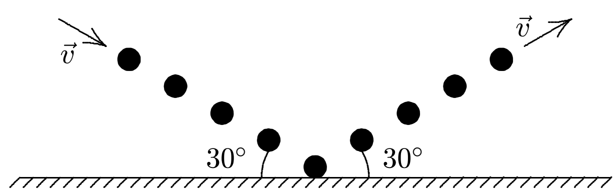
ans: B

80. A block moves at 5.0 m/s in the positive x direction and hits an identical block, initially at rest. A small amount of gunpowder had been placed on one of the blocks. The explosion does not harm the blocks but it doubles their total kinetic energy. After the explosion the blocks move along the x axis and the incident block has a speed in of:

A. 1.8 m/s
B. 5.0 m/s
C. 6.8 m/s
D. 7.1 m/s
E. 11.8 m/s

ans: A

81. A stream of gas consists of n molecules. Each molecule has mass m and speed v. The stream is reflected elastically from a rigid surface as shown. The magnitude of the change in the total momentum of the stream is:



A. $2mnv$
B. $2mnv \sin 30°$
C. $mnv \sin 30°$
D. $mnv \cos 30°$
E. mnv

ans: B

Chapter 22: ELECTRIC FIELDS

1. An electric field is most directly related to:
   A. the momentum of a test charge
   B. the kinetic energy of a test charge
   C. the potential energy of a test charge
   D. the force acting on a test charge
   E. the charge carried by a test charge
   ans: D

2. As used in the definition of electric field, a "test charge":
   A. has zero charge
   B. has charge of magnitude 1 C
   C. has charge of magnitude 1.6×10^{-19} C
   D. must be an electron
   E. none of the above
   ans: E

3. Experimenter A uses a test charge q_0 and experimenter B uses a test charge $-2q_0$ to measure an electric field produced by stationary charges. A finds a field that is:
   A. the same in both magnitude and direction as the field found by B
   B. greater in magnitude than the field found by B
   C. less in magnitude than the field found by B
   D. opposite in direction to the field found by B
   E. either greater or less than the field found by B, depending on the accelerations of the test charges
   ans: A

4. The units of the electric field are:
   A. $\mathrm{N \cdot C^2}$
   B. C/N
   C. N
   D. N/C
   E. $\mathrm{C/m^2}$
   ans: D

5. The units of the electric field are:
   A. J/(C·m)
   B. J/C
   C. J·C
   D. J/m
   E. none of these
   ans: A

6. Electric field lines:
   A. are trajectories of a test charge
   B. are vectors in the direction of the electric field
   C. form closed loops
   D. cross each other in the region between two point charges
   E. are none of the above

   ans: E

7. Two thin spherical shells, one with radius R and the other with radius $2R$, surround an isolated charged point particle. The ratio of the number of field lines through the larger sphere to the number through the smaller is:
   A. 1
   B. 2
   C. 4
   D. 1/2
   E. 1/4

   ans: A

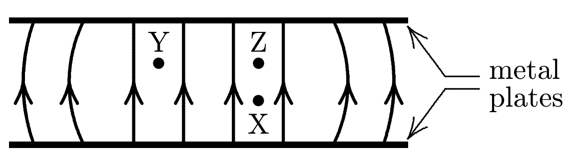
8. A certain physics textbook shows a region of space in which two electric field lines cross each other. We conclude that:
   A. at least two point charges are present
   B. an electrical conductor is present
   C. an insulator is present
   D. the field points in two directions at the same place
   E. the author made a mistake

   ans: E

9. Choose the correct statement concerning electric field lines:
   A. field lines may cross
   B. field lines are close together where the field is large
   C. field lines point away from a negatively charged particle
   D. a charged point particle released from rest moves along a field line
   E. none of these are correct

   ans: B

10. The diagram shows the electric field lines due to two charged parallel metal plates. We conclude that:



   A. the upper plate is positive and the lower plate is negative
   B. a proton at X would experience the same force if it were placed at Y
   C. a proton at X experiences a greater force than if it were placed at Z
   D. a proton at X experiences less force than if it were placed at Z
   E. an electron at X could have its weight balanced by the electrical force

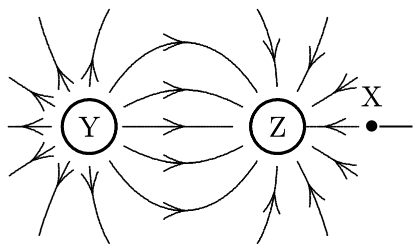
   ans: B

11. Let k denote $1/4\pi\epsilon_0$. The magnitude of the electric field at a distance r from an isolated point particle with charge q is:

A. kq/r
B. kr/q
C. kq/r^3
D. kq/r^2
E. kq^2/r^2

ans: D

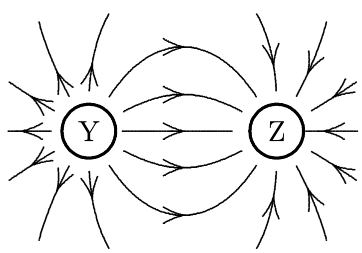
12. The diagram shows the electric field lines in a region of space containing two small charged spheres (Y and Z). Then:



A. Y is negative and Z is positive
B. the magnitude of the electric field is the same everywhere
C. the electric field is strongest midway between Y and Z
D. the electric field is not zero anywhere (except infinitely far from the spheres)
E. Y and Z must have the same sign

ans: D

13. The diagram shows the electric field lines in a region of space containing two small charged spheres (Y and Z). Then:



A. Y is negative and Z is positive
B. the magnitude of the electric field is the same everywhere
C. the electric field is strongest midway between Y and Z
D. Y is positive and Z is negative
E. Y and Z must have the same sign

ans: D

14. The electric field at a distance of 10 cm from an isolated point particle with a charge of 2×10^{-9} C is:

A. 1.8 N/C
B. 180 N/C
C. 18 N/C
D. 1800 N/C
E. none of these

ans: D

15. An isolated charged point particle produces an electric field with magnitude E at a point 2 m away from the charge. A point at which the field magnitude is $E/4$ is:

A. 1 m away from the particle
B. 0.5 m away from the particle
C. 2 m away from the particle
D. 4 m away from the particle
E. 8 m away from the particle

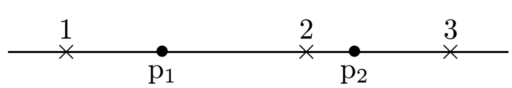
ans: D

16. An isolated charged point particle produces an electric field with magnitude E at a point 2 m away. At a point 1 m from the particle the magnitude of the field is:

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

ans: C

17. Two protons (p_1 and p_2) are on the x axis, as shown below. The directions of the electric field at points 1, 2, and 3, respectively, are:



A. $\longrightarrow, \longleftarrow, \longrightarrow$
B. $\longleftarrow, \longrightarrow, \longleftarrow$
C. $\longleftarrow, \longrightarrow, \longrightarrow$
D. $\longleftarrow, \longleftarrow, \longleftarrow$
E. $\longleftarrow, \longleftarrow, \longrightarrow$

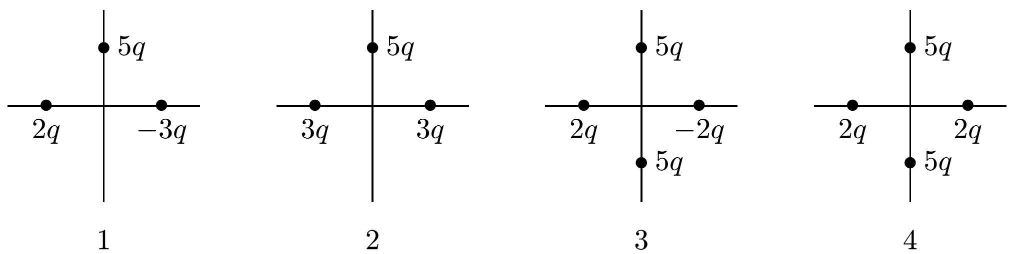
ans: E

18. Two point particles, with a charges of q_1 and q_2, are placed a distance r apart. The electric field is zero at a point P between the particles on the line segment connecting them. We conclude that:

A. q_1 and q_2 must have the same magnitude and sign
B. P must be midway between the particles
C. q_1 and q_2 must have the same sign but may have different magnitudes
D. q_1 and q_2 must have equal magnitudes and opposite signs
E. q_1 and q_2 must have opposite signs and may have different magnitudes

ans: C

19. The diagrams below depict four different charge distributions. The charge particles are all the same distance from the origin. The electric field at the origin:



A. is greatest for situation 1
B. is greatest for situation 3
C. is zero for situation 4
D. is downward for situation 1
E. is downward for situation 3

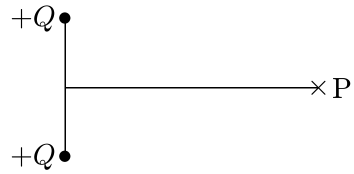
ans: C

20. The diagram shows a particle with positive charge Q and a particle with negative charge $-Q$. The electric field at point P on the perpendicular bisector of the line joining them is:

A. $\uparrow$
B. $\downarrow$
C. $\rightarrow$
D. $\leftarrow$
E. zero

ans: A

21. The diagram shows two identical particles, each with positive charge Q. The electric field at point P on the perpendicular bisector of the line joining them is:



A. $\uparrow$
B. $\downarrow$
C. $\rightarrow$
D. $\leftarrow$
E. zero

ans: C

22. Two point particles, one with charge $+8 \times 10^{-9}$ C and the other with charge -2×10^{-9} C, are separated by 4 m. The electric field in N/C midway between them is:

A. 9×10^{9}
B. $13,500$
C. $135,000$
D. 36×10^{-9}
E. 22.5

ans: E

23. Two charged point particles are located at two vertices of an equilateral triangle and the electric field is zero at the third vertex. We conclude:

A. the two particles have charges with opposite signs and the same magnitude
B. the two particles have charges with opposite signs and different magnitudes
C. the two particles have identical charges
D. the two particles have charges with the same sign but different magnitudes
E. at least one other charged particle is present

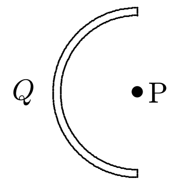
ans: E

24. Two point particles, with the same charge, are located at two vertices of an equilateral triangle. A third charged particle is placed so the electric field at the third vertex is zero. The third particle must:

A. be on the perpendicular bisector of the line joining the first two charges
B. be on the line joining the first two charges
C. have the same charge as the first two particles
D. have charge of the same magnitude as the first two charges but its charge may have a different sign
E. be at the center of the triangle

ans: A

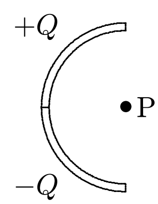
25. Positive charge Q is uniformly distributed on a semicircular rod. What is the direction of the electric field at point P, the center of the semicircle?



A. ↑
B. ↓
C. ←
D. →
E. ↗

ans: D

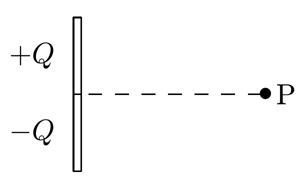
26. Positive charge $+Q$ is uniformly distributed on the upper half a semicircular rod and negative charge $-Q$ is uniformly distributed on the lower half. What is the direction of the electric field at point P, the center of the semicircle?



A. ↑
B. ↓
C. ←
D. →
E. ↗

ans: B

27. Positive charge $+Q$ is uniformly distributed on the upper half a rod and negative charge $-Q$ is uniformly distributed on the lower half. What is the direction of the electric field at point P, on the perpendicular bisector of the rod?



A. ↑
B. ↓
C. ←
D. →
E. ↗

ans: B

28. The electric field due to a uniform distribution of charge on a spherical shell is zero:

A. everywhere
B. nowhere
C. only at the center of the shell
D. only inside the shell
E. only outside the shell

ans: D

29. A charged particle is placed in an electric field that varies with location. No force is exerted on this charge:

A. at locations where the electric field is zero
B. at locations where the electric field strength is $1/(1.6 \times 10^{-19})$ N/C
C. if the particle is moving along a field line
D. if the particle is moving perpendicularly to a field line
E. if the field is caused by an equal amount of positive and negative charge

ans: A

30. The magnitude of the force of a 400-N/C electric field on a 0.02-C point charge is:

A. 8.0 N
B. 8×10^{-5} N
C. 8×10^{-3} N
D. 0.08 N
E. 2×10^{11} N

ans: A

31. A 200-N/C electric field is in the positive x direction. The force on an electron in this field is:

A. 200 N in the positive x direction
B. 200 N in the negative x direction
C. 3.2×10^{-17} N in the positive x direction
D. 3.2×10^{-17} N in the negative x direction
E. 0

ans: D

32. An electron traveling north enters a region where the electric field is uniform and points north. The electron:

A. speeds up
B. slows down
C. veers east
D. veers west
E. continues with the same speed in the same direction

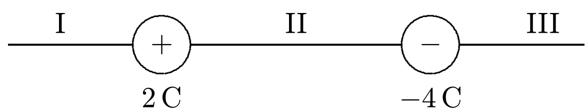
ans: B

33. An electron traveling north enters a region where the electric field is uniform and points west. The electron:

A. speeds up
B. slows down
C. veers east
D. veers west
E. continues with the same speed in the same direction

ans: C

34. Two charged particles are arranged as shown. In which region could a third particle, with charge +1 C, be placed so that the net electrostatic force on it is zero?



A. I only
B. I and II only
C. lII only
D. I and III only
E. II only

ans: A

35. An electric dipole consists of a particle with a charge of $+6\times10^{-6}$ C at the origin and a particle with a charge of -6×10^{-6} C on the x axis at $x = 3\times10^{-3}$ m. Its dipole moment is:

A. $1.8\times10^{-8}\,\mathrm{C\cdot m}$, in the positive x direction
B. $1.8\times10^{-8}\,\mathrm{C\cdot m}$, in the negative x direction
C. 0 because the net charge is 0
D. $1.8\times10^{-8}\,\mathrm{C\cdot m}$, in the positive y direction
E. $1.8\times10^{-8}\,\mathrm{C\cdot m}$, in the negative y direction

ans: B

36. The force exerted by a uniform electric field on a dipole is:

A. parallel to the dipole moment
B. perpendicular to the dipole moment
C. parallel to the electric field
D. perpendicular to the electric field
E. none of the above

ans: E

37. An electric field exerts a torque on a dipole only if:

A. the field is parallel to the dipole moment
B. the field is not parallel to the dipole moment
C. the field is perpendicular to the dipole moment
D. the field is not perpendicular to the dipole moment
E. the field is uniform

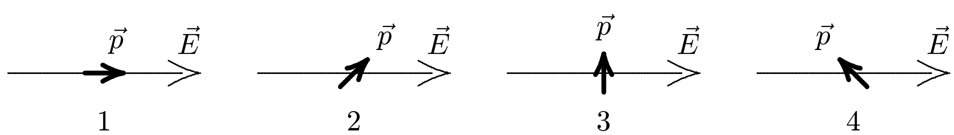
ans: B

38. The torque exerted by an electric field on a dipole is:

A. parallel to the field and perpendicular to the dipole moment
B. parallel to both the field and dipole moment
C. perpendicular to both the field and dipole moment
D. parallel to the dipole moment and perpendicular to the field
E. not related to the directions of the field and dipole moment

ans: C

39. The diagrams show four possible orientations of an electric dipole in a uniform electric field $\vec{E}$. Rank them according to the magnitude of the torque exerted on the dipole by the field, least to greatest.



A. 1, 2, 3, 4
B. 4, 3, 2, 1
C. 1, 2, 4, 3
D. 3, 2 and 4 tie, then 1
E. 1, 2 and 4 tie, then 3

ans: E

40. A uniform electric field of 300 N/C makes an angle of 25° with the dipole moment of an electric dipole. If the torque exerted by the field has a magnitude of $2.5 \times 10^{-7}\,\mathrm{N \cdot m}$, the dipole moment must be:

A. $8.3 \times 10^{-10}\,\mathrm{C \cdot m}$
B. $9.2 \times 10^{-10}\,\mathrm{C \cdot m}$
C. $2.0 \times 10^{-9}\,\mathrm{C \cdot m}$
D. $8.3 \times 10^{-5}\,\mathrm{C \cdot m}$
E. $1.8 \times 10^{-4}\,\mathrm{C \cdot m}$

ans: C

41. When the dipole moment of a dipole in a uniform electric field rotates to become more nearly aligned with the field:

A. the field does positive work and the potential energy increases
B. the field does positive work and the potential energy decreases
C. the field does negative work and the potential energy increases
D. the field does negative work and the potential energy decreases
E. the field does no work

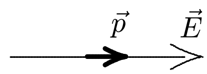
ans: B

42. The dipole moment of a dipole in a 300-N/C electric field is initially perpendicular to the field, but it rotates so it is in the same direction as the field. If the moment has a magnitude of $2 \times 10^{-9}\,\mathrm{C \cdot m}$, the work done by the field is:

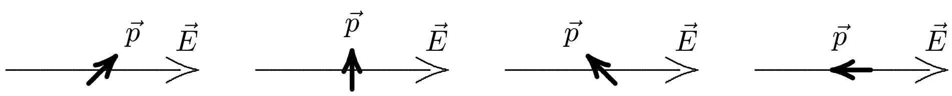
A. $-12 \times 10^{-7}\,\mathrm{J}$
B. $-6 \times 10^{-7}\,\mathrm{J}$
C. 0
D. $6 \times 10^{-7}\,\mathrm{J}$
E. $12 \times 10^{-7}\,\mathrm{J}$

ans: D

43. An electric dipole is oriented parallel to a uniform electric field, as shown.



It is rotated to one of the five orientations shown below. Rank the final orientations according to the change in the potential energy of the dipole-field system, most negative to most positive.



1 2 3 4

A. 1, 2, 3, 4
B. 4, 3, 2, 1
C. 1, 2, 4, 3
D. 3, 2 and 4 tie, then 1
E. 1, 2 and 4 tie, then 3

ans: A

44. The purpose of Milliken's oil drop experiment was to determine:

A. the mass of an electron
B. the charge of an electron
C. the ratio of charge to mass for an electron
D. the sign of the charge on an electron
E. viscosity

ans: B

45. A charged oil drop with a mass of $2 \times 10^{-4}\,\mathrm{kg}$ is held suspended by a downward electric field of $300\,\mathrm{N/C}$. The charge on the drop is:

A. $+1.5 \times 10^{-6}\,\mathrm{C}$
B. $-1.5 \times 10^{-6}\,\mathrm{C}$
C. $+6.5 \times 10^{-6}\,\mathrm{C}$
D. $-6.5 \times 10^{-6}\,\mathrm{C}$
E. 0

ans: D

Chapter 10: ROTATION

1. A radian is about:
   A. 25°
   B. 37°
   C. 45°
   D. 57°
   E. 90°
   ans: D

2. One revolution is the same as:
   A. 1 rad
   B. 57 rad
   C. $\pi/2$ rad
   D. π rad
   E. 2π rad
   ans: E

3. One revolution per minute is about:
   A. 0.0524 rad/s
   B. 0.105 rad/s
   C. 0.95 rad/s
   D. 1.57 rad/s
   E. 6.28 rad/s
   ans: B

4. If a wheel turns with constant angular speed then:
   A. each point on its rim moves with constant velocity
   B. each point on its rim moves with constant acceleration
   C. the wheel turns through equal angles in equal times
   D. the angle through which the wheel turns in each second increases as time goes on
   E. the angle through which the wheel turns in each second decreases as time goes on
   ans: C

5. If a wheel is turning at 3.0 rad/s, the time it takes to complete one revolution is about:
   A. 0.33 s
   B. 0.67 s
   C. 1.0 s
   D. 1.3 s
   E. 2.1 s
   ans: E

6. If wheel turning at a constant rate completes 100 revolutions in 10 s its angular speed is:
   A. 0.31 rad/s
   B. 0.63 rad/s
   C. 10 rad/s
   D. 31 rad/s
   E. 63 rad/s

   ans: E

7. The angular speed of the second hand of a watch is:
   A. $(\pi/1800)$ rad/s
   B. $(\pi/60)$ m/s
   C. $(\pi/30)$ m/s
   D. (2π) m/s
   E. (60) m/s

   ans: C

8. The angular speed of the minute hand of a watch is:
   A. $(60/\pi)$ m/s
   B. $(1800/\pi)$ m/s
   C. (π) m/s
   D. $(\pi/1800)$ m/s
   E. $(\pi/60)$ m/s

   ans: D

9. A flywheel is initially rotating at 20 rad/s and has a constant angular acceleration. After 9.0 s it has rotated through 450 rad. Its angular acceleration is:
   A. 3.3 rad/s
   B. 4.4 rad/s
   C. 5.6 rad/s
   D. 6.7 rad/s
   E. 11 rad/s

   ans: D

10. Ten seconds after an electric fan is turned on, the fan rotates at 300 rev/min. Its average angular acceleration is:
    A. 3.14 rad/s^2
    B. 30 rad/s^2
    C. 30 rev/s^2
    D. 50 rev/min^2
    E. 1800 rev/s^2

    ans: A

11. A wheel rotates with a constant angular acceleration of π rad/s^2. During a certain time interval its angular displacement is π rad. At the end of the interval its angular velocity is 2π rad/s. Its angular velocity at the beginning of the interval is:

A. zero
B. 1 rad/s
C. π rad/s
D. $\pi\sqrt{2}$ rad/s
E. 2π rad/s

ans: D

12. A flywheel rotating at 12 rev/s is brought to rest in 6 s. The magnitude of the average angular acceleration in rad/s^2 of the wheel during this process is:

A. $1/\pi$
B. 2
C. 4
D. 4π
E. 72

ans: D

13. A phonograph turntable, initially rotating at 0.75 rev/s, slows down and stops in 30 s. The magnitude of its average angular acceleration in rad/s^2 for this process is:

A. 1.5
B. 1.5π
C. $\pi/40$
D. $\pi/20$
E. 0.75

ans: D

14. The angular velocity of a rotating wheel increases by 2 rev/s every minute. The angular acceleration in rad/s^2 of this wheel is:

A. $4\pi^2$
B. 2π
C. 1/30
D. $\pi/15$
E. 4π

ans: D

15. A wheel initially has an angular velocity of 18 rad/s. It has a constant angular acceleration of 2.0 rad/s^2 and is slowing at first. What time elapses before its angular velocity is 18 rad/s in the direction opposite to its initial angular velocity?

A. 3.0 s
B. 6.0 s
C. 9.0 s
D. 18 s
E. 36 s

ans: D

16. A wheel initially has an angular velocity of 36 rad/s but after 6.0 s its angular velocity is 24 rad/s. If its angular acceleration is constant its value is:

A. 2.0 rad/s^2
B. −2.0 rad/s^2
C. 3.0 rad/s^2
D. −3.0 rad/s^2
E. 6.0 rad/s^2

ans: B

17. A wheel initially has an angular velocity of −36 rad/s but after 6.0 s its angular velocity is −24 rad/s. If its angular acceleration is constant the value is:

A. 2.0 rad/s^2
B. −2.0 rad/s^2
C. 3.0 rad/s^2
D. −3.0 rad/s^2
E. −6.0 rad/s^2

ans: A

18. A wheel initially has an angular velocity of 18 rad/s but it is slowing at a rate of 2.0 rad/s^2. By the time it stops it will have turned through:

A. 81 rad
B. 160 rad
C. 245 rad
D. 330 rad
E. 410 rad

ans: A

19. A wheel starts from rest and has an angular acceleration of 4.0 rad/s^2. When it has made 10 rev its angular velocity is:

A. 16 rad/s
B. 22 rad/s
C. 32 rad/s
D. 250 rad/s
E. 500 rad/s

ans: B

20. A wheel starts from rest and has an angular acceleration of 4.0 rad/s^2. The time it takes to make 10 rev is:

A. 0.50 s
B. 0.71 s
C. 2.2 s
D. 2.8 s
E. 5.6 s

ans: E

21. A wheel starts from rest and has an angular acceleration that is given by $\alpha(t) = (6\,\mathrm{rad/s^4})t^2$. The angle through which it turns in time t is given by:

A. $[(1/8)t^4]$ rad
B. $[(1/4)t^4]$ rad
C. $[(1/2)t^4]$ rad
D. (t^4) rad
E. 12 rad

ans: C

22. A wheel starts from rest and has an angular acceleration that is given by $\alpha(t) = (6.0\,\mathrm{rad/s^4})t^2$. The time it takes to make 10 rev is:

A. 2.8 s
B. 3.3 s
C. 4.0 s
D. 4.7 s
E. 5.3 s

ans: B

23. A wheel starts from rest and has an angular acceleration that is given by $\alpha(t) = (6.0\,\mathrm{rad/s^4})t^2$. After it has turned through 10 rev its angular velocity is:

A. 63 rad/s
B. 75 rad/s
C. 89 rad/s
D. 130 rad/s
E. 210 rad/s

ans: B

24. A wheel is spinning at 27 rad/s but is slowing with an angular acceleration that has a magnitude given by $(3.0\,\mathrm{rad/s^4})t^2$. It stops in a time of:

A. 1.7 s
B. 2.6 s
C. 3.0 s
D. 4.4 s
E. 7.3 s

ans: C

25. If the angular velocity vector of a spinning body points out of the page then, when viewed from above the page, the body is spinning:

A. clockwise about an axis that is perpendicular to the page
B. counterclockwise about an axis that is perpendicular to the page
C. about an axis that is parallel to the page
D. about an axis that is changing orientation
E. about an axis that is getting longer

ans: B

26. The angular velocity vector of a spinning body points out of the page. If the angular acceleration vector points into the page then:

A. the body is slowing down
B. the body is speeding up
C. the body is starting to turn in the opposite direction
D. the axis of rotation is changing orientation
E. none of the above

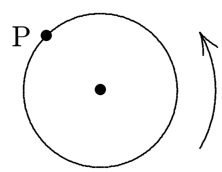
ans: A

27. A child, riding on a large merry-go-round, travels a distance of 3000 m in a circle of diameter 40 m. The total angle through which she revolves is:

A. 50 rad
B. 75 rad
C. 150 rad
D. 314 rad
E. none of these

ans: C

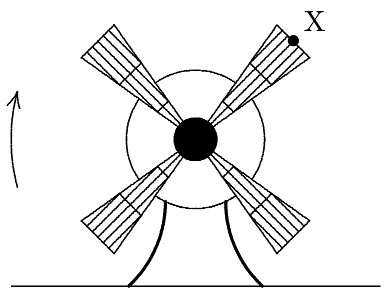
28. The figure shows a cylinder of radius 0.7 m rotating about its axis at 10 rad/s. The speed of the point P is:



A. 7.0 m/s
B. 14π rad/s
C. 7.0π rad/s
D. 0.70 m/s
E. none of these

ans: A

29. The fan shown has been turned on and is now slowing as it rotates clockwise. The direction of the acceleration of the point X on the fan tip could be:



A. ↙
B. ↘
C. ↓
D. ←
E. →

ans: D

30. A wheel of diameter 3.0 cm has a 4.0-m cord wrapped around its periphery. Starting from rest, the wheel is given a constant angular acceleration of 2.0 rad/s^2. The cord will unwind in:

A. 0.82 s
B. 2.0 s
C. 8.0 s
D. 16 s
E. 130 s

ans: D

31. A particle moves in a circular path of radius 0.10 m with a constant angular speed of 5 rev/s. The acceleration of the particle is:

A. $0.10\pi\ \text{m/s}^2$
B. $0.50\ \text{m/s}^2$
C. $500\pi\ \text{m/s}^2$
D. $1000\pi^2\ \text{m/s}^2$
E. $10\pi^2\ \text{m/s}^2$

ans: E

32. A car travels north at constant velocity. It goes over a piece of mud, which sticks to the tire. The initial acceleration of the mud, as it leaves the ground, is:

A. vertically upward
B. horizontally to the north
C. horizontally to the south
D. zero
E. upward and forward at 45° to the horizontal

ans: A

33. Wrapping paper is being from a 5.0-cm radius tube, free to rotate on its axis. If it is pulled at the constant rate of 10 cm/s and does not slip on the tube, the angular velocity of the tube is:

A. 2.0 rad/s
B. 5.0 rad/s
C. 10 rad/s
D. 25 rad/s
E. 50 rad/s

ans: A

34. String is wrapped around the periphery of a 5.0-cm radius cylinder, free to rotate on its axis. The string is pulled straight out at a constant rate of 10 cm/s and does not slip on the cylinder. As each small segment of string leaves the cylinder, its acceleration changes by:

A. 0
B. 0.010 m/s^2
C. 0.020 m/s^2
D. 0.10 m/s^2
E. 0.20 m/s^2

ans: E

35. A flywheel of diameter 1.2 m has a constant angular acceleration of 5.0 rad/s^2. The tangential acceleration of a point on its rim is:

A. 5.0 rad/s^2
B. 3.0 m/s^2
C. 5.0 m/s^2
D. 6.0 m/s^2
E. 12 m/s^2

ans: B

36. For a wheel spinning with constant angular acceleration on an axis through its center, the ratio of the speed of a point on the rim to the speed of a point halfway between the center and the rim is:

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

ans: B

37. For a wheel spinning on an axis through its center, the ratio of the tangential acceleration of a point on the rim to the tangential acceleration of a point halfway between the center and the rim is:

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

ans: B

38. For a wheel spinning on an axis through its center, the ratio of the radial acceleration of a point on the rim to the radial acceleration of a point halfway between the center and the rim is:

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

ans: B

39. Two wheels are identical but wheel B is spinning with twice the angular speed of wheel A. The ratio of the magnitude of the radial acceleration of a point on the rim of B to the magnitude of the radial acceleration of a point on the rim of A is:

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

ans: D

40. A wheel starts from rest and spins with a constant angular acceleration. As time goes on the acceleration vector for a point on the rim:

A. decreases in magnitude and becomes more nearly tangent to the rim
B. decreases in magnitude and becomes more early radial
C. increases in magnitude and becomes more nearly tangent to the rim
D. increases in magnitude and becomes more nearly radial
E. increases in magnitude but retains the same angle with the tangent to the rim

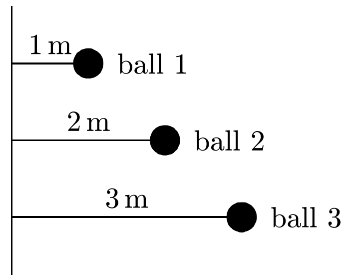
ans: D

41. The magnitude of the acceleration of a point on a spinning wheel is increased by a factor of 4 if:

A. the magnitudes of the angular velocity and the angular acceleration are each multiplied by a factor of 4
B. the magnitude of the angular velocity is multiplied by a factor of 4 and the angular acceleration is not changed
C. the magnitudes of the angular velocity and the angular acceleration are each multiplied by a factor of 2
D. the magnitude of the angular velocity is multiplied by a factor of 2 and the angular acceleration is not changed
E. the magnitude of the angular velocity is multiplied by a factor of 2 and the magnitude of the angular acceleration is multiplied by a factor of 4

ans: E

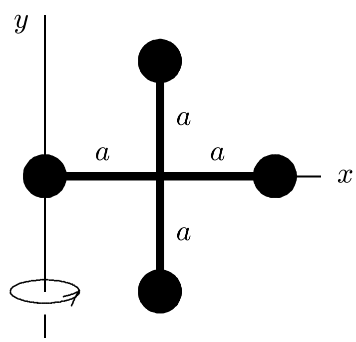
42. Three identical balls are tied by light strings to the same rod and rotate around it, as shown below. Rank the balls according to their rotational inertia, least to greatest.



