Q1.

On a dry road, a car with good tires is able to brake with a constant deceleration of 5.00 m/s^2. If the car is traveling initially at a constant speed of 30.0 m/s, how far does the car travel from the moment the brakes are applied until it comes to a complete stop?

A) 90.0 m
B) 6.00 m
C) 150 m
D) 180 m
E) 30.0 m

Ans:

$$v^2 = v_0^2 + 2a\Delta x$$

$$\Delta x = -\frac{v_0^2}{2a} = \frac{-(30)^2}{2(-5)} = 90.0\ m$$

Q2.

Which ONE of the following statements is TRUE?

A) The kinetic energy of a system of colliding bodies is always conserved in elastic collision.
B) Linear momentum of a system of colliding bodies is always not conserved in inelastic collision.
C) Linear momentum of a system of colliding bodies is always not conserved in elastic collision.
D) The kinetic energy of a system of colliding bodies is always conserved in inelastic collision.
E) If the net external torque on a system is zero, the angular momentum of the system is not conserved.

Ans:

A

Q3.

The water in a river flows due north with a speed of 2.00 m/s. A boat crosses the river with a velocity of 4.20 m/s due east relative to the water. The river is 800 m wide. What is the magnitude of the velocity of the boat relative to the ground?

A) 4.65 m/s
B) 2.85 m/s
C) 2.20 m/s
D) 3.10 m/s
E) 3.69 m/s

Ans:

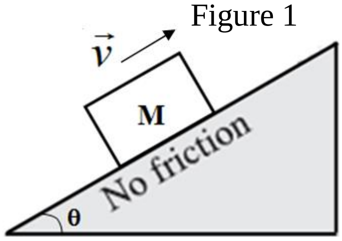
$$\vec{V}_{BG} = \vec{V}_{BW} + \vec{V}_{WG} = -4.20\,\hat{i} + 2.00\,\hat{j}$$

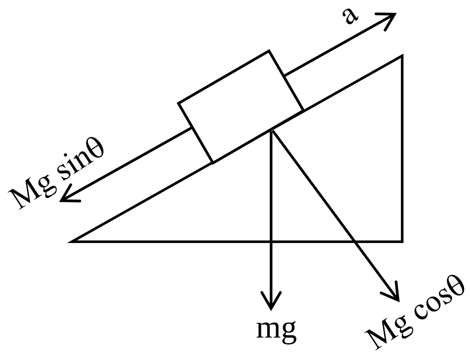
$$V_{BG} = \sqrt{V_{BW}^2 + V_{WG}^2} = \sqrt{(4.20)^2 + (2.00)^2} = 4.65\ m/s$$

Q4.

A block is given an initial velocity of 5.00 m/s up a frictionless incline of angle θ = 20.0°, as shown in **Figure 1**. How far up the incline does the block slide before coming to rest?

Figure 1





A) 3.73 m
B) 1.28 m
C) 2.55 m
D) 7.46 m
E) 5.00 m

Ans:

$$ma = -mg\sin\theta$$

$$a = -g\sin\theta$$

$$a = -3.35\ \text{m/s}^2$$

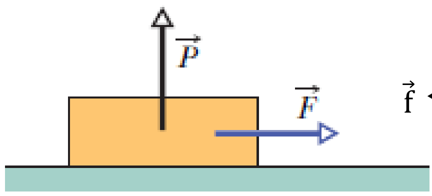
$$v^2 - v_0^2 = 2a\Delta x$$

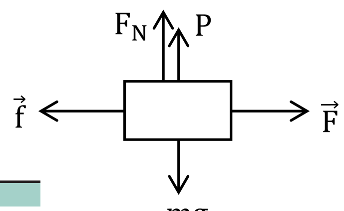
$$\Delta x = \frac{v^2 - v_0^2}{2a} = \frac{0 - (5)^2}{2(-3.35)} = 3.73\ \text{m}$$

Q5.

A 2.5 kg block is initially at rest on a horizontal surface. A horizontal force ***F*** of magnitude 6.0 N and a vertical force ***P*** of magnitude 10 N are then applied to the block, as shown in **Figure 2**. The static and kinetic friction coefficients between the block and surface are $\mu_s = 0.40$ and $\mu_k = 0.25$, respectively. Determine the acceleration of the block.

