Q1.

A particle is moving with constant acceleration of –8.0 m/s^2 along the x-axis. At time t = 0 its position is 10 m and is moving with the velocity of 10 m/s. Find the position of the particle at t = 4.0 s.

A) –14 m
B) +24 m
C) –43 m
D) +7.0 m
E) +9.2 m

Ans:

$$x_0 = 10\ m$$

$$\Delta x = v_0 t + \frac{1}{2} a t^2$$

$$x - x_0 = 10 \times 4 + \frac{1}{2} \times (-8) \times 4^2$$

$$x - 10 = 40 - 64 \Rightarrow x = -14\ m$$

Q2.

If vector $\vec{B}$ is added to vector $\vec{C} = 3.0\hat{\imath} + 4.0\hat{\jmath}$, the result is a vector in the positive direction of the y-axis, with a magnitude equal to that of $\vec{C}$. The magnitude of the vector $\vec{B}$ is:

A) 3.2
B) 2.1
C) 1.5
D) 5.6
E) 7.6

Ans:

$$\vec{B} + \vec{C} = |\vec{C}|\hat{\jmath}$$

$$\Rightarrow \vec{B} + 3\hat{\imath} + 4\,\hat{\jmath} = 5\hat{\jmath}$$

$$\vec{B} = -3\hat{\imath} + \hat{\jmath}$$

$$\Rightarrow |\vec{B}| = \sqrt{3^2 + 1^2} = \sqrt{10} = 3.2$$

Q3.

A particle's position vector is initially $\vec{r} = 5.0\hat{\imath} - 6.0\hat{\jmath}$, and 10 s later it is $\vec{r} = -2.0\hat{\imath} + 8.0\hat{\jmath}$, all distances are in meters. What is the magnitude of the average velocity during this 10 s interval?

A) 1.6 m/s
B) 2.8 m/s
C) 7.2 m/s
D) 6.1 m/s
E) 4.5 m/s

Ans:

$$\vec{v}_{av} = \frac{\Delta\vec{r}}{\Delta t} = \frac{-2\hat{\imath} + 8\hat{\jmath} - 5\hat{\imath} + 6\hat{\jmath}}{10}$$

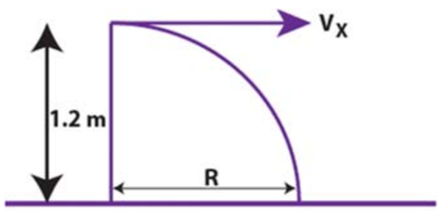
$$\vec{v}_{av} = \frac{-7\hat{\imath} + 14\hat{\jmath}}{10}$$

$$|\vec{v}_{av}| = \sqrt{0.7^2 + 1.4^2} = 1.56\ m/s$$

Q4.

A very small ball rolls horizontally off the edge of a tabletop that is 1.20 m high. It strikes the floor at a point 1.52 m horizontally from the table edge. What is its speed at the instant it leaves the table?

A) 3.07 m/s
B) 2.05 m/s
C) 7.26 m/s
D) 6.24 m/s
E) 1.15 m/s



Ans:

$$V_{oy} = 0;\ a_y = -9.8\frac{m}{s^2};\Delta y = -1.2\ m$$

$$\Delta y = \frac{1}{2}a_y t^2$$

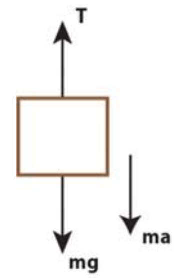
$$t = \sqrt{\frac{2\times 1.2}{9.8}} = 0.49\ s$$

$$\mathrm{v_x} = \frac{R}{t} = \frac{1.52}{0.49} = 3.07\ m/s$$

Q5.

An elevator cab of mass 2780 kg moves downward. What is the tension in the cable if the cab's speed is decreasing at a rate of 1.22 m/s^2?