A. 1, 2, 3
B. 3, 2, 1
C. 3, then 1 and 2 tie
D. 1, 3, 2
E. All are the same

ans: A

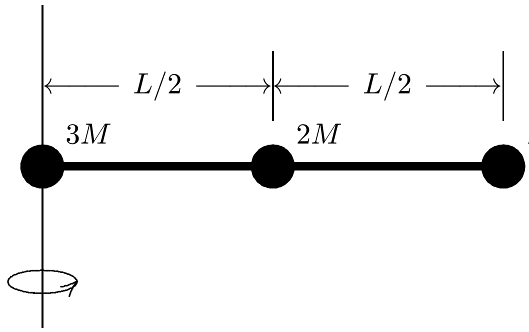
43. Four identical particles, each with mass m, are arranged in the x, y plane as shown. They are connected by light sticks to form a rigid body. If $m = 2.0\,\text{kg}$ and $a = 1.0\,\text{m}$, the rotational inertia of this array about the y axis is:



A. $4.0\,\text{kg}\cdot\text{m}^2$
B. $12\,\text{kg}\cdot\text{m}^2$
C. $9.6\,\text{kg}\cdot\text{m}^2$
D. $4.8\,\text{kg}\cdot\text{m}^2$
E. none of these

ans: B

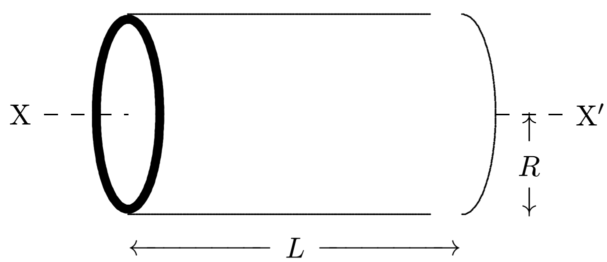
44. Three identical balls, with masses of M, $2M$, and $3M$, are fastened to a massless rod of length L as shown. The rotational inertia about the left end of the rod is:



A. $ML^2/2$
B. ML^2
C. $3ML^2/2$
D. $6ML^2$
E. $3ML^2/4$

ans: E

45. The rotational inertia of a thin cylindrical shell of mass M, radius R, and length L about its central axis (X–X′) is:



A. $MR^2/2$
B. $ML^2/2$
C. ML^2
D. MR^2
E. none of these

ans: D

46. The rotational inertia of a wheel about its axle does not depend upon its:

A. diameter
B. mass
C. distribution of mass
D. speed of rotation
E. material composition

ans: D

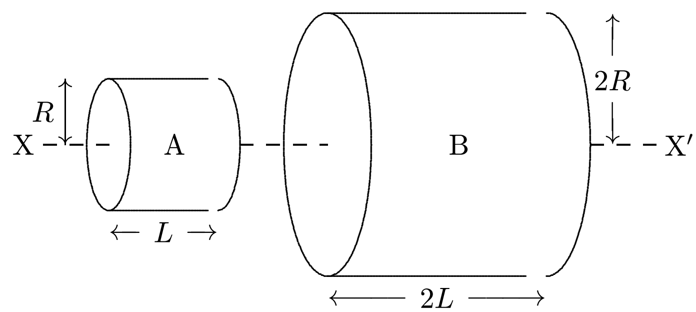
47. Consider four objects, each having the same mass and the same radius:
    1. a solid sphere
    2. a hollow sphere
    3. a flat disk in the x, y plane
    4. a hoop in the x, y plane

The order of increasing rotational inertia about an axis through the center of mass and parallel to the z axis is:

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

ans: C

48. A and B are two solid cylinders made of aluminum. Their dimensions are shown. The ratio of the rotational inertia of B to that of A about the common axis X–X′ is:



A. 2
B. 4
C. 8
D. 16
E. 32

ans: E

49. Two uniform circular disks having the same mass and the same thickness are made from different materials. The disk with the smaller rotational inertia is:

A. the one made from the more dense material
B. the one made from the less dense material
C. neither — both rotational inertias are the same
D. the disk with the larger angular velocity
E. the disk with the larger torque

ans: A

50. A uniform solid cylinder made of lead has the same mass and the same length as a uniform solid cylinder made of wood. The rotational inertia of the lead cylinder compared to the wooden one is:

A. greater
B. less
C. same
D. unknown unless the radii are given
E. unknown unless both the masses and the radii are given

ans: B

51. To increase the rotational inertia of a solid disk about its axis without changing its mass:

A. drill holes near the rim and put the material near the axis
B. drill holes near the axis and put the material near the rim
C. drill holes at points on a circle near the rim and put the material at points between the holes
D. drill holes at points on a circle near the axis and put the material at points between the holes
E. do none of the above (the rotational inertia cannot be changed without changing the mass)

ans: B

52. The rotational inertia of a disk about its axis is $0.70\,\mathrm{kg\cdot m^2}$. When a 2.0-kg weight is added to its rim, 0.40 m from the axis, the rotational inertia becomes:

A. $0.38\,\mathrm{kg\cdot m^2}$
B. $0.54\,\mathrm{kg\cdot m^2}$
C. $0.70\,\mathrm{kg\cdot m^2}$
D. $0.86\,\mathrm{kg\cdot m^2}$
E. $1.0\,\mathrm{kg\cdot m^2}$

ans: E

53. When a thin uniform stick of mass M and length L is pivoted about its midpoint, its rotational inertia is $ML^2/12$. When pivoted about a parallel axis through one end, its rotational inertia is:

A. $ML^2/12$
B. $ML^2/6$
C. $ML^2/3$
D. $7ML^2/12$
E. $13ML^2/12$

ans: C

54. The rotational inertia of a solid uniform sphere about a diameter is $(2/5)MR^2$, where M is its mass and R is its radius. If the sphere is pivoted about an axis that is tangent to its surface, its rotational inertia is:

A. MR^2
B. $(2/5)MR^2$
C. $(3/5)MR^2$
D. $(5/2)MR^2$
E. $(7/5)MR^2$

ans: E

55. A solid uniform sphere of radius R and mass M has a rotational inertia about a diameter that is given by $(2/5)MR^2$. A light string of length $3R$ is attached to the surface and used to suspend the sphere from the ceiling. Its rotational inertia about the point of attachment at the ceiling is:

A. $(2/5)MR^2$
B. $9MR^2$
C. $16MR^2$
D. $(47/5)MR^2$
E. $(82/5)MR^2$

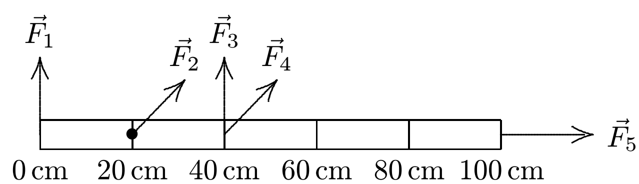
ans: E

56. A force with a given magnitude is to be applied to a wheel. The torque can be maximized by:

A. applying the force near the axle, radially outward from the axle
B. applying the force near the rim, radially outward from the axle
C. applying the force near the axle, parallel to a tangent to the wheel
D. applying the force at the rim, tangent to the rim
E. applying the force at the rim, at 45° to the tangent

ans: D

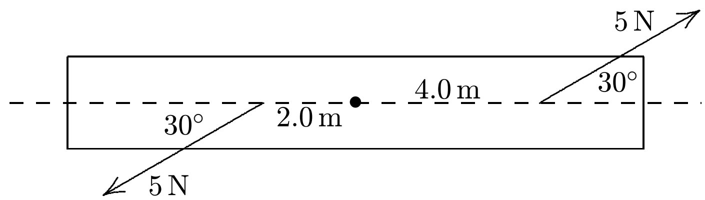
57. The meter stick shown below rotates about an axis through the point marked •, 20 cm from one end. Five forces act on the stick: one at each end, one at the pivot point, and two 40 cm from one end, as shown. The magnitudes of the forces are all the same. Rank the forces according to the magnitudes of the torques they produce about the pivot point, least to greatest.



A. $\vec{F}_1$, $\vec{F}_2$, $\vec{F}_3$, $\vec{F}_4$, $\vec{F}_5$
B. $\vec{F}_1$ and $\vec{F}_2$ tie, then $\vec{F}_3$, $\vec{F}_4$, $\vec{F}_5$
C. $\vec{F}_2$ and $\vec{F}_5$ tie, then $\vec{F}_4$, $\vec{F}_1$, $\vec{F}_3$
D. $\vec{F}_2$, $\vec{F}_5$, $\vec{F}_1$ and $\vec{F}_3$ tie, then $\vec{F}_4$
E. $\vec{F}_2$ and $\vec{F}_5$ tie, then $\vec{F}_4$, then $\vec{F}_1$ and $\vec{F}_3$ tie

ans: E

58. A rod is pivoted about its center. A 5-N force is applied 4 m from the pivot and another 5-N force is applied 2 m from the pivot, as shown. The magnitude of the total torque about the pivot (in N·m) is:



A. 0
B. 5
C. 8.7
D. 15
E. 26

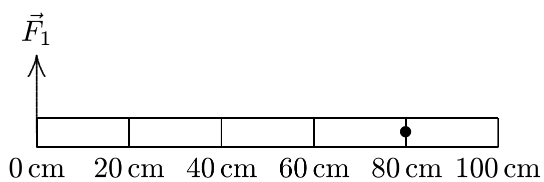
ans: D

59. $\tau = I\alpha$ for an object rotating about a fixed axis, where τ is the net torque acting on it, I is its rotational inertia, and α is its angular acceleration. This expression:

A. is the definition of torque
B. is the definition of rotational inertia
C. is the definition of angular acceleration
D. follows directly from Newton's second law
E. depends on a principle of physics that is unrelated to Newton's second law

ans: D

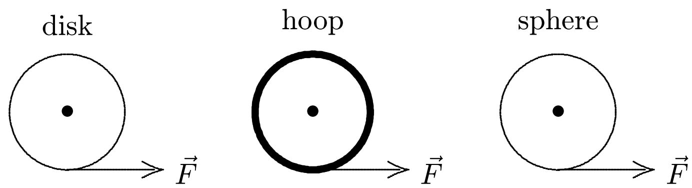
60. A meter stick on a horizontal frictionless table top is pivoted at the 80-cm mark. It is initially at rest. A horizontal force $\vec{F}_1$ is applied perpendicularly to the end of the stick at 0 cm, as shown. A second horizontal force $\vec{F}_2$ (not shown) is applied at the 100-cm end of the stick. If the stick does not rotate:



A. $|\vec{F}_2| > |\vec{F}_1|$ for all orientations of $\vec{F}_2$
B. $|\vec{F}_2| < |\vec{F}_1|$ for all orientations of $\vec{F}_2$
C. $|\vec{F}_2| = |\vec{F}_1|$ for all orientations of $\vec{F}_2$
D. $|\vec{F}_2| > |\vec{F}_1|$ for some orientations of $\vec{F}_2$ and $|\vec{F}_2| < |\vec{F}_1|$ for others
E. $|\vec{F}_2| > |\vec{F}_1|$ for some orientations of $\vec{F}_2$ and $|\vec{F}_2| = |\vec{F}_1|$ for others

ans: A

61. A uniform disk, a thin hoop, and a uniform sphere, all with the same mass and same outer radius, are each free to rotate about a fixed axis through its center. Assume the hoop is connected to the rotation axis by light spokes. With the objects starting from rest, identical forces are simultaneously applied to the rims, as shown. Rank the objects according to their angular accelerations, least to greatest.



A. disk, hoop, sphere
B. hoop, disk, sphere
C. hoop, sphere, disk
D. hoop, disk, sphere
E. sphere, disk, hoop

ans: D

62. A disk is free to rotate on a fixed axis. A force of given magnitude F, in the plane of the disk, is to be applied. Of the following alternatives the greatest angular acceleration is obtained if the force is:

A. applied tangentially halfway between the axis and the rim
B. applied tangentially at the rim
C. applied radially halfway between the axis and the rim
D. applied radially at the rim
E. applied at the rim but neither radially nor tangentially

ans: B

63. A cylinder is 0.10 m in radius and 0.20 m in length. Its rotational inertia, about the cylinder axis on which it is mounted, is $0.020\,\text{kg}\cdot\text{m}^2$. A string is wound around the cylinder and pulled with a force of 1.0 N. The angular acceleration of the cylinder is:

A. $2.5\,\text{rad/s}^2$
B. $5.0\,\text{rad/s}^2$
C. $10\,\text{rad/s}^2$
D. $15\,\text{rad/s}^2$
E. $20\,\text{rad/s}^2$

ans: B

64. A disk with a rotational inertia of $2.0\,\text{kg}\cdot\text{m}^2$ and a radius of $0.40\,\text{m}$ rotates on a frictionless fixed axis perpendicular to the disk faces and through its center. A force of $5.0\,\text{N}$ is applied tangentially to the rim. The angular acceleration of the disk is:

A. $0.40\,\text{rad/s}^2$
B. $0.60\,\text{rad/s}^2$
C. $1.0\,\text{rad/s}^2$
D. $2.5\,\text{rad/s}^2$
E. $10\,\text{rad/s}^2$

ans: C

65. A disk with a rotational inertia of $5.0\,\text{kg}\cdot\text{m}^2$ and a radius of $0.25\,\text{m}$ rotates on a frictionless fixed axis perpendicular to the disk and through its center. A force of $8.0\,\text{N}$ is applied along the rotation axis. The angular acceleration of the disk is:

A. 0
B. $0.40\,\text{rad/s}^2$
C. $0.60\,\text{rad/s}^2$
D. $1.0\,\text{rad/s}^2$
E. $2.5\,\text{rad/s}^2$

ans: A

66. A disk with a rotational inertia of $5.0\,\text{kg}\cdot\text{m}^2$ and a radius of $0.25\,\text{m}$ rotates on a frictionless fixed axis perpendicular to the disk and through its center. A force of $8.0\,\text{N}$ is applied tangentially to the rim. If the disk starts at rest, then after it has turned through half a revolution its angular velocity is:

A. $0.57\,\text{rad/s}$
B. $0.64\,\text{rad/s}$
C. $0.80\,\text{rad/s}$
D. $1.6\,\text{rad/s}$
E. $3.2\,\text{rad/s}$

ans: D

67. A thin circular hoop of mass $1.0\,\text{kg}$ and radius $2.0\,\text{m}$ is rotating about an axis through its center and perpendicular to its plane. It is slowing down at the rate of $7.0\,\text{rad/s}^2$. The net torque acting on it is:

A. $7.0\,\text{N}\cdot\text{m}$
B. $14.0\,\text{N}\cdot\text{m}$
C. $28.0\,\text{N}\cdot\text{m}$
D. $44.0\,\text{N}\cdot\text{m}$
E. none of these

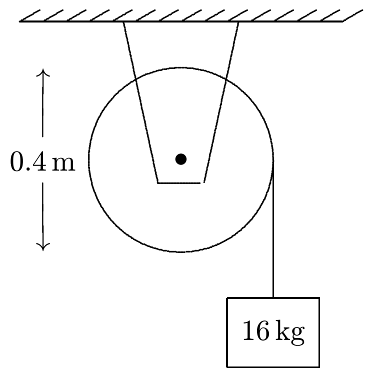
ans: C

68. A certain wheel has a rotational inertia of $12\,\text{kg}\cdot\text{m}^2$. As it turns through 5.0 rev its angular velocity increases from 5.0 rad/s to 6.0 rad/s. If the net torque is constant its value is:

A. $0.016\,\text{N}\cdot\text{m}$
B. $0.18\,\text{N}\cdot\text{m}$
C. $0.57\,\text{N}\cdot\text{m}$
D. $2.1\,\text{N}\cdot\text{m}$
E. $3.6\,\text{N}\cdot\text{m}$

ans: D

69. A 16-kg block is attached to a cord that is wrapped around the rim of a flywheel of diameter 0.40 m and hangs vertically, as shown. The rotational inertia of the flywheel is $0.50\,\text{kg}\cdot\text{m}^2$. When the block is released and the cord unwinds, the acceleration of the block is:



A. $0.15g$
B. $0.56g$
C. $0.84g$
D. g
E. $1.3g$

ans: B

70. A 8.0-cm radius disk with a rotational inertia of $0.12\,\text{kg}\cdot\text{m}^2$ is free to rotate on a horizontal axis. A string is fastened to the surface of the disk and a 10-kg mass hangs from the other end. The mass is raised by using a crank to apply a 9.0-N·m torque to the disk. The acceleration of the mass is:

A. $0.50\,\text{m/s}^2$
B. $1.7\,\text{m/s}^2$
C. $6.2\,\text{m/s}^2$
D. $12\,\text{m/s}^2$
E. $20\,\text{m/s}^2$

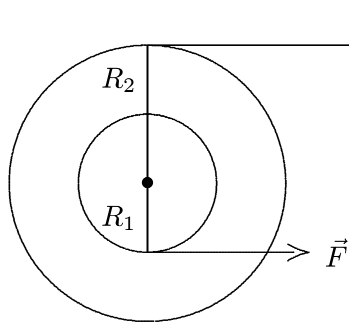
ans: A

71. A 0.70-kg disk with a rotational inertia given by $MR^2/2$ is free to rotate on a fixed horizontal axis suspended from the ceiling. A string is wrapped around the disk and a 2.0-kg mass hangs from the free end. If the string does not slip, then as the mass falls and the cylinder rotates, the suspension holding the cylinder pulls up on the cylinder with a force of:

A. 6.9 N
B. 9.8 N
C. 16 N
D. 26 N
E. 29 N

ans: B

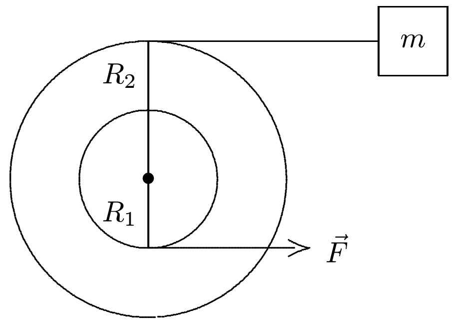
72. A small disk of radius R_1 is mounted coaxially with a larger disk of radius R_2. The disks are securely fastened to each other and the combination is free to rotate on a fixed axle that is perpendicular to a horizontal frictionless table top, as shown in the overhead view below. The rotational inertia of the combination is I. A string is wrapped around the larger disk and attached to a block of mass m, on the table. Another string is wrapped around the smaller disk and is pulled with a force $\vec{F}$ as shown. The acceleration of the block is:



A. R_1F/mR_2
B. $R_1R_2F/(I - mR_2^2)$
C. $R_1R_2F/(I + mR_2^2)$
D. $R_1R_2F/(I - mR_1R_2)$
E. $R_1R_2F/(I + mR_1R_2)$

ans: C

73. A small disk of radius R_1 is fastened coaxially to a larger disk of radius R_2. The combination is free to rotate on a fixed axle, which is perpendicular to a horizontal frictionless table top, as shown in the overhead view below. The rotational inertia of the combination is I. A string is wrapped around the larger disk and attached to a block of mass m, on the table. Another string is wrapped around the smaller disk and is pulled with a force $\vec{F}$ as shown. The tension in the string pulling the block is:



A. R_1F/R_2
B. $mR_1R_2F/(I - mR_2^2)$
C. $mR_1R_2F/(I + mR_2^2)$
D. $mR_1R_2F/(I - mR_1R_2)$
E. $mR_1R_2F/(I + mR_1R_2)$

ans: C

74. A block is attached to each end of a rope that passes over a pulley suspended from the ceiling. The blocks do not have the same mass. If the rope does not slip on the pulley, then at any instant after the blocks start moving, the rope:

A. pulls on both blocks, but exerts a greater force on the heavier block
B. pulls on both blocks, but exerts a greater force on the lighter block
C. pulls on both blocks and exerts the same magnitude force on both
D. does not pull on either block
E. pulls only on the lighter block

ans: A

75. A pulley with a radius of 3.0 cm and a rotational inertia of $4.5 \times 10^{-3}\,\text{kg}\cdot\text{m}^2$ is suspended from the ceiling. A rope passes over it with a 2.0-kg block attached to one end and a 4.0-kg block attached to the other. The rope does not slip on the pulley. When the speed of the heavier block is 2.0 m/s the kinetic energy of the pulley is:

A. 0.15 J
B. 0.30 J
C. 1.0 J
D. 10 J
E. 20 J

ans: D

76. A pulley with a radius of 3.0 cm and a rotational inertia of $4.5 \times 10^{-3}\,\mathrm{kg \cdot m^2}$ is suspended from the ceiling. A rope passes over it with a 2.0-kg block attached to one end and a 4.0-kg block attached to the other. The rope does not slip on the pulley. At any instant after the blocks start moving, the object with the greatest kinetic energy is:

A. the heavier block
B. the lighter block
C. the pulley
D. either block (the two blocks have the same kinetic energy)
E. none (all three objects have the same kinetic energy)

ans: C

77. A disk with a rotational inertia of $5.0\,\mathrm{kg \cdot m^2}$ and a radius of 0.25 m rotates on a fixed axis perpendicular to the disk and through its center. A force of 2.0 N is applied tangentially to the rim. As the disk turns through half a revolution the work done by the force is:

A. 1.6 J
B. 2.5 J
C. 6.3 J
D. 10 J
E. 40 J

ans: A

78. A circular saw is powered by a motor. When the saw is used to cut wood, the wood exerts a torque of $0.80\,\mathrm{N \cdot m}$ on the saw blade. If the blade rotates with a constant angular velocity of 20 rad/s the work done on the blade by the motor in 1.0 min is:

A. 0
B. 480 J
C. 960 J
D. 1400 J
E. 1800 J

ans: C

79. A disk has a rotational inertia of $6.0\,\mathrm{kg \cdot m^2}$ and a constant angular acceleration of $2.0\,\mathrm{rad/s^2}$. If it starts from rest the work done during the first 5.0 s by the net torque acting on it is:

A. 0
B. 30 J
C. 60 J
D. 300 J
E. 600 J

ans: D

80. A disk starts from rest and rotates around a fixed axis, subject to a constant net torque. The work done by the torque during the second 5 s is ______ as the work done during the first 5 s.

A. the same
B. twice as much
C. half as much
D. four times as much
E. one-fourth as much

ans: D

81. A disk starts from rest and rotates about a fixed axis, subject to a constant net torque. The work done by the torque during the second revolution is ______ as the work done during the first revolution.

A. the same
B. twice as much
C. half as much
D. four times as much
E. one-fourth as much

ans: A

Chapter 12: EQUILIBRIUM AND ELASTICITY

1. A net torque applied to a rigid object always tends to produce:
   A. linear acceleration
   B. rotational equilibrium
   C. angular acceleration
   D. rotational inertia
   E. none of these
   ans: C

2. The conditions that the net force and the net torque both vanish:
   A. hold for every rigid body in equilibrium
   B. hold only for elastic solid bodies in equilibrium
   C. hold for every solid body
   D. are always sufficient to calculate the forces on a solid object in equilibrium
   E. are sufficient to calculate the forces on a solid object in equilibrium only if the object is elastic
   ans: A

3. For an object in equilibrium the net torque acting on it vanishes only if each torque is calculated about:
   A. the center of mass
   B. the center of gravity
   C. the geometrical center
   D. the point of application of the force
   E. the same point
   ans: E

4. For a body to be in equilibrium under the combined action of several forces:
   A. all the forces must be applied at the same point
   B. all of the forces form pairs of equal and opposite forces
   C. the sum of the components of all the forces in any direction must equal zero
   D. any two of these forces must be balanced by a third force
   E. the lines of action of all the forces must pass through the center of gravity of the body
   ans: C

5. For a body to be in equilibrium under the combined action of several forces:
   A. all the forces must be applied at the same point
   B. all of the forces form pairs of equal and opposite forces
   C. any two of these forces must be balanced by a third force
   D. the sum of the torques about any point must equal zero
   E. the lines of action of all the forces must pass through the center of gravity of the body
   ans: D

6. To determine if a rigid body is in equilibrium the vector sum of the gravitational forces acting on the particles of the body can be replaced by a single force acting at:
   A. the center of mass
   B. the geometrical center
   C. the center of gravity
   D. a point on the boundary
   E. none of the above

   ans: C

7. The center of gravity coincides with the center of mass:
   A. always
   B. never
   C. if the center of mass is at the geometrical center of the body
   D. if the acceleration due to gravity is uniform over the body
   E. if the body has a uniform distribution of mass

   ans: D

8. The location of which of the following points within an object might depend on the orientation of the object?
   A. Its center of mass
   B. Its center of gravity
   C. Its geometrical center
   D. Its center of momentum
   E. None of the above

   ans: B

9. A cylinder placed so it can roll on a horizontal table top, with its center of gravity above its geometrical center, is:
   A. in stable equilibrium
   B. in unstable equilibrium
   C. in neutral equilibrium
   D. not in equilibrium
   E. none of the above

   ans: B

10. A cylinder placed so it can roll on a horizontal table top, with its center of gravity below its geometrical center, is:
    A. in stable equilibrium
    B. in unstable equilibrium
    C. in neutral equilibrium
    D. not in equilibrium
    E. none of the above

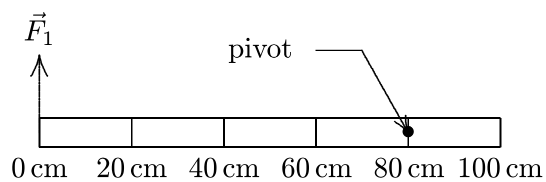
    ans: A

11. A cube balanced with one edge in contact with a table top and with its center of gravity directly above the edge is in ______ equilibrium with respect to rotation about the edge and in ______ equilibrium with respect to rotation about a horizontal axis that is perpendicular to the edge.

A. stable, stable
B. stable, unstable
C. unstable, stable
D. unstable, unstable
E. unstable, neutral

ans: C

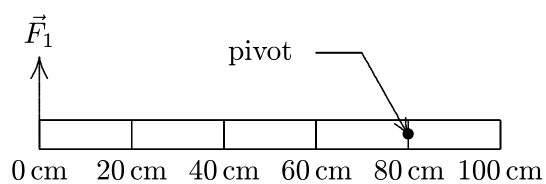
12. A meter stick on a horizontal frictionless table top is pivoted at the 80-cm mark. A force $\vec{F}_1$ is applied perpendicularly to the end of the stick at 0 cm, as shown. A second force $\vec{F}_2$ (not shown) is applied perpendicularly at the 100-cm end of the stick. The forces are horizontal. If the stick does not move, the force exerted by the pivot on the stick:



A. must be zero
B. must be in the same direction as $\vec{F}_1$ and have magnitude $|\vec{F}_2| - |\vec{F}_1|$
C. must be directed opposite to $\vec{F}_1$ and have magnitude $|\vec{F}_2| - |\vec{F}_1|$
D. must be in the same direction as $\vec{F}_1$ and have magnitude $|\vec{F}_2| + |\vec{F}_1|$
E. must be directed opposite to $\vec{F}_1$ and have magnitude $|\vec{F}_2| + |\vec{F}_1|$

ans: E

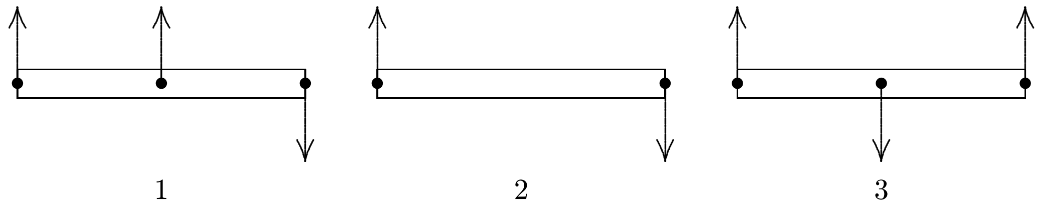
13. A meter stick on a horizontal frictionless table top is pivoted at the 80-cm mark. A force $\vec{F}_1$ is applied perpendicularly to the end of the stick at 0 cm, as shown. A second force $\vec{F}_2$ (not shown) is applied perpendicularly at the 60-cm mark. The forces are horizontal. If the stick does not move, the force exerted by the pivot on the stick:



A. must be zero
B. must be in the same direction as $\vec{F}_1$ and have magnitude $|\vec{F}_2| - |\vec{F}_1|$
C. must be directed opposite to $\vec{F}_1$ and have magnitude $|\vec{F}_2| - |\vec{F}_1|$
D. must be in the same direction as $\vec{F}_1$ and have magnitude $|\vec{F}_2| + |\vec{F}_1|$
E. must be directed opposite to $\vec{F}_1$ and have magnitude $|\vec{F}_2| + |\vec{F}_1|$

ans: B

14. Three identical uniform rods are each acted on by two or more forces, all perpendicular to the rods and all equal in magnitude. Which of the rods could be in static equilibrium if an additional force is applied at the center of mass of the rod?



A. Only 1
B. Only 2
C. Only 3
D. Only 1 and 2
E. All three

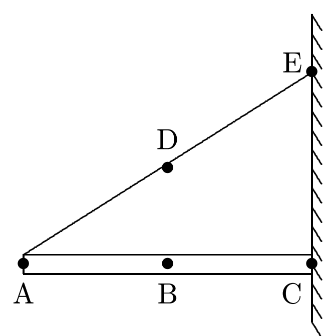
ans: C

15. A 160-N child sits on a light swing and is pulled back and held with a horizontal force of 100 N. The magnitude of the tension force of each of the two supporting ropes is:

A. 60 N
B. 94 N
C. 120 N
D. 190 N
E. 260 N

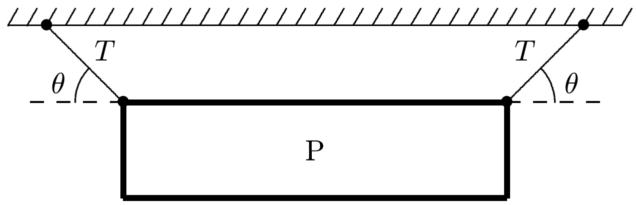
ans: B

16. The diagram shows a stationary 5-kg uniform rod (AC), 1 m long, held against a wall by a rope (AE) and friction between the rod and the wall. To use a single equation to find the force exerted on the rod by the rope at which point should you place the reference point for computing torque?



ans: C

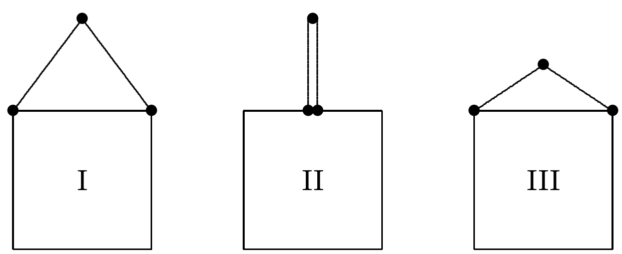
17. A picture P of weight W is hung by two strings as shown. The magnitude of the tension force of each string is T. The total upward pull of the strings on the picture is:



A. $2W \cos\theta$
B. $T \sin\theta$
C. $T \cos\theta$
D. $2T \sin\theta$
E. $2T \cos\theta$

ans: D

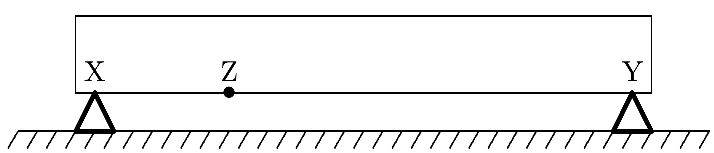
18. A picture can be hung on a wall with string in three different ways, as shown. The magnitude of the tension force of the string is:



A. least in I
B. greatest in I
C. greatest in II
D. least in III
E. greatest in III

ans: E

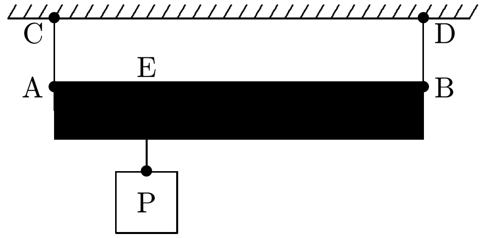
19. A uniform plank is supported by two equal 120-N forces at X and Y, as shown. The support at X is then moved to Z (half-way to the plank center). The supporting forces at Y and Z are then:



A. $F_Y = 240\,\text{N}$, $F_Z = 120\,\text{N}$
B. $F_Y = 200\,\text{N}$, $F_Z = 40\,\text{N}$
C. $F_Y = 40\,\text{N}$, $F_Z = 200\,\text{N}$
D. $F_Y = 80\,\text{N}$, $F_Z = 160\,\text{N}$
E. $F_Y = 160\,\text{N}$, $F_Z = 80\,\text{N}$

ans: D

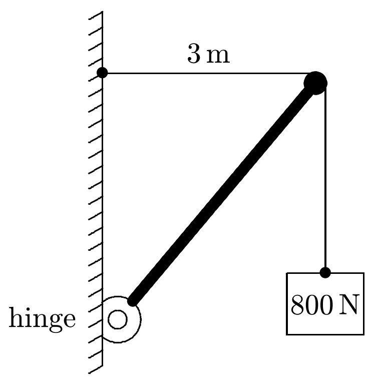
20. A uniform rod AB is 1.2 m long and weighs 16 N. It is suspended by strings AC and BD as shown. A block P weighing 96 N is attached at E, 0.30 m from A. The magnitude of the tension force of the string BD is:



A. 8.0 N
B. 24 N
C. 32 N
D. 48 N
E. 80 N

ans: C

21. A 5.0-m weightless strut, hinged to a wall, is used to support an 800-N block as shown. The horizontal and vertical components of the force of the hinge on the strut are:



A. $F_H = 800\,\text{N}$, $F_Y = 800\,\text{N}$
B. $F_H = 600\,\text{N}$, $F_Y = 800\,\text{N}$
C. $F_H = 800\,\text{N}$, $F_Y = 600\,\text{N}$
D. $F_H = 1200\,\text{N}$, $F_Y = 800\,\text{N}$
E. $F_H = 0$, $F_Y = 800\,\text{N}$

ans: B

22. A uniform plank is 6.0 m long and weighs 80 N. It is balanced on a sawhorse at its center. An additional 160 N weight is now placed on the left end of the plank. To keep the plank balanced, it must be moved what distance to the left?

A. 6.0 m
B. 2.0 m
C. 1.5 m
D. 1.0 m
E. 0.50 m

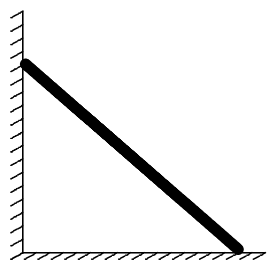
ans: B

23. A uniform 240-g meter stick can be balanced by a 240-g weight placed at the 100-cm mark if the fulcrum is placed at the point marked:

A. 75 cm
B. 60 cm
C. 50 cm
D. 40 cm
E. 80 cm

ans: A

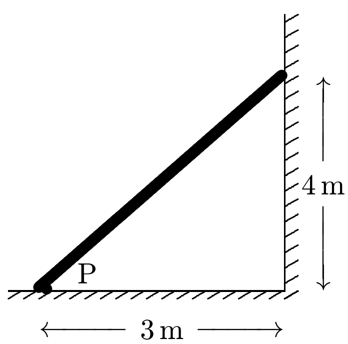
24. A ladder leans against a wall. If the ladder is not to slip, which one of the following must be true?



