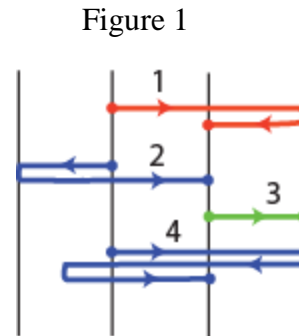


Q1.

Figure 1 shows four paths along which objects move from a starting point to a final point as indicated by the arrows. The paths pass over a grid of **equally spaced** straight lines. All the objects take the same amount of time for their trips. Rank the paths according to the average speed of the objects, greatest first.

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



Ans:

A**Q2.**

If vector \vec{A} is added to vector \vec{B} , the result is $6\hat{i} - 1\hat{j}$. If vector \vec{B} is subtracted from vector \vec{A} , the result is $2\hat{i} + 7\hat{j}$. What is the magnitude of vector \vec{A} ?

- A) 5
 B) 3
 C) 4
 D) 6
 E) 7

Ans:

$$\vec{A} + \vec{B} = 6\hat{i} - 1\hat{j} \rightarrow (1)$$

$$\vec{A} - \vec{B} = 2\hat{i} + 7\hat{j} \rightarrow (2)$$

Adding equations (1) and (2) we get, $2\vec{A} = 8\hat{i} + 6\hat{j}$

$$\vec{A} = 4\hat{i} + 3\hat{j}$$

$$|\vec{A}| = (16 + 9)^{1/2} = 5$$

Q3.

A projectile, fired over a level ground, reaches a maximum height of 40.0 m and hits the ground 300 m from its launching point. Find its initial velocity in unit vector notation.

A) $(52.5 \hat{i} + 28.0 \hat{j}) \text{ m/s}$

B) $(28.0 \hat{i} + 52.5 \hat{j}) \text{ m/s}$

C) $(26.3 \hat{i} + 28.0 \hat{j}) \text{ m/s}$

D) $(26.3 \hat{i} + 14.0 \hat{j}) \text{ m/s}$

E) $(30.0 \hat{i} + 20.0 \hat{j}) \text{ m/s}$

Ans:

$$H = \frac{v_0^2}{g} \sin^2 \theta \Rightarrow v_0 \sin \theta = v_{0y} = \sqrt{2gH} = 28.0 \text{ m/s}$$

$$R = \frac{v_0^2}{g} \sin 2\theta \Rightarrow (2v_0 \sin \theta \times v_0 \cos \theta) / g$$

$$= \frac{2v_{0y}v_{0x}}{g} = R$$

$$v_{0x} = \frac{gR}{2v_{0y}} = \frac{9.8 \times 300}{2 \times 28.0} = 52.5 \text{ m/s}$$

Q4.

Consider the following two situations: (I) A box does not move while you are pushing on it, and (II) the box moves with increasing speed while you are pushing on it. Which of the following statements is TRUE about the magnitudes of your force on the box and the force of the box on you?

A) They are equal in both situations

B) They are equal in situation (I) only

C) They are equal in situation (II) only

D) The force of the box on you is smaller than your force on the box in situation (II)

E) The force of the box on you is larger than your force on the box in situation (I)

Ans:

A

Q5.

A box of mass 20.0 kg is pulled along a horizontal floor by a constant force \vec{F} making an angle of 30.0° with the horizontal. The coefficients of static and kinetic friction between the box and the horizontal floor are 0.600 and 0.300, respectively. Find the magnitude of \vec{F} if the box is moving at a constant velocity of 3.00 m/s.