A) 3.06×10^4 N
B) 1.13×10^4 N
C) 8.43×10^4 N
D) 5.16×10^4 N
E) 7.12×10^4 N



Ans:

$$T - mg = -ma$$

$$T = mg - m(-a)$$

$$T = m(g + a)$$

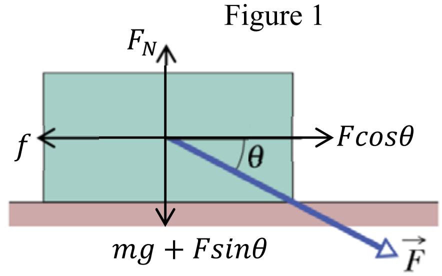
$$T = 2780(9.8 + 1.22) = 30636\ N$$

Q6.

A 3.5 kg block is pushed along a horizontal floor by a force $\vec{F}$ of magnitude 15 N at an angle $\theta = 40^0$ with the horizontal as shown in **Figure 1**. The coefficient of kinetic friction between the block and the floor is 0.25. Calculate the magnitude of the block's acceleration.

A) 0.14 m/s^2
B) 0.26 m/s^2
C) 0.37 m/s^2
D) 0.71 m/s^2
E) 0.45 m/s^2

Figure 1



Ans:

$$Fcos\theta - f = ma$$

$$Fcos\theta - \mu_k(mg + Fsin\theta) = ma$$

$$\frac{F}{m}(cos\theta - \mu_k sin\theta) - \mu_k g = a$$

$$a = \frac{15}{3.5}(cos40° - 0.25sin40°) - 0.25 \times 9.8 = 0.14\ m/s^2$$

Q7.

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 $x = 0$. For which values of x_i and x_f, is the work done by spring on the block positive?

A) $x_i = -6$ cm and $x_f = -4$ cm
B) $x_i = -4$ cm and $x_f = 6$ cm
C) $x_i = 4$ cm and $x_f = 6$ cm
D) $x_i = -4$ cm and $x_f = -4$ cm
E) $x_i = -6$ cm and $x_f = 7$ cm

Ans:

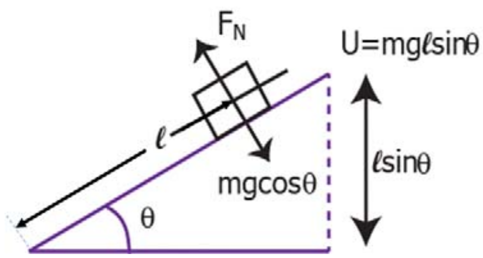
$$W_s = -\Delta U_s = U_{os} - U_s$$

$$W_s = \frac{1}{2}k\left(x_i^2 - x_f^2\right)$$

Q8.

A 5.00-kg box starts to slide up a 30.0° incline with 275 J of kinetic energy. How far will it slide up the incline if the coefficient of kinetic friction between the box and the incline is 0.350?

A) 6.99 m
B) 2.25 m
C) 8.80 m
D) 5.23 m
E) 3.43 m



Ans:

$$\Delta K + \Delta U_g = W_f$$

$$\cancelto{0}{K} - K_0 + U_g - \cancelto{0}{U_{0g}} = -fl$$

$$-275 + mglsin\theta = -\mu_k mglcos\theta$$

$$l = \frac{275}{mg(sin\theta + \mu_k cos\theta)}$$

$$l = \frac{275}{5 \times 9.8(sin30° + 0.35cos30°)} = 6.99\ m$$

Q9.

Two objects, A and B, each of mass 2.0 kg, move with velocities $\vec{v}_A = (2.0\hat{\imath} + 5.0\hat{\jmath})$ m/s and $\vec{v}_B = (2.0\hat{\imath} - 5.0\hat{\jmath})$ m/s collide and stick together. After the collision, what is the kinetic energy of the composite object?

A) 8.0 J
B) 2.6 J
C) 4.5 J
D) 5.0 J
E) 1.5 J

Ans:

$$m_A\vec{v}_A + m_B\vec{v}_B = (m_A + m_B)\vec{v}_f$$

$$4\hat{\imath} + 10\,\hat{\jmath} + 4\hat{\imath} - 10\hat{\jmath} = 4\vec{v}_f$$

$$8\hat{\imath} = 4\vec{v}_f \Rightarrow \vec{v}_f = 2\hat{\imath}$$

$$k_f = \frac{1}{2}(m_A + m_B)v_f^2$$

$$k_f = \frac{1}{2}(2+2) \times 4 = 8\,\text{J}$$

Q10.

