Q1.

A car travels along a straight line for 8.00 s. At first starting from rest, it accelerates with a constant acceleration of 1.00 m/s^2 for 3.00 s. Then it continues moving further for 5.00 s at constant velocity. How far has the car traveled from its starting point in 8.00 s interval?

A) 19.5 m
B) 24.0 m
C) 9.00 m
D) 4.50 m
E) 15.0 m

Ans:

$$x_{tot} = x_1 + x_2\ ;\ x_1 = v_0 t + \frac{1}{2}at^2 = \frac{1}{2}at^2 = \frac{1}{2} \times 1 \times (3)^2 = \frac{9}{2}\ m$$

$$x_2 = v't \quad where \quad v' = v_0 + at = at = 1 \times 3 = 3\ m/s$$

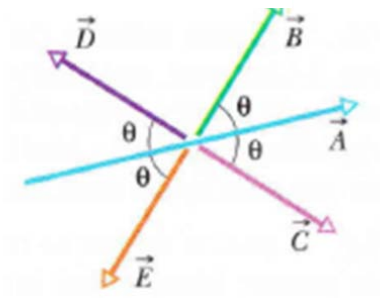
$$x_2 = v't = 3 \times 5 = 15\ m$$

$$x_{tot} = \frac{9}{2} + 15 = 19.5\ m$$

Q2.

Figure 1 shows vector $\vec{A}$ and four other vectors, $\vec{B}$, $\vec{C}$, $\vec{D}$, and $\vec{E}$ that have the same magnitude but differ in orientation. Which of these vectors have negative dot product with vector $\vec{A}$?

Figure 1



A) $\vec{D}$, $\vec{E}$
B) $\vec{C}$, $\vec{D}$
C) $\vec{B}$, $\vec{C}$
D) $\vec{E}$, $\vec{B}$
E) $\vec{D}$, $\vec{B}$

Ans:

$$\vec{a} \cdot \vec{b} = |a|\,|b| cos\theta$$

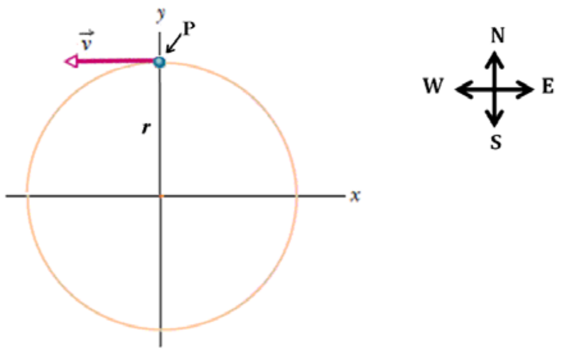
$$-ve\ value\ of\ \vec{a} \cdot \vec{b} \quad if\ \ \cos\theta\ is -ve\ \ (\theta > 90°)$$

$$\vec{A} \cdot \vec{D}\ \text{and}\ \vec{A} \cdot \vec{E}\ have - ve\ values$$

Q3.

A particle P moves in counterclockwise nonuniform circular motion around a circle of radius r as shown in **Figure 2**. At a certain instant the velocity $\vec{v}$ of the particle is 24 m/s west, and the acceleration of the particle has components of 2.4 m/s^2 east and 1.8 m/s^2 south. What is the radius of the circle?

Figure 2



A) 0.32 km
B) 0.19 km
C) 0.54 km
D) 0.14 km
E) 0.27 km

Ans:

$$a_r = \frac{v^2}{r}\ ; then\ r = \frac{v^2}{a_r}$$

$$r = \frac{v^2}{a_r} = \frac{(24)^2}{1.8} = 320\ m = 0.32\ km$$

Q4.

A 50 kg boy and a 10 kg box are on a frictionless ice of a frozen pond. They are 15 m apart and connected by a rope of negligible mass. The boy exerts a horizontal 5.0 N force on the rope to pull the box. How far from the boy's initial position do they meet?

A) 2.5 m
B) 3.0 m
C) 5.6 m
D) 0.50 m
E) 4.3 m

Ans:

$$a_{boy} = \frac{5}{50} = 0.1\ m/s^2;\ \ a_{sled} = \frac{5}{10} = 0.5\ m/s^2$$

$$t = \frac{d}{\cancel{1/2}\,a_{boy}} = \frac{15-d}{\cancel{1/2}\,a_{sled}}\ \ ;\ then\ \ d \times a_{sled} = (15-d)\ a_{boy}$$

$$d = \frac{15 \times a_{boy}}{a_{sled} + a_{boy}} = \frac{15 \times 0.1}{0.1 + 0.5} = 2.5\ m$$

Q5.