- A) 57.9 N
- B) 45.7 N
- C) 10.8 N
- D) 34.5 N
- E) 5.32 N

Ans:

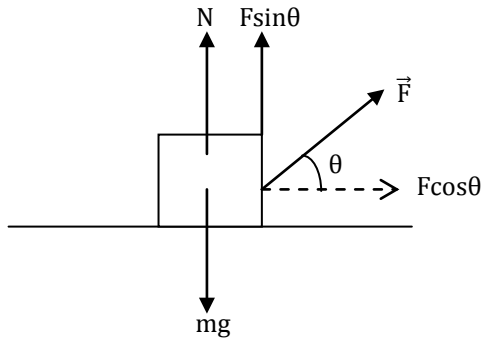
$$N + F\sin\theta = mg$$

$$N = mg - F\sin\theta$$

$$F\cos\theta = \mu_k (mg - F\sin\theta)$$

$$F(\cos\theta + \mu_k\sin\theta) = \mu_k mg$$

$$F = \frac{\mu_k mg}{\cos\theta + \mu_k\sin\theta} = 57.87 \text{ N}$$

**Q6.**

The position of a 3.0 kg object as a function of time is given by $x = -6.0t - 3.0t^2 + 1.0t^3$, with x in meters and t in seconds. Find the net work done on the object from $t = 0$ to $t = 2.0$ s.

- A) 0 J
- B) 36 J
- C) 72 J
- D) 45 J
- E) -36 J

Ans:

$$x = -6.0t - 3.0t^2 + 1.0t^3$$

$$\frac{dx}{dt} = v(t) = -6 - 6t + 3t^2$$

$$v(0) = -6 \text{ m/s}; v(2) = -6 - 12 + 12 = -6 \text{ m/s}$$

$$\Delta k = \frac{1}{2}mv^2(2) - \frac{1}{2}mv^2(1) = 0$$

Q7.

A 2.5 kg block is released from rest 20 m above the ground. Find its mechanical energy when it is 15 m above the ground. Ignore air resistance.

- A) $4.9 \times 10^2 \text{ J}$
- B) $3.7 \times 10^2 \text{ J}$
- C) $1.2 \times 10^2 \text{ J}$
- D) $8.8 \times 10^2 \text{ J}$
- E) $9.8 \times 10^2 \text{ J}$

Ans:

$$\begin{aligned} E &= mg \times 20 = (\text{constant}) \\ &= 2.5 \times 9.8 \times 20 = 4.9 \times 10^2 \text{ J} \end{aligned}$$

Q8.

A 10.0 g bullet travelling horizontally with a speed of $1.00 \times 10^3 \text{ m/s}$ strikes and passes through the center of mass of a 5.00 kg block initially at rest. The speed of the bullet just after it emerges from the block is 250 m/s in the same horizontal direction. Find the magnitude of the impulse delivered to the block.

- A) $7.50 \text{ kg}\cdot\text{m/s}$
- B) $3.40 \text{ kg}\cdot\text{m/s}$
- C) $1.43 \text{ kg}\cdot\text{m/s}$
- D) $9.80 \text{ kg}\cdot\text{m/s}$
- E) $8.54 \text{ kg}\cdot\text{m/s}$

Ans:

$$\begin{aligned} \vec{p}_i &= \vec{p}_f \\ m_b \vec{v}_{bi} + M_B \vec{v}_{Bi} &= m_b \vec{v}_{bf} + M_B \vec{v}_{Bf} \\ M_B (\vec{v}_{Bf} - \vec{v}_{Bi}) &= \vec{m}_b \vec{v}_{bi} - \vec{m}_b \vec{u}_{bf} \\ &= 10^{-2}(1000 - 250) \\ &= 7.50 \text{ kg}\cdot\text{m/s} \end{aligned}$$

Q9.

A 2.0 kg particle moving with a velocity of $(2.0 \hat{i} - 3.0 \hat{j}) \text{ m/s}$, and a 3.0 kg particle moving with a velocity of $(1.0 \hat{i} + 6.0 \hat{j}) \text{ m/s}$ collide elastically. Find the velocity of the center of mass of these two particles after collision.

