Q1.

A hot-air balloon is ascending (going up) at the rate of 14 m/s and when the balloon is 98 m above the ground a package is dropped from it, vertically downward. With what speed does the package hit the ground?

A) 46 m/s
B) 21 m/s
C) 17 m/s
D) 52 m/s
E) 82 m/s

Ans:

$v_0 = 14\, m/s$

$a = -9 \cdot 8\, m/s^2$

$v = 0$

$\Delta y = 98\, m$

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

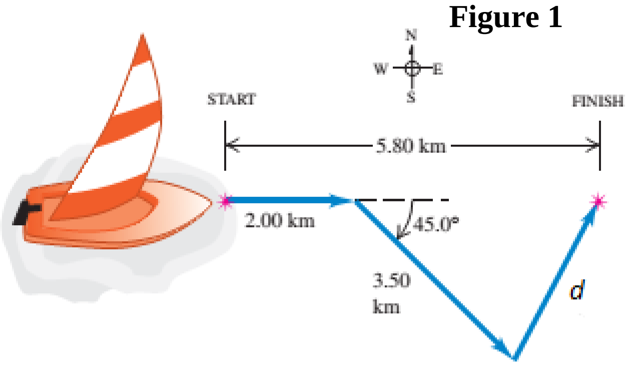
$v = \sqrt{(14^2 + 2(-9 \cdot 8) \times (-98)}$

$v = 46\ \mathrm{m/s}$

Q2.

A sailor in a small boat sails (moves) 2.00 km east, then 3.50 km southeast, and then an additional distance *d*. His final position is 5.80 km directly east of his starting point as shown in **Figure 1**. Find the distance *d*.

Figure 1



A) 2.81 km
B) 3.71 km
C) 2.02 km
D) 4.10 km
E) 5.32 km

Ans:

$2.0 + 3 \cdot 5 \cos 45^0 + \mathrm{d}_x = 5 \cdot 8$

$d_x = 3.8 - 3.5 \cos 45°$

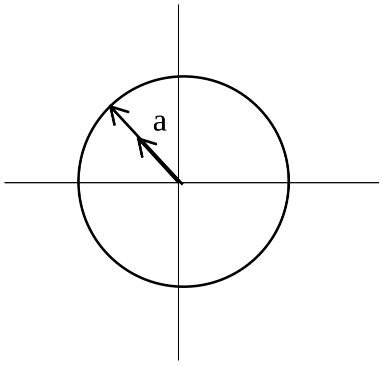
$-3.5 \sin 45° + d_y = 0$

$d_y = 3.5 \sin 45°$

$d = \sqrt{d_x^2 + d_y^2} = 2.81\, m/s$

Q3.

An object is in uniform circular motion with radius 3.00 m. At one instant its acceleration is $\vec{a} = (6.00\hat{i} - 4.00\hat{j})$ m/s^2. What is the speed of the object at that instant?



A) 4.65 m/s
B) 1.23 m/s
C) 7.15 m/s
D) 9.12 m/s
E) 2.45 m/s

Ans:

$\vec{a} = 6\hat{\imath} - 4\hat{\jmath}$

$a = \sqrt{6^2 + (-4)^2}$

$r = 3$ m

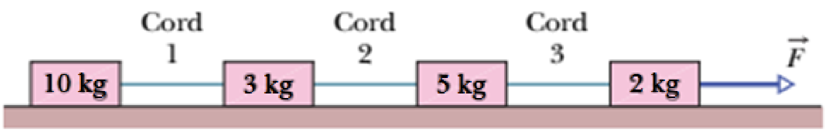
$a = \omega^2 r$

$\omega = \sqrt{ar} = 4.65\ m/s$

Q4.

Figure 2 shows four blocks being pulled across a frictionless floor by a force $|\vec{F}|$ = 40 N. Find the magnitude of tension in cord 2.

Figure 2



A) 26 N
B) 11 N
C) 40 N
D) 93 N
E) 65 N

Ans:

$\mathrm{F} = \Sigma ma$

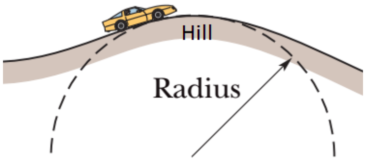
$40 = 20\ \mathrm{a} \Rightarrow a = 2\ \mathrm{m}/s^2$

$\mathrm{T}_2 = 13a = 13 \times 2 = 26N$

Q5.