The angular speed of an automobile engine is increased at a constant rate from rest to 50 rev/s in 10 s. How many revolutions does the engine make during this 10 s interval?

A) 250
B) 100
C) 430
D) 500
E) 360

Ans:

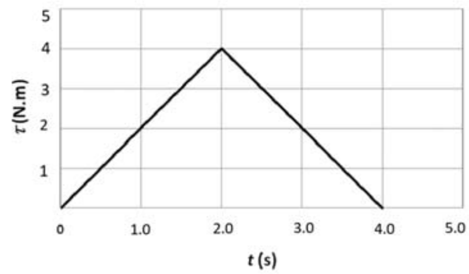
$$\theta = \frac{1}{2}\alpha t^2 = \frac{1}{2}\left(\frac{50-0}{t}\right)t^2$$

$$\theta = \frac{1}{2} \times 50 \times 10 = 250 \text{ revolutions}$$

Q11.

Figure 2 shows a graph of a torque applied to a rotating body as a function of time. What is the magnitude of the angular momentum of the rotating body at t = 4.0 s, assuming it was initially at rest?

Figure 2



A) 8.0 kg.m²/s
B) 1.0 kg.m²/s
C) 4.3 kg.m²/s
D) 5.0 kg.m²/s
E) 2.6 kg.m²/s

Ans:

$$\frac{\Delta L}{\Delta t} = \tau$$

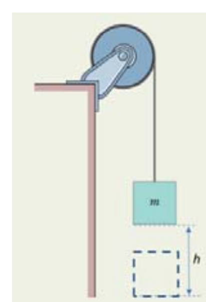
$$\Delta L = Area\ under\ the\ curve$$

$$L - \cancel{L_0}^{\,0} = \frac{1}{2} \times 4 \times 4 = 8\ kg \cdot m^2/s$$

Q12.

A disc of radius 0.20 m is mounted on a fixed frictionless horizontal axis passing through the center of the disc as shown in **Figure 3**. The rotational inertia of the disc about this axis is 0.50 kg.m^2. A massless cord wrapped around the circumference of the disc is attached to a block of mass m = 2.5 kg. The block is then released from rest. Find the speed of the block when it falls a height of h = 0.70 m.

Figure 3



A) 1.5 m/s
B) 3.0 m/s
C) 4.3 m/s
D) 5.0 m/s
E) 8.6 m/s

Ans:

$$K_R = \frac{1}{2} I\omega^2 = \frac{1}{2} I \frac{v^2}{R^2}$$

$$K_0 = 0; U_0 = mgh;\ K_T = \frac{1}{2} mv^2;\ U = 0$$

$$\Delta K + \Delta\, U_g = 0$$

$$\frac{1}{2} I \frac{v^2}{R^2} + \frac{1}{2} mv^2 - mgh = 0$$

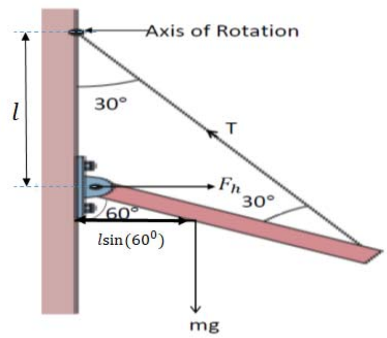
$$v = \sqrt{\frac{2mgh}{\left(\frac{I}{R^2} + m\right)}} = \sqrt{\frac{2 \times 2.5 \times 9.8 \times 0.7}{\left(\frac{0.5}{0.2^2} + 2.5\right)}} = 1.5\ m/s$$

Q13.