A) $(1.4 \hat{i} + 2.4 \hat{j}) \text{ m/s}$

B) $(3.0 \hat{i} + 3.0 \hat{j}) \text{ m/s}$

C) $(1.0 \hat{i} - 9.0 \hat{j}) \text{ m/s}$

D) $(2.0 \hat{i} - 18 \hat{j}) \text{ m/s}$

E) $(1.4 \hat{i} - 2.4 \hat{j}) \text{ m/s}$

Ans:

$$\vec{v}_{\text{com}} = \frac{m_1 \vec{v}_1 + m_2 \vec{v}_2}{m_1 + m_2} = \frac{4 \hat{i} - 6 \hat{j} + 3 \hat{i} + 18 \hat{j}}{5} = \frac{7 \hat{i} + 12 \hat{j}}{5} = 1.4 \hat{i} + 2.4 \hat{j} \text{ m/s}$$

Q10.

A thin hoop of mass 32.0 kg and radius 1.20 m is rotating about its central axis at 29.3 rad/s. What is the required average power to bring the hoop to a stop in 15.0 s?

A) 1.32 kW

B) 3.40 kW

C) 2.56 kW

D) 0.982 kW

E) 0.543 kW

Ans:

$$P = \frac{W}{t} = \frac{\Delta k}{t}$$

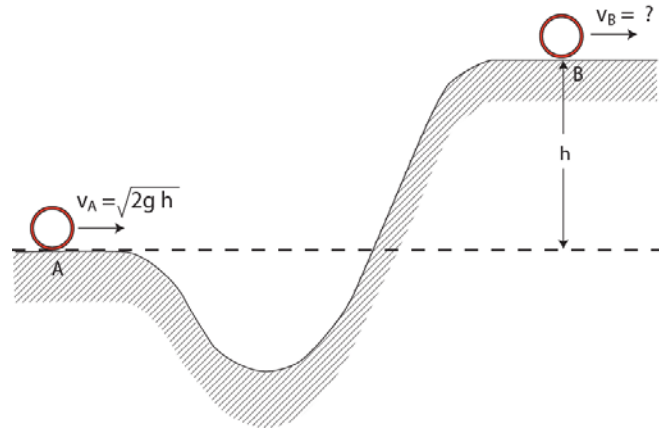
$$= \frac{\frac{1}{2} I \omega_f^2 - \frac{1}{2} I \omega_i^2}{t} = \frac{\frac{1}{2} I \omega_f^2 - 0}{t} = \frac{\frac{1}{2} (MR^2) \omega^2}{t}$$

$$= \frac{\frac{1}{2} \times 32 \times (1.25)^2 (29.3)^2}{15} = 1,318.6 \text{ W} = 1.32 \text{ kW}$$

Q11.

A thin hoop of mass M and radius R rolls without slipping over a track (**Figure 2**). When it goes by point A, its center of mass speed is $\sqrt{2gh}$. With what center of mass speed will the hoop pass point B?

Figure 2



- A) \sqrt{gh}
- B) $\sqrt{2gh}$
- C) \sqrt{Mgh}
- D) $\frac{2gh}{R^2}$
- E) $\sqrt{3gh}$

Ans:

$$\begin{aligned} K_{\text{Roll}} &= \frac{1}{2}I\omega^2 + \frac{1}{2}Mv_{\text{com}}^2 \\ &= \frac{1}{2}(MR^2)\omega^2 + \frac{1}{2}Mv_{\text{com}}^2 \\ &= \frac{1}{2}Mv_{\text{com}}^2 + \frac{1}{2}Mv_{\text{com}}^2 \end{aligned}$$

$$K_{\text{Roll}} = Mv_{\text{com}}^2$$

$$(K_{\text{Roll}})_A = (K_{\text{Roll}})_B + U$$

$$\cancel{M}(v_{\text{com}}^2)_A = \cancel{M}(v_{\text{com}}^2)_B + \cancel{M}gh = 2gh - gh = (v_{\text{com}}^2)_B$$

$$(v_{\text{com}})_B = \sqrt{gh}$$

Q12.

A uniform thin rod of length 1.00 m and mass 1.00 kg is pivoted at one end and is hanging vertically at rest. A 10.0 g bullet travelling horizontally with a speed of 400 m/s strikes the rod and embeds itself into it at its center of mass (**Figure 3**). Find the angular speed of the rod-bullet system just after impact.