In **Figure 3**, a person drives a car over the top of a hill with a circular arc of radius 250 m. At what greatest speed he can drive without the car leaving the road at the top of the hill?

Figure 3



A) 49.5 m/s
B) 19.8 m/s
C) 12.4 m/s
D) 79.2 m/s
E) 33.6 m/s

Ans:

$$F_n - mg = -\frac{mv^2}{r}$$

$$0 - mg = -\frac{m\mathrm{v}_{max}^2}{r}$$

$$v_{max} = \sqrt{rg}$$

$$v_{max} = \sqrt{250 \times 9.8} = 49 \cdot 5 \text{ m/s}$$

Q6.

A 2.0 kg object, on a frictionless horizontal table, is subjected to three forces that give it an acceleration $\vec{a} = -(8.0\text{m/s}^2)\hat{i} + (6.0\text{m/s}^2)\hat{j}$. If two of the three forces are $\vec{F}_1 = (30\text{N})\hat{i} + (16\text{N})\hat{j}$ and $\vec{F}_2 = -(12\text{N})\hat{i} + (8.0\text{N})\hat{j}$, find the magnitude of the third force.

A) 36 N
B) 12 N
C) 24 N
D) 48 N
E) 60 N

Ans:

$$F + F_2 + F_3 = ma$$

$$30\hat{\imath} + 16\hat{\jmath} - 12\hat{\imath} + 8\hat{\jmath} + F_3 = 2(-8\hat{\imath} + 6\hat{\jmath})$$

$$F_3 = -34\hat{\imath} - 12\,\hat{\jmath}$$

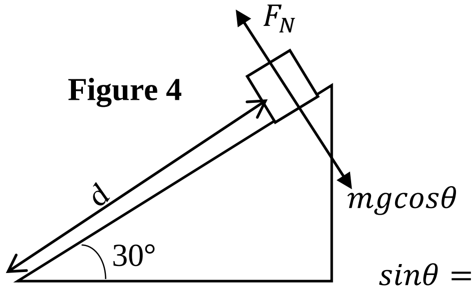
$$|F_3| = \sqrt{34^2 + 12^2} = 36N$$

Q7.

A 5.0 kg block initially at rest, slides down the ramp of an inclined plane of angle 30°, from the height of 5.0 m. Find the speed of the block at the end of the ramp if the coefficient of kinetic friction between the block and the surface of the ramp is 0.23.

A) 7.7 m/s
B) 4.2 m/s
C) 3.5 m/s
D) 1.6 m/s
E) 2.3 m/s

Figure 4



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

Ans:

$$\Delta k + \Delta U = W_f$$

$$\frac{1}{2}mv^2 - mgh = -f_k d$$

$$\frac{1}{2}mv^2 - mgh = -\mu_k mgdcos\theta$$

$$v = \sqrt{2g\left(h - \mu_k \frac{h}{sin\theta} cos\theta\right)}$$

$$v = \sqrt{2 \times 9.8 \times 5(1 - 0.23 \times cot30^{\circ})} = 7.7\ m/s$$

Q8.

A box open from the top slides across a frictionless horizontal surface. What happen to the box as water from a rain shower falls vertically downward into the box?

A) Its speed decreases
B) Its speed increases
C) Its speed remains constant
D) Its momentum changes
E) The vertical falling rain has no effect on the box

Ans:

No external force, $P_i = P_f$

$$P_i = mv_0$$

$$P_f = (m + \Delta m)v$$

$$\therefore P_f = P_i$$

$$\Rightarrow \text{v} = \left(\frac{m}{m + \Delta m}\right) v_0 \Rightarrow speed\ decreases$$

Q9.