If it takes 2.0 J of work to stretch a spring 20 cm from its unstretched length, what is the extra work required to stretch it an additional 20 cm.

A) 6.0 J
B) 3.0 J
C) 4.0 J
D) 9.0 J
E) 2.0 J

Ans:

$x_1 = 20\ cm = 0.2\ m, W_1 = \frac{1}{2} k x_1^2$

$x_2 = 40\ cm = 0.4\ m, W_2 = \frac{1}{2} k x_2^2$

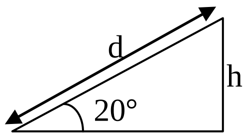
$$\frac{W_2}{W_1} = \frac{\frac{1}{2} k\, x_2^2}{\frac{1}{2} k\, x_1^2} \Rightarrow W_2 = W_1 \left(\frac{x_2}{x_1}\right)^2 = 2 \times \left(\frac{0.4}{0.2}\right)^2 = 8\, J$$

$W_{ext} = W_2 - W_1 = 8 - 2 = 6.0\ J$

Q6.

A skier is accelerating down a 50.0 m long frictionless hill slope. The slope makes an angle of 20.0° with the horizontal. What is his speed at the bottom of the hill slope if he starts from rest with a uniform acceleration?

A) 18.3 m/s
B) 13.4 m/s
C) 9.21 m/s
D) 16.3 m/s
E) 21.3 m/s



Ans:

$h = d \times sin20° = 50 \times sin20° = 17.1\ m$

$\Delta K = W_g$

$K_f - K_i = mgh$

$\frac{1}{2} m v_f^2 = mgh$

$v_f = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 17.1} = 18.3\ m/s$

Q7.

A driver in a 1.0×10^3 kg car traveling at 20 m/s slams on the brakes and skids to a stop. If the coefficient of kinetic friction between the tires and the road is 0.40, how far will it skid before stopping?

A) 51 m
B) 21 m
C) 33 m
D) 24 m
E) 62 m

Ans:

$$\Delta K = W_f = -f \times d = -\mu_k mgd$$

$$\Delta K = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_1^2 = -\mu_k mgd \quad \Rightarrow \not{-}\frac{1}{2}\not{m}v_1^2 = \not{-}\mu_k \not{m}gd$$

$$d = \frac{v_1^2}{2\mu_k g} = \frac{(20)^2}{2\times 0.4\times 9.8} = 51\ m$$

Q8.

The center of mass of a system of two point masses m_1 and m_2 is located on the x-axis at x = 2.0 m and has a velocity of (5.0 m/s) $\hat{i}$. The mass m_1 is at the origin with non-zero velocity while m_2 = 0.10 kg is at rest at x = 8.0 m. Calculate the magnitude of the total momentum of the system.

A) 2.0 kg.m/s
B) 3.1 kg.m/s
C) 1.2 kg.m/s
D) 3.2 kg.m/s
E) 4.2 kg.m/s

Ans:

$$x_{com} = \frac{m_2 \times x_2}{m_1 + m_2} \Rightarrow m_2 \times x_2 = x_{com} \times (m_1 + m_2)$$

$$m_1 = \frac{m_2 \times x_2}{x_{com}} - m_2 = \frac{0.1\times 8}{2} - 0.1 = 0.3\ kg$$

$$\vec{P}_{com} = (m_1 + m_2)v_{com}$$

$$\vec{P}_{com} = (0.3 + 0.1)\times 5 = 2.0\ kg.m/s$$

Q9.

A uniform solid disk of radius 80.0 cm is rotating about its central axis with constant angular acceleration of 50.0 rad/s^2. At a certain instant, the disk is rotating at 10.0 rad/s. What is the magnitude of the net linear acceleration of a point on the rim (edge) of the disk?

A) 89.4 m/s^2
B) 40.0 m/s^2
C) 50.2 m/s^2
D) 34.5 m/s^2
E) 94.2 m/s^2

Ans:

$$a_t = r\alpha = 0.8 \times 50 = 40\ m/s^2$$

$$a_r = r\omega^2 = 0.8 \times (10)^2 = 80\ m/s^2$$

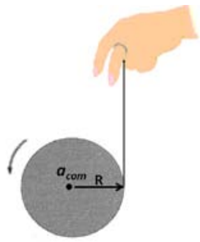
$$a = \sqrt{{a_t}^2 + {a_r}^2}$$

$$a = \sqrt{(40)^2 + (80)^2} = 89.4\ m/s^2$$

Q10.