A) 5.96 rad/s

B) 1.23 rad/s

C) 6.53 rad/s

D) 5.32 rad/s

E) 2.54 rad/s

Ans:

$$L_i = L_f$$

$$m_b v_b \frac{L}{2} = (I_b + I_R) \omega$$

$$m_b v_b \frac{L}{2} = \left[m_b \left(\frac{L}{2} \right)^2 + \frac{1}{3} M L^2 \right] \omega$$

$$\omega = \frac{m_b v_b L}{2 \left[m_b \frac{L^2}{4} + \frac{1}{3} M L^2 \right]}$$

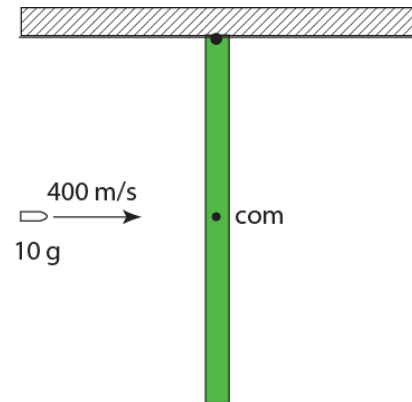
$$\omega = \frac{10^{-2} \times 400}{2 \left[10^{-2} \times 0.25 + \frac{1}{3} \right]}$$

$$10^{-2} \times 400 - 0.5 = 2$$

$$m_b \left(\frac{L}{2} \right)^2 = 10^{-2} \times (0.5)^2 = 0.0025$$

$$\Rightarrow \omega = 5.96 \text{ rad/s}$$

Figure 3



Q13.

When water freezes, it expands by about 9.0 %. What would be the pressure increase inside the radiator of your car if the water in it freezes? The bulk modulus of ice is $2.0 \times 10^9 \text{ N/m}^2$.

- A) $1.8 \times 10^8 \text{ Pa}$.
- B) $1.8 \times 10^5 \text{ Pa}$.
- C) $4.5 \times 10^8 \text{ Pa}$.
- D) $4.5 \times 10^3 \text{ Pa}$.
- E) $2.0 \times 10^9 \text{ Pa}$.

Ans:

$$B = \frac{\Delta P}{\frac{\Delta V}{V}} \Rightarrow \Delta P = B \frac{\Delta V}{V}$$

$$\Delta P = 2 \times 10^9 \times 0.09 = 0.18 \times 10^9 = 1.8 \times 10^8 \text{ Pa}$$

Q14.

A uniform and symmetric sign board is supported by two strings as shown in **Figure 4**. Find the ratio of the tension in string 1 to the weight of the sign board.

- A) 0.33
- B) 0.50
- C) 0.67
- D) 0.25
- E) 0.75

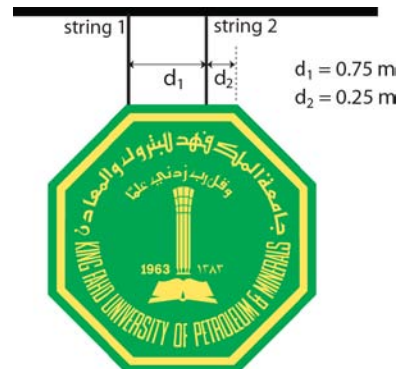
Ans:

$$T_1 d_1 = Mg \times 0.25$$

$$T_1 \times 0.75 = Mg \times 0.25$$

$$T_1 = \frac{Mg \times 0.25}{0.75} = \frac{Mg}{3} = 0.33 Mg \Rightarrow \frac{T_1}{Mg} = 0.33$$

Figure 4



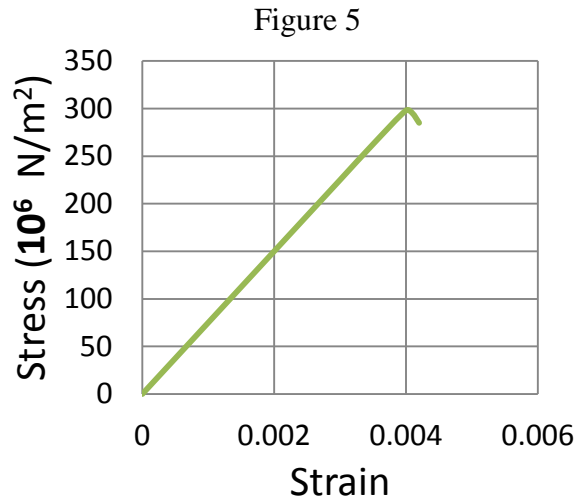
Q15.