In **Figure 4**, one end of a uniform beam of weight 222 N is hinged to a wall; the other end is supported by a wire of negligible mass that makes angles θ = 30.0° with both wall and beam. Find the horizontal component of the force of the hinge on the beam

A) 96.1 N
B) 66.1 N
C) 41.3 N
D) 23.5 N
E) 87.3 N

Figure 4



Ans:

$$F_h l - \frac{l}{2} sin60° mg = 0$$

$$F_h = \frac{sin60° \times 222}{2} = 96.1\ N$$

Q14.

Aluminum Rod 1 has a length *L* and a diameter *d*. Aluminum Rod 2 has a length 2*L* and a diameter 2*d*. When Rod 1 is under tension *T* and Rod 2 is under tension 2*T*, the changes in lengths of rods 1 and 2 are ΔL_1 and ΔL_2, respectively. Which one of the following is **TRUE**?

A) $\Delta L_2 = \Delta L_1$
B) $\Delta L_2 = 2\ \Delta L_1$
C) $\Delta L_1 = 2\ \Delta L_2$
D) $\Delta L_1 = 4\Delta L_2$
E) $\Delta L_2 = 4\Delta L_1$

Ans:

$$\frac{T}{\frac{\pi}{4}d^2} \cdot \frac{L}{\Delta L_1} = \frac{2T}{\frac{\pi}{4}(2d)^2} \cdot \frac{2L}{\Delta L_2}$$

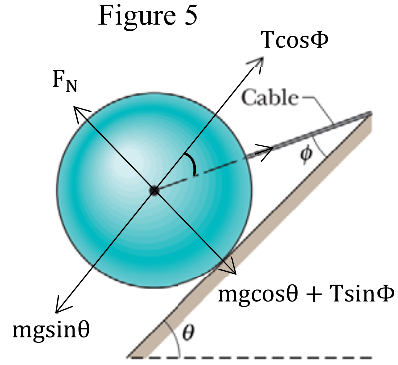
$$\frac{1}{\Delta L_1} = \frac{4}{4}\frac{1}{\Delta L_2} \Rightarrow \Delta L_1 = \Delta L_2$$

Q15.

In **Figure 5**, a 10 kg sphere is supported on a frictionless plane inclined at angle θ = 45° from the horizontal. Angle ϕ is 25°. Calculate the tension in the cable.

A) 76 N
B) 35 N
C) 48 N
D) 52 N
E) 15 N

Figure 5



Ans:

$$T cos\Phi = mg sin\theta$$

$$T = \frac{mg sin\theta}{cos\Phi}$$

$$T = \frac{10 \times 9.8\, sin(45°)}{cos(25°)} = 76\ N$$

Q16.

A satellite is in a circular orbit about the Earth at an altitude at which air resistance is negligible. Which of the following statements is true?

A) There is only one force acting on the satellite.
B) There are two forces acting on the satellite, and their resultant is zero.
C) There are two forces acting on the satellite, and their resultant is not zero.
D) There are three forces acting on the satellite.
E) No force is acting on the satellite.

Ans:

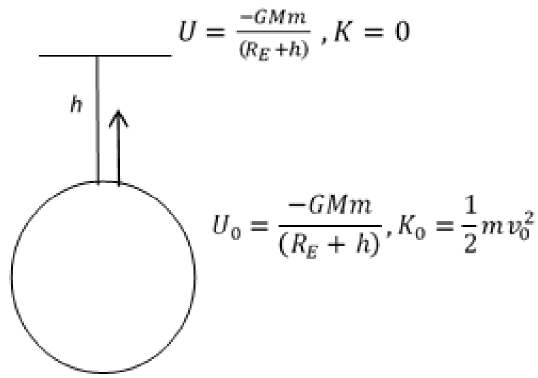
A

Q17.

A projectile is fired vertically upward from Earth's surface with an initial speed of 10 km/s. Neglecting air resistance, how far above the surface of Earth will it go?