Figure 2





A) 0.95 m/s²
B) Zero
C) 2.40 m/s²
D) 1.40 m/s²
E) 1.20 m/s²

Ans:

$$F_N = mg - P = 24.5 - 10 = 14.5\ \text{N}$$

$$f_{s,max} = \mu_s F_N = 0.4 \times 14.5 = 5.8\ \text{N}$$

$$f_k = \mu_k F_N = 0.25 \times 14.5 = 3.62\ \text{s}$$

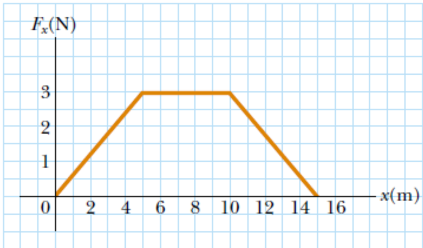
$$F - f_k = ma$$

$$a = \frac{F - f_k}{m} = \frac{6.00 - 3.62\ \text{s}}{2.50} = 0.95\ \text{m/s}^2$$

Q6.

A 4.00-kg particle is subject to a force that varies with position, as shown in **Figure 3**. The particle starts from rest at $x = 0$. What is its speed at $x = 15.0$ m?

Figure 3



A) 3.87 m/s
B) 2.74 m/s
C) 7.50 m/s
D) Zero
E) 4.70 m/s

Ans:

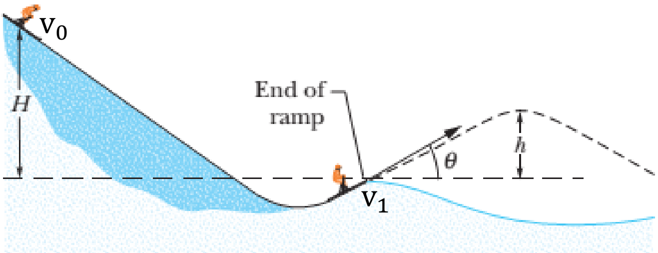
$W = \Delta K$

$\Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - 0 = W =$ (area under the curve from x = 0 to 15 m)

$$\frac{1}{2}mv_f^2 = 30 \Rightarrow v_f^2 = \frac{2 \times 30}{4} \Rightarrow v_f = 3.87 \text{ m/s}$$

Q7.

A 60 kg skier starts from rest at height $H = 20$ m above the end of a ski-jump ramp (see **Figure 4**) and leaves the ramp at angle $\theta = 28°$. Neglect the effects of air resistance and assume the ramp is frictionless. What is the maximum height (h) of his jump above the end of the ramp?



A) 4.4 m
B) 8.5 m
C) 16 m
D) 5.7 m
E) 3.6 m

Figure 4

Ans:

Using the conservation of energy

$$mgh = \frac{1}{2}mv_1^2 \Rightarrow v_1 = \sqrt{2gh} = 19.8 \text{ m/s}$$

$$h = \left(\frac{v_1 \sin\theta}{2g}\right)^2$$

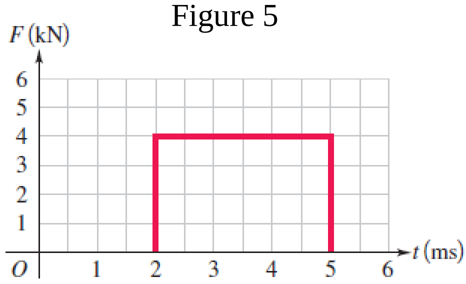
$$= \frac{(9.8 \sin 28)^2}{2 \times 9.8} = 4.4 \text{ m}$$

Q8.

A 150 gram baseball is hit toward the left by a bat. The magnitude of the force the bat exerts on the ball as a function of time is shown in **Figure 5**. Find the magnitude and direction of the impulse that the ball imparts to the bat.

A) 12.0 N.s to the right
B) 12.0 N.s to the left
C) 20.0 N.s to the right
D) 20.0 N.s to the left
E) 14.0 N.s to the right

Figure 5



Ans:

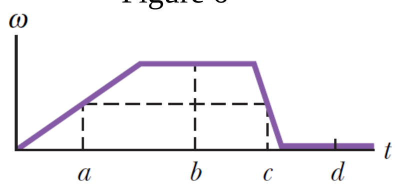
$$\vec{J} = \Delta\vec{P} = \int \vec{F}\,dt$$

$$= \text{area under the curve} = 3 \times 10^{-3} \times 4 \times 10^{-3} = 12\ \text{N}\cdot\text{s} \quad \text{to the right}$$

Q9.