Figure 5 shows the stress-strain curve for a material. What is Young's modulus of this material?

- A) $7.50 \times 10^{10} \text{ N/m}^2$
- B) $3.00 \times 10^8 \text{ N/m}^2$
- C) $1.50 \times 10^{11} \text{ N/m}^2$
- D) $2.00 \times 10^{-9} \text{ N/m}^2$
- E) $6.70 \times 10^{-11} \text{ N/m}^2$

Ans:

$$\begin{aligned}
 E &= \text{Slope} \\
 &= \frac{150 \times 10^6}{0.002} \\
 &= 7.50 \times 10^{10} \text{ N/m}^2
 \end{aligned}$$

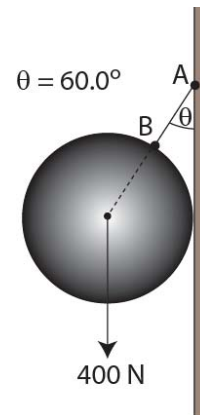
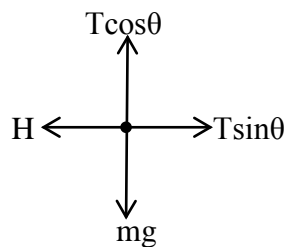


Q16.

Figure 6 shows a uniform solid sphere of weight 400 N suspended by string AB and resting against a frictionless vertical wall. The string makes an angle of 60.0° with the wall. Find the magnitude of the force exerted by the wall on the sphere.

Figure 6

- A) 693 N
- B) 400 N
- C) 600 N
- D) 800 N
- E) 200 N



Ans:

$$\begin{aligned}
 H &= T \sin \theta \\
 mg &= T \cos \theta \\
 H &= mg \tan \theta = 400 \tan 60 = 693 \text{ N}
 \end{aligned}$$

Q17.

A rocket of mass m is launched from the surface of a planet of mass M and radius R . What is the minimum **total energy** the rocket must have to escape from the planet?

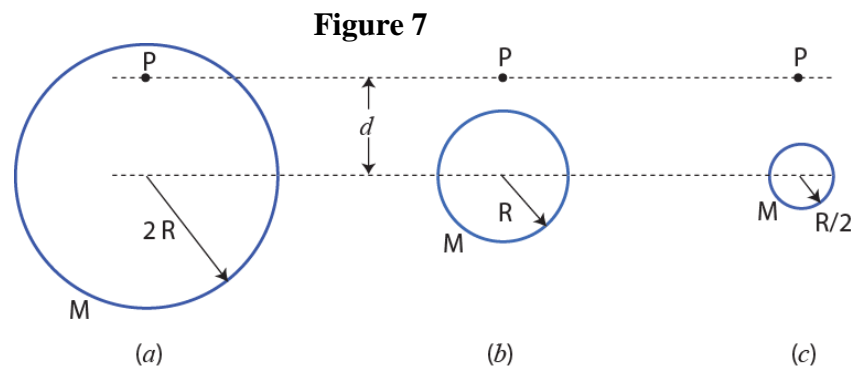
- A) 0
 B) $\sqrt{\frac{2GM}{R}}$
 C) $\sqrt{\frac{GMm}{R}}$
 D) $\sqrt{\frac{2GMm}{R}}$
 E) $\sqrt{\frac{3GM}{R^2}}$

Ans:

$$E = K + u = 0$$

Q18.