A) 2.5×10^7 m
B) 3.5×10^7 m
C) 1.0×10^7 m
D) 6.5×10^7 m
E) 7.5×10^7 m

Ans:



$$\Delta K + \Delta U_g = 0$$

$$-\frac{1}{2} m v_0^2 + GMm\left(\frac{1}{R_E} - \frac{1}{R_E + h}\right) = 0$$

$$\frac{GM}{R_E} - \frac{1}{2} v_0^2 = \frac{GM}{R_E + h}$$

$$h = -R_E + \frac{GM}{\left(\frac{GM}{R_E} - \frac{1}{2} v_0^2\right)}$$

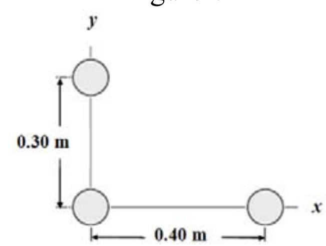
$$= -R_E + \frac{gR_E^2}{\left(gR_E - \frac{1}{2} v_0^2\right)}; \; R_E = 6.37 \times 10^6 m \Rightarrow h = 2.5 \times 10^7 m$$

Q18.

Three 5.00-kg masses are located at three points in the *xy* plane, as shown in **Figure 6**. Find the magnitude of work required to take the mass at x = 0, y = 0; to infinity.

A) 9.73×10^{-9} J
B) 3.17×10^{-9} J
C) 5.36×10^{-9} J
D) 1.35×10^{-9} J
E) 7.14×10^{-9} J

Figure 6



Ans:

$$U_0 = -\frac{GM^2}{0.3} - \frac{Gm^2}{0.4} - \frac{GM^2}{0.5}$$

$$U = -\frac{GM^2}{0.5}$$

$$W_a = \Delta U_g = U - U_0$$

$$W_a = 6.67 \times 10^{-11} \times 25\left(\frac{1}{0.3} + \frac{1}{0.4}\right) = 9.37 \times 10^{-9} \text{J}$$

Q19.

At what altitude above Earth's surface would the magnitude of gravitational acceleration be 3.2 m/s^2?

A) 4.8×10^6 m
B) 7.2×10^6 m
C) 2.5×10^6 m
D) 1.3×10^6 m
E) 8.7×10^6 m

Ans:

$$a_g = \frac{GM}{r^2}$$

$$r = \sqrt{\frac{GM}{3.2}} = \sqrt{\frac{6.67\times10^{-11}\times5.98\times10^{24}}{3.2}}$$

$$R_E + h = 1.12\times10^7 \Rightarrow h = 1.12\times10^7 - 6.37\times10^6 = 4.8\times10^6\ m$$

Q20.

A satellite travels around the planet Mars in a circular orbit of radius 9.4×10^6 m with a period of 7 h 39 min. Calculate the mechanical energy of the satellite if its mass is 1.1×10^{16} kg.

A) -2.5×10^{22} J
B) $+2.5\times10^{22}$ J
C) -3.5×10^{22} J
D) $+3.5\times10^{22}$ J
E) -4.3×10^{22} J

Ans:

$$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3 \Longrightarrow \frac{GM}{r} = \frac{4\pi^2}{T^2}r^2$$

$$\Longrightarrow -\frac{GMm}{2r} = -\frac{4\pi^2}{2T^2}mr^2 \Rightarrow E = -\frac{2\pi^2mr^2}{T^2}$$

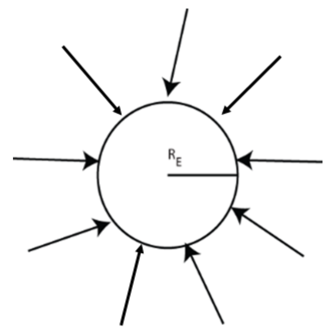
$$\Rightarrow E = \frac{-2\times3.14^2\times1.11\times10^{16}\times(9.4\times10^6)^2}{(7\times3600+39\times60)^2} = -2.5\times10^{22}\ \text{J}$$

Q21.

Based on the fact that one atmospheric pressure is being exerted on the Earth's surface, find the total mass of the Earth's atmosphere. The radius of the Earth is 6.37×10^{6} m.

A) 5.26×10^{18} kg
B) 2.15×10^{18} kg
C) 1.53×10^{18} kg
D) 7.40×10^{18} kg
E) 4.37×10^{18} kg

Ans:



$$P = \frac{F}{A} = \frac{mg}{4\pi R_E^2}$$

$$m = \frac{P\times 4\pi R_E^2}{g} = \frac{1.01\times10^5\times4\pi\times(6.37\times10^6)^2}{9.8}$$
$$= 5.26\times10^{18}\ \text{kg}$$

Q22.