A. The coefficient of friction between the ladder and the wall must not be zero
B. The coefficient of friction between the ladder and the floor must not be zero
C. Both A and B
D. Either A or B
E. Neither A nor B

ans: B

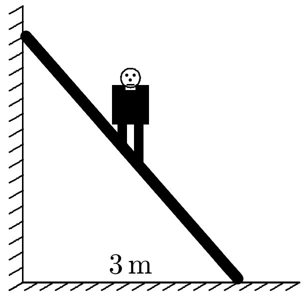
25. An 80-N uniform plank leans against a frictionless wall as shown. The magnitude of the torque (about point P) applied to the plank by the wall is:



A. $40\,\mathrm{N\cdot m}$
B. $60\,\mathrm{N\cdot m}$
C. $120\,\mathrm{N\cdot m}$
D. $160\,\mathrm{N\cdot m}$
E. $240\,\mathrm{N\cdot m}$

ans: C

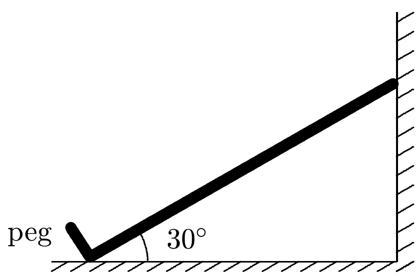
26. An 800-N man stands halfway up a 5.0-m long ladder of negligible weight. The base of the ladder is 3.0 m from the wall as shown. Assuming that the wall-ladder contact is frictionless, the wall pushes against the ladder with a force of magnitude:



A. 150 N
B. 300 N
C. 400 N
D. 600 N
E. 800 N

ans: B

27. A uniform ladder is 10 m long and weighs 400 N. It rests with its upper end against a frictionless vertical wall. Its lower end rests on the ground and is prevented from slipping by a peg driven into the ground. The ladder makes a 30° angle with the horizontal. The magnitude of the force exerted on the peg by the ladder is:



A. zero
B. 200 N
C. 400 N
D. 470 N
E. 670 N

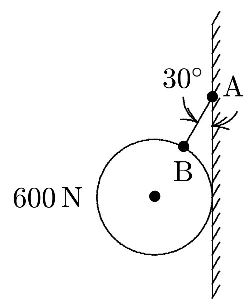
ans: D

28. A window washer attempts to lean a ladder against a frictionless wall. He finds that the ladder slips on the ground when it is placed at an angle of less than 75° to the ground but remains in place when the angle is greater than 75°. The coefficient of static friction between the ladder and the ground:

A. is about 0.13
B. is about 0.27
C. is about 1.0
D. depends on the mass of the ladder
E. depends on the length of the ladder

ans: A

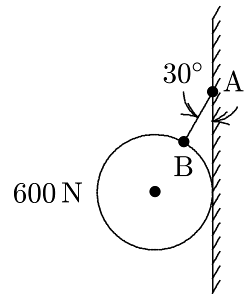
29. The 600-N ball shown is suspended on a string AB and rests against a frictionless vertical wall. The string makes an angle of 30° with the wall. The magnitude of the tension force of the string is:



A. 690 N
B. 1200 N
C. 2100 N
D. 2400 N
E. none of these

ans: A

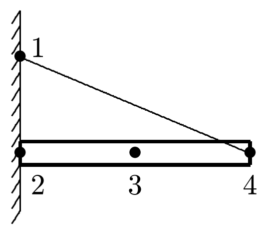
30. The 600-N ball shown is suspended on a string AB and rests against a frictionless vertical wall. The string makes an angle of 30° with the wall. The ball presses against the wall with a force of mangitude:



A. 120 N
B. 300 N
C. 350 N
D. 600 N
E. 690 N

ans: C

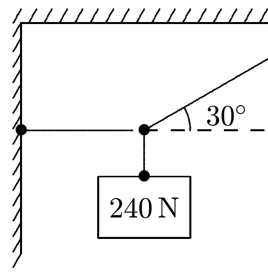
31. The uniform rod shown below is held in place by the rope and wall. Suppose you know the weight of the rod and all dimensions. Then you can solve a single equation for the force of the rope on the rod, provided you write expressions for the torques about the point:



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

ans: B

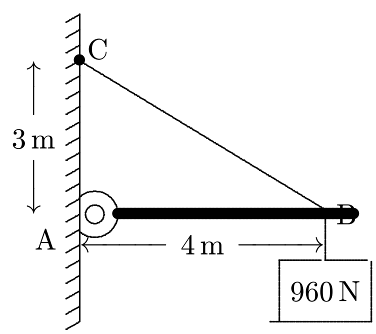
32. A 240-N weight is hung from two ropes as shown. The tension force of the horizontal rope has magnitude:



A. 0
B. 656 N
C. 480 N
D. 416 N
E. 176 N

ans: D

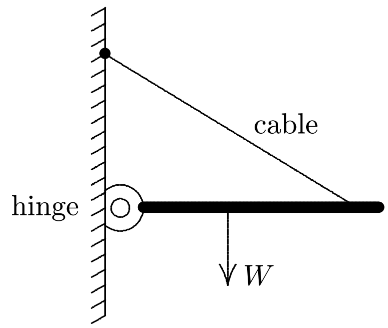
33. A 960-N block is suspended as shown. The beam AB is weightless and is hinged to the wall at A. The tension force of the cable BC has magnitude:



A. 720 N
B. 1200 N
C. 1280 N
D. 1600 N
E. none of these

ans: D

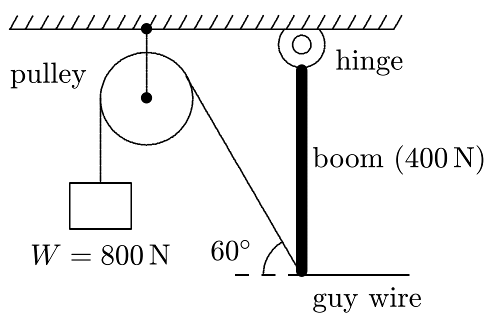
34. A horizontal beam of weight W is supported by a hinge and cable as shown. The force exerted on the beam by the hinge has a vertical component that must be:



A. nonzero and up
B. nonzero and down
C. nonzero but not enough information given to know whether up or down
D. zero
E. equal to W

ans: A

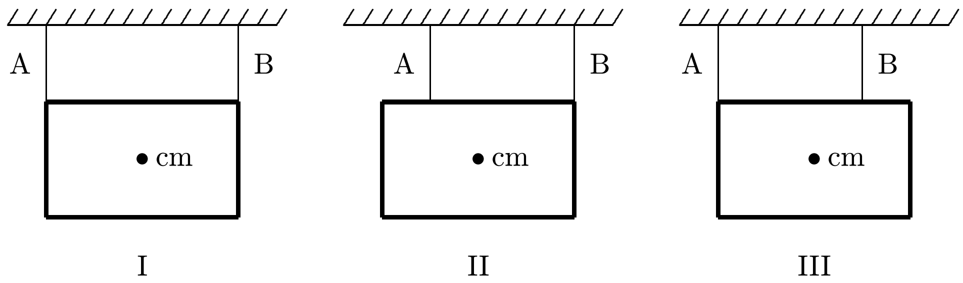
35. A 400-N uniform vertical boom is attached to the ceiling by a hinge, as shown. An 800-N weight W and a horizontal guy wire are attached to the lower end of the boom as indicated. The pulley is massless and frictionless. The tension force T of the horizontal guy wire has magnitude:



A. 340 N
B. 400 N
C. 690 N
D. 800 N
E. 1200 N

ans: B

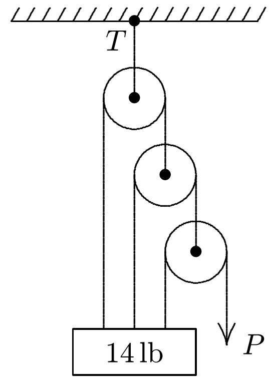
36. A picture is to be hung from the ceiling by means of two wires. Order the following arrangements of the wires according to the tension force of wire B, from least to greatest.



A. I, II, III
B. III, II, I
C. I and II tie, then III
D. II, I, III
E. all tie

ans: D

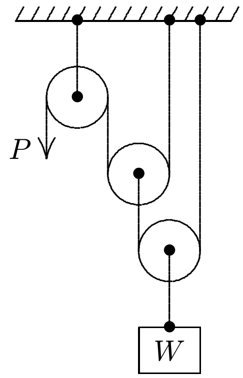
37. The pull P is just sufficient to keep the 14-N block and the weightless pulleys in equilibrium as shown. The magnitude T of the tension force of the upper cable is:



A. 14 N
B. 28 N
C. 16 N
D. 9.33 N
E. 18.7 N

ans: C

38. The ideal mechanical advantage (i.e. the ratio of the weight W to the pull P for equilibrium) of the combination of pulleys shown is:



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

ans: D

39. Stress can be measured in:

A. N/m^2
B. $N{\cdot}m^2$
C. N/m
D. N·m
E. none of these (it is unitless)

ans: A

40. Strain can be measured in:

A. N/m^2
B. $N{\cdot}m^2$
C. N/m
D. N·m
E. none of these (it is unitless)

ans: E

41. Young's modulus can be correctly given in:

A. N·m
B. N/m^2
C. N·m/s
D. N/m
E. joules

ans: B

42. Young's modulus is a proportionality constant that relates the force per unit area applied perpendicularly at the surface of an object to:

A. the shear
B. the fractional change in volume
C. the fractional change in length
D. the pressure
E. the spring constant

ans: C

43. Young's modulus can be used to calculate the strain for a stress that is:

A. just below the ultimate strength
B. just above the ultimate strength
C. well below the yield strength
D. well above the yield strength
E. none of the above

ans: C

44. The ultimate strength of a sample is the stress at which the sample:

A. returns to its original shape when the stress is removed
B. remains underwater
C. breaks
D. bends 180°
E. does none of these

ans: C

45. A certain wire stretches 0.90 cm when outward forces with magnitude F are applied to each end. The same forces are applied to a wire of the same material but with three times the diameter and three times the length. The second wire stretches:

A. 0.10 cm
B. 0.30 cm
C. 0.90 cm
D. 2.7 cm
E. 8.1 cm

ans: B

46. A force of 5000 N is applied outwardly to each end of a 5.0-m long rod with a radius of 34.0 cm and a Young's modulus of $125 \times 10^8\,\mathrm{N/m^2}$. The elongation of the rod is:

A. 0.0020 mm
B. 0.0040 mm
C. 0.14 mm
D. 0.55 mm
E. 1.42 mm

ans: D

47. A 4.0-m long steel beam with a cross-sectional area of $1.0 \times 10^{-2}\,\mathrm{m}^2$ and a Young's modulus of $2.0 \times 10^{11}\,\mathrm{N/m}^2$ is wedged horizontally between two vertical walls. In order to wedge the beam, it is compressed by 0.020 mm. If the coefficient of static friction between the beam and the walls is 0.70 the maximum mass (including its own) it can bear without slipping is:

A. 0
B. 3.6 kg
C. 36 kg
D. 71 kg
E. 710 kg

ans: E

48. Two supports, made of the same material and initially of equal length, are 2.0 m apart. A stiff board with a length of 4.0 m and a mass of 10 kg is placed on the supports, with one support at the left end and the other at the midpoint. A block is placed on the board a distance of 0.50 m from the left end. As a result the board is horizontal. The mass of the block is:

A. zero
B. 2.3 kg
C. 6.6 kg
D. 10 kg
E. 20 kg

ans: E

49. The bulk modulus is a proportionality constant that relates the pressure acting on an object to:

A. the shear
B. the fractional change in volume
C. the fractional change in length
D. Young's modulus
E. the spring constant

ans: B

50. A cube with edges exactly 2 cm long is made of material with a bulk modulus of $3.5 \times 10^9\,\mathrm{N/m}^2$. When it is subjected to a pressure of $3.0 \times 10^5\,\mathrm{Pa}$ its volume is:

A. $7.31\,\mathrm{cm}^3$
B. $7.99931\,\mathrm{cm}^3$
C. $8.00069\,\mathrm{cm}^3$
D. $8.69\,\mathrm{cm}^3$
E. none of these

ans: B

51. A cube with 2.0-cm sides is made of material with a bulk modulus of $4.7 \times 10^5\,\mathrm{N/m}^2$. When it is subjected to a pressure of $2.0 \times 10^5\,\mathrm{Pa}$ the length of its any of its sides is:

A. 0.85 cm
B. 1.15 cm
C. 1.66 cm
D. 2.0 cm
E. none of these

ans: C

52. To shear a cube-shaped object, forces of equal magnitude and opposite directions might be applied:

A. to opposite faces, perpendicular to the faces
B. to opposite faces, parallel to the faces
C. to adjacent faces, perpendicular to the faces
D. to adjacent faces, neither parallel or perpendicular to the faces
E. to a single face, in any direction

ans: B

53. A shearing force of 50 N is applied to an aluminum rod with a length of 10 m, a cross-sectional area of 1.0×10^{-5} m, and a shear modulus of $2.5 \times 10^{10}\ \text{N/m}^2$. As a result the rod is sheared through a distance of:

A. zero
B. 1.9 mm
C. 1.9 cm
D. 19 cm
E. 1.9 m

ans: B

Chapter 2: MOTION ALONG A STRAIGHT LINE

1. A particle moves along the x axis from x_i to x_f. Of the following values of the initial and final coordinates, which results in the displacement with the largest magnitude?
   A. $x_i = 4\,\text{m}$, $x_f = 6\,\text{m}$
   B. $x_i = -4\,\text{m}$, $x_f = -8\,\text{m}$
   C. $x_i = -4\,\text{m}$, $x_f = 2\,\text{m}$
   D. $x_i = 4\,\text{m}$, $x_f = -2\,\text{m}$
   E. $x_i = -4\,\text{m}$, $x_f = 4\,\text{m}$

   ans: E

2. A particle moves along the x axis from x_i to x_f. Of the following values of the initial and final coordinates, which results in a negative displacement?
   A. $x_i = 4\,\text{m}$, $x_f = 6\,\text{m}$
   B. $x_i = -4\,\text{m}$, $x_f = -8\,\text{m}$
   C. $x_i = -4\,\text{m}$, $x_f = 2\,\text{m}$
   D. $x_i = -4\,\text{m}$, $x_f = -2\,\text{m}$
   E. $x_i = -4\,\text{m}$, $x_f = 4\,\text{m}$

   ans: B

3. The average speed of a moving object during a given interval of time is always:
   A. the magnitude of its average velocity over the interval
   B. the distance covered during the time interval divided by the time interval
   C. one-half its speed at the end of the interval
   D. its acceleration multiplied by the time interval
   E. one-half its acceleration multiplied by the time interval.

   ans: B

4. Two automobiles are 150 kilometers apart and traveling toward each other. One automobile is moving at 60 km/h and the other is moving at 40 km/h mph. In how many hours will they meet?
   A. 2.5
   B. 2.0
   C. 1.75
   D. 1.5
   E. 1.25

   ans: D

5. A car travels 40 kilometers at an average speed of 80 km/h and then travels 40 kilometers at an average speed of 40 km/h. The average speed of the car for this 80-km trip is:
   A. 40 km/h
   B. 45 km/h
   C. 48 km/h
   D. 53 km/h
   E. 80 km/h

   ans: D

6. A car starts from Hither, goes 50 km in a straight line to Yon, immediately turns around, and returns to Hither. The time for this round trip is 2 hours. The magnitude of the average velocity of the car for this round trip is:
   A. 0
   B. 50 km/hr
   C. 100 km/hr
   D. 200 km/hr
   E. cannot be calculated without knowing the acceleration

   ans: A

7. A car starts from Hither, goes 50 km in a straight line to Yon, immediately turns around, and returns to Hither. The time for this round trip is 2 hours. The average speed of the car for this round trip is:
   A. 0
   B. 50 km/h
   C. 100 km/h
   D. 200 km/h
   E. cannot be calculated without knowing the acceleration

   ans: B

8. The coordinate of a particle in meters is given by $x(t) = 16t - 3.0t^3$, where the time t is in seconds. The particle is momentarily at rest at $t =$
   A. 0.75 s
   B. 1.3 s
   C. 5.3 s
   D. 7.3 s
   E. 9.3 s

   ans: B

9. A drag racing car starts from rest at $t = 0$ and moves along a straight line with velocity given by $v = bt^2$, where b is a constant. The expression for the distance traveled by this car from its position at $t = 0$ is:
   A. bt^3
   B. $bt^3/3$
   C. $4bt^2$
   D. $3bt^2$
   E. $bt^{3/2}$

   ans: B

10. A ball rolls up a slope. At the end of three seconds its velocity is 20 cm/s; at the end of eight seconds its velocity is 0. What is the average acceleration from the third to the eighth second?
   A. $2.5\,\text{cm/s}^2$
   B. $4.0\,\text{cm/s}^2$
   C. $5.0\,\text{cm/s}^2$
   D. $6.0\,\text{cm/s}^2$
   E. $6.67\,\text{cm/s}^2$

   ans: B

11. The coordinate of an object is given as a function of time by $x = 7t - 3t^2$, where x is in meters and t is in seconds. Its average velocity over the interval from $t = 0$ to $t = 4\,\text{s}$ is:

A. $5\,\text{m/s}$
B. $-5\,\text{m/s}$
C. $11\,\text{m/s}$
D. $-11\,\text{m/s}$
E. $-14.5\,\text{m/s}$

ans: B

12. The velocity of an object is given as a function of time by $v = 4t - 3t^2$, where v is in m/s and t is in seconds. Its average velocity over the interval from $t = 0$ to $t = 2\,\text{s}$:

A. is 0
B. is $-2\,\text{m/s}$
C. is $2\,\text{m/s}$
D. is $-4\,\text{m/s}$
E. cannot be calculated unless the initial position is given

ans: A

13. The coordinate of an object is given as a function of time by $x = 4t^2 - 3t^3$, where x is in meters and t is in seconds. Its average acceleration over the interval from $t = 0$ to $t = 2\,\text{s}$ is:

A. $-4\,\text{m/s}^2$
B. $4\,\text{m/s}^2$
C. $-10\,\text{m/s}^2$
D. $10\,\text{m/s}^2$
E. $-13\,\text{m/s}^2$

ans: C

14. Each of four particles move along an x axis. Their coordinates (in meters) as functions of time (in seconds) are given by

particle 1: $x(t) = 3.5 - 2.7t^3$
particle 2: $x(t) = 3.5 + 2.7t^3$
particle 3: $x(t) = 3.5 + 2.7t^2$
particle 4: $x(t) = 3.5 - 3.4t - 2.7t^2$

Which of these particles have constant acceleration?

A. All four
B. Only 1 and 2
C. Only 2 and 3
D. Only 3 and 4
E. None of them

ans: D

15. Each of four particles move along an x axis. Their coordinates (in meters) as functions of time (in seconds) are given by

particle 1: $x(t) = 3.5 - 2.7t^3$
particle 2: $x(t) = 3.5 + 2.7t^3$
particle 3: $x(t) = 3.5 + 2.7t^2$
particle 4: $x(t) = 3.5 - 3.4t - 2.7t^2$

Which of these particles is speeding up for $t > 0$?

A. All four
B. Only 1
C. Only 2 and 3
D. Only 2, 3, and 4
E. None of them

ans: A

16. An object starts from rest at the origin and moves along the x axis with a constant acceleration of $4\,\text{m/s}^2$. Its average velocity as it goes from $x = 2\,\text{m}$ to $x = 8\,\text{m}$ is:

A. $1\,\text{m/s}$
B. $2\,\text{m/s}$
C. $3\,\text{m/s}$
D. $5\,\text{m/s}$
E. $6\,\text{m/s}$

ans: E

17. Of the following situations, which one is impossible?

A. A body having velocity east and acceleration east
B. A body having velocity east and acceleration west
C. A body having zero velocity and non-zero acceleration
D. A body having constant acceleration and variable velocity
E. A body having constant velocity and variable acceleration

ans: E

18. Throughout a time interval, while the speed of a particle increases as it moves along the x axis, its velocity and acceleration might be:

A. positive and negative, respectively
B. negative and positive, respectively
C. negative and negative, respectively
D. negative and zero, respectively
E. positive and zero, respectively

ans: C

19. A particle moves on the x axis. When its acceleration is positive and increasing:

A. its velocity must be positive
B. its velocity must be negative
C. it must be slowing down
D. it must be speeding up
E. none of the above must be true

ans: E

20. The position y of a particle moving along the y axis depends on the time t according to the equation $y = at - bt^2$. The dimensions of the quantities a and b are respectively:
A. L^2/T, L^3/T^2
B. L/T^2, L^2/T
C. L/T, L/T^2
D. L^3/T, T^2/L
E. none of these
ans: C

21. A particle moves along the x axis according to the equation $x = 6t^2$, where x is in meters and t is in seconds. Therefore:
A. the acceleration of the particle is 6 m/s^2
B. t cannot be negative
C. the particle follows a parabolic path
D. each second the velocity of the particle changes by 9.8 m/s
E. none of the above
ans: E

22. Over a short interval near time $t = 0$ the coordinate of an automobile in meters is given by $x(t) = 27t - 4.0t^3$, where t is in seconds. At the end of 1.0 s the acceleration of the auto is:
A. 27 m/s^2
B. 4.0 m/s^2
C. -4.0 m/s^2
D. -12 m/s^2
E. -24 m/s^2
ans: E

23. Over a short interval, starting at time $t = 0$, the coordinate of an automobile in meters is given by $x(t) = 27t - 4.0t^3$, where t is in seconds. The magnitudes of the initial (at $t = 0$) velocity and acceleration of the auto respectively are:
A. 0; 12 m/s^2
B. 0; 24 m/s^2
C. 27 m/s; 0
D. 27 m/s; 12 m/s^2
E. 27 m/s; 24 m/s^2
ans: C

24. At time $t = 0$ a car has a velocity of 16 m/s. It slows down with an acceleration given by $-0.50t$, in m/s^2 for t in seconds. It stops at $t =$
A. 64 s
B. 32 s
C. 16 s
D. 8.0 s
E. 4.0 s
ans: D

25. At time $t = 0$ a car has a velocity of 16 m/s. It slows down with an acceleration given by $-0.50t$, in m/s^2 for t in seconds. At the end of 4.0 s it has traveled:

A. 0
B. 12 m
C. 14 m
D. 25 m
E. 59 m

ans: E

26. At time $t = 0$ a car has a velocity of 16 m/s. It slows down with an acceleration given by $-0.50t$, in m/s^2 for t in seconds. By the time it stops it has traveled:

A. 15 m
B. 31 m
C. 62 m
D. 85 m
E. 100 m

ans: D

27. Starting at time $t = 0$, an object moves along a straight line with velocity in m/s given by $v(t) = 98 - 2t^2$, where t is in seconds. When it momentarily stops its acceleration is:

A. 0
B. -4.0 m/s^2
C. -9.8 m/s^2
D. -28 m/s^2
E. 49 m/s^2

ans: D

28. Starting at time $t = 0$, an object moves along a straight line. Its coordinate in meters is given by $x(t) = 75t - 1.0t^3$, where t is in seconds. When it momentarily stops its acceleration is:

A. 0
B. -73 m/s^2
C. -30 m/s^2
D. -9.8 m/s^2
E. 9.2×10^3 m/s^2

ans: C

29. A car, initially at rest, travels 20 m in 4 s along a straight line with constant acceleration. The acceleration of the car is:

A. $0.4\,m/s^2$
B. $1.3\,m/s^2$
C. $2.5\,m/s^2$
D. $4.9\,m/s^2$
E. $9.8\,m/s^2$

ans: C

30. A racing car traveling with constant acceleration increases its speed from 10 m/s to 50 m/s over a distance of 60 m. How long does this take?

A. 2.0 s
B. 4.0 s
C. 5.0 s
D. 8.0 s
E. The time cannot be calculated since the speed is not constant

ans: B

31. A car starts from rest and goes down a slope with a constant acceleration of 5 m/s^2. After 5 s the car reaches the bottom of the hill. Its speed at the bottom of the hill, in meters per second, is:

A. 1
B. 12.5
C. 25
D. 50
E. 160

ans: C

32. A car moving with an initial velocity of 25 m/s north has a constant acceleration of 3 m/s^2 south. After 6 seconds its velocity will be:

A. 7 m/s north
B. 7 m/s south
C. 43 m/s north
D. 20 m/s north
E. 20 m/s south

ans: A

33. An object with an initial velocity of 12 m/s west experiences a constant acceleration of 4 m/s^2 west for 3 seconds. During this time the object travels a distance of:

A. 12 m
B. 24 m
C. 36 m
D. 54 m
E. 144 m

ans: D

34. How far does a car travel in 6 s if its initial velocity is 2 m/s and its acceleration is 2 m/s^2 in the forward direction?

A. 12 m
B. 14 m
C. 24 m
D. 36 m
E. 48 m

ans: E

35. At a stop light, a truck traveling at 15 m/s passes a car as it starts from rest. The truck travels at constant velocity and the car accelerates at 3 m/s^2. How much time does the car take to catch up to the truck?

A. 5 s
B. 10 s
C. 15 s
D. 20 s
E. 25 s

ans: B

36. A ball is in free fall. Its acceleration is:

A. downward during both ascent and descent
B. downward during ascent and upward during descent
C. upward during ascent and downward during descent
D. upward during both ascent and descent
E. downward at all times except at the very top, when it is zero

ans: A

37. A ball is in free fall. Upward is taken to be the positive direction. The displacement of the ball during a short time interval is:

A. positive during both ascent and descent
B. negative during both ascent and descent
C. negative during ascent and positive during descent
D. positive during ascent and negative during descent
E. none of the above

ans: D

38. A baseball is thrown vertically into the air. The acceleration of the ball at its highest point is:

A. zero
B. g, down
C. g, up
D. $2g$, down
E. $2g$, up

ans: B

39. Which one of the following statements is correct for an object released from rest?

A. The average velocity during the first second of time is 4.9 m/s
B. During each second the object falls 9.8 m
C. The acceleration changes by 9.8 m/s^2 every second
D. The object falls 9.8 m during the first second of time
E. The acceleration of the object is proportional to its weight

ans: A

40. A freely falling body has a constant acceleration of 9.8 m/s^2. This means that:

A. the body falls 9.8 m during each second
B. the body falls 9.8 m during the first second only
C. the speed of the body increases by 9.8 m/s during each second
D. the acceleration of the body increases by 9.8 m/s^2 during each second
E. the acceleration of the body decreases by 9.8 m/s^2 during each second

ans: C

41. An object is shot vertically upward. While it is rising:

A. its velocity and acceleration are both upward
B. its velocity is upward and its acceleration is downward
C. its velocity and acceleration are both downward
D. its velocity is downward and its acceleration is upward
E. its velocity and acceleration are both decreasing

ans: B

42. An object is thrown straight up from ground level with a speed of 50 m/s. If $g = 10$ m/s^2 its distance above ground level 1.0 s later is:

A. 40 m
B. 45 m
C. 50 m
D. 55 m
E. 60 m

ans: B

43. An object is thrown straight up from ground level with a speed of 50 m/s. If $g = 10$ m/s^2 its distance above ground level 6.0 s later is:

A. 0.00 m
B. 270 m
C. 330 m
D. 480 m
E. none of these

ans: E

44. At a location where $g = 9.80$ m/s^2, an object is thrown vertically down with an initial speed of 1.00 m/s. After 5.00 s the object will have traveled:

A. 125 m
B. 127.5 m
C. 245 m
D. 250 m
E. 255 m

ans: B

45. An object is thrown vertically upward at 35 m/s. Taking $g = 10$ m/s^2, the velocity of the object 5 s later is:

A. 7.0 m/s up
B. 15 m/s down
C. 15 m/s up
D. 85 m/s down
E. 85 m/s up

ans: B

46. A feather, initially at rest, is released in a vacuum 12 m above the surface of the earth. Which of the following statements is correct?

A. The maximum velocity of the feather is 9.8 m/s
B. The acceleration of the feather decreases until terminal velocity is reached
C. The acceleration of the feather remains constant during the fall
D. The acceleration of the feather increases during the fall
E. The acceleration of the feather is zero

ans: C

47. An object is released from rest. How far does it fall during the second second of its fall?

A. 4.9 m
B. 9.8 m
C. 15 m
D. 20 m
E. 25 m

ans: C

48. A heavy ball falls freely, starting from rest. Between the third and fourth second of time it travels a distance of:

A. 4.9 m
B. 9.8 m
C. 29.4 m
D. 34.3 m
E. 39.8 m

ans: D

49. As a rocket is accelerating vertically upward at 9.8 m/s^2 near Earth's surface, it releases a projectile. Immediately after release the acceleration (in m/s^2) of the projectile is:

A. 9.8 down
B. 0
C. 9.8 up
D. 19.6 up
E. none of the above

ans: A

50. A stone is released from a balloon that is descending at a constant speed of 10 m/s. Neglecting air resistance, after 20 s the speed of the stone is:

A. 2160 m/s
B. 1760 m/s
C. 206 m/s
D. 196 m/s
E. 186 m/s

ans: C

51. An object dropped from the window of a tall building hits the ground in 12.0 s. If its acceleration is 9.80 m/s^2, the height of the window above the ground is:

A. 29.4 m
B. 58.8 m
C. 118 m
D. 353 m
E. 706 m

ans: E

52. Neglecting the effect of air resistance a stone dropped off a 175-m high building lands on the ground in:

A. 3 s
B. 4 s
C. 6 s
D. 18 s
E. 36 s

ans: C

53. A stone is thrown vertically upward with an initial speed of 19.5 m/s. It will rise to a maximum height of:

A. 4.9 m
B. 9.8 m
C. 19.4 m
D. 38.8 m
E. none of these

ans: C

54. A baseball is hit straight up and is caught by the catcher 2.0 s later. The maximum height of the ball during this interval is:

A. 4.9 m
B. 7.4 m
C. 9.8 m
D. 12.6 m
E. 19.6 m

ans: A

55. An object is thrown straight down with an initial speed of 4 m/s from a window which is 8 m above the ground. The time it takes the object to reach the ground is:

A. 0.80 s
B. 0.93 s
C. 1.3 s
D. 1.7 s
E. 2.0 s

ans: B

56. A stone is released from rest from the edge of a building roof 190 m above the ground. Neglecting air resistance, the speed of the stone, just before striking the ground, is:

A. 43 m/s
B. 61 m/s
C. 120 m/s
D. 190 m/s
E. 1400 m/s

ans: B

57. An object is thrown vertically upward with a certain initial velocity in a world where the acceleration due to gravity is 19.6 m/s^2. The height to which it rises is ____ that to which the object would rise if thrown upward with the same initial velocity on the Earth. Neglect friction.

A. half
B. $\sqrt{2}$ times
C. twice
D. four times
E. cannot be calculated from the given data

ans: A

58. A projectile is shot vertically upward with a given initial velocity. It reaches a maximum height of 100 m. If, on a second shot, the initial velocity is doubled then the projectile will reach a maximum height of:

A. 70.7 m
B. 141.4 m
C. 200 m
D. 241 m
E. 400 m

ans: E

59. One object is thrown vertically upward with an initial velocity of 100 m/s and another object with an initial velocity of 10 m/s. The maximum height reached by the first object will be ____ that of the other.