A thin light string is wrapped around a uniform solid disk of mass 1.0 kg and radius R = 35 cm as shown in **Figure 3**. The disk is then released from rest and rolls downward along the string. Calculate the magnitude of the acceleration of the center of mass of the disk.

Figure 3



A) 6.5 m/s^2
B) 7.6 m/s^2
C) 2.5 m/s^2
D) 3.5 m/s^2
E) 9.2 m/s^2

Ans:

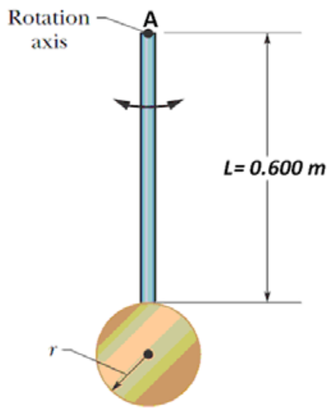
$$|a_{com}| = \frac{g\ sin\theta}{1 + \frac{I_{com}}{MR^2}} = \frac{g}{1 + \frac{MR^2/2}{MR^2}} = \frac{2}{3}\ g$$

$$|a_{com}| = \frac{2}{3} \times 9.8 = 6.5\ m/s^2$$

Q11.

Figure 4 shows a pendulum consisting of a uniform disk of mass M = 0.350 kg and radius r = 20.0 cm, attached at its rim to one end of a thin 0.600 m long rod with negligible mass. The pendulum swings freely about an axis perpendicular to the rod and passing through point A. Calculate the period of the pendulum for small oscillations.

Figure 4



A) 1.82 s
B) 2.75 s
C) 1.01 s
D) 3.01 s
E) 2.22 s

Ans:

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

$$I = \frac{MR^2}{2} + M(L+R)^2 = M\left(\frac{R^2 + 2(L+R)^2}{2}\right)$$

$$Mgd = Mg(L+R)$$

$$T = 2\pi\sqrt{\frac{\cancel{M}\left(\frac{R^2+2(L+R)^2}{2}\right)}{\cancel{M}g(L+R)}}$$

$$T = 2\pi\sqrt{\frac{(0.2)^2 + 2\times(0.6+0.2)^2}{2\times 9.8\times(0.6+0.2)}}$$

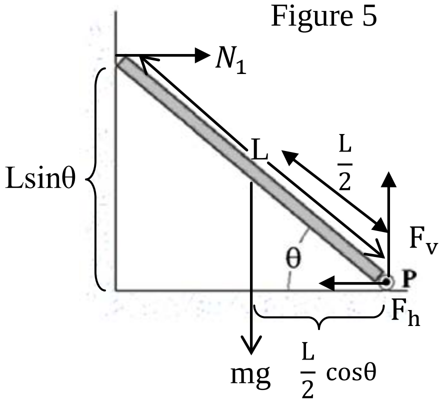
$$= 1.82\ s$$

Q12.

Figure 5 shows a uniform beam having a mass of 90 kg and a length of 4.0 m. It is held in place at its lower end by a pin P and its upper end leans against a vertical frictionless wall. Find the magnitude of the force the pin exerts on the beam if its lower end makes an angle θ = 40° with the horizontal.

A) 1.0 kN
B) 0.10 kN
C) 2.9 kN
D) 4.0 kN
E) 0.40 kN

Figure 5



Ans:

$$\sum F_x = N_1 - F_h = 0 \Rightarrow F_h = N_1$$

$$\sum F_y = F_v - mg = 0 \Rightarrow F_v = mg = 90 \times 9.8 = 882.0\ N$$

To solve for N_1

$$\sum \tau_p = mg \times \frac{L}{2} cos\theta - N_1 \times L\ sin\theta = 0$$

$$N_1 = \frac{mg}{2}\frac{cos\theta}{sin\theta} = mg\ cot\theta$$

$$N_1 = \frac{90 \times 9.8}{2} \times cot(40°)$$

$$F_h = N_1 = 525.6\ N$$

$$|F_{pin}| = \sqrt{F_h^2 + F_v^2}$$

$$= \sqrt{(525.6)^2 + (882)^2} = 1027\ N = 1.0\ kN$$

Q13.

A uniform spherical shell of mass 1.00×10^{3} kg has a radius of 5.00 m. Find the gravitational force this shell exerts on a 2.00 kg point mass placed at a point 2.72 m from the center of the shell.