Figure 6 is a plot of the angular velocity versus time for a rotating disk. For a point on the disk rim, rank the instants *a*, *b*, *c*, and *d* according to the magnitude of the radial acceleration, **greatest** first.

Figure 6



A) *b*, then *a* and *c* tie, then *d*
B) *c*, *a*, then *b* and *d* tie
C) a, c, then *b* and *d* tie
D) *c*, *b*, *a*, *d*
E) *c*, then *a* and *b* tie, then *d*

Ans:

A; $(a_r = \omega^2 r)$

Q10.

A uniform rod (length 6.00 m, mass 1.00 kg) rotates at 240 rev/min in a horizontal plane about a vertical axis through one end. Calculate the magnitude of its angular momentum about the axis of rotation.

A) 302 $kg.m^2/s$
B) 75.4 $kg.m^2/s$
C) 50.3 $kg.m^2/s$
D) 173 $kg.m^2/s$
E) 86.4 $kg.m^2/s$

Ans:

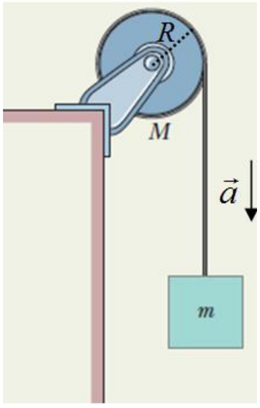
$$L = I\omega; \quad I = I_{com} + md^2 = \frac{1}{12}ML^2 + M\left(\frac{L}{2}\right)^2 = \frac{1}{3}ML^2$$

$$L = \frac{1}{3}ML^2 \times 240 \times \frac{2\pi}{60} = 302\ \text{kg}\cdot\text{m}^2/\text{s}$$

Q11.

Figure 7 shows a uniform disk, with mass M = 2.5 kg and radius R = 20 cm, mounted on a fixed horizontal axle. A block with mass m =1.2 kg hangs from a massless cord that is wrapped around the rim of the disk. The cord does not slip, and there is no friction at the axle. What is the magnitude of the tension in the cord, when the block is moving downward?

Figure 7



A) 6.0 N
B) 27 N
C) 44 N
D) 50 N
E) 18 N

Ans:

$$\mathrm{ma} = \mathrm{mg} - \mathrm{T} \quad (1)$$

$$\tau = \mathrm{I}\alpha = \mathrm{TR} \quad (2)$$

$$\frac{\mathrm{Ia}}{\mathrm{R}} = \mathrm{TR}\,;\, \mathrm{a} = \frac{\mathrm{TR}^2}{\mathrm{I}} = \frac{\mathrm{TR}^2}{\frac{\mathrm{L}}{2}\mathrm{MR}^2} = \frac{2\mathrm{T}}{\mathrm{M}}$$

Using equ. (1)

$$\mathrm{m}\left(\frac{2\mathrm{T}}{\mathrm{M}}\right) = \mathrm{mg} - \mathrm{T} \Rightarrow \mathrm{T}\left(1 + \frac{2\mathrm{m}}{\mathrm{M}}\right) = \mathrm{mg}$$

$$\mathrm{T} = \frac{\mathrm{mg}}{\left(1 + \frac{2\mathrm{m}}{\mathrm{M}}\right)} = 6.0\ \mathrm{N}$$

Q12.

What is the applied pressure to a solid copper cube in order to reduce its volume to 40 % of the original volume? The bulk modulus of copper is 1.4×10^{11} N/m^2.

A) 8.4×10^{10} N/m^2
B) 5.6×10^{10} N/m^2
C) 3.5×10^{11} N/m^2
D) 2.3×10^{11} N/m^2
E) 1.4×10^{11} N/m^2

Ans:

$$\mathrm{P} = \mathrm{B}\,\frac{\Delta \mathrm{V}}{\mathrm{V}} = 1.4\times10^{11} \times \frac{60}{100} = 8.4\times10^{10}\ \mathrm{N/m^2}$$

Q13.

The mass of a planet is 1/100 that of Earth and its radius is 1/4 that of Earth. If the weight of a person on the surface of Earth is 600 N, what is the weight of the same person on the surface of this planet?

