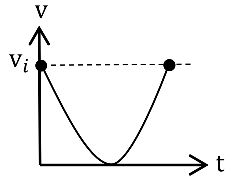
Q1.

A ball is thrown vertically upward into the air from the ground and returns to the ground. What happens to its speed?

A) decreases then increases
B) increases then decreases
C) always increases
D) always decreases
E) remains the same

Free Fall

$v = v_i - gt$



Ans:

A

Q2.

Two cars (A and B) start from rest from the same point at the same instant and move along the same straight line in the same direction, with accelerations a_A = 3.5 m/s^2 and a_B = 4.9 m/s^2. What is the distance between them after 2.0 s?

A) 2.8 m
B) 1.7 m
C) 8.4 m
D) 5.4 m

Ans:

$$x = v_i t + \frac{1}{2} at^2 = \frac{1}{2} at^2 \ \{\text{since } v_i = 0\}$$

$$x_A = \frac{1}{2} a_A t^2 = \frac{1}{2} \times 3.5 \times 4.0 = 7.0 \text{ m}$$

$$x_B = \frac{1}{2} a_B t^2 = \frac{1}{2} \times 4.9 \times 4.0 = 9.8 \text{ m}$$

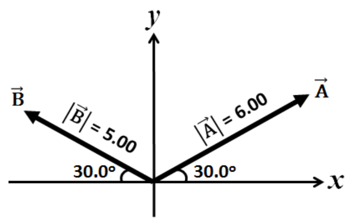
$$\Delta x = x_B - x_A = 2.8 \text{ m}$$

Q3.

Two vectors ($\vec{A}$ and $\vec{B}$) are shown in **FIGURE 1**. The vector $\vec{A}$-$\vec{B}$ is

A) $9.53\hat{i} + 0.50\hat{j}$
B) $0.87\hat{i} + 5.50\hat{j}$
C) $-9.53\hat{i} - 0.50\hat{j}$
D) $1.70\hat{i} + 0.50\hat{j}$
E) $1.70\hat{i} + 5.50\hat{j}$

Figure 1



Ans:

$$\vec{A} = (6 \times \cos 30°)\hat{\mathbf{i}} + (6 \times \sin 30°)\hat{\mathbf{j}} = 5.20\ \hat{\mathbf{i}} + 3.00\ \hat{\mathbf{j}}$$

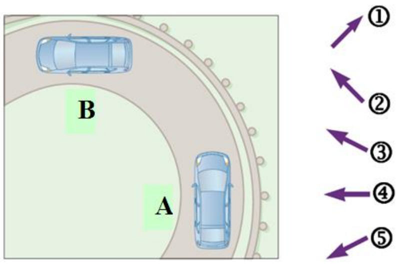
$$\vec{B} = (5.0 \times \cos 150°)\hat{\mathbf{i}} + (5.0 \times \sin 150°)\hat{\mathbf{j}} = -4.33\ \hat{\mathbf{i}} + 2.50\ \hat{\mathbf{j}}$$

$$\vec{A} - \vec{B} = 9.53\ \hat{\mathbf{i}} + 0.50\ \hat{\mathbf{j}}$$

Q4.

FIGURE 2 shows a top view of a car moving in uniform circular motion. As the car moves from point A to point B, which of the vectors (1 through 5) shows the direction of the car's average acceleration between these two points?

Figure 2



A) 5
B) 1
C) 3
D) 4
E) 2

Ans:

$$\vec{\mathbf{a}}_{avg} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{\mathbf{v}}_B - \vec{\mathbf{v}}_A}{\Delta t} = \frac{-v\hat{\mathbf{i}} - (v\hat{\mathbf{j}})}{\Delta t}$$

$$= \frac{v}{\Delta t}(-\hat{\mathbf{i}} - \hat{\mathbf{j}}) \leftarrow 3rd\ quadrant\ \Rightarrow 5$$

Q5.

A car starts from rest at the origin and accelerates at the rate of $3.0\hat{i} - 2.0\hat{j}$ (m/s^2). How far is the car from the origin after 5.0 s?