The average power needed to spin (rotate about its axis) a uniform, solid disk of mass 5.0 kg and radius 0.50 m from rest to a final angular velocity ω_f in 3.0 s is 2.6 W. The value of ω_f is:

A) 5.0 rad/s
B) 3.9 rad/s
C) 2.7 rad/s
D) 1.3 rad/s
E) 8.5 rad/s

Ans:

$$P_{av} = \frac{\Delta k}{t}$$

$$P_{av} \times t = \frac{1}{2} I \omega_f^2 - 0$$

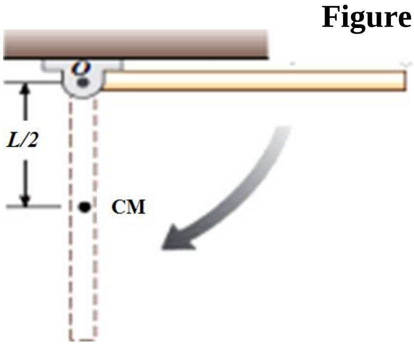
$$\omega_f = \sqrt{\frac{2P_{av}t}{0.5mR^2}}$$

$$\omega_f = \sqrt{\frac{2 \times 2.6 \times 3}{0.5 \times 5 \times (0.5)^2}} = 5.0\, rad/s$$

Q10.

A uniform rod of length *L = 40 cm* and mass *M = 2.0 kg* is free to rotate on a frictionless pin (pivot) passing through one end as shown in **Figure 4**. The rod is released from rest in the horizontal position, determine the angular speed of the rod when it is in the vertical position.

Figure 4



A) 8.6 rad/s
B) 2.5 rad /s
C) 1.4 rad /s
D) 5.5 rad /s
E) 4.9 rad /s

Ans:

$$\Delta k + \Delta U = 0$$

$$\frac{1}{2} I\omega^2 - mg\frac{L}{2} = 0$$

$$\omega = \sqrt{\frac{2mg\left(\frac{L}{2}\right)}{\frac{1}{3}mL^2}} = \sqrt{\frac{3g}{L}} = \sqrt{\frac{3 \times 9.8}{0.4}} = 8.6\, rad/s$$

Q11.

What increase in pressure is necessary to decrease the volume of a sphere by 0.23%? Take the bulk modulus of the sphere B = 2.8×10^{10} N/m^2.

A) 6.4×10^{7} N/m^2
B) 6.4×10^{9} N/m^2
C) 1.2×10^{7} N/m^2
D) 1.2×10^{9} N/m^2
E) 5.7×10^{10} N/m^2

Ans:

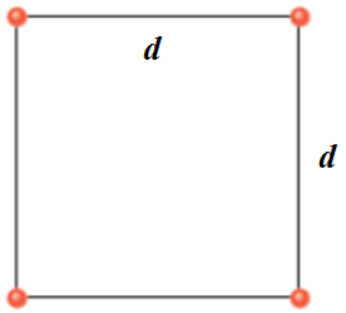
$$B = \frac{p}{\frac{dV}{V}}$$

$$p = B\frac{dV}{V} = 2.8\times10^{10}\times\frac{0.23}{100} = 6.4\times10^{7} N/m^2$$

Q12.

Four particles, each of mass 25 g, that form a square of side length d = 0.60 m as shown in **Figure 5**. If the particles are forced to form a new square with side length d = 0.20 m, find the work done by the gravitational force. [consider the system as isolated system]

Figure 5



A) 7.5×10^{-13} J
B) 2.3×10^{-13} J
C) 1.2×10^{-13} J
D) 3.6×10^{-13} J
E) Zero

Ans:

$$W = \Delta U = U_0 - U$$

$$W = -G\left[\frac{4m^2}{d_0} + \frac{2m^2}{\sqrt{2}d_0} - \frac{4m^2}{d} - \frac{2m^2}{\sqrt{2}d}\right]$$

$$= -Gm^2\left[\frac{4}{d_0} + \frac{\sqrt{2}}{d_0} - \frac{4}{d} - \frac{\sqrt{2}}{d}\right]$$

$$= -Gm^2\left[\frac{4+\sqrt{2}}{d_0} - \frac{4+\sqrt{2}}{d}\right]$$

$$= (4+\sqrt{2})Gm^2\left[\frac{1}{d} - \frac{1}{d_0}\right]$$

$$m = 25\times10^{-3}\,kg,\; d_0 = 0.6\,m, d = 0.2\,m$$

$$W = 7.52\times10^{-13}\,J$$

Q13.