A) 0
B) 1.80×10^{-8} N
C) 5.33×10^{-9} N
D) 1.80×10^{-6} N
E) 3.45×10^{-10} N

Ans:

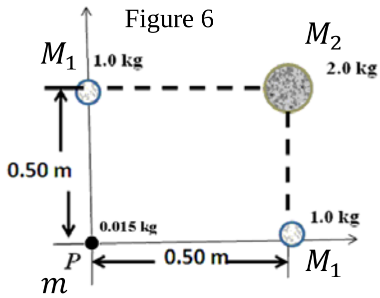
A

Q14.

Three uniform spheres are fixed at the positions shown in **Figure 6**. Find the magnitude and direction of the net gravitational force on a 0.015 kg particle placed at point P.

A) 9.67×10^{-12} N, at 45° above the positive x-axis.
B) 9.67×10^{-12} N, at 65° above the positive x-axis.
C) 5.63×10^{-10} N, at 50° above the positive x-axis.
D) 7.32×10^{-11} N, at 45° above the positive x-axis.
E) 3.45×10^{-8} N, at 45° above the positive x-axis.

Figure 6



Ans:

$$F'_x = \sum F_x = Gm\left(\frac{M_1}{(0.5)^2} + \frac{M_2}{(0.707)^2}\cos 45°\right)$$

$$= 6.67\times10^{-11}\times0.015\left(\frac{1}{(0.5)^2} + \frac{2\times\cos 45°}{(0.707)^2}\right) = 0.683\times10^{-11}\ N$$

$$F'_y = \sum F_y = Gm\left(\frac{M_1}{(0.5)^2} + \frac{M_2}{(0.707)^2}\sin 45°\right) = 0.683\times10^{-11}\ N$$

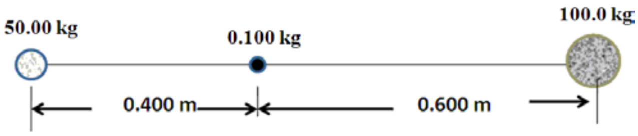
$$|F'| = \sqrt{(0.683\times10^{-11})^2 + (0.683\times10^{-11})^2} = 9.66\times10^{-12}\ N$$

$$\theta'_F = \tan^{-1}\left(\frac{F'_y}{F'_x}\right) = \tan^{-1}(1) = 45°$$

Q15.

Three solid uniform spheres are located in space, as shown in **Figure 7**. The 50.0 kg and 100 kg spheres are fixed and the 0.100 kg sphere is released from its initial position with its center 0.400 m from the center of the 50.0 kg sphere. Find the kinetic energy of the 0.100 kg sphere when it has moved 0.400 m to the right from its initial position.

Figure 7



A) +1.81 nJ
B) –1.81 nJ
C) – 5.34 nJ
D) +5.34 nJ
E) +7. 45 nJ

Ans:

$$\Delta K = -\Delta U = U_i - U_f;\ K_i = 0$$

$$K_f = \frac{1}{2}mv_f^2 = U_i - U_f$$

$$U_i = -Gm_{0.1}\left(\frac{m_{50}}{0.4} - \frac{m_{100}}{0.6}\right) - \frac{Gm_{50}m_{100}}{1}$$

$$U_f = -Gm_{0.1}\left(\frac{m_{50}}{0.8} - \frac{m_{100}}{0.2}\right) - \frac{Gm_{50}m_{100}}{1}$$

$$K_f = \frac{1}{2}m_{0.1}v_f^2 = U_i - U_f = Gm_{0.1}\left(\frac{m_{50}}{0.8} + \frac{m_{100}}{0.2} - \frac{m_{50}}{0.4} - \frac{m_{100}}{0.6}\right)$$

$$K_f = 0.1 \times 6.67 \times 10^{-11}\left(\frac{50}{0.8} + \frac{100}{0.2} - \frac{50}{0.4} - \frac{100}{0.6}\right) = 1.80 \times 10^{-9} J$$

Q16.

The potential energy of a satellite of mass 1.00×10^2kg on a surface of a planet is -1.00×10^6 J. Find the escape speed of the satellite from the surface of the planet.

A) 1.41×10^2 m/s
B) 2.00×10^2 m/s
C) 3.54×10^4m/s
D) 9.80×10^6 m/s
E) 9.80×10^3m/s

Ans:

$$K_i + U_i = 0 \Rightarrow K_i = \frac{1}{2}mv_{esc}^2 = -U_i \Rightarrow v_{esc} = \sqrt{\frac{-2U_i}{m}}$$

$$v_{esc} = \sqrt{\frac{2\times10^6}{100}} = 1.41\times10^2\ m/s$$

Q17.