A) 45 m
B) 37 m
C) 25 m
D) 57 m
E) 41 m

Ans:

$$\vec{r} = \vec{v}_i\, t + \frac{1}{2}\vec{a}\, t^2 = \frac{1}{2}\vec{a}\, t^2 \qquad \{\vec{v}_i = 0\}$$

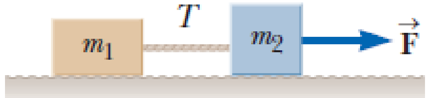
$$= \left(\frac{1}{2}\right)(3\hat{\mathbf{i}} - 2\hat{\mathbf{j}})(25) = 37.5\,\hat{\mathbf{i}} - 25.0\,\hat{\mathbf{j}}\ (\mathrm{m})$$

$$distance = |\vec{r}| = \sqrt{(37.5)^2 + (25.0)^2} = 45\ \mathrm{m}$$

Q6.

Two blocks, connected by a massless string, are pulled on a frictionless surface by a horizontal force $\vec{F}$, as shown in **FIGURE 3**. Take m_1 = 10 kg, m_2 = 15 kg, and F = 65 N. What is the magnitude of the tension T in the string?

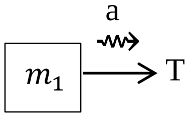
Figure 3



A) 26 N
B) 39 N
C) 32 N
D) 17 N
E) 29 N

Ans:

$$a = \frac{F}{M} = \frac{65}{10+15} = 2.6\ m/s^2$$

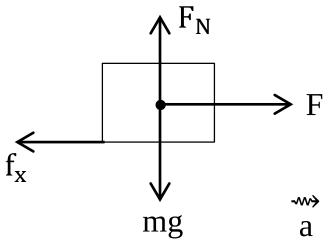


$$m_1 a = T \Longrightarrow T = 10 \times 2.6 = 26\ N$$

Q7.

A person pushes horizontally with a force of 16.0 N on a 4.00-kg block to move it across a horizontal floor. The coefficient of kinetic friction between the block and the floor is 0.250. What is the magnitude of the acceleration of the block?

A) 1.55 m/s^2
B) 4.00 m/s^2
C) 2.45 m/s^2
D) 6.45 m/s^2
E) 3.65 m/s^2



Ans:

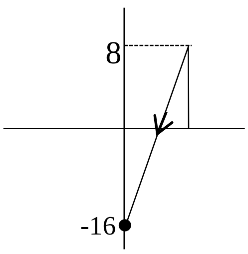
$$ma = F - f_k = F - \mu_k F_N = F - \mu_k mg$$

$$a = \frac{F}{m} - \mu_k g = \frac{16}{4} - (0.25 \times 9.8) = 1.55\ m/s^2$$

Q8.

The force acting on a particle is $F_x = (8.0x - 16)$, where F is in Newtons and x is in meters. Find the work done by this force on the particle as it moves from x = 0 to x = 3.0 m.

A) – 12 J
B) + 12 J
C) – 20 J
D) + 20 J
E) + 36 J



Ans:

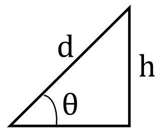
$$W = -\left(\frac{1}{2} \times 2 \times 16\right) + \left(\frac{1}{2} \times 1 \times 8\right)$$

$$= -16 + 4 = -12\ J$$

Q9.

A 5.0-kg block is sent up a plane inclined at 30^{o} with an initial speed of 6.0 m/s. The block comes to rest after travelling 2.0 m along the plane. What is the change in the mechanical energy of the block during its motion on the plane?

A) – 41 J
B) + 140 J
C) + 49 J
D) – 90 J
E) + 14 J



Ans:

$$\Delta K = \cancel{K_f}^{\,0} - K_i = -\tfrac{1}{2}mv_i^2 = -\tfrac{1}{2}\times 5 \times 36 = -90\ \text{J}$$

$$\sin\theta = \frac{h}{d} \Rightarrow h = d \cdot sin\theta$$

$$= 2 \times \frac{1}{2} = 1.0\ \text{m}$$

$$\Delta U_g = mgh = 5 \times 9.8 \times 1.0 = +49\ \text{J}$$

$$\Delta E_{mec} = \Delta K + \Delta U_g = -90 + 49 = -41\ \text{J}$$

Q10.