Figure 7 shows three situations involving a point particle P with mass m and a spherical shell with a uniformly distributed mass M . The radii of the shells are given. Rank the situations according to the magnitude of the gravitational force on particle P due to the shell, greatest first.



- A) (b) and (c) tie, then (a)
 B) (a), (b), (c)
 C) (c), (b), (a)
 D) (b), (a), (c)
 E) All tie

Ans:

A

Q19.

If you weigh 675 N on Earth, what would you weigh at the surface of a neutron star that has the same mass as our sun (1.99×10^{30} kg) and a radius of 20.0 km?

A) 2.28×10^{13} N

B) 675 N

C) 6.85×10^7 N

D) 7.15×10^{10} N

E) 3.38×10^{10} N

Ans:

$$mg = 675 = \frac{GmM_e}{R_e^2}$$

$$W = \frac{GmM_s}{(20 \times 10^3)^2}$$

$$\frac{W}{675} = \frac{\cancel{Gm}M_s}{(20 \times 10^3)^2} \times \frac{R_e^2}{\cancel{Gm}M_e}$$

$$\frac{W}{675} = \frac{M_s}{(20 \times 10^3)^2} \times \frac{R_e^2}{M_e}$$

$$\frac{W}{675} = \frac{1.99 \times 10^{30}}{(20 \times 10^3)^2} \times \frac{(6.37 \times 10^6)^2}{5.98 \times 10^{24}} = 22.8 \times 10^{13} \text{ N}$$

Q20.

Calculate the work needed to take a satellite of mass 1.00×10^3 kg from the surface of Earth and place it in a circular orbit at an **altitude** equal to Earth's radius. Ignore the rotation of Earth.

A) 4.70×10^{10} J

B) 2.99×10^{10} J

C) 6.25×10^{10} J

D) 9.24×10^{10} J

E) 1.98×10^{10} J

Ans:

$$E_i = -\frac{GmM_e}{R_e} ; E_f = -\frac{GmM_e}{4R_e}$$

$$W = E_f - E_i$$

$$W = \frac{GmM_e}{R_e} \left(\frac{3}{4} \right) = \frac{6.67 \times 10^{-11} \times 10^3 \times 5.98 \times 10^{24}}{6.37 \times 10^6} \times 0.75 = 4.70 \times 10^{10} \text{ J}$$

Q21.

The International Space Station satellite orbits Earth at an **altitude** of 380 km. Assuming a circular orbit find the time in hours for the satellite to complete one revolution around Earth.

- A) 1.53 h
- B) 3.45 h
- C) 0.450 h
- D) 12.0 h
- E) 24.0 h

Ans:

$$T^2 = \frac{4\pi^2}{GM_e} r^3$$

$$T^2 = \frac{4(\pi^2) \times (380 \times 10^3)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}$$

$$\Rightarrow T = 1.53 \text{ h}$$

Q22.

Water flows through a cylindrical pipe of radius R with a speed of 5.0 m/s. Find the value of R if the mass flow rate of water is 6.0 kg/s.

- A) 2.0 cm
- B) 3.5 cm
- C) 1.5 cm
- D) 4.0 cm
- E) 3.0 cm

Ans:

$$\rho v A = 6$$

$$\rho v (\pi R^2) = 6$$

$$R = \sqrt{\frac{6}{\rho v \pi}} = 1.95 \text{ cm} \approx 2.0 \text{ cm}$$

Q23.

As shown in **Figure 8**, a cube of wood (density 700 kg/m^3) is held in equilibrium under water by a string tied to the bottom of the container. If the tension $T = 5.88 \text{ N}$, find the length of the cube's edge.