A. 10 times
B. 100 times
C. 1000 times
D. 10,000 times
E. none of these

ans: B

60. The area under a velocity-time graph represents:

A. acceleration
B. change in acceleration
C. speed
D. change in velocity
E. displacement

ans: E

61. Displacement can be obtained from:

A. the slope of an acceleration-time graph
B. the slope of a velocity-time graph
C. the area under an acceleration-time graph
D. the area under a velocity-time graph
E. the slope of an acceleration-time graph

ans: D

62. An object has a constant acceleration of 3 m/s^2. The coordinate versus time graph for this object has a slope:

A. that increases with time
B. that is constant
C. that decreases with time
D. of 3 m/s
E. of 3 m/s^2

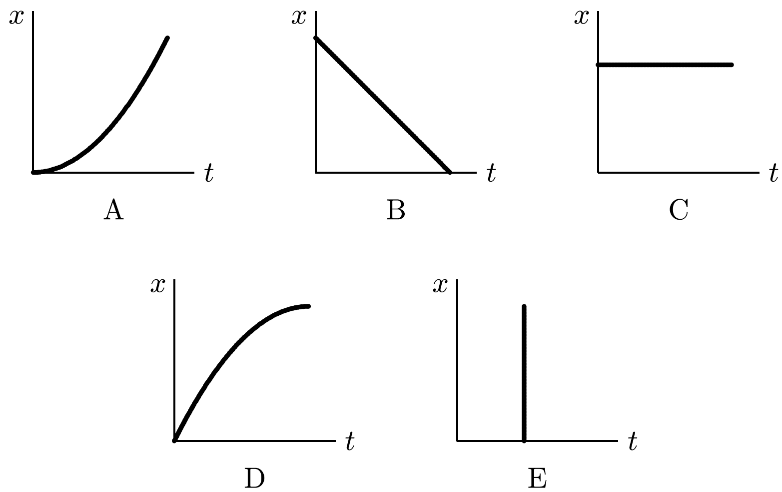
ans: A

63. The coordinate-time graph of an object is a straight line with a positive slope. The object has:

A. constant displacement
B. steadily increasing acceleration
C. steadily decreasing acceleration
D. constant velocity
E. steadily increasing velocity

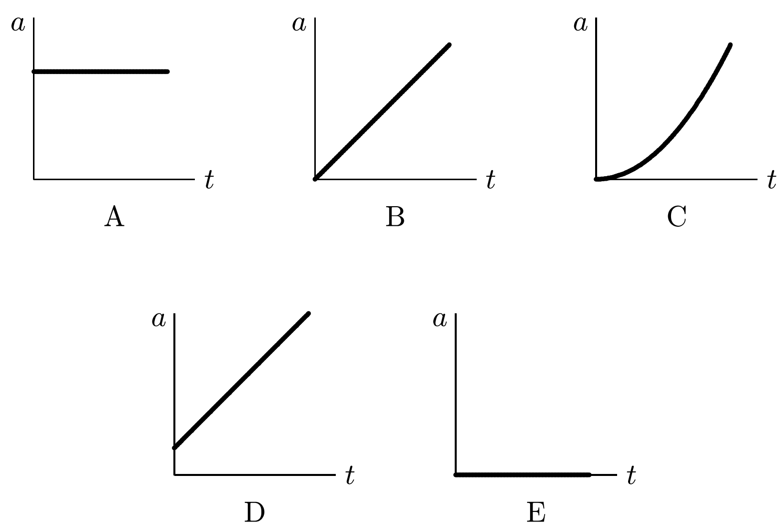
ans: D

64. Which of the following five coordinate versus time graphs represents the motion of an object moving with a constant nonzero speed?



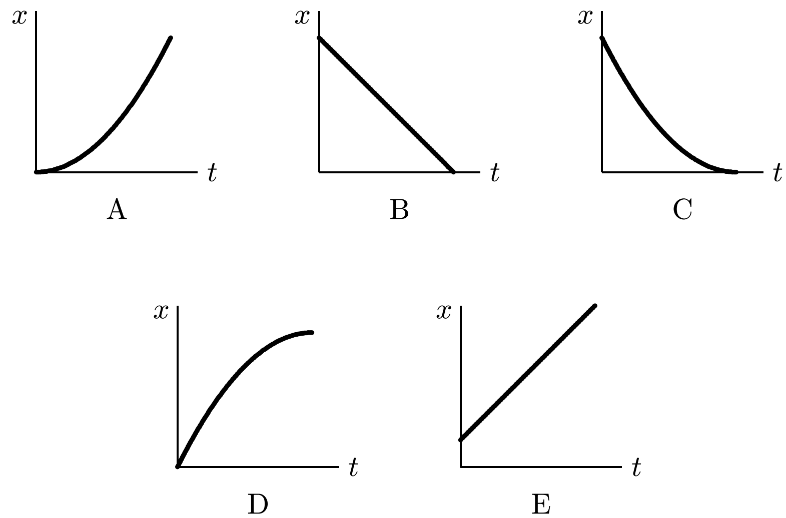
ans: B

65. Which of the following five acceleration versus time graphs is correct for an object moving in a straight line at a constant velocity of 20 m/s?



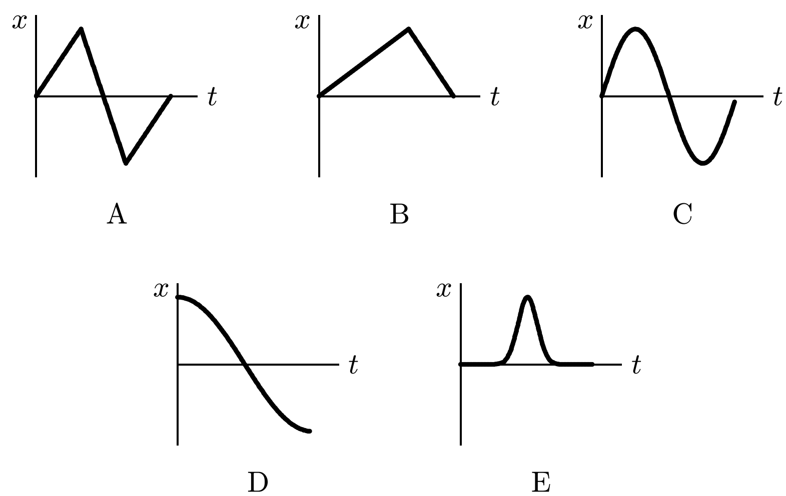
ans: E

66. Which of the following five coordinate versus time graphs represents the motion of an object whose speed is increasing?



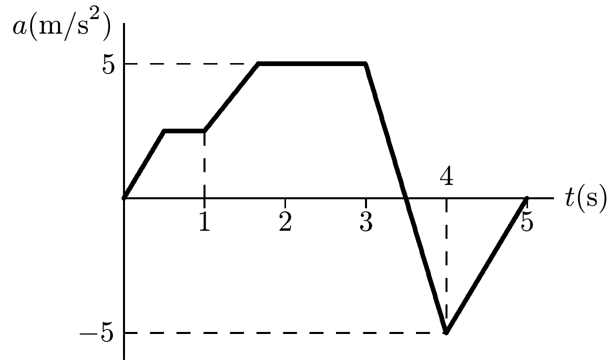
ans: A

67. A car accelerates from rest on a straight road. A short time later, the car decelerates to a stop and then returns to its original position in a similar manner, by speeding up and then slowing to a stop. Which of the following five coordinate versus time graphs best describes the motion?



ans: E

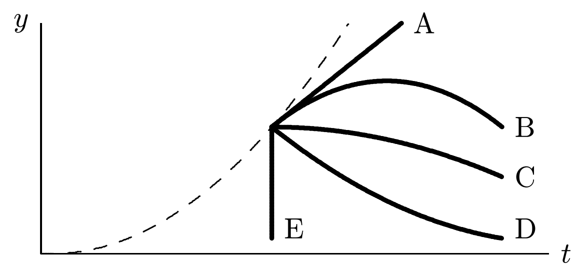
68. The acceleration of an object, starting from rest, is shown in the graph below. Other than at $t = 0$, when is the velocity of the object equal to zero?



A. During the interval from 1.0 s to 3.0 s
B. At $t = 3.5\,\mathrm{s}$
C. At $t = 4.0\,\mathrm{s}$
D. At $t = 5.0\,\mathrm{s}$
E. At no other time less than or equal to 5 s

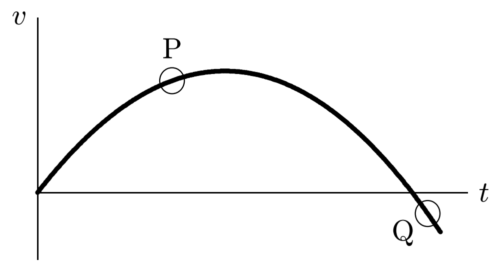
ans: E

69. An elevator is moving upward with constant acceleration. The dashed curve shows the position y of the ceiling of the elevator as a function of the time t. At the instant indicated by the dot, a bolt breaks loose and drops from the ceiling. Which curve best represents the position of the bolt as a function of time?



ans: B

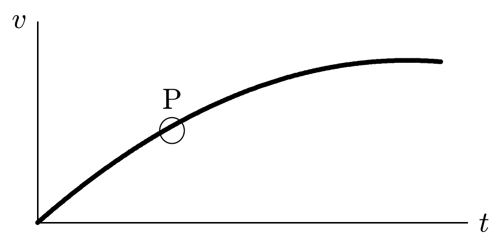
70. The diagram shows a velocity-time graph for a car moving in a straight line. At point Q the car must be:



A. moving with zero acceleration
B. traveling downhill
C. traveling below ground-level
D. reducing speed
E. traveling in the reverse direction to that at point P

ans: E

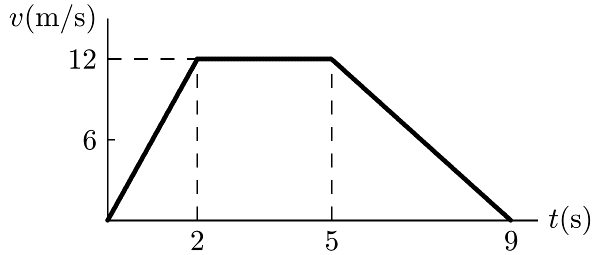
71. The diagram shows a velocity-time graph for a car moving in a straight line. At point P the car must be:



A. moving with zero acceleration
B. climbing the hill
C. accelerating
D. stationary
E. moving at about 45° with respect to the x axis

ans: C

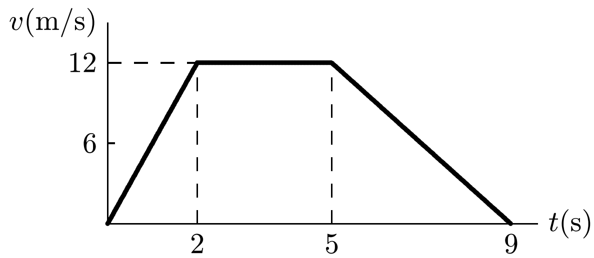
72. The graph represents the straight line motion of a car. How far does the car travel between $t = 2$ s and $t = 5$ s?



A. 4 m
B. 12 m
C. 24 m
D. 36 m
E. 60 m

ans: D

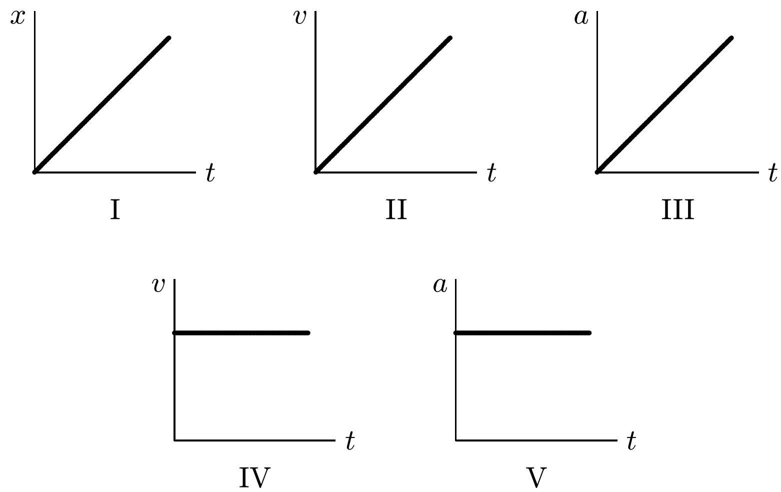
73. The diagram represents the straight line motion of a car. Which of the following statements is true?



A. The car accelerates, stops, and reverses
B. The car accelerates at 6 m/s^2 for the first 2 s
C. The car is moving for a total time of 12 s
D. The car decelerates at 12 m/s^2 for the last 4 s
E. The car returns to its starting point when $t = 9$ s

ans: B

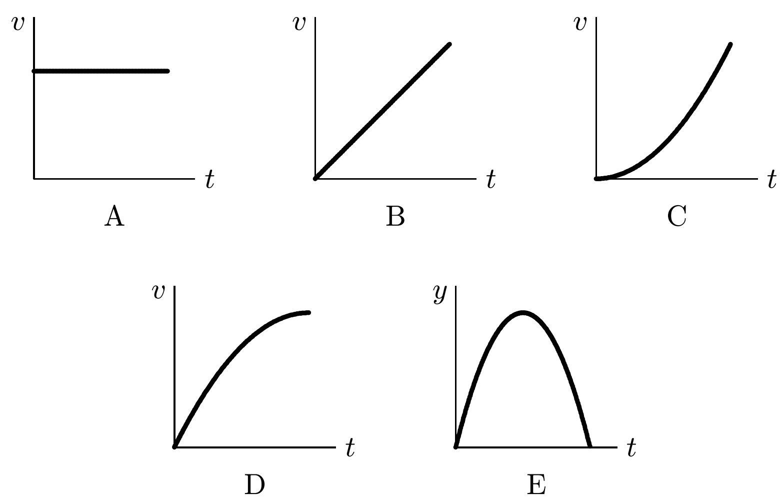
74. Consider the following five graphs (note the axes carefully). Which of these represents motion at constant speed?



A. IV only
B. IV and V only
C. I, II, and III only
D. I and II only
E. I and IV only

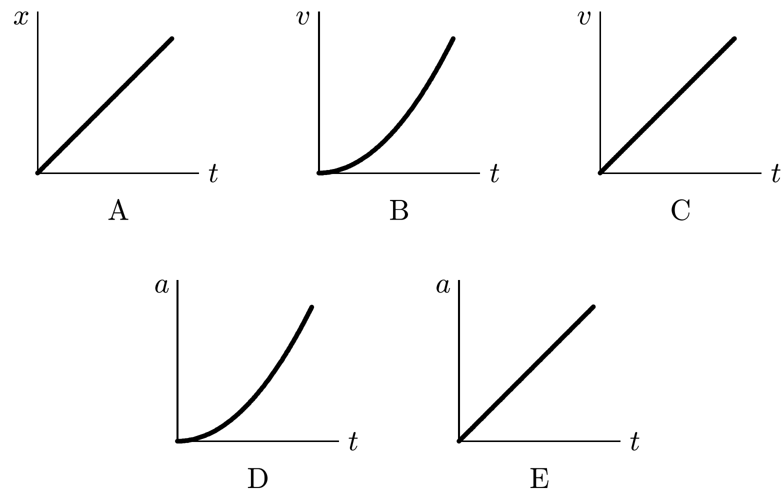
ans: E

75. An object is dropped from rest. Which of the following five graphs correctly represents its motion? The positive direction is taken to be downward.



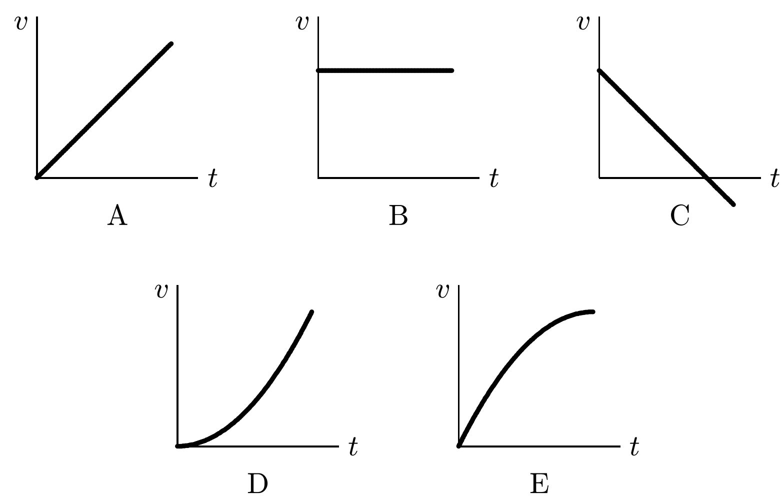
ans: B

76. A stone is dropped from a cliff. The graph (carefully note the axes) which best represents its motion while it falls is:



ans: C

77. An object is thrown vertically into the air. Which of the following five graphs represents the velocity (v) of the object as a function of the time (t)? The positive direction is taken to be upward.



ans: C

Chapter 6: FORCE AND MOTION — II

1. A brick slides on a horizontal surface. Which of the following will increase the magnitude of the frictional force on it?
   A. Putting a second brick on top
   B. Decreasing the surface area of contact
   C. Increasing the surface area of contact
   D. Decreasing the mass of the brick
   E. None of the above

   ans: A

2. The coefficient of kinetic friction:
   A. is in the direction of the frictional force
   B. is in the direction of the normal force
   C. is the ratio of force to area
   D. can have units of newtons
   E. is none of the above

   ans: E

3. When the brakes of an automobile are applied, the road exerts the greatest retarding force:
   A. while the wheels are sliding
   B. just before the wheels start to slide
   C. when the automobile is going fastest
   D. when the acceleration is least
   E. at the instant when the speed begins to change

   ans: B

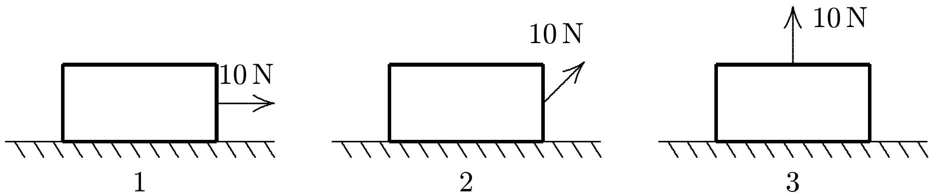
4. A forward horizontal force of 12 N is used to pull a 240-N crate at constant velocity across a horizontal floor. The coefficient of friction is:
   A. 0.5
   B. 0.05
   C. 2
   D. 0.2
   E. 20

   ans: B

5. The speed of a 4.0-N hockey puck, sliding across a level ice surface, decreases at the rate of $0.61\,\mathrm{m/s^2}$. The coefficient of kinetic friction between the puck and ice is:
   A. 0.062
   B. 0.41
   C. 0.62
   D. 1.2
   E. 9.8

   ans: A

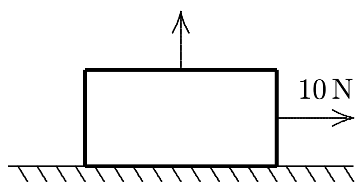
6. A crate rests on a horizontal surface and a woman pulls on it with a 10-N force. No matter what the orientation of the force, the crate does not move. Rank the situations shown below according to the magnitude of the frictional force of the surface on the crate, least to greatest.



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

ans: E

7. A crate with a weight of 50 N rests on a horizontal surface. A person pulls horizontally on it with a force of 10 N and it does not move. To start it moving, a second person pulls vertically upward on the crate. If the coefficient of static friction is 0.4, what is the smallest vertical force for which the crate moves?



A. 4 N
B. 10 N
C. 14 N
D. 25 N
E. 35 N

ans: D

8. A 40-N crate rests on a rough horizontal floor. A 12-N horizontal force is then applied to it. If the coefficients of friction are $\mu_s = 0.5$ and $\mu_k = 0.4$, the magnitude of the frictional force on the crate is:

A. 8 N
B. 12 N
C. 16 N
D. 20 N
E. 40 N

ans: B

9. A 24-N horizontal force is applied to a 40-N block initially at rest on a rough horizontal surface. If the coefficients of friction are $\mu_s = 0.5$ and $\mu_k = 0.4$, the magnitude of the frictional force on the block is:

A. 8 N
B. 12 N
C. 16 N
D. 20 N
E. 400 N

ans: C

10. A horizontal shove of at least 200 N is required to start moving a 800-N crate initially at rest on a horizontal floor. The coefficient of static friction is:

A. 0.25
B. 0.125
C. 0.50
D. 4.00
E. none of these

ans: A

11. A force $\vec{F}$ (larger than the largest possible force of static friction) is applied to the left to an object moving to the right on a horizontal surface. Then:

A. the object must be moving at constant speed
B. $\vec{F}$ and the friction force act in opposite directions
C. the object must be slowing down
D. the object must be speeding up
E. the object must come to rest and remain at rest

ans: C

12. A bureau rests on a rough horizontal surface ($\mu_s = 0.50$, $\mu_k = 0.40$). A constant horizontal force, just sufficient to start the bureau in motion, is then applied. The acceleration of the bureau is:

A. 0
B. $0.98\,\mathrm{m/s^2}$
C. $3.3\,\mathrm{m/s^2}$
D. $4.5\,\mathrm{m/s^2}$
E. $8.9\,\mathrm{m/s^2}$

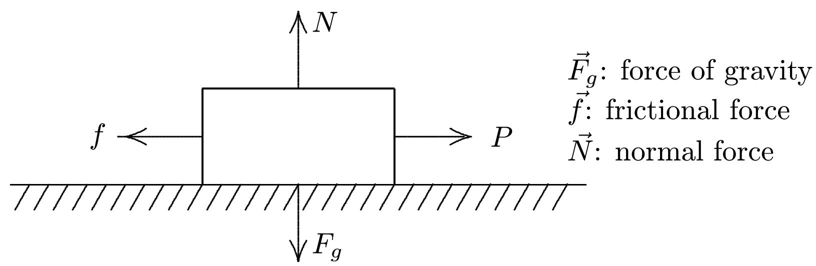
ans: B

13. A car is traveling at 15 m/s on a horizontal road. The brakes are applied and the car skids to a stop in 4.0 s. The coefficient of kinetic friction between the tires and road is:

A. 0.38
B. 0.69
C. 0.76
D. 0.92
E. 1.11

ans: A

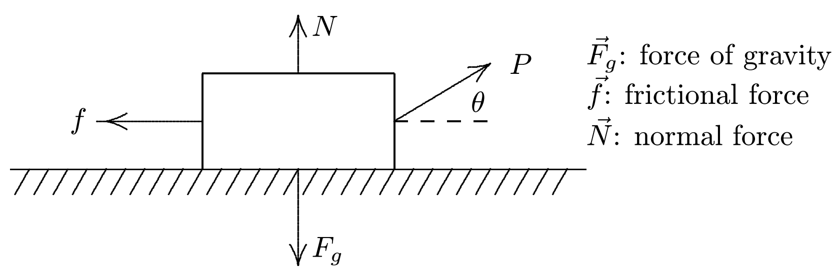
14. A boy pulls a wooden box along a rough horizontal floor at constant speed by means of a force $\vec{P}$ as shown. In the diagram f is the magnitude of the force of friction, N is the magnitude of the normal force, and F_g is the magnitude of the force of gravity. Which of the following must be true?



A. $P = f$ and $N = F_g$
B. $P = f$ and $N > F_g$
C. $P > f$ and $N < F_g$
D. $P > f$ and $N = F_g$
E. none of these

ans: A

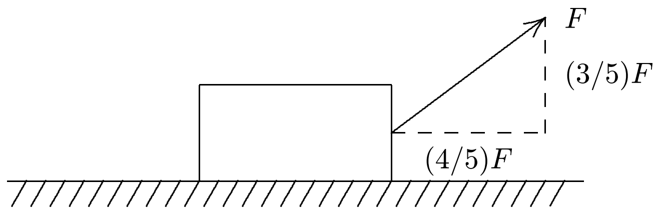
15. A boy pulls a wooden box along a rough horizontal floor at constant speed by means of a force $\vec{P}$ as shown. In the diagram f is the magnitude of the force of friction, N is the magnitude of the normal force, and F_g is the magnitude of the force of gravity. Which of the following must be true?



A. $P = f$ and $N = F_g$
B. $P = f$ and $N > F_g$
C. $P > f$ and $N < F_g$
D. $P > f$ and $N = F_g$
E. none of these

ans: C

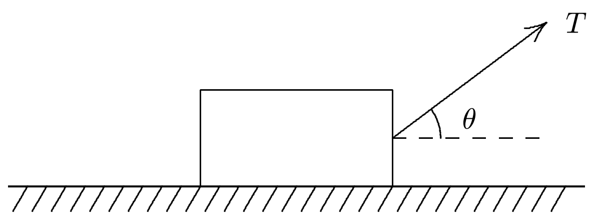
16. A 400-N block is dragged along a horizontal surface by an applied force $\vec{F}$ as shown. The coefficient of kinetic friction is $\mu_k = 0.4$ and the block moves at constant velocity. The magnitude of $\vec{F}$ is:



A. 100 N
B. 150 N
C. 200 N
D. 290 N
E. 400 Nb

ans: B

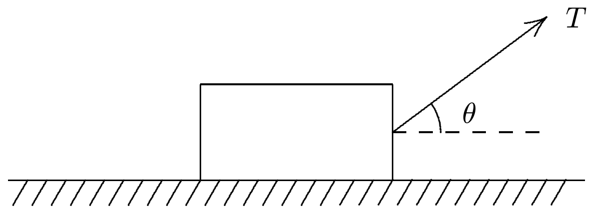
17. A block of mass m is pulled at constant velocity along a rough horizontal floor by an applied force $\vec{T}$ as shown. The magnitude of the frictional force is:



A. $T \cos\theta$
B. $T \sin\theta$
C. zero
D. mg
E. $mg \cos\theta$

ans: A

18. A block of mass m is pulled along a rough horizontal floor by an applied force $\vec{T}$ as shown. The vertical component of the force exerted on the block by the floor is:



A. mg
B. $mg - T\cos\theta$
C. $mg + T\cos\theta$
D. $mg - T\sin\theta$
E. $mg + T\sin\theta$

ans: D

19. A 12-kg crate rests on a horizontal surface and a boy pulls on it with a force that is 30° below the horizontal. If the coefficient of static friction is 0.40, the minimum magnitude force he needs to start the crate moving is:

A. 44 N
B. 47 N
C. 54 N
D. 56 N
E. 71 N

ans: E

20. A crate resting on a rough horizontal floor is to be moved horizontally. The coefficient of static friction is 0.40. To start the crate moving with the weakest possible applied force, in what direction should the force be applied?

A. Horizontal
B. 24° below the horizontal
C. 22° above the horizontal
D. 24° above the horizontal
E. 66° below the horizontal

ans: C

21. A 50-N force is applied to a crate on a horizontal rough floor, causing it to move horizontally. If the coefficient of kinetic friction is 0.50, in what direction should the force be applied to obtain the greatest acceleration?

A. Horizontal
B. 60° above the horizontal
C. 30° above the horizontal
D. 27° above the horizontal
E. 30° below the horizontal

ans: D

22. A professor holds an eraser against a vertical chalkboard by pushing horizontally on it. He pushes with a force that is much greater than is required to hold the eraser. The force of friction exerted by the board on the eraser increases if he:

A. pushes with slightly greater force
B. pushes with slightly less force
C. stops pushing
D. pushes so his force is slightly downward but has the same magnitude
E. pushes so his force is slightly upward but has the same magnitude

ans: D

23. A horizontal force of 12 N pushes a 0.5-kg book against a vertical wall. The book is initially at rest. If the coefficients of friction are $\mu_s = 0.6$ and $\mu_k = 0.8$ which of the following is true?

A. The magnitude of the frictional force is 4.9 N
B. The magnitude of the frictional force is 7.2 N
C. The normal force is 4.9 N
D. The book will start moving and accelerate
E. If started moving downward, the book will decelerate

ans: A

24. A horizontal force of 5.0 N pushes a 0.50-kg book against a vertical wall. The book is initially at rest. If the coefficients of friction are $\mu_s = 0.6$ and $\mu_k = 0.80$, the magnitude of the frictional force is:

A. 0
B. 4.9 N
C. 3.0 N
D. 5.0 N
E. 4.0 N

ans: E

25. A horizontal force of 12 N pushes a 0.50-kg book against a vertical wall. The book is initially at rest. If $\mu_s = 0.6$ and $\mu_k = 0.80$, the acceleration of the book in m/s^2 is:

A. 0
B. $9.4\,m/s^2$
C. $9.8\,m/s^2$
D. $14.4\,m/s^2$
E. $19.2\,m/s^2$

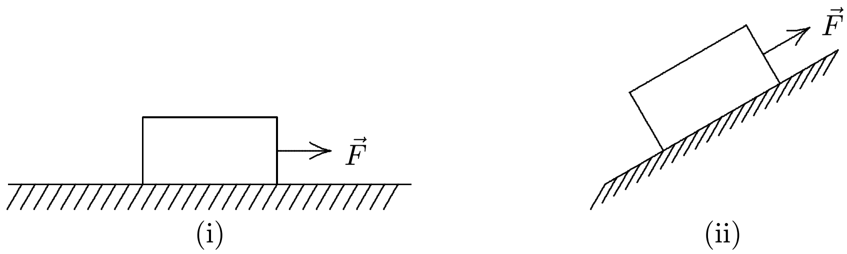
ans: A

26. A horizontal force of 5.0 N pushes a 0.50-kg block against a vertical wall. The block is initially at rest. If $\mu_s = 0.60$ and $\mu_k = 0.80$, the acceleration of the block in m/s^2 is:

A. 0
B. 1.8
C. 6.0
D. 8.0
E. 9.8

ans: B

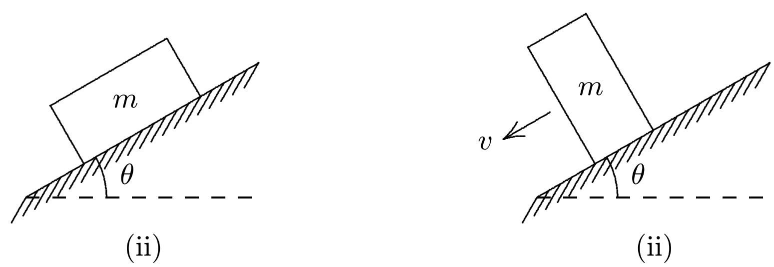
27. A heavy wooden block is dragged by a force $\vec{F}$ along a rough steel plate, as shown below for two possible situations. The magnitude of $\vec{F}$ is the same for the two situations. The magnitude of the frictional force in (ii), as compared with that in (i) is:



A. the same
B. greater
C. less
D. less for some angles and greater for others
E. can be less or greater, depending on the magnitude of the applied force.

ans: C

28. A block is first placed on its long side and then on its short side on the same inclined plane, as shown. The block slides down the plane on its short side but remains at rest on its long side. A possible explanation is:



A. the short side is smoother
B. the frictional force is less because the contact area is less
C. the center of gravity is higher in the second case
D. the normal force is less in the second case
E. the force of gravity is more nearly down the plane in the second case

ans: A

29. A box rests on a rough board 10 meters long. When one end of the board is slowly raised to a height of 6 meters above the other end, the box begins to slide. The coefficient of static friction is:

A. 0.8
B. 0.25
C. 0.4
D. 0.6
E. 0.75

ans: E

30. A block is placed on a rough wooden plane. It is found that when the plane is tilted 30° to the horizontal, the block will slide down at constant speed. The coefficient of kinetic friction of the block with the plane is:

A. 0.500
B. 0.577
C. 1.73
D. 0.866
E. 4.90

ans: B

31. A crate is sliding down an incline that is 35° above the horizontal. If the coefficient of kinetic friction is 0.40, the acceleration of the crate is:

A. 0
B. $2.4\,\mathrm{m/s^2}$
C. $5.8\,\mathrm{m/s^2}$
D. $8.8\,\mathrm{m/s^2}$
E. $10.3\,\mathrm{m/s^2}$

ans: B

32. A 5.0-kg crate is resting on a horizontal plank. The coefficient of static friction is 0.50 and the coefficient of kinetic friction is 0.40. After one end of the plank is raised so the plank makes an angle of 25° with the horizontal, the force of friction is:

A. 0
B. 18 N
C. 21 N
D. 22 N
E. 44 N

ans: C

33. A 5.0-kg crate is resting on a horizontal plank. The coefficient of static friction is 0.50 and the coefficient of kinetic friction is 0.40. After one end of the plank is raised so the plank makes an angle of 30° with the horizontal, the force of friction is:

A. 0
B. 18 N
C. 21 N
D. 22 N
E. 44 N

ans: B

34. A 5.0-kg crate is on an incline that makes an angle of 30° with the horizontal. If the coefficient of static friction is 0.50, the minimum force that can be applied parallel to the plane to hold the crate at rest is:

A. 0
B. 3.3 N
C. 30 N
D. 46 N
E. 55 N

ans: B

35. A 5.0-kg crate is on an incline that makes an angle of 30° with the horizontal. If the coefficient of static friction is 0.5, the maximum force that can be applied parallel to the plane without moving the crate is:

A. 0
B. 3.3 N
C. 30 N
D. 46 N
E. 55 N

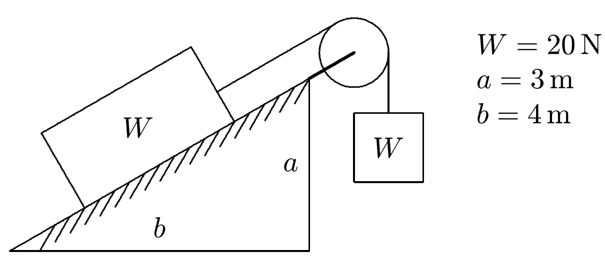
ans: D

36. Block A, with mass m_A, is initially at rest on a horizontal floor. Block B, with mass m_B, is initially at rest on the horizontal top surface of A. The coefficient of static friction between the two blocks is μ_s. Block A is pulled with a horizontal force. It begins to slide out from under B if the force is greater than:

A. $m_A g$
B. $m_B g$
C. $\mu_s m_A g$
D. $\mu_s m_B g$
E. $\mu_s(m_A + m_B)g$

ans: E

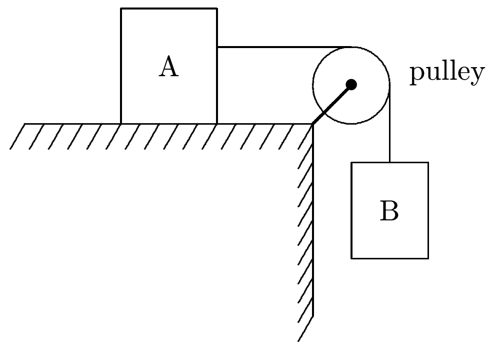
37. The system shown remains at rest. Each block weighs 20 N. The force of friction on the upper block is:



A. 4 N
B. 8 N
C. 12 N
D. 16 N
E. 20 N

ans: B

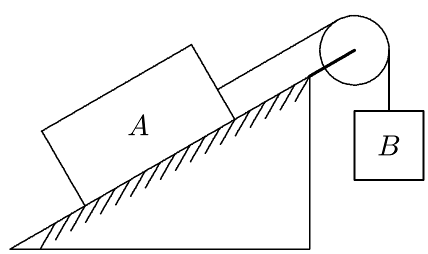
38. Block A, with a mass of 50 kg, rests on a horizontal table top. The coefficient of static friction is 0.40. A horizontal string is attached to A and passes over a massless, frictionless pulley as shown. The smallest mass m_B of block B, attached to the dangling end, that will start A moving when it is attached to the other end of the string is:



A. 20 kg
B. 30 kg
C. 40 kg
D. 50 kg
E. 70 kg

ans: A

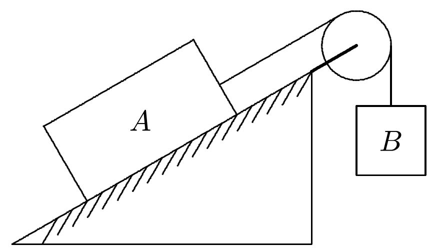
39. Block A, with a mass of 10 kg, rests on a 35° incline. The coefficient of static friction is 0.40. An attached string is parallel to the incline and passes over a massless, frictionless pulley at the top. The largest mass m_B of block B, attached to the dangling end, for which A begins to slide down the incline is:



A. 2.5 kg
B. 3.5 kg
C. 5.9 kg
D. 9.0 kg
E. 10.5 kg

ans: A

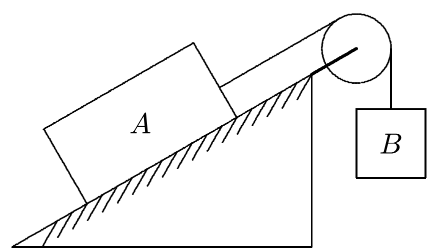
40. Block A, with a mass of 10 kg, rests on a 35° incline. The coefficient of static friction is 0.40. An attached string is parallel to the incline and passes over a massless, frictionless pulley at the top. The largest mass m_B, attached to the dangling end, for which A remains at rest is:



A. 2.5 kg
B. 3.5 kg
C. 5.9 kg
D. 9.0 kg
E. 10.5 kg

ans: D

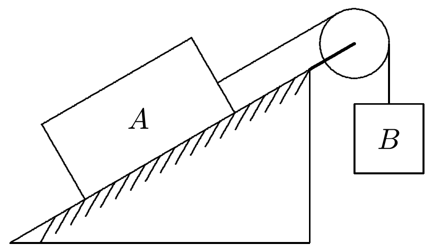
41. Block A, with a mass of 10 kg, rests on a 30° incline. The coefficient of kinetic friction is 0.20. The attached string is parallel to the incline and passes over a massless, frictionless pulley at the top. Block B, with a mass of 8.0 kg, is attached to the dangling end of the string. The acceleration of B is:



A. $0.69\,\mathrm{m/s^2}$, up the plane
B. $0.69\,\mathrm{m/s^2}$, down the plane
C. $2.6\,\mathrm{m/s^2}$, up the plane
D. $2.6\,\mathrm{m/s^2}$, down the plane
E. 0

ans: B

42. Block A, with a mass of 10 kg, rests on a 30° incline. The coefficient of kinetic friction is 0.20. The attached string is parallel to the incline and passes over a massless, frictionless pulley at the top. Block B, with a mass of 3.0 kg, is attached to the dangling end of the string. The acceleration of B is:



A. $0.20\,\mathrm{m/s^2}$, up
B. $0.20\,\mathrm{m/s^2}$, down
C. $2.8\,\mathrm{m/s^2}$, up
D. $2.8\,\mathrm{m/s^2}$, down
E. 0

ans: A

43. A 1000-kg airplane moves in straight flight at constant speed. The force of air friction is 1800 N. The net force on the plane is:

A. zero
B. 11800 N
C. 1800 N
D. 9800 N
E. none of these

ans: A

44. Why do raindrops fall with constant speed during the later stages of their descent?

A. The gravitational force is the same for all drops
B. Air resistance just balances the force of gravity
C. The drops all fall from the same height
D. The force of gravity is negligible for objects as small as raindrops
E. Gravity cannot increase the speed of a falling object to more than 9.8 m/s

ans: B

45. A ball is thrown downward from the edge of a cliff with an initial speed that is three times the terminal speed. Initially its acceleration is

A. upward and greater than g
B. upward and less than g
C. downward and greater than g
D. downward and less than g
E. downward and equal to g

ans: A

46. A ball is thrown upward into the air with a speed that is greater than terminal speed. On the way up it slows down and, after its speed equals the terminal speed but before it gets to the top of its trajectory:

A. its speed is constant
B. it continues to slow down
C. it speeds up
D. its motion becomes jerky
E. none of the above

ans: B

47. A ball is thrown upward into the air with a speed that is greater than terminal speed. It lands at the place where it was thrown. During its flight the force of air resistance is the greatest:

A. just after it is thrown
B. halfway up
C. at the top of its trajectory
D. halfway down
E. just before it lands.

ans: A

48. Uniform circular motion is the direct consequence of:

A. Newton's third law
B. a force that is always tangent to the path
C. an acceleration tangent to the path
D. a force of constant magnitude that is always directed away from the same fixed point
E. a force of constant magnitude that is always directed toward the same fixed point

ans: E

49. An object moving in a circle at constant speed:

A. must have only one force acting on it
B. is not accelerating
C. is held to its path by centrifugal force
D. has an acceleration of constant magnitude
E. has an acceleration that is tangent to the circle

ans: D

50. An object of mass m and another object of mass $2m$ are each forced to move along a circle of radius 1.0 m at a constant speed of 1.0 m/s. The magnitudes of their accelerations are:

A. equal
B. in the ratio of $\sqrt{2} : 1$
C. in the ratio of $2 : 1$
D. in the ratio of $4 : 1$
E. zero

ans: A

51. The magnitude of the force required to cause a 0.04-kg object to move at 0.6 m/s in a circle of radius 1.0 m is:

A. 2.4×10^{-2} N
B. 1.4×10^{-2} N
C. $1.4\pi \times 10^{-2}$ N
D. $2.4\pi^2 \times 10^{-2}$ N
E. 3.13 N

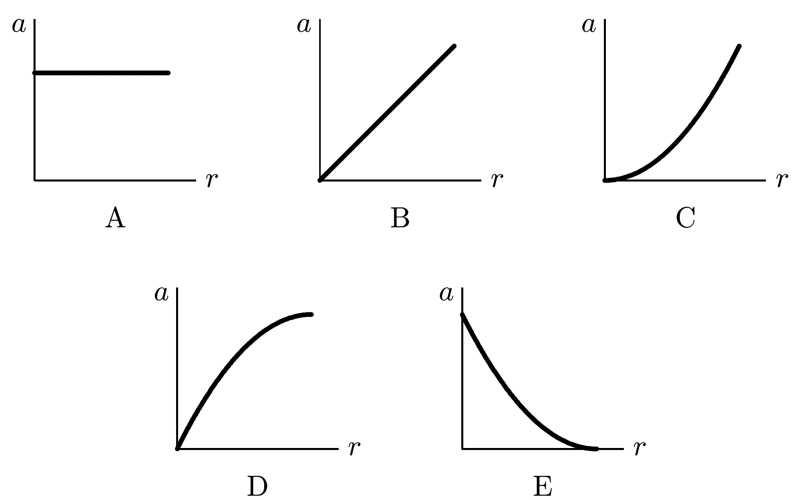
ans: B

52. A 0.2-kg stone is attached to a string and swung in a circle of radius 0.6 m on a horizontal and frictionless surface. If the stone makes 150 revolutions per minute, the tension force of the string on the stone is:

A. 0.03 N
B. 0.2 N
C. 0.9 N
D. 1.96 N
E. 30 N

ans: E

53. Which of the following five graphs is correct for a particle moving in a circle of radius r at a constant speed of 10 m/s?



ans: E

54. An object moves around a circle. If the radius is doubled keeping the speed the same then the magnitude of the centripetal force must be:

A. twice as great
B. half as great
C. four times as great
D. one-fourth as great
E. the same

ans: B

55. An object moves in a circle. If the mass is tripled, the speed halved, and the radius unchanged, then the magnitude of the centripetal force must be multiplied by a factor of:

A. 3/2
B. 3/4
C. 9/4
D. 6
E. 12

ans: B

56. If a satellite moves above Earth's atmosphere in a circular orbit with constant speed, then:

A. its acceleration and velocity are always in the same direction
B. the net force on it is zero
C. its velocity is constant
D. it will fall back to Earth when its fuel is used up
E. its acceleration is toward the Earth

ans: E

57. A 800-N passenger in a car presses against the car door with a 200 N force when the car makes a left turn at 13 m/s. The (faulty) door will pop open under a force of 800 N. Of the following, the least speed for which the passenger is thrown out of the car is:

A. 14 m/s
B. 19 m/s
C. 20 m/s
D. 26 m/s
E. 54 m/s

ans: D

58. If a certain car, going with speed v_1, rounds a level curve with a radius R_1, it is just on the verge of skidding. If its speed is now doubled, the radius of the tightest curve on the same road that it can round without skidding is:

A. $2R_1$
B. $4R_1$
C. $R_1/2$
D. $R_1/4$
E. R_1

ans: B

59. An automobile moves on a level horizontal road in a circle of radius 30 m. The coefficient of friction between tires and road is 0.50. The maximum speed with which this car can round this curve is:

A. 3.0 m/s
B. 4.9 m/s
C. 9.8 m/s
D. 12 m/s
E. 13 m/s

ans: D

60. The driver of a 1000-kg car tries to turn through a circle of radius 100 m on an unbanked curve at a speed of 10 m/s. The actual frictional force between the tires and slippery road has a magnitude of 900 N. The car:

A. slides into the inside of the curve
B. makes the turn
C. slows down due to the frictional force
D. makes the turn only if it goes faster
E. slides off to the outside of the curve

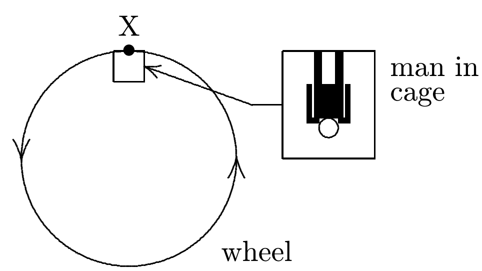
ans: E

61. A car rounds a 75-m radius curve at a constant speed of 18 m/s. A ball is suspended by a string from the ceiling the car and moves with the car. The angle between the string and the vertical is:

A. 0
B. 1.4°
C. 24°
D. 90°
E. cannot be found without knowing the mass of the ball

ans: C

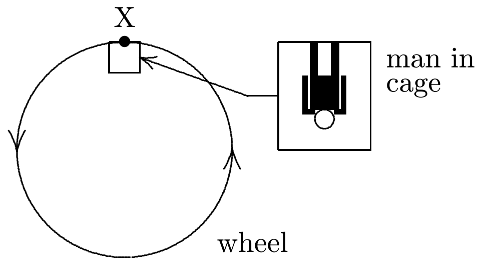
62. A giant wheel, having a diameter of 40 m, is fitted with a cage and platform on which a man of mass m stands. The wheel is rotated in a vertical plane at such a speed that the force exerted by the man on the platform is equal to his weight when the cage is at X, as shown. The net force on the man at point X is:



A. zero
B. mg, down
C. mg, up
D. $2mg$, down
E. $2mg$, up

ans: D

63. A giant wheel, 40 m in diameter, is fitted with a cage and platform on which a man can stand. The wheel rotates at such a speed that when the cage is at X (as shown) the force exerted by the man on the platform is equal to his weight. The speed of the man is:



A. 14 m/s
B. 20 m/s
C. 28 m/s
D. 80 m/s
E. 120 m/s

ans: B

64. A person riding a Ferris wheel is strapped into her seat by a seat belt. The wheel is spun so that the centripetal acceleration is g. Select the correct combination of forces that act on her when she is at the top. In the table F_g = force of gravity, down; F_b = seat belt force, down; and F_s = seat force, up.

	F_g	F_b	F_s
A.	0	mg	0
B.	mg	0	0
C.	0	0	mg
D.	mg	mg	0
E.	mg	0	mg

ans: B

65. One end of a 1.0-m long string is fixed, the other end is attached to a 2.0-kg stone. The stone swings in a vertical circle, passing the bottom point at 4.0 m/s. The tension force of the string at this point is about:

A. 0
B. 12 N
C. 20 N
D. 32 N
E. 52 N

ans: E

66. One end of a 1.0-m string is fixed, the other end is attached to a 2.0-kg stone. The stone swings in a vertical circle, passing the top point at 4.0 m/s. The tension force of the string (in newtons) at this point is about:

A. 0
B. 12
C. 20
D. 32
E. 52

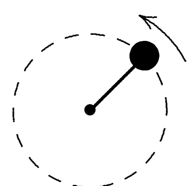
ans: B

67. A coin is placed on a horizontal phonograph turntable. Let N be the magnitude of the normal force exerted by the turntable on the coin, f be the magnitude of the frictional force exerted by the turntable on the coin, and $f_{\text{s, max}}$ be the maximum possible force of static friction. The speed of the turntable is increased in small steps. If the coin does not slide, then

A. N increases, f increases, and $f_{\text{s, max}}$ stays the same
B. N increases, f increases, and $f_{\text{s, max}}$ increases
C. f increases and both N and $f_{\text{s, max}}$ stay the same
D. N, f, and $f_{\text{s, max}}$ all stay the same
E. N, f, and $f_{\text{s, max}}$ all increase

ans: C

68. The iron ball shown is being swung in a vertical circle at the end of a 0.7-m long string. How slowly can the ball go through its top position without having the string go slack?



A. 1.3 m/s
B. 2.6 m/s
C. 3.9 m/s
D. 6.9 m/s
E. 9.8 m/s

ans: B

69. A block is suspended by a rope from the ceiling of a car. When the car rounds a 45-m radius horizontal curve at 22 m/s (about 50 mph), what angle does the rope make with the vertical?

A. 0
B. 25°
C. 48°
D. 65°
E. 90°

ans: C

70. Circular freeway entrance and exit ramps are commonly banked to handle a car moving at 13 m/s. To design a similar ramp for 26 m/s one should:

A. increase radius by factor of 2
B. decrease radius by factor of 2
C. increase radius by factor of 4
D. decrease radius by factor of 4
E. increase radius by factor of $\sqrt{2}$

ans: C

71. At what angle should the roadway on a curve with a 50 m radius be banked to allow cars to negotiate the curve at 12 m/s even if the roadway is icy (and the frictional force is zero)?

A. 0
B. 16°
C. 18°
D. 35°
E. 73°

ans: B

Chapter 5: FORCE AND MOTION — I

1. An example of an inertial reference frame is:
   A. any reference frame that is not accelerating
   B. a frame attached to a particle on which there are no forces
   C. any reference frame that is at rest
   D. a reference frame attached to the center of the universe
   E. a reference frame attached to Earth

   ans: B

2. An object moving at constant velocity in an inertial frame must:
   A. have a net force on it
   B. eventually stop due to gravity
   C. not have any force of gravity on it
   D. have zero net force on it
   E. have no frictional force on it

   ans: D

3. In SI units a force is numerically equal to the ______, when the force is applied to it.
   A. velocity of the standard kilogram
   B. speed of the standard kilogram
   C. velocity of any object
   D. acceleration of the standard kilogram
   E. acceleration of any object

   ans: D

4. Which of the following quantities is NOT a vector?
   A. Mass
   B. Displacement
   C. Weight
   D. Acceleration
   E. Force

   ans: A

5. A newton is the force:
   A. of gravity on a 1 kg body
   B. of gravity on a 1 g body
   C. that gives a 1 g body an acceleration of 1 cm/s^2
   D. that gives a 1 kg body an acceleration of 1 m/s^2
   E. that gives a 1 kg body an acceleration of 9.8 m/s^2

   ans: D

6. The unit of force called the newton is:
   A. $9.8\,\text{kg}\cdot\text{m/s}^2$
   B. $1\,\text{kg}\cdot\text{m/s}^2$
   C. defined by means of Newton's third law
   D. 1 kg of mass
   E. 1 kg of force

   ans: B

7. A force of 1 N is:
   A. $1\,\text{kg/s}$
   B. $1\,\text{kg}\cdot\text{m/s}$
   C. $1\,\text{kg}\cdot\text{m/s}^2$
   D. $1\,\text{kg}\cdot\text{m}^2\text{/s}$
   E. $1\,\text{kg}\cdot\text{m}^2\text{/s}^2$

   ans: C

8. The standard 1-kg mass is attached to a compressed spring and the spring is released. If the mass initially has an acceleration of $5.6\,\text{m/s}^2$, the force of the spring has a magnitude of:
   A. 2.8 N
   B. 5.6 N
   C. 11.2 N
   D. 0
   E. an undetermined amount

   ans: B

9. Acceleration is always in the direction:
   A. of the displacement
   B. of the initial velocity
   C. of the final velocity
   D. of the net force
   E. opposite to the frictional force

   ans: D

10. The term "mass" refers to the same physical concept as:
   A. weight
   B. inertia
   C. force
   D. acceleration
   C. volume

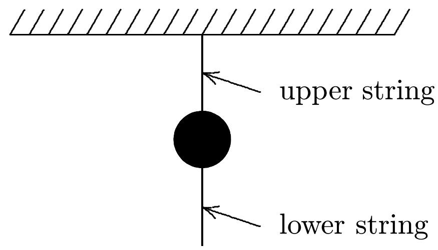
   ans: B

11. The inertia of a body tends to cause the body to:

A. speed up
B. slow down
C. resist any change in its motion
D. fall toward Earth
E. decelerate due to friction

ans: C

12. A heavy ball is suspended as shown. A quick jerk on the lower string will break that string but a slow pull on the lower string will break the upper string. The first result occurs because:



A. the force is too small to move the ball
B. action and reaction is operating
C. the ball has inertia
D. air friction holds the ball back
E. the ball has too much energy

ans: C

13. When a certain force is applied to the standard kilogram its acceleration is $5.0\,\mathrm{m/s^2}$. When the same force is applied to another object its acceleration is one-fifth as much. The mass of the object is:

A. 0.2 kg
B. 0.5 kg
C. 1.0 kg
D. 5.0 kg
E. 10 kg

ans: D

14. Mass differs from weight in that:

A. all objects have weight but some lack mass
B. weight is a force and mass is not
C. the mass of an object is always more than its weight
D. mass can be expressed only in the metric system
E. there is no difference

ans: B

15. The mass of a body:

A. is slightly different at different places on Earth
B. is a vector
C. is independent of the free-fall acceleration
D. is the same for all bodies of the same volume
E. can be measured most accurately on a spring scale

ans: C

16. The mass and weight of a body:

A. differ by a factor of 9.8
B. are identical
C. are the same physical quantities expressed in different units
D. are both a direct measure of the inertia of the body
E. have the same ratio as that of any other body placed at that location

ans: E

17. An object placed on an equal-arm balance requires 12 kg to balance it. When placed on a spring scale, the scale reads 12 kg. Everything (balance, scale, set of weights and object) is now transported to the Moon where the free-fall acceleration is one-sixth that on Earth. The new readings of the balance and spring scale (respectively) are:

A. 12 kg, 12 kg
B. 2 kg, 2 kg
C. 12 kg, 2 kg
D. 2 kg, 12 kg
E. 12 kg, 72 kg

ans: C

18. Two objects, one having three times the mass of the other, are dropped from the same height in a vacuum. At the end of their fall, their velocities are equal because:

A. anything falling in vacuum has constant velocity
B. all objects reach the same terminal velocity
C. the acceleration of the larger object is three times greater than that of the smaller object
D. the force of gravity is the same for both objects
E. none of the above

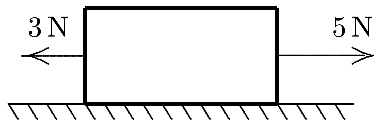
ans: E

19. A feather and a lead ball are dropped from rest in vacuum on the Moon. The acceleration of the feather is:

A. more than that of the lead ball
B. the same as that of the lead ball
C. less than that of the lead ball
D. $9.8\,\mathrm{m/s^2}$
E. zero since it floats in a vacuum

ans: B

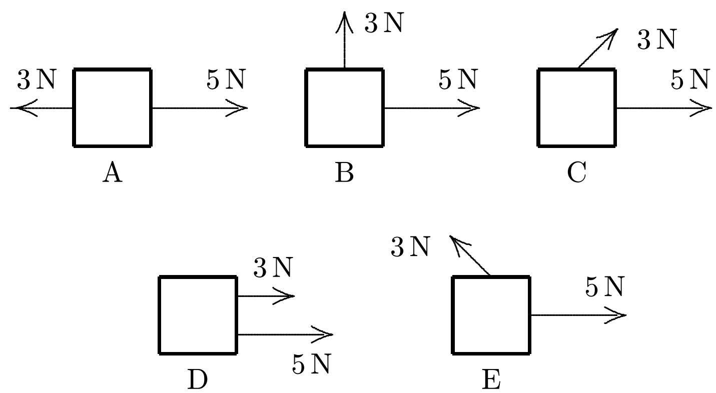
20. The block shown moves with constant velocity on a horizontal surface. Two of the forces on it are shown. A frictional force exerted by the surface is the only other horizontal force on the block. The frictional force is:



A. 0
B. 2 N, leftward
C. 2 N, rightward
D. slightly more than 2 N, leftward
E. slightly less than 2 N, leftward

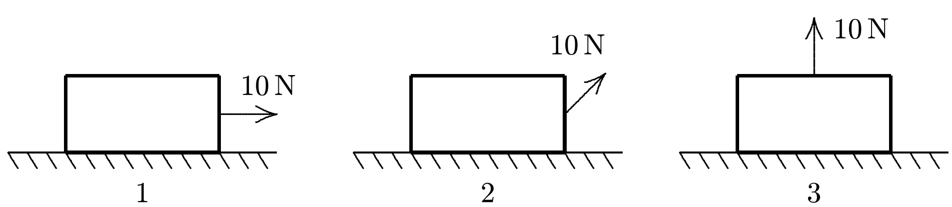
ans: B

21. Two forces, one with a magnitude of 3 N and the other with a magnitude of 5 N, are applied to an object. For which orientations of the forces shown in the diagrams is the magnitude of the acceleration of the object the least?



ans: A

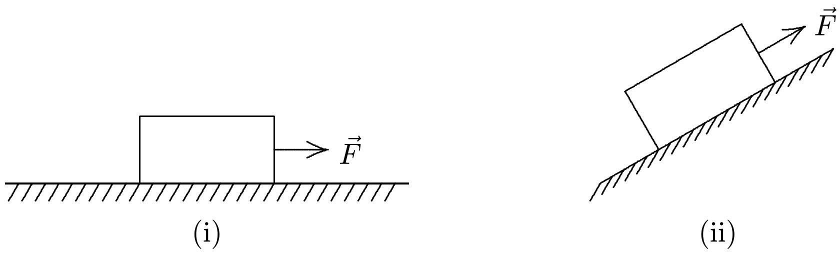
22. A crate rests on a horizontal surface and a woman pulls on it with a 10-N force. Rank the situations shown below according to the magnitude of the normal force exerted by the surface on the crate, least to greatest.



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

ans: E

23. A heavy wooden block is dragged by a force $\vec{F}$ along a rough steel plate, as shown in the diagrams for two cases. The magnitude of the applied force $\vec{F}$ is the same for both cases. The normal force in (ii), as compared with the normal force in (i) is:



A. the same
B. greater
C. less
D. less for some angles of the incline and greater for others
E. less or greater, depending on the magnitude of the applied force $\vec{F}$.

ans: C

24. Equal forces $\vec{F}$ act on isolated bodies A and B. The mass of B is three times that of A. The magnitude of the acceleration of A is:

A. three times that of B
B. 1/3 that of B
C. the same as B
D. nine times that of B
E. 1/9 that of B

ans: A

25. A car travels east at constant velocity. The net force on the car is:

A. east
B. west
C. up
D. down
E. zero

ans: E

26. A constant force of 8.0 N is exerted for 4.0 s on a 16-kg object initially at rest. The change in speed of this object will be:

A. 0.5 m/s
B. 2 m/s
C. 4 m/s
D. 8 m/s
E. 32 m/s

ans: B

27. A 6-kg object is moving south. A net force of 12 N north on it results in the object having an acceleration of:

A. $2\,\text{m/s}^2$, north
B. $2\,\text{m/s}^2$, south
C. $6\,\text{m/s}^2$, north
D. $18\,\text{m/s}^2$, north
E. $18\,\text{m/s}^2$, south

ans: A

28. A 9000-N automobile is pushed along a level road by four students who apply a total forward force of 500 N. Neglecting friction, the acceleration of the automobile is:

A. $0.055\,\text{m/s}^2$
B. $0.54\,\text{m/s}^2$
C. $1.8\,\text{m/s}^2$
D. $9.8\,\text{m/s}^2$
E. $18\,\text{m/s}^2$

ans: B

29. An object rests on a horizontal frictionless surface. A horizontal force of magnitude F is applied. This force produces an acceleration:

A. only if F is larger than the weight of the object
B. only while the object suddenly changes from rest to motion
C. always
D. only if the inertia of the object decreases
E. only if F is increasing

ans: C

30. A 25-kg crate is pushed across a frictionless horizontal floor with a force of 20 N, directed 20° below the horizontal. The acceleration of the crate is:

A. $0.27\,\text{m/s}^2$
B. $0.75\,\text{m/s}^2$
C. $0.80\,\text{m/s}^2$
D. $170\,\text{m/s}^2$
E. $470\,\text{m/s}^2$

ans: B

31. A ball with a weight of 1.5 N is thrown at an angle of 30° above the horizontal with an initial speed of 12 m/s. At its highest point, the net force on the ball is:

A. 9.8 N, 30° below horizontal
B. zero
C. 9.8 N, up
D. 9.8 N, down
E. 1.5 N, down

ans: E

32. Two forces are applied to a 5.0-kg crate; one is 6.0 N to the north and the other is 8.0 N to the west. The magnitude of the acceleration of the crate is:

A. $0.50\,\mathrm{m/s^2}$
B. $2.0\,\mathrm{m/s^2}$
C. $2.8\,\mathrm{m/s^2}$
D. $10\,\mathrm{m/s^2}$
E. $50\,\mathrm{m/s^2}$

ans: B

33. A 400-N steel ball is suspended by a light rope from the ceiling. The tension in the rope is:

A. 400 N
B. 800 N
C. zero
D. 200 N
E. 560 N

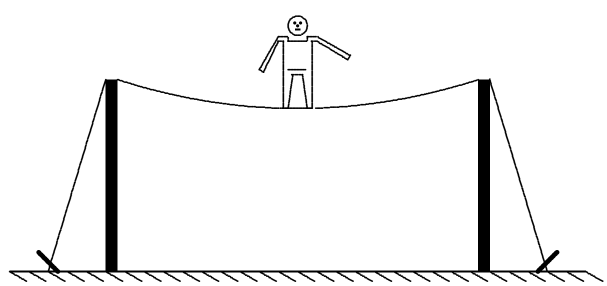
ans: A

34. A heavy steel ball B is suspended by a cord from a block of wood W. The entire system is dropped through the air. Neglecting air resistance, the tension in the cord is:

A. zero
B. the difference in the masses of B and W
C. the difference in the weights of B and W
D. the weight of B
E. none of these

ans: A

35. A circus performer of weight W is walking along a "high wire" as shown. The tension in the wire:



A. is approximately W
B. is approximately $W/2$
C. is much less than W
D. is much more than W
E. depends on whether he stands on one foot or two feet

ans: D

36. A 1000-kg elevator is rising and its speed is increasing at $3\,\text{m/s}^2$. The tension force of the cable on the elevator is:

A. 6800 N
B. 1000 N
C. 3000 N
D. 9800 N
E. 12800 N

ans: E

*37. A 5-kg block is suspended by a rope from the ceiling of an elevator as the elevator accelerates downward at $3.0\,\text{m/s}^2$. The tension force of the rope on the block is:

A. 15 N, up
B. 34 N, up
C. 34 N, down
D. 64 N, up
E. 64 N, down

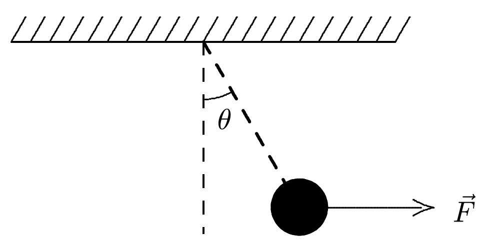
ans: B

38. A crane operator lowers a 16,000-N steel ball with a downward acceleration of $3\,\text{m/s}^2$. The tension force of the cable is:

A. 4900 N
B. 11,000 N
C. 16,000 N
D. 21,000 N
E. 48,000 N

ans: B

39. A 1-N pendulum bob is held at an angle θ from the vertical by a 2-N horizontal force F as shown. The tension in the string supporting the pendulum bob (in newtons) is:



A. $\cos\theta$
B. $2/\cos\theta$
C. $\sqrt{5}$
D. 1
E. none of these

ans: C

40. A car moves horizontally with a constant acceleration of $3\,\mathrm{m/s^2}$. A ball is suspended by a string from the ceiling of the car. The ball does not swing, being at rest with respect to the car. What angle does the string make with the vertical?