An object of mass *m* moves along the positive *x*-axis with kinetic energy *K*. It collides with an object of mass *2m* that is initially at rest. The collision is completely inelastic, and the objects move along the positive *x*-axis after the collision. What is the kinetic energy of the composite system just after the collision?

A) K/3
B) K
C) K/2
D) K/4
E) K/9

Ans:

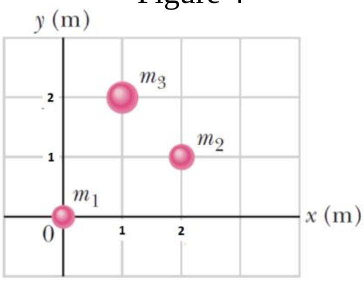
$$P_i = P_f: mv = (m + 2m) = 3mV \rightarrow V = \frac{v}{3}$$

$$k_f = \frac{1}{2}MV^2 = \frac{1}{2} \times 3m \times \frac{v^2}{9} = \left(\frac{1}{2} \times mv^2\right) \times \left(\frac{1}{3}\right) = \frac{K}{3}$$

Q11.

In **FIGURE 4**, the three particles have masses m_1 = 3.0 kg, m_2 = 2.0 kg, and m_3 = 5.0 kg. What are the coordinates of the center of mass of the system?

Figure 4



A) (0.90, 1.2) m
B) (1.2, 0.90) m
C) (1.2, 1.2) m
D) (0.90, 0.90) m
E) (1.0, 1.0) m

Ans:

$$M = \sum m_i = 3 + 4 + 5 = 12 \text{ kg}$$

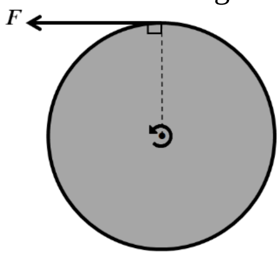
$$x_{com} = \frac{1}{12}[(0 \times 3) + (1 \times 5) + (2 \times 4)] = 1.1 \text{ m}$$

$$y_{com} = \frac{1}{12}[(0 \times 3) + (2 \times 5) + (1 \times 4)] = 1.2 \text{ m}$$

Q12.

A uniform disk, of radius 20 cm and mass 350 g, rotates about an axis through its center and perpendicular to its plane. Starting from rest, a force **F**, applied as shown in **FIGURE 5**, brings the disk to an angular speed of 315 rad/s in 15 s. What is the magnitude of force **F**?

Figure 5



A) 0.74 N
B) 0.85 N
C) 0.64 N
D) 0.37 N
E) 1.3 N

Ans:

$$\omega = \overset{0}{\cancel{\omega_i}} + \alpha t \Rightarrow \alpha = \frac{\omega}{t} = \frac{315}{15} = 21 \text{ rad}/s^2$$

$$\tau = I\alpha$$

$$FR = \frac{1}{2}MR^2\alpha \Rightarrow F = \frac{MR\alpha}{2}$$

$$\therefore F = \frac{0.35 \times 0.2 \times 21}{2} = 0.735 \text{ N} \rightarrow 0.74 \text{ N}$$

Q13.

A uniform disk rolls smoothly down a 30° incline. What is the magnitude of the linear acceleration of the center of mass of the disk?

A) 3.3 m/s²
B) 9.8 m/s²
C) 4.9 m/s²
D) 2.4 m/s²
E) 5.1 m/s²

Ans:

$$\frac{I_{com}}{MR^2} = \frac{0.5MR^2}{MR^2} = 0.5$$

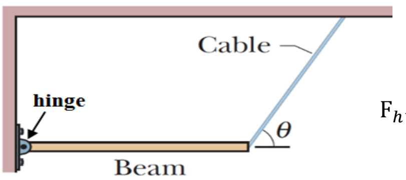
$$a_{com} = \frac{g\sin\theta}{1+\left(\frac{Icom}{MR^2}\right)} = \frac{9.8\times\frac{1}{2}}{1+0.5} = 3.3\ m/s^2$$

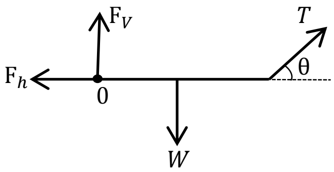
Q14.