Three liquids that will not mix are poured into a uniform cylindrical container of cross-section area 20 cm². The volumes and densities of the liquids are 0.50 L, 2.6 g/cm³; 0.25 L, 1.0 g/cm³; and 0.40 L, 0.80 g/cm³.What is the pressure on the bottom of the container due to these liquids? One liter = 1 L = 1000 cm³. (Ignore the contribution due to the atmosphere.)

A) 9.2×10^{3} Pa
B) 1.3×10^{3} Pa
C) 3.4×10^{3} Pa
D) 6.5×10^{3} Pa
E) 4.5×10^{3} Pa

Ans:

$$P_b = \cancelto{0}{P_0} + P_1 + P_2 + P_3 = \frac{\rho_1 V_1 g}{A} + \frac{\rho_2 V_2 g}{A} + \frac{\rho_3 V_3 g}{A}$$

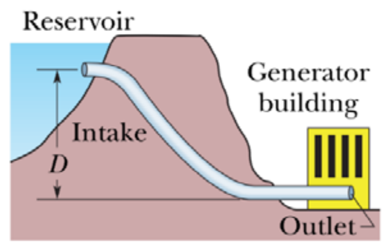
$$P_b = \frac{1000}{20\times10^{-4}}\left(\frac{0.5\times2.6}{1000} + \frac{0.25\times1}{1000} + \frac{0.4\times0.8}{1000}\right)\times 9.8$$

$$P_b = 9163\ P_a$$

Q23.

The intake in **Figure 7** has a cross-sectional area of 0.74 m^2 and water flows in at 0.40 m/s. At the outlet, a distance D =180 m below the intake, the cross-sectional area is smaller than at the intake and the water flows out at 9.5 m/s. What is the magnitude of pressure difference between inlet and outlet?

Figure 7



A) 1.7×10^6 Pa
B) 2.5×10^6 Pa
C) 3.2×10^6 Pa
D) 8.6×10^6 Pa
E) 5.5×10^6 Pa

Ans:

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 \quad (\rho g h_2 \to 0)$$

$$p_1 - p_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) - \rho g D$$

$$p_1 - p_2 = 1000\left[\frac{1}{2}(9.5^2 - 0.4^2) - 9.8 \times 180\right]$$

$$|p_1 - p_2| = 1.7 \times 10^6 Pa$$

Q24.

An iron casting (block) containing a number of cavities weighs 6000 N in air and 4000 N in water. What is the total volume of all the cavities in the casting? The density of iron (that is, a sample with no cavities) is 7870 kg/m^3.

A) 0.126 m^3
B) 0.235 m^3
C) 0.723 m^3
D) 0.427 m^3
E) 0.315 m^3

Ans:

$$F_b - W = -W_a$$

$$F_b = W - W_a$$

$$m_\omega g = 6000 - 4000$$

$$\rho_\omega V g = 2000$$

$$V = \frac{2000}{1000 \times 9.8} = 0.204\, m^3$$

$$\text{Volume of Pure Iron } V_0 = \frac{6000}{9.8} = 0.078\, m^3$$

$$\text{Volume of Cavities} = V - V_0 = 0.126\, m^3$$

Q25.

A natural gas pipeline with a diameter 0.250 m delivers 1.55 cubic meters of gas per second. What is the flow speed of the gas in the pipeline?

A) 31.6 m/s
B) 17.0 m/s
C) 24.8 m/s
D) 83.0 m/s
E) 62.5 m/s

Ans:

$$\frac{V}{t} = A\frac{x}{t} = Av$$

$$\Rightarrow v = \left(\frac{V}{t}\right)\frac{1}{A} = \frac{1.55}{\pi r^2} = \frac{1.55}{\pi (0.125)^2} = 31.6\ m/s$$

Q26.