If the mass of Mars is 0.11 times that of Earth, and its radius is 0.53 that of Earth. Find the gravitational acceleration *g* at the surface of Mars.

A) 3.8 m/s^2
B) 2.2 m/s^2
C) 4.9 m/s^2
D) 5.5 m/s^2
E) 8.0 m/s^2

Ans:

$$mg_{mars} = \frac{GM_{mars} \cdot m}{r_{mars}^2}$$

$$g_{mars} = \frac{G\ 0.11M_E}{(0.53\ r_E)^2}$$

$$g_{mars} = \frac{0.11}{(0.53\ )^2}\ g = 3.8\ m/s^2$$

Q14.

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

A) 2.5×10^7 m
B) 3.1×10^7 m
C) 1.9×10^7 m
D) 6.4×10^6 m
E) 1.0×10^4 m

Ans:

$$\Delta K + \Delta U = 0$$

$$(K - K_0) + (U - U_0) = 0$$

$$-\frac{1}{2}mv_0^2 - \frac{GMm}{(r_E + h)} + \frac{GMm}{r_E} = 0 \Rightarrow GM\left(\frac{1}{r_E} - \frac{1}{r_{E+h}}\right) = \frac{1}{2}v_0^2$$

$$\frac{1}{2}\frac{v_0^2}{GM} = \frac{1}{r_E} - \frac{1}{r_{E+h}} \Rightarrow \frac{1}{r_{E+h}} = \left(\frac{1}{r_E} - \frac{v_0^2}{2GM}\right)$$

$$r_{E+h} + h = \frac{r_E \cdot GM \times 2}{2GM - v_0^2 r_E} \Rightarrow h = \left(\frac{r_E \cdot GM \times 2}{2GM - v_0^2 r_E}\right) - r_E$$

$$r_E = 6.37 \times 10^6 m; M\ = 9.98\ \times 10^{14} kg; G = 6.67 \times 10^{-11} Nm^2/kg^2; v_0 = 1060\ m/s$$

$$h = 2.52 \times 10^7 m$$

Q15.

Two satellites are orbiting the Earth; satellite X is eight times as far from the Earth's center as is satellite Y. The period of the satellite X is: (note T_y is the period of Satellite Y)

A) 22.6 T_y
B) 52.8 T_y
C) 14.4 T_y
D) 1.32 T_y
E) 72.5 T_y

Ans:

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

$$\frac{T_y^2}{T_X^2} = \frac{\frac{4\pi^2}{GM} r_y^3}{\frac{4\pi^2}{GM} (8r_y)^3}$$

$$\therefore T_X^2 = 8^3 T_y^2$$

$$T_X = \sqrt{512} T_y$$

$$T_X = 22.6\, T_y$$

Q16.

Which of the following best describes the energy of a satellite rotating about the Earth?

A) The total mechanical energy is constant.
B) The kinetic energy is three times larger than its potential energy.
C) The kinetic energy is three times smaller than its potential energy.
D) Its kinetic energy does not depend on its mass.
E) Its potential energy is always zero.

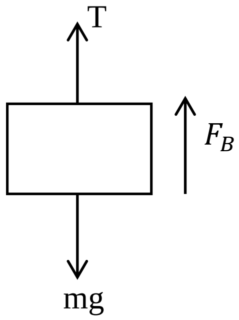
Ans:

A

Q17.

In **Figure 6**, a cube of edge length L = 0.600 m and mass 450 kg is suspended by a rope in an open (from the top) tank of liquid of density 1030 kg/m^3. Find the tension in the rope.