A uniform beam is 5.00 m long and has a mass of 60.0 kg. The beam is supported in a horizontal position by a hinge and a cable, as shown in **FIGURE 6**, with angle θ = 30.0°. What is the magnitude of the horizontal component of the force of the hinge on the beam?

Figure 6

A) 509 N
B) 588 N
C) 339 N
D) 170 N
E) 402 N





Ans:

$$\sum \tau_0 = 0:\ -W\cdot\frac{L}{2} + T\cdot L\cdot\sin\theta = 0$$

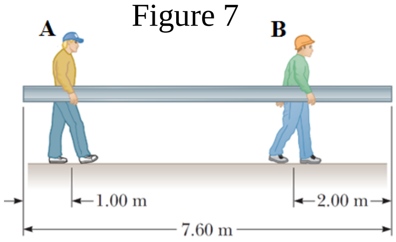
$$\Rightarrow T = \frac{W}{\sin\theta} = \frac{W}{2\times\frac{1}{2}} = W = mg = 60\times 9.8 = 588\ N$$

$$\sum F_x = 0: T\cos\theta - F_h = 0\ \Rightarrow F_h = T\cdot\cos\theta = 509\ N$$

Q15.

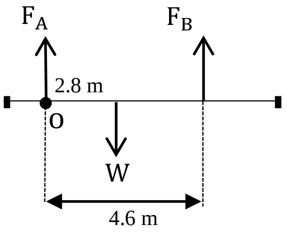
A uniform beam, of length 7.60 m and weight 375 N, is carried by two persons (A and B), as shown in **FIGURE 7**. Determine the magnitude of the force that each person exerts on the beam.

Figure 7



A) $F_A = 147$ N, $F_B = 228$ N
B) $F_A = 241$ N, $F_B = 134$ N
C) $F_A = 134$ N, $F_B = 241$ N
D) $F_A = 228$ N, $F_B = 147$ N
E) $F_A = 188$ N, $F_B = 188$ N

Ans:



$$\sum \tau_0 = 0: -(W \times 2.8) + F_B \times 4.6 = 0$$

$$F_B = \frac{2.8\,W}{4.6} = 228\,N$$

No need to look at the rest of the answers!

Q16.

A rod, of length 1.5 m and radius 4.8 mm, is hung vertically to a ceiling. A box of mass 85 kg is attached to the free end of the rod, stretching it by 2.5 mm. What is Young's modulus of the rod?

A) 6.9×10^{9} N/m^2
B) 2.9×10^{9} N/m^2
C) 3.7×10^{9} N/m^2
D) 1.5×10^{9} N/m^2
E) 4.3×10^{9} N/m^2

Ans:

$$\frac{F}{A} = E \cdot \frac{\Delta L}{L}$$

$$\Rightarrow E = \frac{F \cdot L}{A \cdot \Delta L} = \frac{F \cdot L}{\pi r^2 \cdot \Delta L} = \frac{mgL}{\pi r^2\, \Delta L} = \frac{85 \times 9.8 \times 1.5}{\pi \times (4.8 \times 10^{-3})^2 \times 2.5 \times 10^{-3}}$$

$$= 6.9 \times 10^{9}\ \mathrm{N/m^2}$$

Q17.

In deep space, two particles, each of mass *m*, are held at rest a distance *d* apart. They are released and start to move toward each other. What is the speed of each particle when they are separated by *d/2*?

A) $v = \sqrt{Gm/d}$
B) $v = \sqrt{2Gm/d}$
C) $v = \sqrt{Gm/2d}$
D) $v = Gm/d$
E) $v = Gm/2d$

Ans:

$$K_i + U_i = K_f + U_f \quad (K_i \to 0)$$

$$-\frac{Gm^2}{d} = 2 \times \frac{1}{2} mv^2 - \frac{Gm^2}{d/2}$$

$$mv^2 = -\frac{Gm^2}{d} + \frac{2Gm^2}{d} = \frac{Gm^2}{d}$$

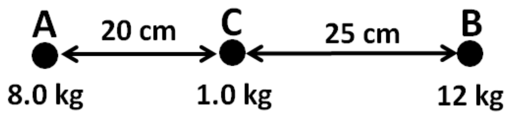
$$v^2 = \frac{Gm}{d} \Rightarrow v = \sqrt{\frac{Gm}{d}}$$

Q18.