A planet is in an elliptical orbit about the sun. Its maximum distance from the sun at point A equals three times its minimum distance at point B from it. Calculate the ratio (K_A/K_B) where K_A is the kinetic energy of the planet at point A and K_B is the kinetic energy of the planet at point B.

A) 1/9
B) 1/3
C) 1/2
D) 1/5
E) 1

Ans:

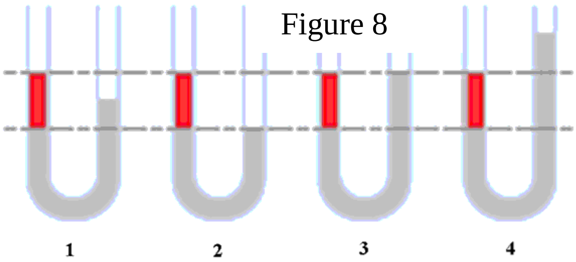
$$L_A = L_B \Rightarrow mv_A r_A = mv_B r_B \Rightarrow \frac{v_A}{v_B} = \frac{r_B}{r_A}$$

$$\frac{K_A}{K_B} = \frac{\frac{1}{2}mv_A^2}{\frac{1}{2}mv_B^2} = \frac{v_A^2}{v_B^2} = \frac{r_B{}^2}{r_A{}^2} = \frac{r^2}{9r^2} = \frac{1}{9}$$

Q18.

Figure 8 shows four situations in which two liquids are in a U-tube. In which situations the liquids **cannot** be in static equilibrium?

A) 2 only
B) 1 and 3
C) 1 only
D) 4 only
E) 3 and 4

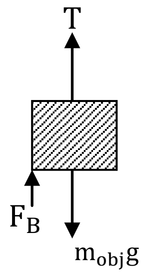


Ans:

A

Q19.

A 15.0 kg concrete block is raised from the sea bottom by a cable with negligible mass. What is the tension in the cable when the block is at rest hanging from the cable and completely submerged in the water? (Density of concrete = 2.00×10^3 kg/m^3, and density of seawater = 1.03×10^3 kg/m^3)



A) 71.3 N
B) 98.4 N
C) 59.5 N
D) 80.1 N
E) 40.5 N

Ans:

$$m_f = \rho_f \times V_{obj} \quad ; \; m_{obj} = \rho_{obj} \times V_{obj}$$

$$m_f = \frac{m_{obj} \times \rho_f}{\rho_{obj}}$$

$$T + F_B = m_{obj}g \Rightarrow T = m_{obj}g - F_B = m_{obj}g - m_f g$$

$$T = \left(m_{obj} - m_{obj}\frac{\rho_f}{\rho_{obj}}\right)g = m_{obj}\left(1 - \frac{\rho_f}{\rho_{obj}}\right)g$$

$$T = 15\left(1 - \frac{1.03 \times 10^3}{2 \times 10^3}\right) \times 9.8 = 71.3\ N$$

Q20.

Incompressible oil of density 850 kg/m^3 is pumped through a cylindrical pipe at a rate of 9.50 L/s. The first section of the pipe has a diameter of 8.00 cm and the second section of the pipe has a diameter of 4.00 cm. What is the flow speed in the second section?

A) 7.6 m/s
B) 5.4 m/s
C) 2.3 m/s
D) 1.9 m/s
E) 9.3 m/s

Ans:

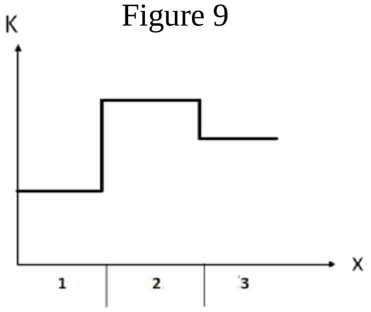
$$R_v = Av \Rightarrow v = \frac{R_v}{A} \; but \; R_v = 9.5 \times 10^{-3}\ m^3/s$$

$$Then\ v_2 = \frac{R_v}{A_2} = \frac{9.5 \times 10^{-3}}{\pi \times (0.02)^2} = 7.6\ m/s$$

Q21.

Water flows smoothly in a horizontal pipe. **Figure 9** shows the kinetic energy K of a water element as it moves along the x-axis that runs along the pipe. Rank the numbered sections of the pipe according to the pipe radius, smallest first.