A. 17°
B. 35°
C. 52°
D. 73°
E. Cannot be found without knowing the length of the string

ans: A

41. A man weighing 700 Nb is in an elevator that is accelerating upward at $4\,\mathrm{m/s^2}$. The force exerted on him by the elevator floor is:

A. 71 N
B. 290 N
C. 410 N
D. 700 N
E. 990 N

ans: E

42. You stand on a spring scale on the floor of an elevator. Of the following, the scale shows the highest reading when the elevator:

A. moves upward with increasing speed
B. moves upward with decreasing speed
C. remains stationary
D. moves downward with increasing speed
E. moves downward at constant speed

ans: A

43. You stand on a spring scale on the floor of an elevator. Of the following, the scale shows the highest reading when the elevator:

A. moves downward with increasing speed
B. moves downward with decreasing speed
C. remains stationary
D. moves upward with decreasing speed
E. moves upward at constant speed

ans: B

44. When a 25-kg crate is pushed across a frictionless horizontal floor with a force of 200 N, directed 20° below the horizontal, the magnitude of the normal force of the floor on the crate is:

A. 25 N
B. 68 N
C. 180 N
D. 250 N
E. 310 N

ans: E

45. A block slides down a frictionless plane that makes an angle of 30° with the horizontal. The acceleration of the block is:

A. $980\,\mathrm{cm/s^2}$
B. $566\,\mathrm{cm/s^2}$
C. $849\,\mathrm{cm/s^2}$
D. zero
E. $490\,\mathrm{cm/s^2}$

ans: E

46. A 25-N crate slides down a frictionless incline that is 25° above the horizontal. The magnitude of the normal force of the incline on the crate is:

A. 11 N
B. 23 N
C. 25 N
D. 100 N
E. 220 N

ans: B

47. A 25-N crate is held at rest on a frictionless incline by a force that is parallel to the incline. If the incline is 25° above the horizontal the magnitude of the applied force is:

A. 4.1 N
B. 4.6 N
C. 8.9 N
D. 11 N
E. 23 N

ans: D

48. A 25-N crate is held at rest on a frictionless incline by a force that is parallel to the incline. If the incline is 25° above the horizontal the magnitude of the normal force of the incline on the crate is:

A. 4.1 N
B. 4.6 N
C. 8.9 N
D. 11 N
E. 23 N

ans: E

49. A 32-N force, parallel to the incline, is required to push a certain crate at constant velocity up a frictionless incline that is 30° above the horizontal. The mass of the crate is:

A. 3.3 kg
B. 3.8 kg
C. 5.7 kg
D. 6.5 kg
E. 160 kg

ans: D

50. A sled is on an icy (frictionless) slope that is 30° above the horizontal. When a 40-N force, parallel to the incline and directed up the incline, is applied to the sled, the acceleration of the sled is $2.0\,\mathrm{m/s^2}$, down the incline. The mass of the sled is:

A. 3.8 kg
B. 4.1 kg
C. 5.8 kg
D. 6.2 kg
E. 10 kg

ans: E

51. When a 40-N force, parallel to the incline and directed up the incline, is applied to a crate on a frictionless incline that is 30° above the horizontal, the acceleration of the crate is $2.0\,\mathrm{m/s^2}$, up the incline. The mass of the crate is:

A. 3.8 kg
B. 4.1 kg
C. 5.8 kg
D. 6.2 kg
E. 10 kg

ans: C

52. The "reaction" force does not cancel the "action" force because:

A. the action force is greater than the reaction force
B. they are on different bodies
C. they are in the same direction
D. the reaction force exists only after the action force is removed
E. the reaction force is greater than the action force

ans: B

53. A book rests on a table, exerting a downward force on the table. The reaction to this force is:

A. the force of Earth on the book
B. the force of the table on the book
C. the force of Earth on the table
D. the force of the book on Earth
E. the inertia of the book

ans: B

54. A lead block is suspended from your hand by a string. The reaction to the force of gravity on the block is the force exerted by:

A. the string on the block
B. the block on the string
C. the string on the hand
D. the hand on the string
E. the block on Earth

ans: E

55. A 5-kg concrete block is lowered with a downward acceleration of $2.8\,\mathrm{m/s^2}$ by means of a rope. The force of the block on the rope is:

A. 14 N, up
B. 14 N, down
C. 35 N, up
D. 35 N, down
E. 49 N, up

ans: D

56. A 90-kg man stands in an elevator that is moving up at a constant speed of $5.0\,\mathrm{m/s}$. The force exerted by him on the floor is about:

A. zero
B. 90 N
C. 880 N
D. 450 N
E. 49 N

ans: C

57. A 90-kg man stands in an elevator that has a downward acceleration of $1.4\,\mathrm{m/s^2}$. The force exerted by him on the floor is about:

A. zero
B. 90 N
C. 760 N
D. 880 N
E. 1010 N

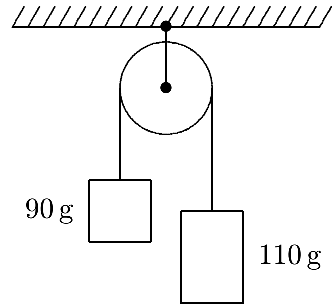
ans: C

58. A 5-kg concrete block is lowered with a downward acceleration of $2.8\,\mathrm{m/s^2}$ by means of a rope. The force of the block on Earth is:

A. 14 N, up
B. 14 N, down
C. 35 N, up
D. 35 N, down
E. 49 N, up

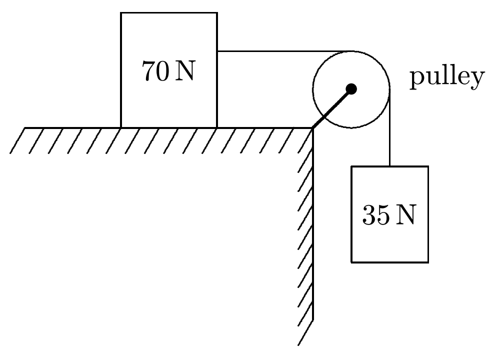
ans: E

59. Two blocks are connected by a string and pulley as shown. Assuming that the string and pulley are massless, the magnitude of the acceleration of each block is:



A. $0.049\,\mathrm{m/s^2}$
B. $0.020\,\mathrm{m/s^2}$
C. $0.0098\,\mathrm{m/s^2}$
D. $0.54\,\mathrm{m/s^2}$
E. $0.98\,\mathrm{m/s^2}$
ans: E

60. A 70-N block and a 35-N block are connected by a string as shown. If the pulley is massless and the surface is frictionless, the magnitude of the acceleration of the 35-N block is:



A. $1.6\,\mathrm{m/s^2}$
B. $3.3\,\mathrm{m/s^2}$
C. $4.9\,\mathrm{m/s^2}$
D. $6.7\,\mathrm{m/s^2}$
E. $9.8\,\mathrm{m/s^2}$
ans: B

61. A 13-N weight and a 12-N weight are connected by a massless string over a massless, frictionless pulley. The 13-N weight has a downward acceleration with magnitude equal to that of a freely falling body times:

A. 1
B. 1/12
C. 1/13
D. 1/25
E. 13/25

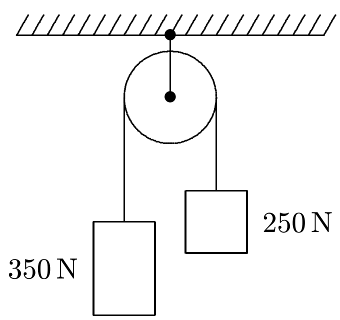
ans: D

62. A massless rope passes over a massless pulley suspended from the ceiling. A 4-kg block is attached to one end and a 5-kg block is attached to the other end. The acceleration of the 5-kg block is:

A. $g/4$
B. $5g/9$
C. $4g/9$
D. $g/5$
E. $g/9$

ans: E

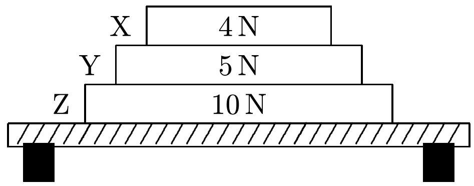
63. Two blocks, weighing 250 N and 350 N, respectively, are connected by a string that passes over a massless pulley as shown. The tension in the string is:



A. 210 N
B. 290 N
C. 410 N
D. 500 N
E. 4900 N

ans: B

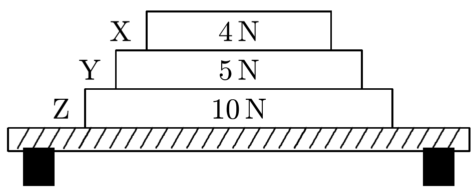
64. Three books (X, Y, and Z) rest on a table. The weight of each book is indicated. The net force acting on book Y is:



A. 4 N down
B. 5 N up
C. 9 N down
D. zero
E. none of these

ans: D

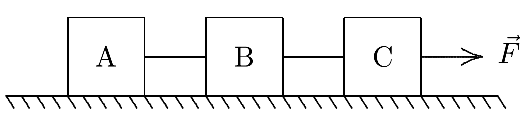
65. Three books (X, Y, and Z) rest on a table. The weight of each book is indicated. The force of book Z on book Y is:



A. 0
B. 5 N
C. 9 N
D. 14 N
E. 19 N

ans: C

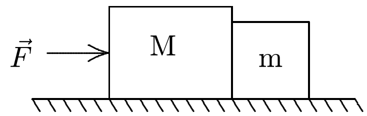
66. Three blocks (A,B,C), each having mass M, are connected by strings as shown. Block C is pulled to the right by a force $\vec{F}$ that causes the entire system to accelerate. Neglecting friction, the net force acting on block B is:



A. zero
B. $\vec{F}/3$
C. $\vec{F}/2$
D. $2\vec{F}/3$
E. $\vec{F}$

ans: B

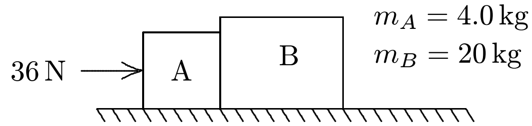
67. Two blocks with masses m and M are pushed along a horizontal frictionless surface by a horizontal applied force $\vec{F}$ as shown. The magnitude of the force of either of these blocks on the other is:



A. $mF/(m+M)$
B. mF/M
C. $mF/(M-m)$
D. $MF/(M+m)$
E. MF/m

ans: A

68. Two blocks (A and B) are in contact on a horizontal frictionless surface. A 36-N constant force is applied to A as shown. The magnitude of the force of A on B is:



A. 1.5 N
B. 6.0 N
C. 29 N
D. 30 N
E. 36 N

ans: D

69. A short 10-g string is used to pull a 50-g toy across a frictionless horizontal surface. If a 3.0×10^{-2}-N force is applied horizontally to the free end, the force of the string on the toy, at the other end, is:

A. 0.15 N
B. 6.0×10^{-3} N
C. 2.5×10^{-2} N
D. 3.0×10^{-2} N
E. 3.5×10^{-2} N

ans: C

Chapter 19: TEMPERATURE, HEAT, AND THE FIRST LAW OF THERMODYNAMICS

1. If two objects are in thermal equilibrium with each other:
   A. they cannot be moving
   B. they cannot be undergoing an elastic collision
   C. they cannot have different pressures
   D. they cannot be at different temperatures
   E. they cannot be falling in Earth's gravitational field

   ans: D

2. When two gases separated by a diathermal wall are in thermal equilibrium with each other:
   A. only their pressures must be the same
   B. only their volumes must be the same
   C. they must have the same number of particles
   D. they must have the same pressure and the same volume
   E. only their temperatures must be the same

   ans: E

3. A balloon is filled with cold air and placed in a warm room. It is NOT in thermal equilibrium with the air of the room until:
   A. it rises to the ceiling
   B. it sinks to the floor
   C. it stops expanding
   D. it starts to contract
   E. none of the above

   ans: C

4. Suppose object C is in thermal equilibrium with object A and with object B. The zeroth law of thermodynamics states:
   A. that C will always be in thermal equilibrium with both A and B
   B. that C must transfer energy to both A and B
   C. that A is in thermal equilibrium with B
   D. that A cannot be in thermal equilibrium with B
   E. nothing about the relationship between A and B

   ans: C

5. The zeroth law of thermodynamics allows us to define:
   A. work
   B. pressure
   C. temperature
   D. thermal equilibrium
   E. internal energy

   ans: C

6. If the zeroth law of thermodynamics were not valid, which of the following could not be considered a property of an object?
   A. Pressure
   B. Center of mass energy
   C. Internal energy
   D. Momentum
   E. Temperature

   ans: E

7. The international standard thermometer is kept:
   A. near Washington, D.C.
   B. near Paris, France
   C. near the north pole
   D. near Rome, Italy
   E. nowhere (there is none)

   ans: E

8. In constructing a thermometer it is NECESSARY to use a substance that:
   A. expands with rising temperature
   B. expands linearly with rising temperature
   C. will not freeze
   D. will not boil
   E. undergoes some change when heated or cooled

   ans: E

9. The "triple point" of a substance is that point for which the temperature and pressure are such that:
   A. only solid and liquid are in equilibrium
   B. only liquid and vapor are in equilibrium
   C. only solid and vapor are in equilibrium
   D. solid, liquid, and vapor are all in equilibrium
   E. the temperature, pressure and density are all numerically equal

   ans: D

10. Constant-volume gas thermometers using different gases all indicate nearly the same temperature when in contact with the same object if:
   A. the volumes are all extremely large
   B. the volumes are all the same
   D. the pressures are all extremely large
   C. the pressures are the same
   E. the particle concentrations are all extremely small

   ans: E

11. A constant-volume gas thermometer is used to measure the temperature of an object. When the thermometer is in contact with water at its triple point (273.16 K) the pressure in the thermometer is 8.500×10^4 Pa. When it is in contact with the object the pressure is 9.650×10^4 Pa. The temperature of the object is:

A. 37.0 K
B. 241 K
C. 310 K
D. 314 K
E. 2020 K

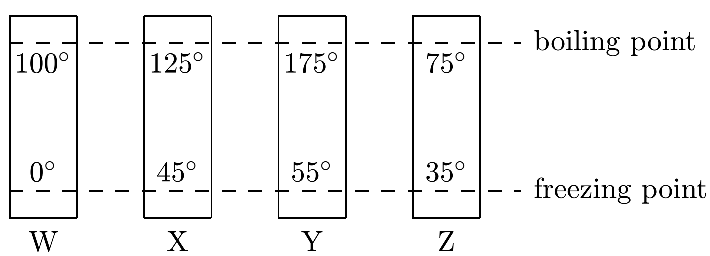
ans: C

12. When a certain constant-volume gas thermometer is in thermal contact with water at its triple point (273.16 K) the pressure is 6.30×10^4 Pa. For this thermometer a kelvin corresponds to a change in pressure of about:

A. 4.34×10^2 Pa
B. 2.31×10^2 Pa
C. 1.72×10^3 Pa
D. 2.31×10^3 Pa
E. 1.72×10^7 Pa

ans: B

13. The diagram shows four thermometers, labeled W, X, Y, and Z. The freezing and boiling points of water are indicated. Rank the thermometers according to the size of a degree on their scales, smallest to largest.



A. W, X, Y, Z
B. Z, Y, X, W
C. Z, Y, W, X
D. Z, X, W, Y
E. W, Y, Z, X

ans: D

14. There is a temperature at which the reading on the Kelvin scale is numerically:

A. equal to that on the Celsius scale
B. lower than that on the Celsius scale
C. equal to that on the Fahrenheit scale
D. less than zero
E. none of the above

ans: C

15. Fahrenheit and Kelvin scales agree numerically at a reading of:
   A. -40
   B. 0
   C. 273
   D. 301
   E. 574

   ans: E

16. Which one of the following statements is true?
   A. Temperatures differing by 25° on the Fahrenheit scale must differ by 45° on the Celsius scale
   B. 40 K corresponds to −40° C
   C. Temperatures which differ by 10° on the Celsius scale must differ by 18° on the Fahrenheit scale
   D. Water at 90° C is warmer than water at 202° F
   E. 0° F corresponds to −32° C

   ans: C

17. A Kelvin thermometer and a Fahrenheit thermometer both give the same reading for a certain sample. The corresponding Celsius temperature is:
   A. 574° C
   B. 232° C
   C. 301° C
   D. 614° C
   E. 276° C

   ans: C

18. Room temperature is about 20 degrees on the:
   A. Kelvin scale
   B. Celsius scale
   C. Fahrenheit scale
   D. absolute scale
   E. C major scale

   ans: B

19. A thermometer indicates 98.6° C. It may be:
   A. outdoors on a cold day
   B. in a comfortable room
   C. in a cup of hot tea
   D. in a normal person's mouth
   E. in liquid air

   ans: C

20. The air temperature on a summer day might be about:

A. 0° C
B. 10° C
C. 25° C
D. 80° C
E. 125° C

ans: C

21. The two metallic strips that constitute some thermostats must differ in:

A. length
B. thickness
C. mass
D. rate at which they conduct heat
E. coefficient of linear expansion

ans: E

22. Thin strips of iron and zinc are riveted together to form a bimetallic strip that bends when heated. The iron is on the inside of the bend because:

A. it has a higher coefficient of linear expansion
B. it has a lower coefficient of linear expansion
C. it has a higher specific heat
D. it has a lower specific heat
E. it conducts heat better

ans: B

23. It is more difficult to measure the coefficient of volume expansion of a liquid than that of a solid because:

A. no relation exists between linear and volume expansion coefficients
B. a liquid tends to evaporate
C. a liquid expands too much when heated
D. a liquid expands too little when heated
E. the containing vessel also expands

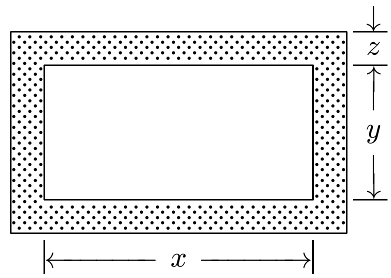
ans: E

24. A surveyor's 30-m steel tape is correct at 68° F. On a hot day the tape has expanded to 30.01 m. On that day, the tape indicates a distance of 15.52 m between two points. The true distance between these points is:

A. 15.50 m
B. 15.51 m
C. 15.52 m
D. 15.53 m
E. 15.54 m

ans: B

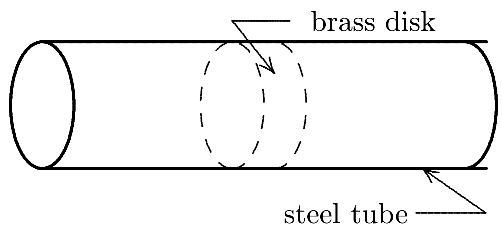
25. The figure shows a rectangular brass plate at 0° C in which there is cut a rectangular hole of dimensions indicated. If the temperature of the plate is raised to 150° C:



A. x will increase and y will decrease
B. both x and y will decrease
C. x will decrease and y will increase
D. both x and y will increase
E. the changes in x and y depend on the dimension z

ans: D

26. The Stanford linear accelerator contains hundreds of brass disks tightly fitted into a steel tube (see figure). The coefficient of linear expansion of the brass is 2.00×10^{-5} per C°. The system was assembled by cooling the disks in dry ice (−57° C) to enable them to just slide into the close-fitting tube. If the diameter of a disk is 80.00 mm at 43° C, what is its diameter in the dry ice?



A. 78.40 mm
B. 79.68 mm
C. 80.16 mm
D. 79.84 mm
E. None of these

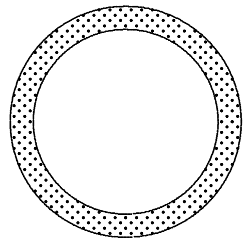
ans: D

27. When the temperature of a copper penny is increased by 100° C, its diameter increases by 0.17%. The area of one of its faces increases by:

A. 0.17%
B. 0.34%
C. 0.51%
D. 0.13%
E. 0.27%

ans: B

28. An annular ring of aluminum is cut from an aluminum sheet as shown. When this ring is heated:



A. the aluminum expands outward and the hole remains the same in size
B. the hole decreases in diameter
C. the area of the hole expands the same percent as any area of the aluminum
D. the area of the hole expands a greater percent than any area of the aluminum
E. linear expansion forces the shape of the hole to be slightly elliptical

ans: C

29. Possible units for the coefficient of volume expansion are:

A. mm/C°
B. mm^3/C°
C. $(C^\circ)^3$
D. $1/(C^\circ)^3$
E. 1/C°

ans: E

30. The mercury column in an ordinary medical thermometer doubles in length when its temperature changes from 95° F to 105° F. Choose the correct statement:

A. the coefficient of volume expansion of mercury is 0.1 per F°
B. the coefficient of volume expansion of mercury is 0.3 per F°
C. the coefficient of volume expansion of mercury is (0.1/3) per F°
D. the vacuum above the column helps to "pull up" the mercury this large amount
E. none of the above is true

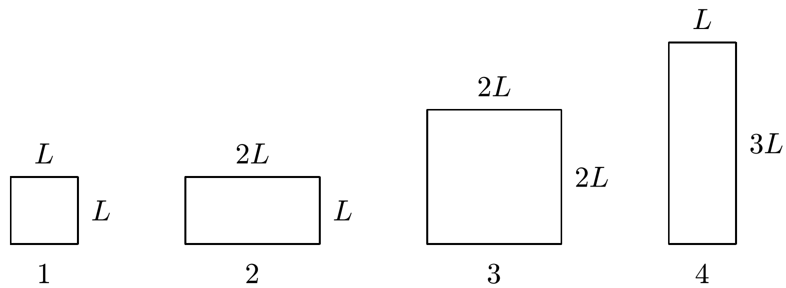
ans: E

31. The coefficient of linear expansion of iron is 1.0×10^{-5} per C° . The surface area of an iron cube, with an edge length of 5.0 cm, will increase by what amount if it is heated from 10° C to 60° C?

A. 0.0125 cm^2
B. 0.025 cm^2
C. 0.075 cm^2
D. 0.15 cm^2
E. 0.30 cm^2

ans: D

32. The diagram shows four rectangular plates and their dimensions. All are made of the same material. The temperature now increases. Of these plates:



A. the vertical dimension of plate 1 increases the most and the area of plate 1 increases the most
B. the vertical dimension of plate 2 increases the most and the area of plate 4 increases the most
C. the vertical dimension of plate 3 increases the most and the area of plate 1 increases the most
D. the vertical dimension of plate 4 increases the most and the area of plate 3 increases the most
E. the vertical dimension of plate 4 increases the most and the area of plate 4 increases the most

ans: D

33. The coefficient of linear expansion of steel is 11×10^{-6} per C° . A steel ball has a volume of exactly $100\,\text{cm}^3$ at 0° C. When heated to 100° C, its volume becomes:
A. $100.33\,\text{cm}^3$
B. $100.0011\,\text{cm}^3$
C. $100.0033\,\text{cm}^3$
D. $100.000011\,\text{cm}^3$
E. none of these

ans: A

34. The coefficient of linear expansion of a certain steel is 0.000012 per C° . The coefficient of volume expansion, in $(\text{C}^\circ)^{-1}$, is:
A. $(0.000012)^3$
B. $(4\pi/3)(0.000012)^3$
C. 3×0.000012
D. 0.000012
E. depends on the shape of the volume to which it will be applied

ans: C

35. Metal pipes, used to carry water, sometimes burst in the winter because:
A. metal contracts more than water
B. outside of the pipe contracts more than the inside
C. metal becomes brittle when cold
D. ice expands when it melts
E. water expands when it freezes

ans: E

36. A gram of distilled water at 4° C:

A. will increase slightly in weight when heated to 6° C
B. will decrease slightly in weight when heated to 6° C
C. will increase slightly in volume when heated to 6° C
D. will decrease slightly in volume when heated to 6° C
E. will not change in either volume or weight

ans: D

37. Heat is:

A. energy transferred by virtue of a temperature difference
B. energy transferred by macroscopic work
C. energy content of an object
D. a temperature difference
E. a property objects have by virtue of their temperatures

ans: A

38. Heat has the same units as:

A. temperature
B. work
C. energy/time
D. heat capacity
E. energy/volume

ans: B

39. A calorie is about:

A. 0.24 J
B. 8.3 J
C. 250 J
D. 4.2 J
E. 4200 J

ans: D

40. The heat capacity of an object is:

A. the amount of heat energy that raises its temperature by 1° C
B. the amount of heat energy that changes its state without changing its temperature
C. the amount of heat energy per kilogram that raises its temperature by 1° C
D. the ratio of its specific heat to that of water
E. the change in its temperature caused by adding 1 J of heat

ans: A

41. The specific heat of a substance is:

A. the amount of heat energy to change the state of one gram of the substance
B. the amount of heat energy per unit mass emitted by oxidizing the substance
C. the amount of heat energy per unit mass to raise the substance from its freezing to its boiling point
D. the amount of heat energy per unit mass to raise the temperature of the substance by 1° C
E. the temperature of the object divided by its mass

ans: D

42. Two different samples have the same mass and temperature. Equal quantities of energy are absorbed as heat by each. Their final temperatures may be different because the samples have different:

A. thermal conductivities
B. coefficients of expansion
C. densities
D. volumes
E. heat capacities

ans: E

43. The same energy Q enters five different substances as heat.

The temperature of 3 g of substance A increases by 10 K
The temperature of 4 g of substance B increases by 4 K
The temperature of 6 g of substance C increases by 15 K
The temperature of 8 g of substance D increases by 6 K
The temperature of 10 g of substance E increases by 10 K

Which substance has the greatest specific heat?

ans: B

44. For constant-volume processes the heat capacity of gas A is greater than the heat capacity of gas B. We conclude that when they both absorb the same energy as heat at constant volume:

A. the temperature of A increases more than the temperature of B
B. the temperature of B increases more than the temperature of A
C. the internal energy of A increases more than the internal energy of B
D. the internal energy of B increases more than the internal energy of A
E. A does more positive work than B

ans: B

45. The heat capacity at constant volume and the heat capacity at constant pressure have different values because:

A. heat increases the temperature at constant volume but not at constant pressure
B. heat increases the temperature at constant pressure but not at constant volume
C. the system does work at constant volume but not at constant pressure
D. the system does work at constant pressure but not at constant volume
E. the system does more work at constant volume than at constant pressure

ans: D

46. A cube of aluminum has an edge length of 20 cm. Aluminum has a density 2.7 times that of water ($1\,g/cm^3$) and a specific heat 0.217 times that of water ($1\,cal/g \cdot C^\circ$). When the internal energy of the cube increases by 47000 cal its temperature increases by:

A. $5\,C^\circ$
B. $10\,C^\circ$
C. $20\,C^\circ$
D. $100\,C^\circ$
E. $200\,C^\circ$

ans: B

47. An insulated container, filled with water, contains a thermometer and a paddle wheel. The paddle wheel can be rotated by an external source. This apparatus can be used to determine:

A. specific heat of water
B. relation between kinetic energy and absolute temperature
C. thermal conductivity of water
D. efficiency of changing work into heat
E. mechanical equivalent of heat

ans: E

48. Take the mechanical equivalent of heat as 4 J/cal. A 10-g bullet moving at 2000 m/s plunges into 1 kg of paraffin wax (specific heat $0.7\,cal/g \cdot C^\circ$). The wax was initially at 20° C. Assuming that all the bullet's energy heats the wax, its final temperature (in $^\circ$ C) is:

A. 20.14
B. 23.5
C. 20.006
D. 27.1
E. 30.23

ans: D

49. The energy given off as heat by 300 g of an alloy as it cools through $50\,C^\circ$ raises the temperature of 300 g of water from 30° C to 40° C. The specific heat of the alloy (in $cal/g \cdot C^\circ$) is:

A. 0.015
B. 0.10
C. 0.15
D. 0.20
E. 0.50

ans: D

50. The specific heat of lead is $0.030\,cal/g \cdot C^\circ$. 300 g of lead shot at 100° C is mixed with 100 g of water at 70° C in an insulated container. The final temperature of the mixture is:

A. 100° C
B. 85.5° C
C. 79.5° C
D. 74.5° C
E. 72.5° C

ans: E

51. Object A, with heat capacity C_A and initially at temperature T_A, is placed in thermal contact with object B, with heat capacity C_B and initially at temperature T_B. The combination is thermally isolated. If the heat capacities are independent of the temperature and no phase changes occur, the final temperature of both objects is:

A. $(C_A T_A - C_B T_B)/(C_A + C_B)$
B. $(C_A T_A + C_B T_B)/(C_A + C_B)$
C. $(C_A T_A - C_B T_B)/(C_A - C_B)$
D. $(C_A - C_B)|T_A - T_B|$
E. $(C_A + C_B)|T_A - T_B|$

ans: B

52. The heat capacity of object B is twice that of object A. Initially A is at 300 K and B is at 450 K. They are placed in thermal contact and the combination is isolated. The final temperature of both objects is:

A. 200 K
B. 300 K
C. 400 K
D. 450 K
E. 600 K

ans: C

53. A heat of transformation of a substance is:

A. the energy absorbed as heat during a phase transformation
B. the energy per unit mass absorbed as heat during a phase transformation
C. the same as the heat capacity
D. the same as the specific heat
E. the same as the molar specific heat

ans: B

54. The heat of fusion of water is cal/g. This means 80 cal of energy are required to:

A. raise the temperature of 1 g of water by 1 K
B. turn 1 g of water to steam
C. raise the temperature of 1 g of ice by 1 K
D. melt 1 g of ice
E. increase the internal energy of 80 g of water by 1 cal

ans: D

55. Solid A, with mass M, is at its melting point T_A. It is placed in thermal contact with solid B, with heat capacity C_B and initially at temperature T_B ($T_B > T_A$). The combination is thermally isolated. A has latent heat of fusion L and when it has melted has heat capacity C_A. If A completely melts the final temperature of both A and B is:

A. $(C_A T_A + C_B T_B - ML)/(C_A + C_B)$
B. $(C_A T_A - C_B T_B + ML)/(C_A + C_B)$
C. $(C_A T_A - C_B T_B - ML)/(C_A + C_B)$
D. $(C_A T_A + C_B T_B + ML)/(C_A - C_B)$
E. $(C_A T_A + C_B T_B + ML)/(C_A - C_B)$

ans: A

56. During the time that latent heat is involved in a change of state:

A. the temperature does not change
B. the substance always expands
C. a chemical reaction takes place
D. molecular activity remains constant
E. kinetic energy changes into potential energy

ans: A

57. The formation of ice from water is accompanied by:

A. absorption of energy as heat
B. temperature increase
C. decrease in volume
D. an evolution of heat
E. temperature decrease

ans: A

58. How many calories are required to change one gram of 0° C ice to 100° C steam? The latent heat of fusion is 80 cal/g and the latent heat of vaporization is 540 cal/g. The specific heat of water is $1.00\,\mathrm{cal/g\cdot K}$.

A. 100
B. 540
C. 620
D. 720
E. 900

ans: D

59. Ten grams of ice at -20° C is to be changed to steam at 130° C. The specific heat of both ice and steam is $0.5\,\mathrm{cal/g\cdot C^\circ}$. The heat of fusion is 80 cal/g and the heat of vaporization is 540 cal/g. The entire process requires:

A. 750 cal
B. 1250 cal
C. 6950 cal
D. 7450 cal
E. 7700 cal

ans: D

60. Steam at 1 atm and 100° C enters a radiator and leaves as water at 1 atm and 80° C. Take the heat of vaporization to be 540 cal/g. Of the total energy given off as heat, what percent arises from the cooling of the water?

A. 100
B. 54
C. 26
D. 14
E. 3.6

ans: E

61. A certain humidifier operates by raising water to the boiling point and then evaporating it. Every minute 30 g of water at 20° C are added to replace the 30 g that are evaporated. The heat of fusion of water is 333 kJ/kg, the heat of vaporization is 2256 kJ/kg, and the specific heat is 4190 J/kg · K. How many joules of energy per minute does this humidifier require?

A. 3.0×10^4
B. 8.8×10^4
C. 7.8×10^4
D. 1.1×10^5
E. 2.0×10^4

ans: B

62. A metal sample of mass M requires a power input P to just remain molten. When the heater is turned off, the metal solidifies in a time T. The specific latent heat of fusion of this metal is:

A. P/MT
B. T/PM
C. PM/T
D. PMT
E. PT/M

ans: E

63. Fifty grams of ice at 0° C is placed in a thermos bottle containing one hundred grams of water at 6° C. How many grams of ice will melt? The heat of fusion of water is 333 kJ/kg and the specific heat is 4190 J/kg · K.

A. 7.5
B. 2.0
C. 8.3
D. 17
E. 50

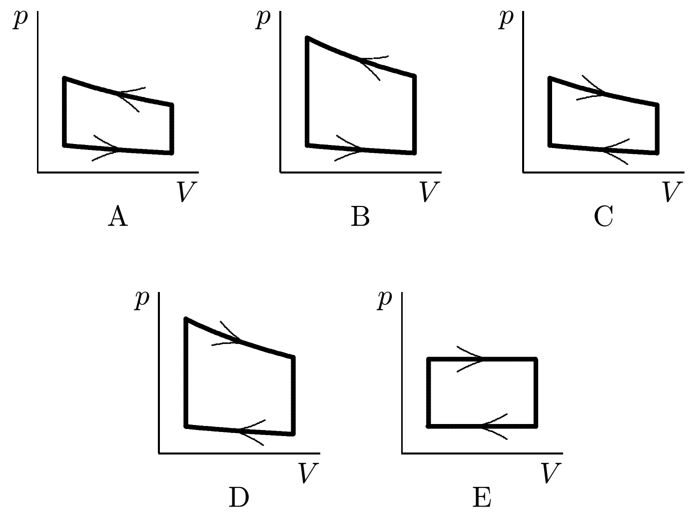
ans: A

64. According to the first law of thermodynamics, applied to a gas, the increase in the internal energy during any process:

A. equals the heat input minus the work done on the gas
B. equals the heat input plus the work done on the gas
C. equals the work done on the gas minus the heat input
D. is independent of the heat input
E. is independent of the work done on the gas

ans: B

65. Pressure versus volume graphs for a certain gas undergoing five different cyclic processes are shown below. During which cycle does the gas do the greatest positive work?



ans: D

66. During an adiabatic process an object does 100 J of work and its temperature decreases by 5 K. During another process it does 25 J of work and its temperature decreases by 5 K. Its heat capacity for the second process is:

A. 20 J/K
B. 24 J/K
C. 5 J/K
D. 15 J/K
E. 100 J/K

ans: D

67. A system undergoes an adiabatic process in which its internal energy increases by 20 J. Which of the following statements is true?

A. 20 J of work was done on the system
B. 20 J of work was done by the system
C. the system received 20 J of energy as heat
D. the system lost 20 J of energy as heat
E. none of the above are true

ans: A

68. In an adiabatic process:

A. the energy absorbed as heat equals the work done by the system on its environment
B. the energy absorbed as heat equals the work done by the environment on the system
C. the absorbed as heat equals the change in internal energy
D. the work done by the environment on the system equals the change in internal energy
E. the work done by the system on its environment equals to the change in internal energy

ans: D

69. In a certain process a gas ends in its original thermodynamic state. Of the following, which is possible as the net result of the process?

A. It is adiabatic and the gas does 50 J of work
B. The gas does no work but absorbs 50 J of energy as heat
C. The gas does no work but loses 50 J of energy as heat
D. The gas loses 50 J of energy as heat and does 50 J of work
E. The gas absorbs 50 J of energy as heat and does 50 J of work

ans: E

70. Of the following which might NOT vanish over one cycle of a cyclic process?

A. the change in the internal energy of the substance
B. the change in pressure of the substance
C. the work done by the substance
D. the change in the volume of the substance
E. the change in the temperature of the substance

ans: C

71. Of the following which might NOT vanish over one cycle of a cyclic process?

A. the work done by the substance minus the energy absorbed by the substance as heat
B. the change in the pressure of the substance
C. the energy absorbed by the substance as heat
D. the change in the volume of the substance
E. the change in the temperature of the substance

ans: C

72. The unit of thermal conductivity might be:

A. $\text{cal} \cdot \text{cm}/(\text{s} \cdot \text{C}^\circ)$
B. $\text{cal}/(\text{cm} \cdot \text{s} \cdot \text{C}^\circ)$
C. $\text{cal} \cdot \text{s}/(\text{cm} \cdot \text{C}^\circ)$
D. $\text{cm} \cdot \text{s} \cdot \text{C}^\circ\text{C}/\text{cal}$
E. $\text{C}^\circ/(\text{cal} \cdot \text{cm} \cdot \text{s})$

ans: B

73. A slab of material has area A, thickness L, and thermal conductivity k. One of its surfaces (P) is maintained at temperature T_1 and the other surface (Q) is maintained at a lower temperature T_2. The rate of heat flow by conduction from P to Q is:

A. $kA(T_1 - T_2)/L^2$
B. $kL(T_1 - T_2)/A$
C. $kA(T_1 - T_2)/L$
D. $k(T_1 - T_2)/(LA)$
E. $LA(T_1 - T_2)/k$

ans: C

74. The rate of heat flow by conduction through a slab does NOT depend upon the:

A. temperature difference between opposite faces of the slab
B. thermal conductivity of the slab
C. slab thickness
D. cross-sectional area of the slab
E. specific heat of the slab

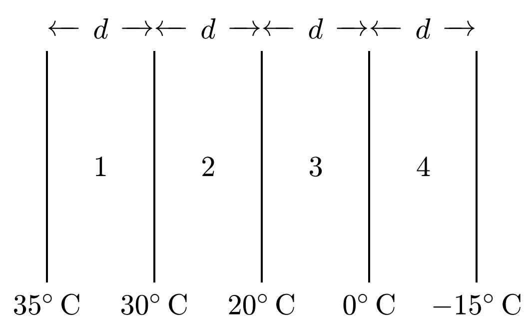
ans: E

75. The rate of heat flow by conduction through a slab is P_{cond}. If the slab thickness is doubled, its cross-sectional area is halved, and the temperature difference across it is doubled, then the rate of heat flow becomes:

A. $2P_{\text{cond}}$
B. $P_{\text{cond}}/2$
C. P_{cond}
D. $P_{\text{cond}}/8$
E. $8P_{\text{cond}}$

ans: B

76. The diagram shows four slabs of different materials with equal thickness, placed side by side. Heat flows from left to right and the steady-state temperatures of the interfaces are given. Rank the materials according to their thermal conductivities, smallest to largest.