- A) 12.6 cm
- B) 10.0 cm
- C) 5.36 cm
- D) 25.6 cm
- E) 9.80 cm

Ans:

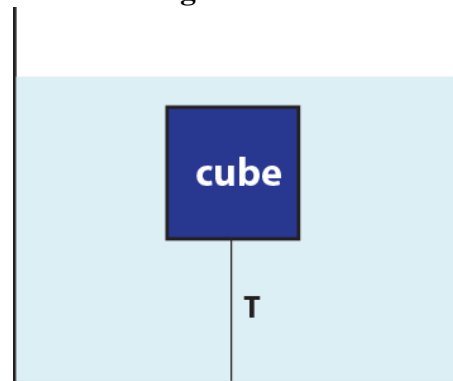
$$T + \rho_w Vg = \rho_f Vg$$

$$V(\rho_f g - \rho_w g) = T$$

$$V = \frac{T}{\rho_f g - \rho_w g} = \frac{T}{g(300)}$$

$$V = a^3 \Rightarrow a = (V)^{1/3} = 12.6 \text{ cm}$$

Figure 8

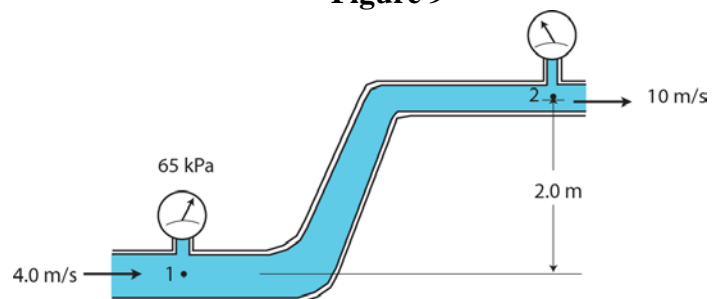


Q24.

Water flows through a pipe as shown in **Figure 9**. The speed of water is 4.0 m/s at point 1 and 10 m/s at point 2. Find the gauge pressure at point 2 if the gauge pressure at point 1 is 65 kPa .

- A) 3.4 kPa
- B) 4.5 kPa
- C) 5.4 kPa
- D) 2.5 kPa
- E) 7.8 kPa

Figure 9



Ans:

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2$$

$$65 \times 10^3 + \frac{1}{2} \times 10^3 \times 16 = P_2 + \frac{1}{2} \times 10^3 \times 100 + 10^3 \times 9.8 \times 2$$

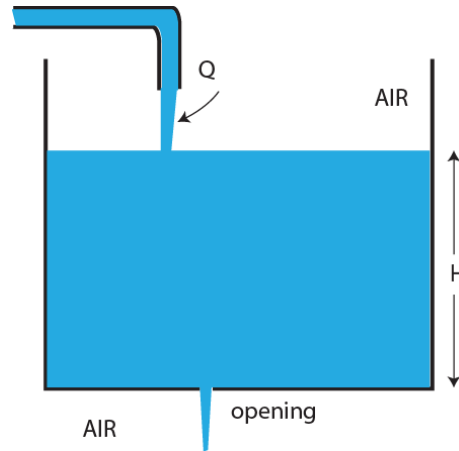
$$P_2 = 3.4 \text{ kPa}$$

Q25.

Water pours into a very large open tank at a volume flow rate of Q (**Figure 10**). The tank has an opening at the bottom. The area of this opening for the water level in the tank to be maintained at a fixed level H is given by:

- A) $\frac{Q}{\sqrt{2gH}}$
 B) $\frac{3Q}{(2gH)^2}$
 C) $\frac{Q}{(gH)^2}$
 D) $\frac{2Q}{\sqrt{gH}}$
 E) $\frac{Q}{(2gH)^2}$

Figure 10



Ans:

$$Q = v_2 A$$

To find v_2 :

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

$$\rho g H = \frac{1}{2}\rho v_2^2$$

$$v_2 = \sqrt{2gH}$$

$$\therefore Q = \frac{Q}{\sqrt{2gH}}$$

Q26.

Find the gas pressure inside the box shown in **Figure 11**. Take the density of mercury $\rho_{\text{Hg}} = 13.6 \times 10^3 \text{ kg/m}^3$.