A) 2.23×10^{3} N
B) 7.18×10^{3} N
C) 4.41×10^{3} N
D) 1.05×10^{3} N
E) 3.96×10^{4} N



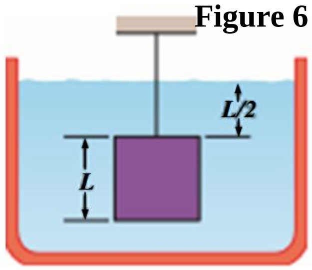


Figure 6

Ans:

$$T + F_B = mg$$

$$T + m_l g = mg \Rightarrow T = (m - m_l)g$$

$$T = (m - \rho_l L^3)g$$

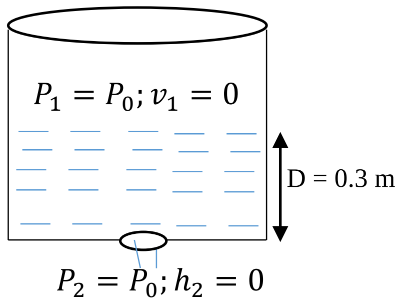
$$m = 450\ kg; \rho_l = 1030\ kg/m^3; L = 0.6\ m$$

$$T = 2.23\ \times 10^3\ N$$

Q18.

A cylindrical tank with a large diameter is filled with water to a depth D = 0.30 m. A hole of cross-sectional area A= 6.5 cm^2 in the bottom of the tank allows water to flow out. What is the rate at which water flows out?

A) 1.57×10^{-3} m^3/s
B) 2.42×10^{-3} m^3/s
C) 8.51×10^{-4} m^3/s
D) 3.06×10^{-3} m^3/s
E) 4.15×10^{-3} m^3/s



Ans:

$$\rho g h_1 + \frac{1}{2}\rho v_1^2 + P_1 = \rho g h_2 + \frac{1}{2}\rho v_2^2 + P_2$$

$$\rho g D + 0 + P_0 = 0 + \frac{1}{2}\rho v_2^2 + P_0$$

$$v_2 = \sqrt{2gD} = 2.42\ m/s$$

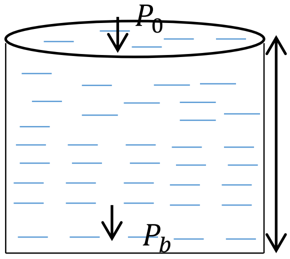
$$\frac{V}{t} = \frac{Ax}{t} = Av_2$$

$$A = 6.5 \times 10^{-4} m^2$$

$$\therefore \frac{V}{t} = 1.57\ \times 10^{-3} m^3/s$$

Q19.

A circular pool of uniform depth is completely filled with water to a depth of 1.0 m. If the radius of the pool is 1.0 m what is the total force at the bottom of the pool?



A) 3.5×10^{5} N
B) 2.3×10^{6} N
C) 4.2×10^{5} N
D) 6.5×10^{5} N
E) 5.7×10^{4} N

Ans:

$$P_b = P_0 + \rho g h$$

$$F_b = P_b \times A$$

$$= (P_0 + \rho g h) \times \pi r^2$$

$$P_0 = 1.01 \times 10^5\,, h = 1.0\ m, \rho\ = 1000\ kg/m^3, r\ = 1.0\ m$$

$$\therefore F_b = 3.5\ \times 10^5 N$$

Q20.

A hollow spherical iron shell floats and is completely submerged in water. The outer radius is 60.0 cm, and the density of iron is 7.87 g/cm^3. Find the inner radius.

A) 57.3 cm
B) 77.5 cm
C) 96.0 cm
D) 19.2 cm
E) 41.2 cm

Ans:

$$mg = \rho_w V g$$

$$V_i \rho = \rho_w \frac{4}{3}\pi r_0^2$$

$$\frac{4}{3}\pi(r_0^3 - r_{in}^3)\rho = \rho_w \frac{4}{3}\pi r_0^3$$

$$\rho r_0^3 - r_{in}^3 \rho = \rho_w r_0^3$$

$$r_{in}^3 \rho = \frac{(\rho - \rho_w)}{\rho} r_0^3$$

$$\therefore r_{in} = \left(1 - \frac{\rho_w}{\rho}\right)^{\frac{1}{3}} r_0$$

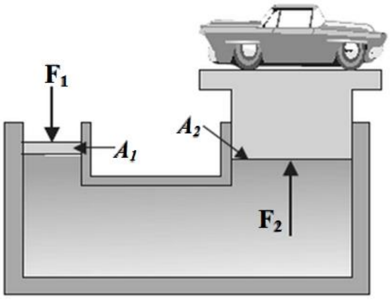
$$\rho_w = 1.0 \frac{g}{cm^3};\ \rho = 7.8 \frac{g}{cm^3}\ , r_0 = 60\ cm$$

$$r_{in} = 57.3\ cm$$

Q21.