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

ans: D

77. Inside a room at a uniform comfortable temperature, metallic objects generally feel cooler to the touch than wooden objects do. This is because:

A. a given mass of wood contains more heat than the same mass of metal
B. metal conducts heat better than wood
C. heat tends to flow from metal to wood
D. the equilibrium temperature of metal in the room is lower than that of wood
E. the human body, being organic, resembles wood more closely than it resembles metal

ans: B

78. On a very cold day, a child puts his tongue against a fence post. It is much more likely that his tongue will stick to a steel post than to a wooden post. This is because:

A. steel has a higher specific heat
B. steel is a better radiator of heat
C. steel has a higher specific gravity
D. steel is a better heat conductor
E. steel is a highly magnetic material

ans: D

79. An iron stove, used for heating a room by radiation, is more efficient if:

A. its inner surface is highly polished
B. its inner surface is covered with aluminum paint
C. its outer surface is covered with aluminum paint
D. its outer surface is rough and black
E. its outer surface is highly polished

ans: D

80. To help keep buildings cool in the summer, dark colored window shades have been replaced by light colored shades. This is because light colored shades:

A. are more pleasing to the eye
B. absorb more sunlight
C. reflect more sunlight
D. transmit more sunlight
E. have a lower thermal conductivity

ans: C

81. Which of the following statements pertaining to a vacuum flask (thermos) is NOT correct?

A. Silvering reduces radiation loss
B. Vacuum reduces conduction loss
C. Vacuum reduces convection loss
D. Vacuum reduces radiation loss
E. Glass walls reduce conduction loss

ans: D

82. A thermos bottle works well because:

A. its glass walls are thin
B. silvering reduces convection
C. vacuum reduces heat radiation
D. silver coating is a poor heat conductor
E. none of the above

ans: E

Chapter 20: ENTROPY AND THE SECOND LAW OF THERMODYNAMICS

1. In a reversible process the system:
   A. is always close to equilibrium states
   B. is close to equilibrium states only at the beginning and end
   C. might never be close to any equilibrium state
   D. is close to equilibrium states throughout, except at the beginning and end
   E. is none of the above

   ans: A

2. A slow (quasi-static) process is NOT reversible if:
   A. the temperature changes
   B. energy is absorbed or emitted as heat
   C. work is done on the system
   D. friction is present
   E. the pressure changes

   ans: D

3. The difference in entropy $\Delta S = S_B - S_A$ for two states A and B of a system can be computed as the integral $\int dQ/T$ provided:
   A. A and B are on the same adiabat
   B. A and B have the same temperature
   C. a reversible path is used for the integral
   D. the change in internal energy is first computed
   E. the energy absorbed as heat by the system is first computed

   ans: C

4. Possible units of entropy are:
   A. J
   B. J/K
   C. J^{-1}
   D. liter·atm
   E. cal/mol

   ans: B

5. Which of the following is NOT a state variable?
   A. Work
   B. Internal energy
   C. Entropy
   D. Temperature
   E. Pressure

   ans: A

6. The change in entropy is zero for:
   A. reversible adiabatic processes
   B. reversible isothermal processes
   C. reversible processes during which no work is done
   D. reversible isobaric processes
   E. all adiabatic processes

   ans: A

7. Which of the following processes leads to a change in entropy of zero for the system undergoing the process?
   A. Non-cyclic isobaric (constant pressure)
   B. Non-cyclic isochoric (constant volume)
   C. Non-cyclic isothermal (constant temperature)
   D. Any closed cycle
   E. None of these

   ans: D

8. Rank, from smallest to largest, the changes in entropy of a pan of water on a hot plate, as the temperature of the water
   1. goes from 20° C to 30° C
   2. goes from 30° C to 40° C
   3. goes from 40° C to 45° C
   4. goes from 80° C to 85° C

   A. 1, 2, 3, 4
   B. 4, 3, 2, 1
   C. 1 and 2 tie, then 3 and 4 tie
   D. 3 and 4 tie, then 1 and 2 tie
   E. 4, 3, 2, 1

   ans: E

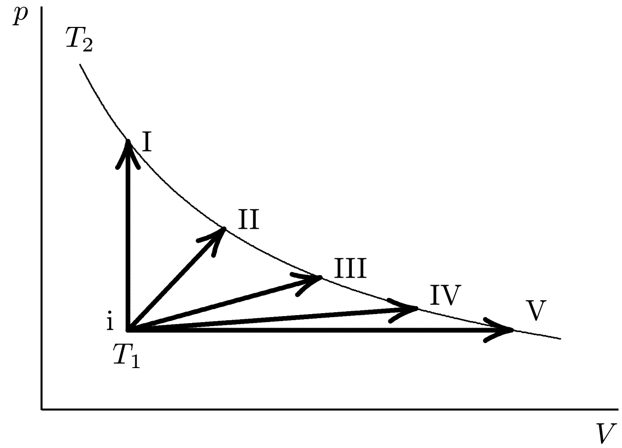
9. An ideal gas expands into a vacuum in a rigid vessel. As a result there is:
   A. a change in entropy
   D. an increase of pressure
   B. a change in temperature
   E. a decrease of internal energy
   C. a change in phase

   ans: A

10. Consider all possible isothermal contractions of an ideal gas. The change in entropy of the gas:
   A. is zero for all of them
   B. does not decrease for any of them
   C. does not increase for any of them
   D. increases for all of them
   E. decreases for all of them

   ans: E

11. An ideal gas is to taken reversibly from state i, at temperature T_1, to any of the other states labeled I, II, III, IV, and V on the p-V diagram below. All are at the same temperature T_2. Rank the five processes according to the change in entropy of the gas, least to greatest.



A. I, II, III, IV, V
B. V, IV, III, II, I
C. I, then II, III, IV, and V tied
D. I, II, III, and IV tied, then V
E. I and V tied, then II, III, IV

ans: A

12. An ideal gas, consisting of n moles, undergoes a reversible isothermal process during which the volume changes from V_i to V_f. The change in entropy of the thermal reservoir in contact with the gas is given by:

A. $nR(V_f - V_i)$
B. $nR\ln(V_f - V_i)$
C. $nR\ln(V_i/V_f)$
D. $nR\ln(V_f/V_i)$
E. none of the above (entropy can't be calculated for a reversible process)

ans: C

13. One mole of an ideal gas expands reversibly and isothermally at temperature T until its volume is doubled. The change of entropy of this gas for this process is:

A. $R\ln 2$
B. $(\ln 2)/T$
C. 0
D. $RT\ln 2$
E. $2R$

ans: A

14. An ideal gas, consisting of n moles, undergoes an irreversible process in which the temperature has the same value at the beginning and end. If the volume changes from V_i to V_f, the change in entropy of the gas is given by:

A. $nR(V_f - V_i)$
B. $nR\ln(V_f - V_i)$
C. $nR\ln(V_i/V_f)$
D. $nR\ln(V_f/V_i)$
E. none of the above (entropy can't be calculated for an irreversible process)

ans: D

15. The temperature of n moles of a gas is increased from T_i to T_f at constant volume. If the molar specific heat at constant volume is C_V and is independent of temperature, then change in the entropy of the gas is:

A. $nC_V\ln(T_f/T_i)$
B. $nC_V\ln(T_i/T_f)$
C. $nC_V\ln(T_f - T_i)$
D. $nC_V\ln(1 - T_i/T_f)$
E. $nC_V(T_f - T_i)$

ans: A

16. Consider the following processes: The temperature of two identical gases are increased from the same initial temperature to the same final temperature. Reversible processes are used. For gas A the process is carried out at constant volume while for gas B it is carried out at constant pressure. The change in entropy:

A. is the same for A and B
B. is greater for A
C. is greater for B
D. is greater for A only if the initial temperature is low
E. is greater for A only if the initial temperature is high

ans: C

17. A hot object and a cold object are placed in thermal contact and the combination is isolated. They transfer energy until they reach a common temperature. The change ΔS_h in the entropy of the hot object, the change ΔS_c in the entropy of the cold object, and the change ΔS_{total} in the entropy of the combination are:

A. $\Delta S_h > 0$, $\Delta S_c > 0$, $\Delta S_{\text{total}} > 0$
B. $\Delta S_h < 0$, $\Delta S_c > 0$, $\Delta S_{\text{total}} > 0$
C. $\Delta S_h < 0$, $\Delta S_c > 0$, $\Delta S_{\text{total}} < 0$
D. $\Delta S_h > 0$, $\Delta S_c < 0$, $\Delta S_{\text{total}} > 0$
E. $\Delta S_h > 0$, $\Delta S_c < 0$, $\Delta S_{\text{total}} < 0$

ans: B

18. Let S_I denote the change in entropy of a sample for an irreversible process from state A to state B. Let S_R denote the change in entropy of the same sample for a reversible process from state A to state B. Then:

A. $S_I > S_R$
B. $S_I = S_R$
C. $S_I < S_R$
D. $S_I = 0$
E. $S_R = 0$

ans: B

19. For all adiabatic processes:

A. the entropy of the system does not change
B. the entropy of the system increases
C. the entropy of the system decreases
D. the entropy of the system does not increase
E. the entropy of the system does not decrease

ans: E

20. For all reversible processes involving a system and its environment:

A. the entropy of the system does not change
B. the entropy of the system increases
C. the total entropy of the system and its environment does not change
D. the total entropy of the system and its environment increases
E. none of the above

ans: C

21. For all irreversible processes involving a system and its environment:

A. the entropy of the system does not change
B. the entropy of the system increases
C. the total entropy of the system and its environment does not change
D. the total entropy of the system and its environment increases
E. none of the above

ans: D

22. According to the second law of thermodynamics:

A. heat energy cannot be completely converted to work
B. work cannot be completely converted to heat energy
C. for all cyclic processes we have $dQ/T < 0$
D. the reason all heat engine efficiencies are less than 100% is friction, which is unavoidable
E. all of the above are true

ans: A

23. Consider the following processes:

I. Energy flows as heat from a hot object to a colder object
II. Work is done on a system and an equivalent amount of energy is rejected as heat by the system
III. Energy is absorbed as heat by a system and an equivalent amount of work is done by the system

Which are never found to occur?

A. Only I
B. Only II
C. Only III
D. Only II and III
E. I, II, and III

ans: C

24. An inventor suggests that a house might be heated by using a refrigerator to draw energy as heat from the ground and reject energy as heat into the house. He claims that the energy supplied to the house as heat can exceed the work required to run the refrigerator. This:

A. is impossible by first law
B. is impossible by second law
C. would only work if the ground and the house were at the same temperature
D. is impossible since heat energy flows from the (hot) house to the (cold) ground
E. is possible

ans: E

25. In a thermally insulated kitchen, an ordinary refrigerator is turned on and its door is left open. The temperature of the room:

A. remains constant according to the first law of thermodynamics
B. increases according to the first law of thermodynamics
C. decreases according to the first law of thermodynamics
D. remains constant according to the second law of thermodynamics
E. increases according to the second law of thermodynamics

ans: B

26. A heat engine:

A. converts heat input to an equivalent amount of work
B. converts work to an equivalent amount of heat
C. takes heat in, does work, and loses energy as heat
D. uses positive work done on the system to transfer heat from a low temperature reservoir to a high temperature reservoir
E. uses positive work done on the system to transfer heat from a high temperature reservoir to a low temperature reservoir.

ans: C

27. A heat engine absorbs energy of magnitude $|Q_H|$ as heat from a high temperature reservoir, does work of magnitude $|W|$, and transfers energy of magnitude $|Q_L|$ as heat to a low temperature reservoir. Its efficiency is:

A. $|Q_H|/|W|$
B. $|Q_L|/|W|$
C. $|Q_H|/|Q_L|$
D. $|W|/|Q_H|$
E. $|W|/|Q_L|$

ans: D

28. The temperatures T_C of the cold reservoirs and the temperatures T_H of the hot reservoirs for four Carnot heat engines are

engine 1: $T_C = 400\,\mathrm{K}$ and $T_H = 500\,\mathrm{K}$
engine 2: $T_C = 500\,\mathrm{K}$ and $T_H = 600\,\mathrm{K}$
engine 3: $T_C = 400\,\mathrm{K}$ and $T_H = 600\,\mathrm{K}$
engine 4: $T_C = 600\,\mathrm{K}$ and $T_H = 800\,\mathrm{K}$

Rank these engines according to their efficiencies, least to greatest

A. 1, 2, 3, 4
B. 1 and 2 tie, then 3 and 4 tie
C. 2, 1, 3, 4
D. 1, 2, 4, 3
E. 2, 1, 4, 3

ans: E

29. A Carnot heat engine runs between a cold reservoir at temperature T_C and a hot reservoir at temperature T_H. You want to increase its efficiency. Of the following, which change results in the greatest increase in efficiency? The value of ΔT is the same for all changes.

A. Raise the temperature of the hot reservoir by ΔT
B. Raise the temperature of the cold reservoir by ΔT
C. Lower the temperature of the hot reservoir by ΔT
D. Lower the temperature of the cold reservoir by ΔT
E. Lower the temperature of the hot reservoir by $\frac{1}{2}\Delta T$ and raise the temperature of the cold reservoir by $\frac{1}{2}\Delta T$

ans: D

30. 31. A certain heat engine draws 500 cal/s from a water bath at 27° C and transfers 400 cal/s to a reservoir at a lower temperature. The efficiency of this engine is:

A. 80%
B. 75%
C. 55%
D. 25%
E. 20%

ans: E

32. A heat engine that in each cycle does positive work and loses energy as heat, with no heat energy input, would violate:

A. the zeroth law of thermodynamics
B. the first law of thermodynamics
C. the second law of thermodynamics
D. the third law of thermodynamics
E. Newton's second law

ans: B

33. A cyclical process that transfers energy as heat from a high temperature reservoir to a low temperature reservoir with no other change would violate:

A. the zeroth law of thermodynamics
B. the first law of thermodynamics
C. the second law of thermodynamics
D. the third law of thermodynamics
E. none of the above

ans: E

34. On a warm day a pool of water transfers energy to the air as heat and freezes. This is a direct violation of:

A. the zeroth law of thermodynamics
B. the first law of thermodynamics
C. the second law of thermodynamics
D. the third law of thermodynamics
E. none of the above

ans: C

35. A heat engine in each cycle absorbs energy of magnitude $|Q_H|$ as heat from a high temperature reservoir, does work of magnitude $|W|$, and then absorbs energy of magnitude $|Q_L|$ as heat from a low temperature reservoir. If $|W| = |Q_H| + |Q_L|$ this engine violates:

A. the zeroth law of thermodynamics
B. the first law of thermodynamics
C. the second law of thermodynamics
D. the third law of thermodynamics
E. none of the above

ans: C

36. A heat engine in each cycle absorbs energy from a reservoir as heat and does an equivalent amount of work, with no other changes. This engine violates:

A. the zeroth law of thermodynamics
B. the first law of thermodynamics
C. the second law of thermodynamics
D. the third law of thermodynamics
E. none of the above

ans: C

37. A Carnot cycle:

A. is bounded by two isotherms and two adiabats on a p-V graph
B. consists of two isothermal and two constant volume processes
C. is any four-sided process on a p-V graph
D. only exists for an ideal gas
E. has an efficiency equal to the enclosed area on a p-V diagram

ans: A

38. According to the second law of thermodynamics:

A. all heat engines have the same efficiency
B. all reversible heat engines have the same efficiency
C. the efficiency of any heat engine is independent of its working substance
D. the efficiency of a Carnot engine depends only on the temperatures of the two reservoirs
E. all Carnot engines theoretically have 100% efficiency

ans: D

39. A Carnot heat engine operates between 400 K and 500 K. Its efficiency is:

A. 20%
B. 25%
C. 44%
D. 79%
E. 100%

ans: A

40. A Carnot heat engine operates between a hot reservoir at absolute temperature T_H and a cold reservoir at absolute temperature T_C. Its efficiency is:

A. T_H/T_C
B. T_C/T_H
C. $1 - T_H/T_C$
D. $1 - T_C/T_H$
E. 100%

ans: D

41. A heat engine operates between a high temperature reservoir at T_H and a low temperature reservoir at T_L. Its efficiency is given by $1 - T_L/T_H$:

A. only if the working substance is an ideal gas
B. only if the engine is reversible
C. only if the engine is quasi-static
D. only if the engine operates on a Stirling cycle
E. no matter what characteristics the engine has

ans: B

42. The maximum theoretical efficiency of a Carnot heat engine operating between reservoirs at the steam point and at room temperature is about:

A. 10%
B. 20%
C. 50%
D. 80%
E. 99%

ans: B

43. An inventor claims to have a heat engine that has an efficiency of 40% when it operates between a high temperature reservoir of 150° C and a low temperature reservoir of 30° C. This engine:

A. must violate the zeroth law of thermodynamics
B. must violate the first law of thermodynamics
C. must violate the second law of thermodynamics
D. must violate the third law of thermodynamics
E. does not necessarily violate any of the laws of thermodynamics

ans: C

44. A Carnot heat engine and an irreversible heat engine both operate between the same high temperature and low temperature reservoirs. They absorb the same energy from the high temperature reservoir as heat. The irreversible engine:

A. does more work
B. transfers more energy to the low temperature reservoir as heat
C. has the greater efficiency
D. has the same efficiency as the reversible engine
E. cannot absorb the same energy from the high temperature reservoir as heat without violating the second law of thermodynamics

ans: B

45. A perfectly reversible heat pump with a coefficient of performance of 14 supplies energy to a building as heat to maintain its temperature at 27° C. If the pump motor does work at the rate of 1 kW, at what rate does the pump supply energy to the building as heat?

A. 15 kW
B. 3.85 kW
C. 1.35 kW
D. 1.07 kW
E. 1.02 kW

ans: A

46. A heat engine operates between 200 K and 100 K. In each cycle it takes 100 J from the hot reservoir, loses 25 J to the cold reservoir, and does 75 J of work. This heat engine violates:

A. both the first and second laws of thermodynamics
B. the first law but not the second law of thermodynamics
C. the second law but not the first law of thermodynamics
D. neither the first law nor the second law of thermodynamics
E. cannot answer without knowing the mechanical equivalent of heat

ans: C

47. A refrigerator absorbs energy of magnitude $|Q_C|$ as heat from a low temperature reservoir and transfers energy of magnitude $|Q_H|$ as heat to a high temperature reservoir. Work W is done on the working substance. The coefficient of performance is given by:

A. $|Q_C|/W$
B. $|Q_H|/W$
C. $(|Q_C| + |Q_H|)/W$
D. $W/|Q_C|$
E. $W/|Q_H|$

ans: A

48. A reversible refrigerator operates between a low temperature reservoir at T_C and a high temperature reservoir at T_H. Its coefficient of performance is given by:

A. $(T_H - T_C)/T_C$
B. $T_C/(T_H - T_C)$
C. $(T_H - T_C)/T_H$
D. $T_H/(T_H - T_C)$
E. $T_H(T_H + T_C)$

ans: B

49. An Carnot refrigerator runs between a cold reservoir at temperature T_C and a hot reservoir at temperature T_H. You want to increase its coefficient of performance. Of the following, which change results in the greatest increase in the coefficient? The value of ΔT is the same for all changes.

A. Raise the temperature of the hot reservoir by ΔT
B. Raise the temperature of the cold reservoir by ΔT
C. Lower the temperature of the hot reservoir by ΔT
D. Lower the temperature of the cold reservoir by ΔT
E. Lower the temperature of the hot reservoir by $\frac{1}{2}\Delta T$ and raise the temperature of the cold reservoir by $\frac{1}{2}\Delta T$

ans: B

50. For one complete cycle of a reversible heat engine, which of the following quantities is NOT zero?

A. the change in the entropy of the working gas
B. the change in the pressure of the working gas
C. the change in the internal energy of the working gas
D. the work done by the working gas
E. the change in the temperature of the working gas

ans: D

51. Twenty-five identical molecules are in a box. Microstates are designated by identifying the molecules in the left and right halves of the box. The multiplicity of the configuration with 15 molecules in the right half and 10 molecules in the left half is:

A. 1.03×10^{23}
B. 3.27×10^{6}
C. 150
D. 25
E. 5

ans: B

52. Twenty-five identical molecules are in a box. Microstates are designated by identifying the molecules in the left and right halves of the box. The Boltzmann constant is 1.38×10^{-23} J/K. The entropy associated with the configuration for which 15 molecules are in the left half and 10 molecules are in the right half is:

A. 2.07×10^{-22} J/K
B. 7.31×10^{-22} J/K
C. 4.44×10^{-23} J/K
D. 6.91×10^{-23} J/K
E. 2.22×10^{-23} J/K

ans: A

53. The thermodynamic state of a gas changes from one with 3.8×10^{18} microstates to one with 7.9×10^{19} microstates. The Boltzmann constant is 1.38×10^{-23} J/K. The change in entropy is:

A. $\Delta S = 0$
B. $\Delta S = 1.04 \times 10^{-23}$ J/K
C. $\Delta S = -1.04 \times 10^{-23}$ J/K
D. $\Delta S = 4.19 \times 10^{-23}$ J/K
E. $\Delta S = -4.19 \times 10^{-23}$ J/K

ans: D

54. Let k be the Boltzmann constant. If the configuration of the molecules in a gas changes so that the multiplicity is reduced to one-third its previous value, the entropy of the gas changes by:

A. $\Delta S = 0$
B. $\Delta S = 3k \ln 2$
C. $\Delta S = -3k \ln 2$
D. $\Delta S = -k \ln 3$
E. $\Delta S = k \ln 3$

ans: D

55. Let k be the Boltzmann constant. If the configuration of molecules in a gas changes from one with a multiplicity of M_1 to one with a multiplicity of M_2, then entropy changes by:

A. $\Delta S = 0$
B. $\Delta S = k(M_2 - M_1)$
C. $\Delta S = kM_2/M_1$
D. $\Delta S = k \ln(M_2 M_1)$
E. $\Delta S = k \ln(M_2/M_1)$

ans: E

56. Let k be the Boltzmann constant. If the thermodynamic state of a gas at temperature T changes isothermally and reversibly to a state with three times the number of microstates as initially, the energy input to the gas as heat is:

A. $Q = 0$
B. $Q = 3kT$
C. $Q = -3kT$
D. $kT \ln 3$
E. $-kT \ln 3$

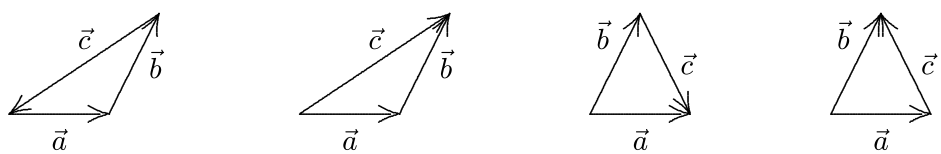
ans: D

Chapter 3: VECTORS

1. We say that the displacement of a particle is a vector quantity. Our best justification for this assertion is:
   A. displacement can be specified by a magnitude and a direction
   B. operating with displacements according to the rules for manipulating vectors leads to results in agreement with experiments
   C. a displacement is obviously not a scalar
   D. displacement can be specified by three numbers
   E. displacement is associated with motion

   ans: B

2. The vectors $\vec{a}$, $\vec{b}$, and $\vec{c}$ are related by $\vec{c} = \vec{b} - \vec{a}$. Which diagram below illustrates this relationship?



A B C D

   E. None of these

   ans: D

3. A vector of magnitude 3 CANNOT be added to a vector of magnitude 4 so that the magnitude of the resultant is:
   A. zero
   B. 1
   C. 3
   D. 5
   E. 7

   ans: A

4. A vector of magnitude 20 is added to a vector of magnitude 25. The magnitude of this sum might be:
   A. zero
   B. 3
   C. 12
   D. 47
   E. 50

   ans: C

5. A vector $\vec{S}$ of magnitude 6 and another vector $\vec{T}$ have a sum of magnitude 12. The vector $\vec{T}$:

A. must have a magnitude of at least 6 but no more than 18
B. may have a magnitude of 20
C. cannot have a magnitude greater than 12
D. must be perpendicular to $\vec{S}$
E. must be perpendicular to the vector sum

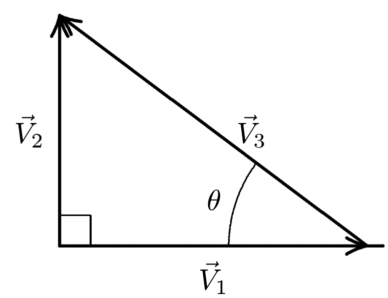
ans: A

6. The vector $-\vec{A}$ is:

A. greater than $\vec{A}$ in magnitude
B. less than $\vec{A}$ in magnitude
C. in the same direction as $\vec{A}$
D. in the direction opposite to $\vec{A}$
E. perpendicular to $\vec{A}$

ans: D

7. The vector $\vec{V}_3$ in the diagram is equal to:



A. $\vec{V}_1 - \vec{V}_2$
B. $\vec{V}_1 + \vec{V}_2$
C. $\vec{V}_2 - \vec{V}_1$
D. $\vec{V}_1 \cos\theta$
E. $\vec{V}_1/(\cos\theta)$

ans: C

8. If $|\vec{A}+\vec{B}|^2 = A^2 + B^2$, then:

A. $\vec{A}$ and $\vec{B}$ must be parallel and in the same direction
B. $\vec{A}$ and $\vec{B}$ must be parallel and in opposite directions
C. either $\vec{A}$ or $\vec{B}$ must be zero
D. the angle between $\vec{A}$ and $\vec{B}$ must be 60°
E. none of the above is true

ans: E

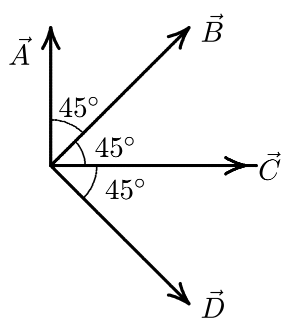
9. If $|\vec{A}+\vec{B}| = A + B$ and neither $\vec{A}$ nor $\vec{B}$ vanish, then:
   A. $\vec{A}$ and $\vec{B}$ are parallel and in the same direction
   B. $\vec{A}$ and $\vec{B}$ are parallel and in opposite directions
   C. the angle between $\vec{A}$ and $\vec{B}$ is 45°
   D. the angle between $\vec{A}$ and $\vec{B}$ is 60°
   E. $\vec{A}$ is perpendicular to $\vec{B}$

   ans: A

10. If $|\vec{A}-\vec{B}| = A + B$ and neither $\vec{A}$ nor $\vec{B}$ vanish, then:
   A. $\vec{A}$ and $\vec{B}$ are parallel and in the same direction
   B. $\vec{A}$ and $\vec{B}$ are parallel and in opposite directions
   C. the angle between $\vec{A}$ and $\vec{B}$ is 45°
   D. the angle between $\vec{A}$ and $\vec{B}$ is 60°
   E. $\vec{A}$ is perpendicular to $\vec{B}$

   ans: B

11. Four vectors ($\vec{A}$, $\vec{B}$, $\vec{C}$, $\vec{D}$) all have the same magnitude. The angle θ between adjacent vectors is 45° as shown. The correct vector equation is:



   A. $\vec{A}-\vec{B}-\vec{C}+\vec{D}=0$
   B. $\vec{B}+\vec{D}-\sqrt{2}\vec{C}=0$
   C. $\vec{A}+\vec{B}=\vec{B}+\vec{D}$
   D. $\vec{A}+\vec{B}+\vec{C}+\vec{D}=0$
   E. $(\vec{A}+\vec{C})/\sqrt{2}=-\vec{B}$

   ans: B

12. Vectors $\vec{A}$ and $\vec{B}$ lie in the xy plane. We can deduce that $\vec{A}=\vec{B}$ if:
   A. $A_x^2 + A_y^2 = B_x^2 + B_y^2$
   B. $A_x + A_y = B_x + B_y$
   C. $A_x = B_x$ and $A_y = B_y$
   D. $A_y/A_x = B_y/B_x$
   E. $A_x = A_y$ and $B_x = B_y$

   ans: C

13. A vector has a magnitude of 12. When its tail is at the origin it lies between the positive x axis and the negative y axis and makes an angle of 30° with the x axis. Its y component is:
A. $6/\sqrt{3}$
B. $-6\sqrt{3}$
C. 6
D. -6
E. 12
ans: D

14. If the x component of a vector $\vec{A}$, in the xy plane, is half as large as the magnitude of the vector, the tangent of the angle between the vector and the x axis is:
A. $\sqrt{3}$
B. $1/2$
C. $\sqrt{3}/2$
D. $3/2$
E. 3
ans: D

15. If $\vec{A} = (6\,\mathrm{m})\,\hat{\mathrm{i}} - (8\,\mathrm{m})\,\hat{\mathrm{j}}$ then $4\vec{A}$ has magnitude:
A. 10 m
B. 20 m
C. 30 m
D. 40 m
E. 50 m
ans: D

16. A vector has a component of 10 m in the $+x$ direction, a component of 10 m in the $+y$ direction, and a component of 5 m in the $+z$ direction. The magnitude of this vector is:
A. zero
B. 15 m
C. 20 m
D. 25 m
E. 225 m
ans: B

17. Let $\vec{V} = (2.00\,\mathrm{m})\,\hat{\mathrm{i}} + (6.00\,\mathrm{m})\,\hat{\mathrm{j}} - (3.00\,\mathrm{m})\,\hat{\mathrm{k}}$. The magnitude of $\vec{V}$ is:
A. 5.00 m
B. 5.57 m
C. 7.00 m
D. 7.42 m
E. 8.54 m
ans: C

18. A vector in the xy plane has a magnitude of 25 m and an x component of 12 m. The angle it makes with the positive x axis is:

A. 26°
B. 29°
C. 61°
D. 64°
E. 241°

ans: C

19. The angle between $\vec{A} = (25\,\text{m})\,\hat{\text{i}} + (45\,\text{m})\,\hat{\text{j}}$ and the positive x axis is:

A. 29°
B. 61°
C. 151°
D. 209°
E. 241°

ans: B

20. The angle between $\vec{A} = (-25\,\text{m})\,\hat{\text{i}} + (45\,\text{m})\,\hat{\text{j}}$ and the positive x axis is:

A. 29°
B. 61°
C. 119°
D. 151°
E. 209°

ans: C

21. Let $\vec{A} = (2\,\text{m})\,\hat{\text{i}} + (6\,\text{m})\,\hat{\text{j}} - (3\,\text{m})\,\hat{\text{k}}$ and $\vec{B} = (4\,\text{m})\,\hat{\text{i}} + (2\,\text{m})\,\hat{\text{j}} + (1\,\text{m})\,\hat{\text{k}}$. The vector sum $\vec{S} = \vec{A} + \vec{B}$ is:

A. $(6\,\text{m})\,\hat{\text{i}} + (8\,\text{m})\,\hat{\text{j}} - (2\,\text{m})\,\hat{\text{k}}$
B. $(-2\,\text{m})\,\hat{\text{i}} + (4\,\text{m})\,\hat{\text{j}} - (4\,\text{m})\,\hat{\text{k}}$
C. $(2\,\text{m})\,\hat{\text{i}} - (4\,\text{m})\,\hat{\text{j}} + (4\,\text{m})\,\hat{\text{k}}$
D. $(8\,\text{m})\,\hat{\text{i}} + (12\,\text{m})\,\hat{\text{j}} - (3\,\text{m})\,\hat{\text{k}}$
E. none of these

ans: A

22. Let $\vec{A} = (2\,\text{m})\,\hat{\text{i}} + (6\,\text{m})\,\hat{\text{j}} - (3\,\text{m})\,\hat{\text{k}}$ and $\vec{B} = (4\,\text{m})\,\hat{\text{i}} + (2\,\text{m}\,\hat{\text{j}} + (1\,\text{m})\,\hat{\text{k}}$. The vector difference $\vec{D} = \vec{A} - \vec{B}$ is:

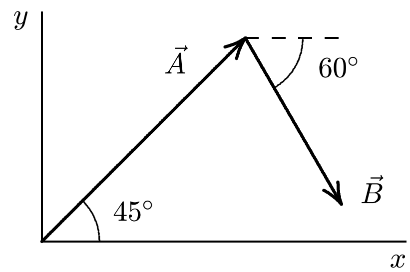
A. $(6\,\text{m})\,\hat{\text{i}} + (8\,\text{m})\,\hat{\text{j}} - (2\,\text{m})\,\hat{\text{k}}$
B. $(-2\,\text{m})\,\hat{\text{i}} + (4\,\text{m})\,\hat{\text{j}} - (4\,\text{m})\,\hat{\text{k}}$
C. $(2\,\text{m})\,\hat{\text{i}} - (4\,\text{m})\,\hat{\text{j}} + (4\,\text{m})\,\hat{\text{k}}$
D. $(8\,\text{m})\,\hat{\text{i}} + (12\,\text{m})\,\hat{\text{j}} - (3\,\text{m})\,\hat{\text{k}}$
E. none of these

ans: B

23. If $\vec{A} = (2\,\text{m})\,\hat{\imath} - (3\,\text{m})\,\hat{\jmath}$ and $\vec{B} = (1\,\text{m})\,\hat{\imath} - (2\,\text{m})\,\hat{\jmath}$, then $\vec{A} - 2\vec{B} =$
   A. $(1\,\text{m})\,\hat{\jmath}$
   B. $(-1\,\text{m})\,\hat{\jmath}$
   C. $(4\,\text{m})\,\hat{\imath} - (7\,\text{m})\,\hat{\jmath}$
   D. $(4\,\text{m})\,\hat{\imath} + (1\,\text{m})\,\hat{\jmath}$
   E. $(-4\,\text{m})\,\hat{\imath} + (7\,\text{m})\,\hat{\jmath}$

   ans: A

24. In the diagram, $\vec{A}$ has magnitude 12 m and $\vec{B}$ has magnitude 8 m. The x component of $\vec{A} + \vec{B}$ is about:



   A. 5.5 m
   B. 7.6 m
   C. 12 m
   D. 14 m
   E. 15 m

   ans: C

25. A certain vector in the xy plane has an x component of 4 m and a y component of 10 m. It is then rotated in the xy plane so its x component is doubled. Its new y component is about:
   A. 20 m
   B. 7.2 m
   C. 5.0 m
   D. 4.5 m
   E. 2.2 m

   ans: B

26. Vectors $\vec{A}$ and $\vec{B}$ each have magnitude L. When drawn with their tails at the same point, the angle between them is 30°. The value of $\vec{A} \cdot \vec{B}$ is:
   A. zero
   B. L^2
   C. $\sqrt{3}L^2/2$
   D. $2L^2$
   E. none of these

   ans: C

27. Let $\vec{A} = (2\,\text{m})\,\hat{\text{i}} + (6\,\text{m})\,\hat{\text{j}} - (3\,\text{m})\,\hat{\text{k}}$ and $\vec{B} = (4\,\text{m})\,\hat{\text{i}} + (2\,\text{m})\,\hat{\text{j}} + (1\,\text{m})\,\hat{\text{k}}$. Then $\vec{A} \cdot \vec{B} =$
   A. $(8\,\text{m})\,\hat{\text{i}} + (12\,\text{m})\,\hat{\text{j}} - (3\,\text{m})\,\hat{\text{k}}$
   B. $(12\,\text{m})\,\hat{\text{i}} - (14\,\text{m})\,\hat{\text{j}} - (20\,\text{m})\,\hat{\text{k}}$
   C. $23\,\text{m}^2$
   D. $17\,\text{m}^2$
   E. none of these

   ans: D

28. Two vectors have magnitudes of 10 m and 15 m. The angle between them when they are drawn with their tails at the same point is 65°. The component of the longer vector along the line of the shorter is:
   A. 0
   B. 4.2 m
   C. 6.3 m
   D. 9.1 m
   E. 14 m

   ans: C

29. Let $\vec{S} = (1\,\text{m})\,\hat{\text{i}} + (2\,\text{m})\,\hat{\text{j}} + (2\,\text{m})\,\hat{\text{k}}$ and $\vec{T} = (3\,\text{m})\,\hat{\text{i}} + (4\,\text{m})\,\hat{\text{k}}$. The angle between these two vectors is given by:
   A. $\cos^{-1}(14/15)$
   B. $\cos^{-1}(11/225)$
   C. $\cos^{-1}(104/225)$
   D. $\cos^{-1}(11/15)$
   E. cannot be found since $\vec{S}$ and $\vec{T}$ do not lie in the same plane

   ans: D

30. Two vectors lie with their tails at the same point. When the angle between them is increased by 20° their scalar product has the same magnitude but changes from positive to negative. The original angle between them was:
   A. 0
   B. 60°
   C. 70°
   D. 80°
   E. 90°

   ans: D

31. If the magnitude of the sum of two vectors is less than the magnitude of either vector, then:
   A. the scalar product of the vectors must be negative
   B. the scalar product of the vectors must be positive
   C. the vectors must be parallel and in opposite directions
   D. the vectors must be parallel and in the same direction
   E. none of the above

   ans: A

32. If the magnitude of the sum of two vectors is greater than the magnitude of either vector, then:
A. the scalar product of the vectors must be negative
B. the scalar product of the vectors must be positive
C. the vectors must be parallel and in opposite directions
D. the vectors must be parallel and in the same direction
E. none of the above
ans: E

33. Vectors $\vec{A}$ and $\vec{B}$ each have magnitude L. When drawn with their tails at the same point, the angle between them is 60°. The magnitude of the vector product $\vec{A} \times \vec{B}$ is:
A. $L^2/2$
B. L^2
C. $\sqrt{3}L^2/2$
D. $2L^2$
E. none of these
ans: C

34. Two vectors lie with their tails at the same point. When the angle between them is increased by 20° the magnitude of their vector product doubles. The original angle between them was about:
A. 0
B. 18°
C. 25°
D. 45°
E. 90°
ans: B

35. Two vectors have magnitudes of 10 m and 15 m. The angle between them when they are drawn with their tails at the same point is 65°. The component of the longer vector along the line perpendicular to the shorter vector, in the plane of the vectors, is:
A. 0
B. 4.2 m
C. 6.3 m
D. 9.1 m
E. 14 m
ans: E

36. The two vectors $(3\,\mathrm{m})\,\hat{\mathrm{i}} - (2\,\mathrm{m})\,\hat{\mathrm{j}}$ and $(2\,\mathrm{m})\,\hat{\mathrm{i}} + (3\,\mathrm{m})\,\hat{\mathrm{j}} - (2\,\mathrm{m})\,\hat{\mathrm{k}}$ define a plane. It is the plane of the triangle with both tails at one vertex and each head at one of the other vertices. Which of the following vectors is perpendicular to the plane?
A. $(4\,\mathrm{m})\,\hat{\mathrm{i}} + (6\,\mathrm{m})\,\hat{\mathrm{j}} + (13\,\mathrm{m})\,\hat{\mathrm{k}}$
B. $(-4\,\mathrm{m})\,\hat{\mathrm{i}} + (6\,\mathrm{m})\,\hat{\mathrm{j}} + (13\,\mathrm{m})\,\hat{\mathrm{k}}$
C. $(4\,\mathrm{m})\,\hat{\mathrm{i}} - (6\,\mathrm{m})\,\hat{\mathrm{j}} + (13\,\mathrm{m})\,\hat{\mathrm{k}}$
D. $(4\,\mathrm{m})\,\hat{\mathrm{i}} + (6\,\mathrm{m}\,\hat{\mathrm{j}} - (13\,\mathrm{m})\,\hat{\mathrm{k}}$
E. $(4\,\mathrm{m})\,\hat{\mathrm{i}} + (6\,\mathrm{m})\,\hat{\mathrm{j}}$
ans: A

37. Let $\vec{R} = \vec{S} \times \vec{T}$ and $\theta \neq 90°$, where θ is the angle between $\vec{S}$ and $\vec{T}$ when they are drawn with their tails at the same point. Which of the following is NOT true?

A. $|\vec{R}| = |\vec{S}||\vec{T}|\sin\theta$
B. $-\vec{R} = \vec{T} \times \vec{S}$
C. $\vec{R} \cdot \vec{S} = 0$
D. $\vec{R} \cdot \vec{T} = 0$
E. $\vec{S} \cdot \vec{T} = 0$

ans: E

38. The value of $\hat{\mathrm{i}} \cdot (\hat{\mathrm{j}} \times \hat{\mathrm{k}})$ is:

A. zero
B. +1
C. −1
D. 3
E. $\sqrt{3}$

ans: B

39. The value of $\hat{\mathrm{k}} \cdot (\hat{\mathrm{k}} \times \hat{\mathrm{i}})$ is:

A. zero
B. +1
C. −1
D. 3
E. $\sqrt{3}$

ans: A

AP Physics C

Chapter 7

Kinetic Energy and Work

Energy

- Kinetic energy is the energy associated with the state of motion of an object.
- $K = 1/2\ mv^2$
- The SI unit of energy is the Joule (J)

Work

- Accelerating an object by applying a force increases the kinetic energy of that object.
- Energy is transferred from you to the object.
- Work is said to be done during this transfer of energy.
- Work has the same units as energy and is also a scalar quantity.

Work and Kinetic Energy

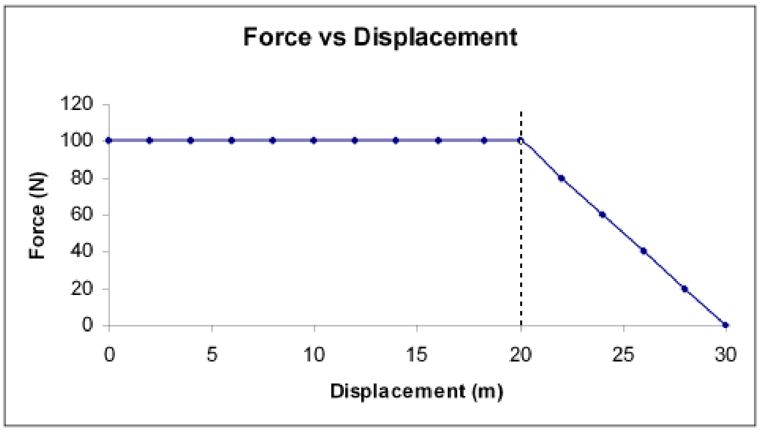
- Combining two common equations: $F_x = ma_x$ and $v^2 = v_o^2 + 2ad$ we arrive at $1/2mv^2 - 1/2mv_o^2 = F_x d$
- Left side represents the change in kinetic energy due to a force and the right side shows that the change is equal to $F_x d$.
- $W = F_x d$
- Use only the component of the force acting along the displacement.
- SIGNS: positive work: force acts along displacement
  negative work: force acts opposite direction of displacement
- Net work done by several forces: sum the individual works or determine the net force first and then use net force to calculate net work.
- Work-Kinetic Energy Theorem $W = \Delta K$

A particle moves along an x axis. Does the kinetic energy increase, decrease, or remain the same if the particle's velocity changes (a) from -3m/s to -2m/s, and (b) from -2m/s to 2m/s? For each case, is the work done on the particle positive or negative, or zero?

During a storm, a crate is sliding across a slick,oily parking lot through a displacement d = (-3.0m)i while a steady wind pushes against the crate with a force F=(2.0N)i - (6.0N)j.

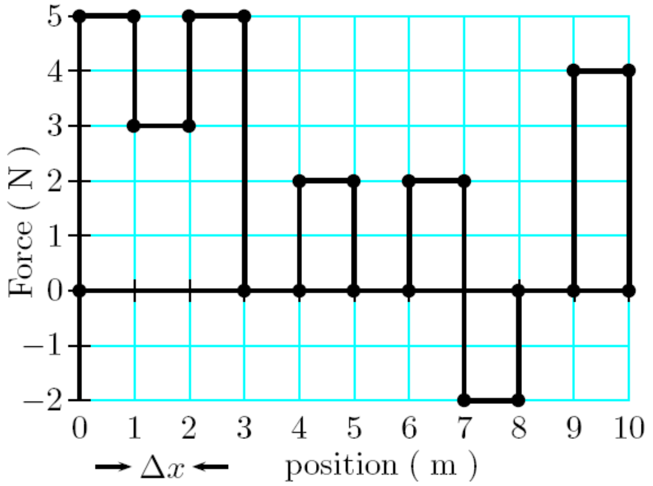
(a) How much work does this force do on the crate during the displacement?

What about a graphical representation of work?



What does slope tell you? Area?

A mass of 0.55 kg is initially at rest on a horizontal surface. A force, given by $\vec{F} = F_x\,\hat{\imath}$, acts on the mass. The horizontal component F_x is plotted below as a function of position along the x-axes. The coefficient of kinetic friction is 0.03.

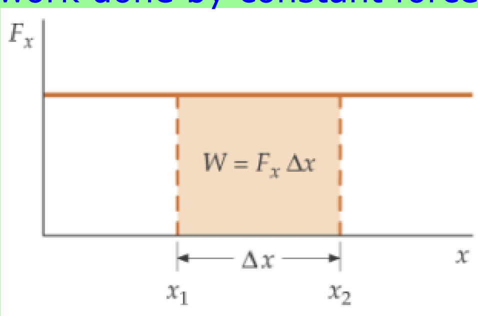


Calculate the kinetic energy K of the mass as it reaches 8 m.

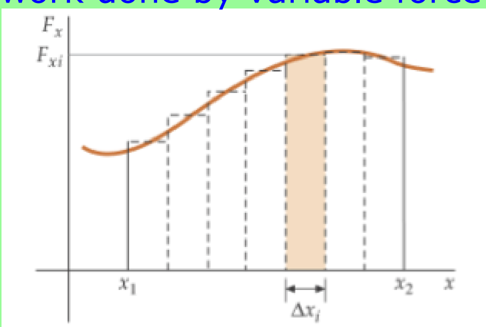
Work Done by a Variable Force - Straight Line

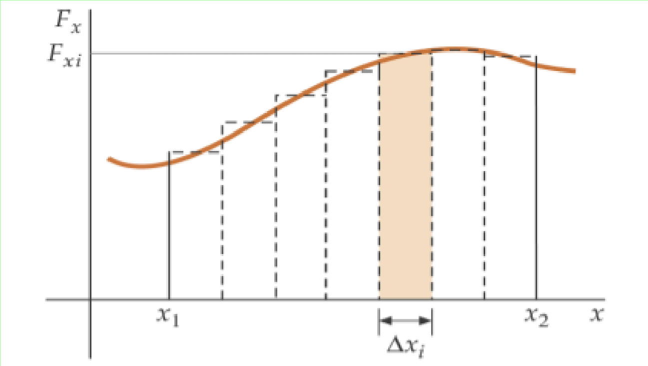
- Many forces vary with position.
- Example: A spring exerts a force proportional to the displacement from equilibrium.
- Example: The gravitational force Earth exerts on a spaceship varies inversely with the square of the center-to-center distance between the two bodies.

work done by constant force

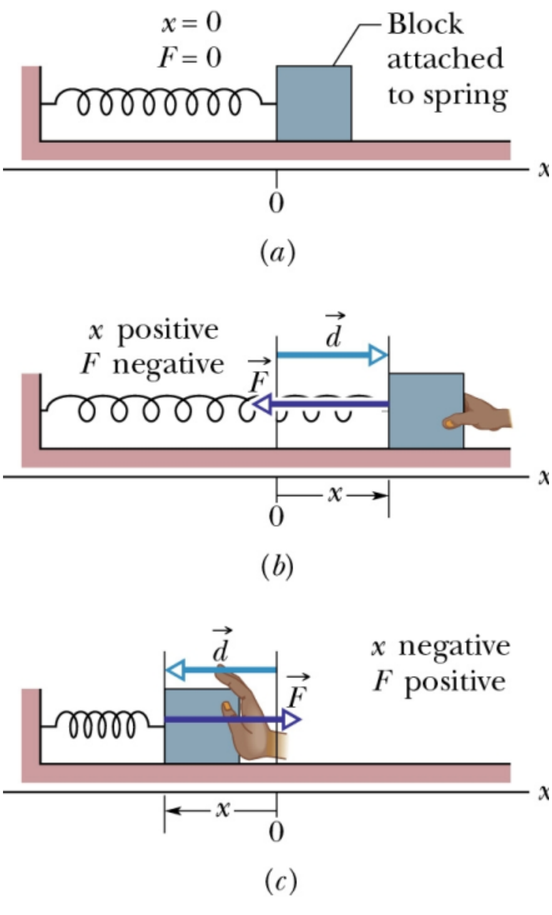


work done by variable force





The work is approximately equal to the area of the rectangle of height F_x and width Δx_i. The work W done by a variable force is then equal to the sum of the areas of these rectangles



The Spring Force

$$F_s = -kx$$

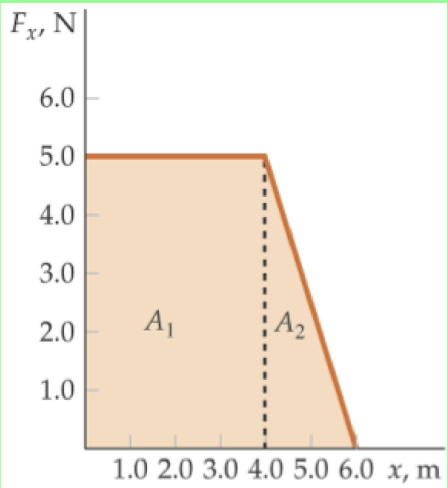
The work done by a variable force (spring force) acting on a particle as it moves from x_1 to x_2 is

$$W_s = \int_{x_1}^{x_2} F_x \, dx \quad = \text{ area under the } F_x \text{ versus x curve}$$

$$W_s = \int_{x_1}^{x_2} (-kx) \, dx$$ ← substitute the function for spring force in for F_x

$$= 1/2kx_1^2 - 1/2kx_2^2$$

assuming $x_1 = 0$ then $$W_s = 1/2kx^2$$



QWIZDOM

(1) A force F_xi varies with x as shown. Find the work done by the force on a particle as it moves from x=0.0 m to x=6.0 m .

(2) If the particle starts from rest at x=0.0m, how fast is it moving when it reaches 6.0m?

Work Done by a Spring Force

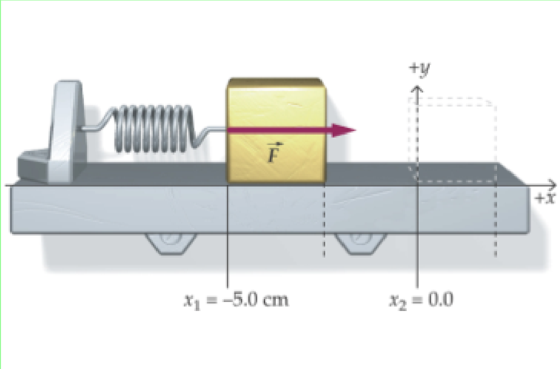
- Force varies with displacement from equilibrium.
- The greater the stretch or compression, the greater the restoring force exerted by the spring.
- $F = -kx$ if x is positive, F is neg and vice versa
- Work done by a spring $W_s = 1/2kx_i^2 - 1/2\ kx_f^2$
- W_s is positive if spring ends up closer to equilibrium, negative if farther from equilibrium.

$F = -kx$ represents Hooke's Law specifically the displacement is directly proportional to the force. Doubling force doubles displacement.

For three situations, the initial and final positions, respectively, along the x axis are (a) -3 cm, 2 cm; (b) 2 cm, 3 cm; (c) -2 cm, 2 cm. In each situation is the work done by the spring force on the block positive, negative, or zero?

A block of mass m=0.40 kg slides across a horizontal frictionless surface with speed v=0.50 m/s. It then runs into and compresses a spring of spring constant k=750 N/m. When the block is momentarily stopped by the spring, by what distance is the spring compressed?

A 4.0 kg block on a frictionless table is attached to a horizontal spring with k=400 N/m. The spring is initially compressed 5.0 cm. Find (a) the work done on the block by the spring as the block moves from x_1 = -5.0 cm to its equilibrium position x_2=0.0 cm, and (b) the speed of the block at x_2 = 0.0cm.



W=0.50 J
v_2 = 0.50 m/s

Work Done by a Variable Force

text p. 131

- $W = \int_{x_i}^{x_f} F(x)\,dx$

because of square, must integrate, force is variable

Example: Force $F = (3x^2\ \text{N})\mathbf{i} + (4\ \text{N})\mathbf{j}$ acts on a particle changing only the kinetic energy of the particle. (a) How much work is done on the particle as it moves from coordinates (2m, 3m) to (3m, 0m)? Does the speed of the particle increase, decrease, or stay the same?

$$W = \int_2^3 3x^2\,dx + \int_3^0 4\,dy = 3\int_2^3 x^2\,dx + 4\int_3^0 dy$$

$$= 3[1/3x^3]\Big|_2^3 + 4[y]\Big|_3^0 = [3^3 - 2^3] + 4[0-3]$$

$$= 7.0\ \text{J}$$

001 (part 1 of 2)

A 106 g bullet is fired from a rifle having a barrel 0.271 m long. Assuming the origin is placed where the bullet begins to move, the force exerted on the bullet by the expanding gas is $F = a + b\,x - c\,x^2$, where $a = 13500$ N, $b = 8170$ N/m, $c = 24000$ N/m^2, with x in meters.

Determine the work done by the gas on the bullet as the bullet travels the length of the barrel.

Correct answer: 3799.29 J.

Explanation:

The work is found by integrating the force over the distance.

$$W = \int_{x_i}^{x_f} F \cdot ds$$

For the force in this problem we have,

$$\begin{aligned}
W &= \int_0^{\ell} (a + b\,x - c\,x^2)\,dx \\
&= a\,x + \frac{1}{2} b\,x^2 - \frac{1}{3} c\,x^3 \Big|_0^{\ell} \\
&= (13500\text{ N})(0.271\text{ m}) \\
&\quad + \frac{1}{2}\,(8170\text{ N/m})\,(0.271\text{ m})^2 \\
&\quad - \frac{1}{3}\,(24000\text{ N/m}^2)\,(0.271\text{ m})^3 \\
&= \boxed{3799.29\text{ J}}\,.
\end{aligned}$$

With what velocity does the bullet exit the barrel?

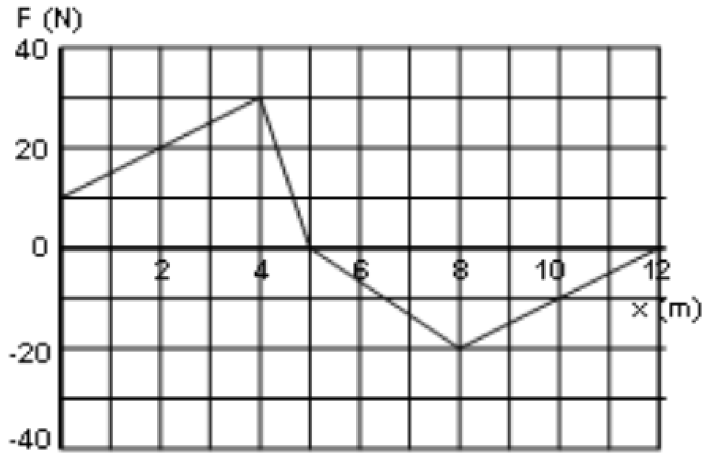
Correct answer: 6061.83 J.

Explanation:
For the barrel of length $\ell_n = 0.441$ m m, we need only change the limits of integration,

$$W = \int_0^{\ell_n} (a + b\,x - c\,x^2)\,dx$$
$$= a\,x + \frac{1}{2} b\,x^2 - \frac{1}{3} c\,x^3 \Big|_0^{\ell_n}$$
$$= (13500 \text{ N})(0.441 \text{ m})$$
$$+ \frac{1}{2}\,(8170 \text{ N/m})\,(0.441 \text{ m})^2$$
$$- \frac{1}{3}\,(24000 \text{ N/m}^2)\,(0.441 \text{ m})^3$$
$$= \boxed{6061.83 \text{ J}}\,.$$

Problem: A force acting on a particle is $F_x = (4x - x^2)$N. Find the work done by the force on the particle when the particle moves along the x-axis from x= 0 to x = 2.0 m.

- Problem: Determine the work done by the force as the particle moves from x = 2 m to x = 8 m.



Power

- The time rate at which work is done.
- $P_{avg} = \frac{W}{t}$

- The unit of power is the Watt which equals J/s
- In certain circumstances, $P = F\bar{v}$

001

A time-varying net force acting on a 3.4 kg particle causes the object to have a displacement given by

$$x = a + b\,t + d\,t^2 + e\,t^3\,,$$

$$\text{where}\quad a = 3\text{ m}\,,$$
$$b = 0.81\text{ m/s}\,,$$
$$d = -1.6\text{ m/s}^2\,,\quad \text{and}$$
$$e = 0.82\text{ m/s}^3\,,$$

with x in meters and t in seconds.

Find the work done on the particle in the first 3.3 s of motion.

Correct answer: 492.465 J.

$$= \frac{1}{2}\, m\, v_f^2 - \frac{1}{2}\, m\, v_i^2 .$$

Therefore work done on the particle is the change in kinetic energy. For this case,

$$W = \Delta K = K_f - K_i$$
$$= \frac{1}{2}\, m\, (v_f^2 - v_i^2)\,,$$

where the velocity is found by differentiating the displacement:

$$v = \frac{d\,x}{dt}$$
$$= b + 2\,d\,t + 3\,e\,t^2$$
$$v_i = 0.81 \text{ m/s}\,, \quad \text{and} \qquad (1)$$
$$v_f = (0.81 \text{ m/s}) + 2\,(-1.6 \text{ m/s}^2)\,(3.3 \text{ s}) + 3\,(0.82 \text{ m/s}^3)\,(3.3 \text{ s})^2$$
$$= 17.0394 \text{ m/s}\,, \qquad (2)$$

cont'd →

where $t_i = 0$ s and $t_f = 3.3$ s.

Evaluation of the velocity at the initial and final times gives the desired result.

$$W = K_f - K_i$$
$$= \frac{1}{2}\, m\, (v_f^2 - v_i^2)$$
$$= \frac{1}{2}\,(3.4 \text{ kg})\,\Big[(17.0394 \text{ m/s})^2 - (0.81 \text{ m/s})^2\Big]$$
$$= (493.58 \text{ J}) - (1.11537 \text{ J})$$
$$= \boxed{492.465 \text{ J}}\,.$$

Power in an Elevator 02

014 (part 1 of 2) 10.0 points

An elevator has a mass of 1100 kg and carries a maximum load of 774 kg. A constant frictional force of 3280 N retards its motion upward.

The acceleration of gravity is 9.8 m/s^2.

What must be the minimum power delivered by the motor to lift the elevator at a constant speed of 4.3 m/s?

Correct answer: 93074.4 W.

015 (part 2 of 2) 10.0 points

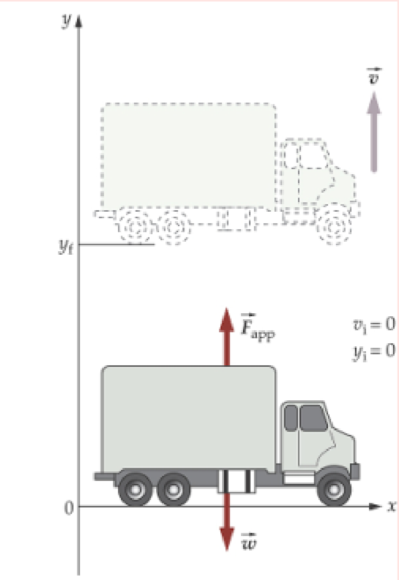
What power must the motor deliver at an instantaneous speed of 4.3 m/s if the elevator is designed to provide an upward acceleration of 0.679 m/s^2?

Correct answer: 98545.9 W.

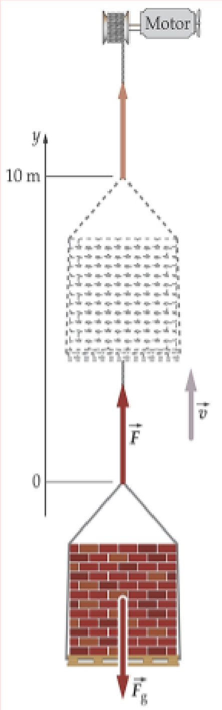
Work Done by the Gravitational Force

Work Done by a Gravitational Force

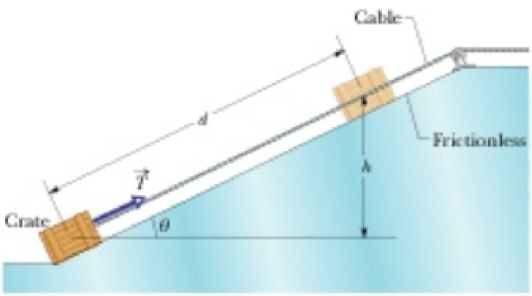
- W_g = mgh for objects moving vertically
- Positive work for a falling object, negative work for ascending object.
- W_a = mgd work done by applied force during lifting and lowering.
- If there is no acceleration during lifting or lowering, then no net work has been done.



A 3000 kg truck is to be loaded onto a ship by a crane that exerts an upward force of 31 kN on the truck. This force is strong enough to overcome the gravitational force and keep the truck moving upward for a distance of 2.0 m. (a)Find the work done on the truck by the crane, (b)by gravity, and (c)the net work done on the truck.



A small motor is used to operate a lift that raises a load of bricks weighing 500 N to a height of 10 m in 20 s at constant speed. (a) What is the power output of the motor? (b) Find the average power output of the motor needed to raise the bricks and lift to a height of 10 m in 40 s. (c) What is the work done by the force of the motor? (d) What is the work done by the force of gravity?

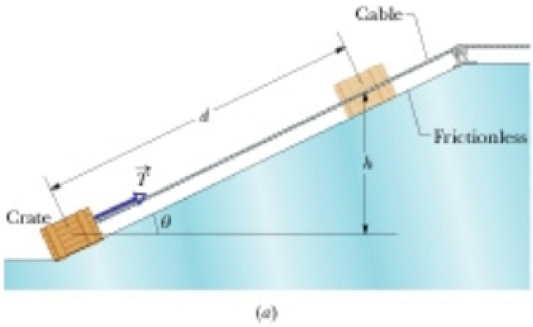


(a)

What makes you think this is a gravitational potential energy problem versus a kinetic energy type of problem?

An initially stationary 15.0 kg crate is pulled a distance of 5.70 m up a frictionless ramp to a height of 2.50 m where it stops. (a) How much work is done on the crate by the gravitational force? (b) How much work is done by tension during the lift?

(a) -368 J (b) 368 J



IF the crate is raised to the same height but on a longer incline, is the work done by tension greater, smaller, or the same as before? Is the magnitude of the tension greater, smaller, or the same as before?

Holt SF 05Rev 08
018 10.0 points

A plane designed for vertical takeoff has a mass of 8.7×10^3 kg.

Find the net work done on the plane as it accelerates upward at 1.5 m/s^2 through a distance of 33.3 m after starting from rest.

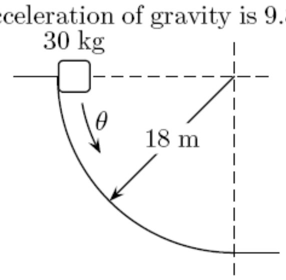
Correct answer: 4.34565×10^5 J.

Slide Down a Quarter Circle 02

038 (part 1 of 2) 10.0 points

Starting from rest at a height equal to the radius of the circular track, a block of mass 30 kg slides down a quarter circular track under the influence of gravity with friction present (of coefficient μ). The radius of the track is 18 m.

The acceleration of gravity is 9.8 m/s^2.



Determine the work done by the conservative forces.

Correct answer: 5292 J.

---

039 (part 2 of 2) 10.0 points

If the kinetic energy of the block at the bottom of the track is 3200 J, what is the work done against friction?

Work Done Against Gravity

044 10.0 points

Pete slides a crate up a ramp with constant speed at an angle of 31.8° by exerting a 125 N force parallel to the ramp.

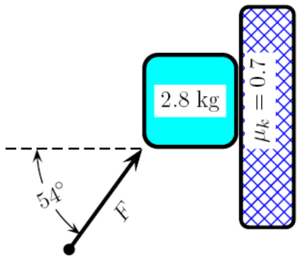
How much work has been done **against gravity** when the crate is raised a vertical distance of 1.33 m? The coefficient of friction is 0.136.

Correct answer: 258.738 J.

Pushing a Block Upward 01

025 (part 1 of 3) 10.0 points

As shown in the figure, a block of mass 2.8 kg is pushed up against the vertical wall by a force of 69 N acting at 54° to the ceiling. The coefficient of kinetic friction between the block and the wall is 0.7.



Find the work done by this force in moving the block upward by a distance 1.4 m.

Correct answer: 78.1511 J.

026 (part 2 of 3) 10.0 points

For a force of $F = 69$ N, find the magnitude of the frictional force.

Correct answer: 28.39 N.

---

027 (part 3 of 3) 10.0 points

Find the force F needed to keep the block moving up with a constant velocity.

Correct answer: 69.0197 N.