Figure 9



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

Ans:

$$K = \frac{1}{2}\rho v^2;\ but\ R_v = Av\ \Rightarrow v = \frac{R_v}{A}$$

$$K = \frac{\rho}{2}\frac{R_v^2}{A^2} = \left(\frac{\rho R_v^2}{2}\right)\frac{1}{A^2}$$

$$K \propto \frac{1}{A^2}$$

Q22.

A body oscillates with simple harmonic motion along the x axis with its displacement given by x = (5.0 m) sin (πt + φ). If the velocity of the body at t = 0.0 s is –8.0 m/s, the phase constant φ is:

A) +2.1 rad
B) –0.50 rad
C) +0.50 rad
D) +3.5 rad
E) –2.8 rad

Ans:

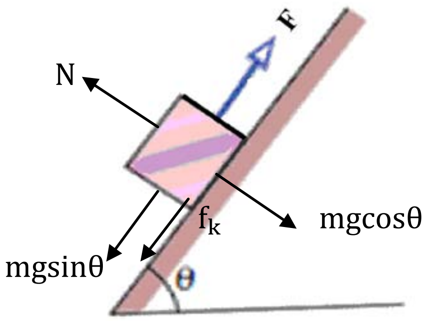
$$v = \frac{dx}{dt} = 5\pi cos(\pi t + \Phi)\ \ For\ \ t = 0\,; v = 5\pi cos(\Phi) \Rightarrow \Phi = \cos^{-1}\left(\frac{v(t=0)}{5\pi}\right)$$

$$\Phi = cos^{-1}\left(\frac{-8}{5\pi}\right) = 120.6° = +2.1\ rad$$

Q23.

As shown in **Figure 10**, a force $\vec{F}$ = 25.0 N is pulling a 20.0 N box up a rough inclined plane. The inclined plane makes an angle θ = 20.0° with the horizontal. Find the magnitude of the acceleration of the box if the coefficient of kinetic friction between the plane and the box is 0.400.

Figure 10



A) 5.21 m/s²
B) 3.35 m/s²
C) 9.80 m/s²
D) 4.20 m/s²
E) 6.50 m/s²

Ans:

$$F - mg\sin\theta - f_k = ma\,;\quad f_k = \mu_k mg\cos\theta$$

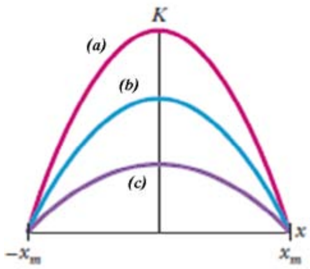
$$a = \frac{F - mg\sin\theta - \mu_k mg\cos\theta}{m}$$

$$= \frac{25 - 20 \times \sin 20° - 0.4 \times 20 \times \cos 20°}{20/9.8} = 5.2\ m/s^2$$

Q24.

Figure 11 shows plots of the kinetic energy *K* versus position *x* for three harmonic oscillators that have the same mass. Rank the plots according to the period of the oscillators, **greatest first**.

Figure 11



A) c, b, a
B) a, b, c
C) b, c, a
D) c, a, b
E) a, c, b

Ans:

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}} \quad but\ K = \frac{1}{2}kx_m^2$$

$$T = 2\pi\sqrt{\frac{m\,x_m^2}{2K}} \quad \Rightarrow \quad T \propto \frac{1}{\sqrt{K}}$$

Q25.

A particle executes simple harmonic motion in one dimension described by: x = (10 cm) sin [(π rad/s)t], where t is in seconds. At what time is the potential energy of the particle equal to its kinetic energy?

A) 0.25 s
B) 1.5 s
C) 0.79 s
D) 0.50 s
E) 1.8 s

Ans:

$$U = \frac{1}{2}kx^2 \quad but \quad U = \frac{E}{2} = \frac{1}{4}kx_m^2 \quad then \quad \frac{1}{2}kx^2 = \frac{1}{4}kx_m^2 \Rightarrow x = \frac{x_m}{\sqrt{2}}$$

$$x = \frac{x_m}{\sqrt{2}} = x_m \, sin[(\pi \, rad/s)t] \Rightarrow t = \frac{1}{\pi} sin^{-1}\left(\frac{1}{\sqrt{2}}\right)$$

$$t = \frac{1}{\pi} \times 45° = \frac{0.785 \, rad}{\pi} = 0.25 \, s$$