Three particles are held at rest, as shown in **FIGURE 8**. Find the net gravitational force on particle C due to particles A and B.

A) 5.3×10^{-10} N, toward A
B) 5.3×10^{-10} N, toward B
C) 2.6×10^{-10} N, toward A
D) 2.6×10^{-10} N, toward B
E) Zero

Figure 8



Ans:

$$F_{CA} = \frac{6.67 \times 10^{-11} \times 1.0 \times 8.0}{0.04} = 1.334 \times 10^{-8}\ \text{N} \rightarrow left$$

$$F_{CB} = \frac{6.67 \times 10^{-11} \times 1.0 \times 12}{0.0625} = 1.28064 \times 10^{-8}\ \text{N} \rightarrow right$$

$$F_{net} = F_{CA} - F_{CB} = 5.336 \times 10^{-10}\ \text{N} \rightarrow \text{towards A}$$

Q19.

Two satellites are in circular orbits around a planet. One satellite has orbital radius 5.00×10^{7} m, and orbital speed 5000 m/s. The second satellite has orbital radius 4.00×10^{7} m. What is the orbital speed of the second satellite?

A) 5590 m/s
B) 6250 m/s
C) 4470 m/s
D) 4000 m/s
E) 5920 m/s

Ans:

$$K = \frac{1}{2}mv^2 : \frac{1}{2}mv^2 = \frac{GmM}{2r} \Rightarrow v^2 = \frac{GM}{r}$$

$$\left.\begin{aligned} v_1^2 &= \frac{GM}{r_1} \\ v_2^2 &= \frac{GM}{r_2} \end{aligned}\right\} \frac{v_2}{v_1} = \sqrt{\frac{r_1}{r_2}} \Rightarrow v_2 = v_1 \cdot \sqrt{\frac{r_1}{r_2}} = 5000 \times \sqrt{\frac{5\times10^7}{4\times10^7}} = 5590\ \mathrm{m/s}$$

Q20.

On planet X, a stone thrown upward from the ground at 12.0 m/s returns to the ground in 3.00 s. If the radius of this planet is 3.18×10^{8} m, what is its mass?

A) 1.21×10^{28} kg
B) 4.64×10^{28} kg
C) 5.51×10^{28} kg
D) 3.57×10^{28} kg
E) 3.73×10^{28} kg

Ans:

Free Fall: $v_f = v_i - gt \Rightarrow 0 = 12 - (g\times1.5) \Rightarrow g = 8\ \mathrm{m/s^2}$

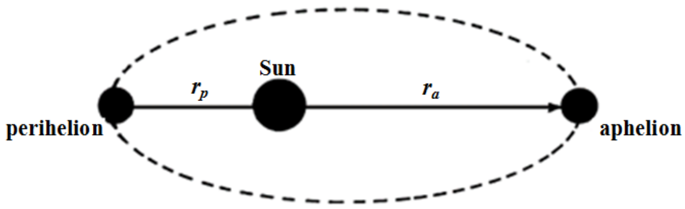
$$g = \frac{GM}{R^2} \rightarrow M = \frac{gR^2}{G} = \frac{8\times(3.18\times10^8)^2}{6.67\times10^{-11}} = 1.21\times10^{28}\ \mathrm{kg}$$

Q21.

In **FIGURE 9**, the maximum distance from the Earth to the Sun (at aphelion) is r_a = 1.52×10^{11} m, and the distance of closest approach (at perihelion) is r_p = 1.47×10^{11} m. The Earth's orbital speed at perihelion is 30.3 km/s. Determine the kinetic energy of the Earth at aphelion.

A) 2.57×10^{33} J
B) 2.94×10^{33} J
C) 2.71×10^{33} J
D) 1.83×10^{33} J
E) 2.45×10^{33} J

Figure 9



Ans:

Angular momentum is constant

$$L_a = L_p : m v_a r_a = m v_p r_p$$

$$\Rightarrow v_a = \frac{r_p}{r_a} \cdot v_p = \frac{1.47 \times 10^{11}}{1.52 \times 10^{11}} \times 3.03 \times 10^4 = 2.93 \times 10^4 \text{ m/s}$$

$$K_a = \frac{1}{2} m\, v_a^2 = \frac{1}{2} \times 5.98 \times 10^{24} \times (2.93 \times 10^4)^2 = 2.57 \times 10^{33} \text{J}$$

Q22.