A) 96.3 N
B) 24.1 N
C) 48.2 N
D) 193 N
E) 600 N

Ans:

$$W = \frac{GmMp}{(Rp)^2} = \frac{1}{100} \times \frac{GmM_E}{\left(\frac{R_E}{4}\right)^2} = 96.3\ N$$

Q14.

A satellite of mass 5.0×10^3 kg moves around a planet in a circular orbit of radius 9.4×10^6 m with a period of 2.8×10^4 s. What is the mass of the planet?

A) 6.3×10^{23} kg
B) 4.8×10^{23} kg
C) 3.1×10^{24} kg
D) 8.3×10^{23} kg
E) 1.5×10^{24} kg

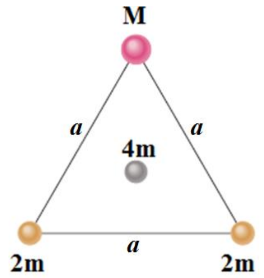
Ans:

$$T^2 = \left(\frac{4\pi^2}{4M}\right) r^3 \Rightarrow M = \frac{4\pi^2}{G\pi^2 r^3} = 6.3 \times 10^{23} kg$$

Q15.

As seen in **Figure 8**, two spheres of mass ***2m*** and a third sphere of mass ***M*** form an equilateral triangle of side ***a***, and a fourth sphere of mass ***4m*** is at the center of the triangle. The net gravitational force on that central sphere from the three other spheres is zero. What is the mass ***M*** in terms of ***m***?

Figure 8



A) M = 2m
B) M = 6m
C) M = 4m
D) M = 3m
E) M = m

Ans:

$$\sum F_x = 0; \quad \sum F_y = F_{ym} - 2F_{y2m} = 0$$

$$F_{y,m} = 2F_{y,2m}$$

$$\frac{GM(4m)}{r^2} = \frac{2G2m(4m)}{r^2} \Rightarrow M = 4m$$

Q16.

A 150.0 kg rocket moving radially outward from Earth has a speed of 3.70 km/s at 200 km above Earth's surface. What is the rocket's kinetic energy when the rocket is 1000 km above Earth's surface? (Neglect the air drag acts on the rocket)

A) 3.83×10^{7} J
B) 1.03×10^{9} J
C) 7.09×10^{7} J
D) 5.88×10^{10} J
E) Zero

Ans:

$$h_i = R_i - R_E;\ h_f = R_f - R_E$$

$$K_i + U_i = K_f + U_f$$

$$\Rightarrow K_f = \frac{1}{2}mv_i^2 + \frac{GMm}{R_E + h_f} - \frac{GMm}{R_E + h_i} = 3.83 \times 10^7 \text{ J}$$

Q17.

A solid uniform sphere has a mass of 5.0×10^{3} kg and a radius of 2.0 m. What is the magnitude of the gravitational force due to the sphere on a particle of mass 1.0 kg located at a distance of 1.0 m from the center of the sphere?

A) 4.2×10^{-8} N
B) 8.3×10^{-8} N
C) 1.7×10^{-7} N
D) Zero
E) 9.8×10^{-7} N

Ans:

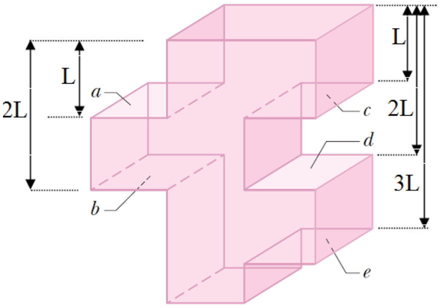
$$F = \frac{GmM'}{r^2};\ \frac{M}{4/3\pi R^2} = \frac{M'}{4/3\pi r^3} \Rightarrow M' = M\frac{r^3}{R^3}$$

$$F = \frac{GmMr}{R^3} = = 4.2 \times 10^{-8} \text{ N}$$

Q18.

Figure 9 shows a tank filled with water. Five horizontal floors and ceilings (a, b, c, d, and e) are indicated; all have the same area and are located at distances L, 2L, or 3L below the top of the tank. Rank the floors and ceilings according to the force on them due to the water, **greatest** first?