The function x = (6.0 m) cos[(2π rad/s)t] describes the simple harmonic motion of a body. The average speed of the body from t = 0 to t = 7.0 s is?

A) 24 m/s
B) 32 m/s
C) 64 m/s
D) 83 m/s
E) 15 m/s

Ans:

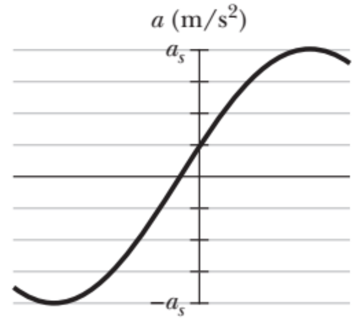
$$2\pi f = 2\pi \Rightarrow f = 1, \qquad Number\ of\ oscillations\ (N) = ft = 7$$

$$v_{av} = \frac{4x_m N}{t} = \frac{4 \times 6 \times 7}{7} = 24\ m/s$$

Q27.

What is the phase constant of the simple harmonic motion with a(t) given in **Figure 8,** if the position function has the form $x = x_m \cos(\omega t + \phi)$ and $a_s = 4.0$ m/s^2?

Figure 8



A) 105°
B) 135°
C) 215°
D) 175°
E) 315°

Ans:

$$a(t) = -a_s cos(\omega t + \Phi)$$

$$when\ t = 0, a(0) = -4cos\Phi$$

$$1 = -4cos\Phi \Rightarrow \Phi = \cos^{-1}\left(-\frac{1}{4}\right) = 105°$$

Q28.

A simple harmonic oscillator consists of a 0.800 kg block attached to a spring (k = 200 N/m). The block slides on a horizontal frictionless surface about the equilibrium point x = 0 with a total mechanical energy of 4.00 J. What is the speed of the block at x = 0.150 m?

A) 2.09 m/s
B) 1.28 m/s
C) 4.50 m/s
D) 3.25 m/s
E) 7.64 m/s

Ans:

$$K + U = E$$

$$\frac{1}{2}mv^2 + \frac{1}{2}kx^2 = 4$$

$$v = \sqrt{\frac{8 - 200 \times 0.15^2}{0.8}} = 2.09\ m/s$$

Q29.

A block of mass m is suspended by a vertical spring and oscillates with angular frequency ω_1. When the mass of the block is doubled it oscillates with angular frequency ω_2. Find the ratio $\frac{\omega_2}{\omega_1}$.

A) $\frac{1}{\sqrt{2}}$
B) 1
C) $\sqrt{2}$
D) 2
E) 4

Ans:

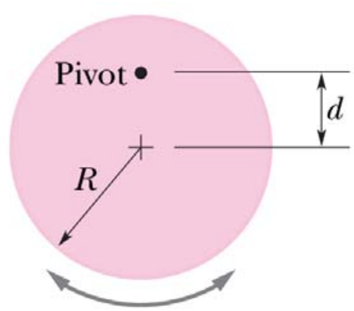
$$k = m\omega^2 \Rightarrow \omega_1 = \sqrt{\frac{k}{m}}, \qquad \omega_2 = \sqrt{\frac{k}{2m}}$$

$$\frac{\omega_2}{\omega_1} = \sqrt{\frac{\frac{k}{2m}}{\frac{k}{m}}} = \frac{1}{\sqrt{2}}$$

Q30.

In **Figure 9**, a physical pendulum consists of a uniform solid disk (radius R = 2.35 cm) supported in a vertical plane by a pivot located a distance d = 1.75 cm from the center of the disk. The disk is displaced by a small angle and released. What is the period of the resulting simple harmonic motion?

Figure 9



A) 0.366 s
B) 0.132 s
C) 0.541 s
D) 0.210 s
E) 0.912 s

Ans:

$$T = \sqrt{\frac{I}{mgd}}$$

$$T = \sqrt{\frac{\frac{1}{2}mR^2 + md^2}{mgd}}$$

$$T = \sqrt{\frac{0.5(2.35\times10^{-2})^2 + (1.75\times10^{-2})^2}{9.8\times1.75\times10^{-2}}} = 0.366\ s$$