An ideal fluid flows through a horizontal pipe whose diameter varies along its length. As the pipe diameter increases

A) the pressure increases
B) the kinetic energy per unit volume increases
C) the pressure decreases
D) neither the kinetic energy nor pressure are affected
E) both kinetic energy and pressure increase

Ans:

$$\left.\begin{array}{l} v \propto \frac{1}{A} \\ v \propto \frac{1}{p} \end{array}\right\} p \propto A$$

Q23.

The human ear has an area of 5.3×10^{-5} m^2 and is damaged if the force on it increases by 1.5 N above the force from atmospheric pressure. If a person is diving in water, below what depth from the surface of the water could damage to his ear start to occur?

A) 2.9 m
B) 1.3 m
C) 3.7 m
D) 4.2 m

Ans:

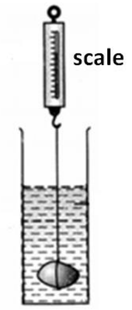
$$p = \frac{F}{A} = \frac{1.5}{5.3\times10^{-5}} = 28.302\times10^{3}\ \text{Pa}$$

$$p = \rho g d \Rightarrow d = \frac{p}{\rho g} = \frac{28.302\times10^{3}}{10^{3}\times9.8} = 2.9\ \text{m}$$

Q24.

An object has a mass of 5.00 kg. Its weight is measured by a scale while it is completely submerged in a fluid of density 1020 kg/m^3, as shown in **FIGURE 10**. If the scale reading is 25.0 N, what is the density of the object?

Figure 10



A) 2.08×10^{3} kg/m^3
B) 2.49×10^{3} kg/m^3
C) 2.37×10^{3} kg/m^3
D) 2.01×10^{3} kg/m^3
E) 2.13×10^{3} kg/m^3

Ans:

$$\text{True Weight: } W = mg = 5\times9.8 = 49\ \text{N}$$

$$\text{Apparent Weight: } W_a = 25\ \text{N}$$

$$\text{Buoyant force}: F_b = W - W_a = 24\ \text{N}$$

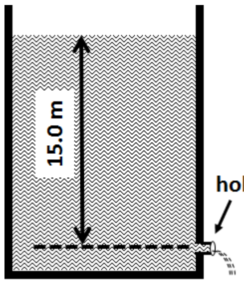
$$F_b = \rho_f V_f g \longrightarrow V_f = \frac{F_b}{\rho_f g} = \frac{24}{1020\times9.8} = 2.4\times10^{-3}\ \text{m}^3$$

$$\rho = \frac{m}{V} = \frac{5}{2.4\times10^{-3}} = 2082.5 = 2.08\times10^{3}\ \text{kg/m}^3$$

Q25.

A small hole is drilled in the side of a large water tank, 15.0 m below the top water level in the tank, as shown in **FIGURE 11**. The top of the tank is open to the atmosphere. Find the speed with which water flows out of the tank.

Figure 11



A) 17.1 m/s
B) 12.1 m/s
C) 8.57 m/s
D) 23.8 m/s
E) 15.4 m/s

Ans:

$$\cancel{p_1} + \cancel{\frac{1}{2}\rho v_1^2}^{\,0} + \rho g y_1 = \cancel{p_2} + \frac{1}{2}\rho v_2^2 + \cancel{\rho g y_2}^{\,0}$$

$v_1 \ll v_2 \Rightarrow v_1 \approx 0$

$p_1 = p_2 =$ atmospheric pressure

$y_2 = 0$ reference ; $y_1 = h$

$\Rightarrow v_2 = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 15} = 17.1\ \text{m/s}$

Q26.

At one point in a pipe, the water speed is 3.60 m/s and the pressure is 5.00×10^4 Pa. Find the pressure at a second point in the pipe that is 12.0 m lower than the first if the pipe diameter at the second point is twice that at the first.