Figure 9



A) *e*, then *b* and *d* tie, then *a* and *c* tie
B) *a* and *c* tie, then *b* and *d* tie, then *e*
C) (*b*, *c* and *e*) tie, then (*a* and *d*) tie
D) *b* and *d* tie, then *a* and *c*, then *e*
E) all tie

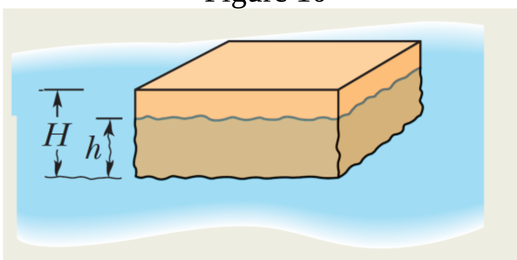
Ans:

A

Q19.

In **Figure 10**, a block of density $\boldsymbol{\rho}$ = 800 kg/m^3 floats face down in a fluid of density $\boldsymbol{\rho_f}$ = 1200 kg/m^3. The block has height $\boldsymbol{H}$ = 12.0 cm. By what depth $\boldsymbol{h}$ is the block submerged?

Figure 10



A) 8.00 cm
B) 10.0 cm
C) 11.0 cm
D) 9.00 cm
E) 6.00 cm

Ans:

$$F_b = m_f g = \rho_f V_f g = \rho_f A h g$$

$$F_g = mg = \rho V g = \rho A H g$$

$$F_b = F_g$$

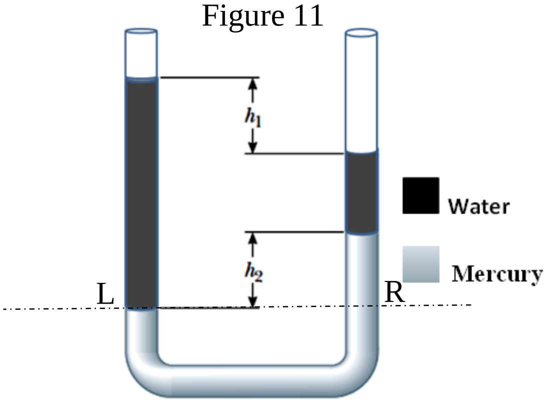
$$\rho_f A h g = \rho A H g$$

$$\frac{\rho_f}{\rho} = \frac{H}{h} \Rightarrow h = H\,\frac{\rho}{\rho_f} = \frac{800}{1200} \times 12 = 8.00\text{ cm}$$

Q20.

A U-tube of uniform cross-sectional area, open to the atmosphere, is partially filled with mercury. Water (is then poured into both arms. If the equilibrium configuration of the tube is as shown in **Figure 11**, with h_2 = 1.00 cm, determine the value of h_1. (Densities of water and mercury are ρ_w= 1.00 g/cm^3 and ρ_m= 13.6 g/cm^3, respectively). (Note that h_1 and h_2 are not drawn to scale).

Figure 11



A) 12.6 cm
B) 14.6 cm
C) 11.6 cm
D) 13.6 cm
E) 10.6 cm

Ans:

$$P_L = P_o + \rho_w g(h_1 + h_2 + h)$$

$$P_R = P_o + \rho_{Hg} g h_2 + \rho_w g h$$

$$P_L = P_R$$

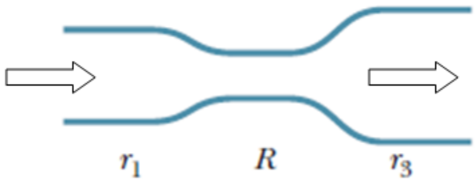
$$P_o + \rho_w g h_1 + \rho_w g h_2 + \rho_w g h = P_o + \rho_w g h + \rho_{Hg} g h_2$$

$$\rho_w h_1 = \frac{\rho_{Hg} - \rho_w}{\rho_w} h_2 = \left(\frac{13.6 - 1.00}{1.00}\right) 1 = 12.6$$

Q21.

In **Figure 12**, water flows steadily from the left pipe section (radius r_1 = 2.00R), through the middle section (radius R), and into the right section (radius r_3 = 3.00R). The speed of the water in the middle section is 0.500 m/s. What is the net work done on 400 kg of the water as it moves from the left section to the right section? (The arrows represent the direction of water flow).