A 15000-N car on a hydraulic lift rests on a cylinder with a piston of radius $r_2 = 0.20$ m as shown in **Figure 7**. If a connecting cylinder with a piston of radius $r_1 = 0.040$ m is driven by compressed liquid, find the force F_1 that must be applied to this smaller piston in order to lift the car.

Figure 7



A) 600 N
B) 750 N
C) 950 N
D) 250 N
E) 400 N

Ans:

$$P_1 = P_2$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_1 = F_2 \frac{A_1}{A_2}$$

$$F_1 = 15000 \times \frac{\pi r_2^2}{\pi r_1^2}$$

$$r_1 = 0.04\ m, r_2 = 0.2\ m$$

$$F_1 = 600\ N$$

Q22.

Which one of the following statements is **False** about a particle which undergoes simple harmonic motion?

A) The kinetic energy of the particle is minimum at minimum displacement.
B) The particle's motion repeats itself after a time period.
C) The acceleration of the particle is not constant.
D) The displacement of the particle in one complete time period is zero.
E) The distance travelled by the particle in one complete time period is 4 times the amplitude.

Ans:

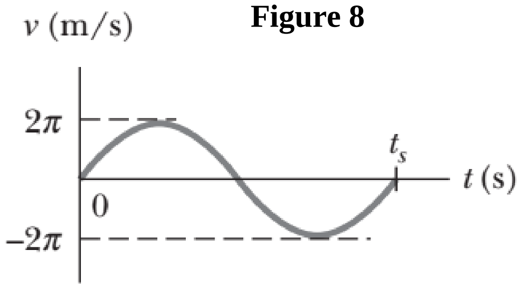
A

Q23.

A simple harmonic oscillator consists of a block attached to a horizontal spring while the other end is fixed to a wall. The block slides on a frictionless surface with equilibrium point $x = 0$ and amplitude 0.340 m. A graph of the block's velocity v as a function of time t is shown in **Figure 8**. Find the angular frequency ω of the block.

A) 18.5 rad/s
B) 23.6 rad/s
C) 7.58 rad/s
D) 2.12 rad/s
E) 6.28 rad/s

Figure 8



Ans:

$$v_{max} = \omega x_m$$

$$\omega = \frac{v_{max}}{x_m}$$

$$\omega = \frac{2\pi}{0.340} = 18.5\ rad/s$$

Q24.

The displacement of a particle oscillating along the x-axis is given as a function of time according to the equation: ***x(t) = 0.40cos(0.20πt+π/2),*** where x is in m and t in s. What is the total distance traveled by the particle in 35 s:

A) 5.6 m
B) 4.1 m
C) 3.0 m
D) 1.2 m
E) 7.4 m

Ans:

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{0.2\ \pi} = 10\ s$$

$$\frac{4x_m}{10} = \frac{x}{35}$$

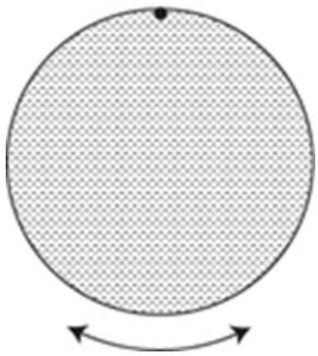
$$x = \frac{4x_m \cdot 35}{10}$$

$$x = 5.6\ m$$

Q25.

A solid circular disk of radius R is oscillating with time period T in a vertical plane about the pivot point P as shown in **Figure 9.** If the oscillating disk has to be replaced by a simple pendulum of same time period T, what should be the length of the simple pendulum?

Figure 9



A) 3R/2
B) 2R
C) R
D) R/2
E) 3R

Ans:

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

$$T = 2\pi\sqrt{\frac{L}{g}}$$

$$\sqrt{\frac{L}{g}} = \sqrt{\frac{\frac{1}{2}mR^2 + mR^2}{mgR}}$$

$$\sqrt{\frac{L}{g}} = \sqrt{\frac{\frac{3}{2}mR^2}{mgR}}$$

$$L = \frac{3R}{2}$$