A) 1.74×10^5 Pa
B) 8.27×10^5 Pa
C) 6.76×10^5 Pa
D) 5.61×10^5 Pa
E) 4.39×10^5 Pa

Ans:

$$A_2 = \pi r_2^2 = \frac{\pi}{4} \cdot d_2^2 = \frac{\pi}{4}(2d_1)^2 = 4\left[\frac{\pi d_1^2}{4}\right] = 4\,A_1$$

$$A_1 v_1 = A_2 v_2 \Rightarrow v_2 = \frac{A_1}{A_2} \cdot v_1 = \frac{A_1}{4A_1} \cdot (3.6) = 0.9\ \text{m/s}$$

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h = p_2 + \frac{1}{2}\rho v_2^2 + \rho g(0)$$

$$\Rightarrow p_2 = p_1 + \frac{1}{2}\rho\,(v_1^2 - v_2^2) + \rho g h$$

$$= 5 \times 10^4 + 500(12.96 - 0.81) + (10^3 \times 9.8 \times 12) = 1.74 \times 10^5\ \text{Pa}$$

Q27.

A particle is oscillating with simple harmonic motion with a period of 0.25 s and has a maximum speed of 3.5 m/s. What is the amplitude of the motion?

A) 0.14 m
B) 0.94 m
C) 0.19 m
D) 0.75 m
E) 0.38 m

Ans:

$$v_{max} = \omega\, y_m = \frac{2\pi}{T} y_m$$

$$\Rightarrow y_m = \frac{T \cdot v_{max}}{2\pi} = \frac{0.25 \times 3.5}{2\pi} = 0.14 \text{ m}$$

Q28.

A block (m = 0.20 kg) is attached to a spring (k = 100 N/m) and is moving in simple harmonic motion on a horizontal frictionless surface with an amplitude of 0.18 m. What is the speed of the block when its displacement from the equilibrium position is 0.15 m?

A) 2.2 m/s
B) 3.7 m/s
C) 4.0 m/s
D) 6.4 m/s
E) 1.3 m/s

Ans:

$$\text{E} = \frac{1}{2}\,\text{k}\,\text{x}_\text{m}^2 = \frac{1}{2} \times 100 \times (0.18)^2 = 1.62 \text{ J}$$

$$\text{E} = \text{K} + \text{U} = \frac{1}{2}\text{mv}^2 + \frac{1}{2}\text{kx}^2$$

$$1.62 = 0.1\text{v}^2 + \left(\frac{1}{2} \times 100 \times 0.15^2\right)$$

$$0.1\text{v}^2 = 0.495 \Rightarrow \text{v} = 2.2 \text{ m/s}$$

Q29.

A thin rod, of length 1.00 m, is pivoted from one end and is allowed to oscillate in a vertical plane like a pendulum. What is the period of oscillation of this system? Ignore air resistance and the friction at the pivot.

A) 1.64 s
B) 2.01 s
C) 24.1 s
D) 19.7 s
E) 2.57 s

Ans:

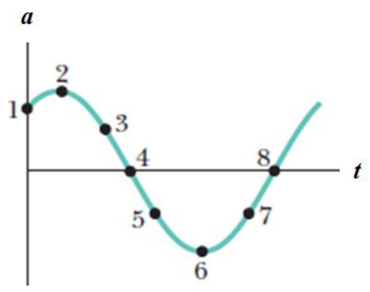
$$I = \frac{1}{3}mL^2;\ h = \frac{L}{2} \Rightarrow \frac{I}{mgh} = \frac{1}{mg}\cdot\frac{mL^2}{3}\cdot\frac{2}{L} = \frac{2L}{3g}$$

$$T = 2\pi\sqrt{\frac{I}{mgh}} = 2\pi\sqrt{\frac{2L}{3g}} = 2\pi\sqrt{\frac{2\times 1.00}{3\times 9.8}} = 1.64\ \text{s}$$

Q30.

The acceleration of a particle undergoing simple harmonic motion is graphed in **FIGURE 12**. At which point is the particle at + x_m, where x_m is the amplitude of the motion and $x = 0$ is the equilibrium position?

A) 6
B) 2
C) 4
D) 8
E) 1



Ans:

a is maximum and negative.