Figure 12



A) - 2.51 J
B) 3.75 J
C) 0.617 J
D) - 1.50 J
E) 3.20 J

Ans:

$$W = \Delta K = \frac{1}{2} m v_3^2 - \frac{1}{2} m v_1^2$$

$$A_1 v_1 = A_2 v_2 \Rightarrow v_1 = \frac{A_2}{A_1} v_2 = \frac{\pi R^2 (0.5)}{\pi r_1^{\,2}} = \left(\frac{R}{r_1}\right)^2 (0.5) = 0.125 \text{ m/s}$$

$$A_2 v_2 = A_3 v_3 \Rightarrow v_3 = \frac{1}{9} v_2 = 0.056 \text{ m/s}$$

$$W = \frac{1}{2} m (v_3^2 - v_1^2) = \frac{1}{2}(4)((0.056)^2 - (0.125)^2) = -2.51 \text{ J}$$

Q22.

An object of mass m = 2.00 kg oscillates with simple harmonic motion along the x axis. Its position varies with time according to the equation $x = 5.00\cos(\pi t + \pi/4)$, where t is in second, x is in meter and the angles are in radians. What is the kinetic energy of the object at time t = 2.00 s?

A) 123 J
B) 25.0 J
C) 9.89 J
D) 11.1 J
E) 78.5 J

Ans:

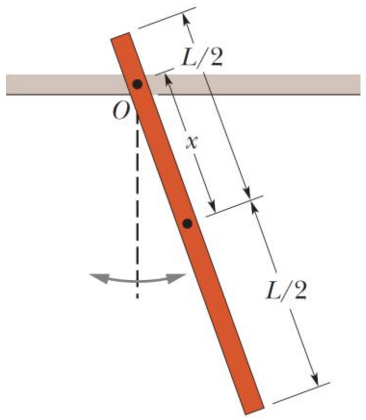
$$v = \frac{dx}{dt} = -5.00\,\pi\sin(\pi t + \pi/4)$$

$$K_{t=2.0} = \frac{1}{2}mv^2 = \frac{1}{2}(2)\,(5\pi)^2 \mathrm{Sin}^2\left(2\pi + \frac{\pi}{4}\right) = 123\ \mathrm{J}$$

Q23.

A physical pendulum consists of a uniform meter stick that is pivoted at a small hole drilled through the stick at point *O*, which is at distance *x* from the center of mass of the stick, as shown in **Figure 13**. The period of oscillation is 2.5 s. What is the value of *x*?

Figure 13



A) 0.056 m
B) 0.123 m
C) 0.215 m
D) 0.079 m
E) 0.432 m

Ans:

$$T = 2\pi\sqrt{\frac{I_0}{mg}}$$

$$I_0 = I_{com} + md^2 = \frac{mL^2}{12} + md^2$$

$$\frac{T^2}{4\pi^2} = \frac{\frac{mL^2}{12} + md^2}{mgd}$$

$$d^2 - \frac{T^2}{4\pi}gd + \frac{L^2}{12} = 0$$

$$d = 0.056\ \mathrm{m}$$

Q24.

A block oscillates in simple harmonic motion on the end of a spring, with position given by $x = x_m \cos(\omega t + \pi/5)$. At t = 0, what percentage of the total mechanical energy is potential energy?

A) 66 %
B) 81 %
C) Zero
D) 31 %
E) 20 %

Ans:

$$E = \frac{1}{2} k x_m^2$$

at t = 0 $\quad x = x_m \cos\left(\frac{\pi}{5}\right)$

$$U = \frac{1}{2} k x^2 = \frac{1}{2} k x_m^2 cos^2\left(\frac{\pi}{5}\right)$$

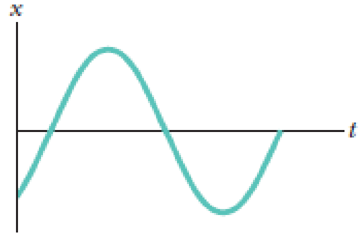
$$\frac{U}{E} = \frac{\frac{1}{2} k x_m^2 cos^2\left(\frac{\pi}{5}\right)}{\frac{1}{2} k x_m^2} = cos^2\left(\frac{\pi}{5}\right) \approx 66\ \%$$

Q25.

Which of the following describe ϕ for the simple harmonic motion, which is represented by $x = x_m \cos(\omega t + \phi)$ and shown in **Figure 14**?

A) $\pi < \phi < 3\pi/2$
B) $0 \le \phi < \pi/6$
C) $\pi/4 \le \phi \le \pi/2$
D) $0 \le \phi < \pi/2$
E) $3\pi/2 < \phi < 2\pi$

Figure 14



Ans:

A