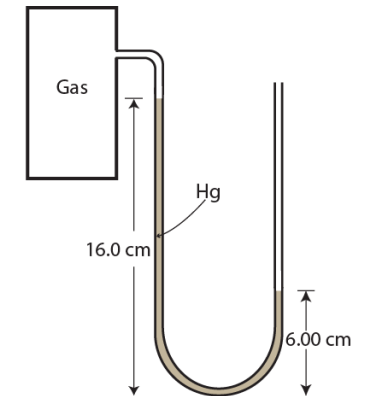
- A) $0.877 \times 10^5 \text{ Pa}$
- B) $0.930 \times 10^5 \text{ Pa}$
- C) $1.01 \times 10^5 \text{ Pa}$
- D) $0.675 \times 10^5 \text{ Pa}$
- E) $1.14 \times 10^5 \text{ Pa}$

Ans:

$$P_a = P_{\text{gas}} + \rho_{\text{Hg}}gh$$

$$P_{\text{gas}} = P_a - \rho_{\text{Hg}}gh$$

$$P_{\text{gas}} = 1.01 \times 10^5 - 13.6 \times 10^3 \times 9.8 \times 0.1 = 0.88 \times 10^5 \text{ Pa}$$

Figure 11**Q27.**

A 2.0 g particle executes simple harmonic motion according to $x = 0.20 \sin(6.0 \pi t + 4.0)$, where x is in centimeters and t is in seconds. Find the total energy of the particle.

- A) $1.4 \times 10^{-6} \text{ J}$
- B) $3.5 \times 10^{-4} \text{ J}$
- C) $1.4 \times 10^{-3} \text{ J}$
- D) $3.5 \times 10^{-2} \text{ J}$
- E) $6.7 \times 10^{-5} \text{ J}$

Ans:

$$\begin{aligned} E &= \frac{1}{2} kx_m^2 = \frac{1}{2} m\omega^2 x_m^2 \\ &= \frac{1}{2} (2 \times 10^{-3})(6\pi)^2 (0.2 \times 10^{-2})^2 \\ &= 14.2 \times 10^{-7} \text{ J} = 1.42 \times 10^{-6} \text{ J} \end{aligned}$$

Q28.

A 0.500 kg mass attached to a spring of force constant 8.00 N/m vibrates in simple harmonic motion with an amplitude of 10.0 cm. Calculate the time it takes the mass to move from $x = 0$ to $x = 10.0$ cm.

A) 0.393 s

B) 1.57 s

C) 0.786 s

D) 0.196 s

E) 0.543 s

Ans:

$$\text{Time taken} = \frac{T}{4}$$

$$\text{where } T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.5}{8}} = 1.57 \text{ s}$$

$$\therefore t = \frac{1.57}{4} \text{ s} = 0.393 \text{ s}$$

Q29.

A uniform thin rod is pivoted at one end and oscillates in simple harmonic motion (SHM) in a vertical plane. Its period is equal to that of a simple pendulum of length 1.0 m also executing SHM in a vertical plane. What is the length of the rod?

A) 1.5 m

B) 0.67 m

C) 1.0 m

D) 2.5 m

E) 0.50 m

Ans:

$$T_R = 2\pi\sqrt{\frac{I}{Mgd}}$$

$$T_{s.p} = 2\pi\sqrt{\frac{L}{g}}$$

$$\therefore 2\pi\sqrt{\frac{I}{Mgd}} = 2\pi\sqrt{\frac{L}{g}} \Rightarrow 2\pi\sqrt{\frac{\frac{1}{3}ML^2}{MgL/2}} = 2\pi\sqrt{\frac{L}{g}}$$

$$L' = \frac{3}{2}L = 1.5 \text{ m}$$

Q30.

Figure 12 shows plots of the kinetic energy K versus position x for three linear simple harmonic oscillators that have the **same** mass. Rank the plots according to the corresponding **period** of the oscillator, greatest first.

- A) C, B, A
- B) A, B, C
- C) B, A, C
- D) A, C, B
- E) B, C, A

Ans:

$$E = \frac{1}{2} kx_m^2 = \frac{1}{2} m\omega^2 x_m^2$$

m and x_m are constant

$$\therefore E \propto \omega^2 \propto \frac{1}{T^2} \Rightarrow \text{Answer A}$$

