Q1.

A ball is thrown from the ground vertically upward and reaches a maximum height of 40 m. Upon descending, the ball hits the ground and rebounds with half its initial velocity. Find the height to which it reaches after rebounding.

A) 10 m
B) 20 m
C) 15 m
D) 8.8 m
E) 25 m

Ans:

$$v_0 = \sqrt{2g(y-y_0)} = 28 m/s, v_0' = \tfrac{1}{2} v_0 = 14\ m/s \Rightarrow y - y_0 = \frac{v_0'^2}{2g} = 10\ m/s$$

Q2.

You are given vectors **A** = 5.00 **i** – 6.00 **j** and **B** = – 3.00 **i** + 7.00 **j**. A third vector **C** lies in the xy-plane. Vector **C** is perpendicular to vector **A**, and the scalar product of **C** with **B** is 15.0. Find the vector **C**.

A) 5.29 i + 4.41 j
B) 7.54 i + 3.42 j
C) 6.32 i + 2.53 j
D) 8.37 i + 4.24 j
E) 7.21 i + 2.23 j

Ans:

$$\vec{A}\cdot\vec{C} = 0,\ \vec{C}\cdot\vec{B} = 15 \Rightarrow A_x C_x + A_y C_y = 0, \text{ and } B_x C_x - B_y C_y = 15$$

Q3.

An object is moving on a horizontal circular path of radius 1.5 meters at a constant speed. The time required for one revolution is 3.2 s. The acceleration of the object is:

A) 5.8 m/s2
B) 2.6 m/s2
C) 7.7 m/s2
D) 1.4 m/s2
E) zero

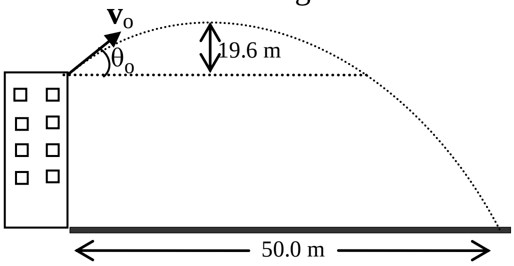
Ans:

$$a = \frac{v^2}{R} = \frac{1}{R}\left(\frac{2\pi R}{T}\right)^2$$

Q4.

A projectile is fired with initial velocity $\mathbf{v}_o$ and angle $\theta_o = 60^o$ from the top of a building (**Figure 1**) and is observed to reach a maximum height of 19.6 m. It later hits the ground at a horizontal distance of 50.0 m from the base of the building. Find the time of flight of the projectile. (Neglect air friction)

Figure 1



A) 4.42 s
B) 5.00 s
C) 9.80 s
D) 3.32 s
E) 2.50 s

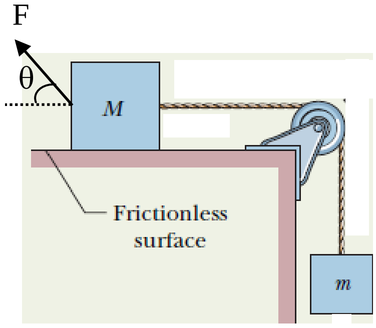
Ans:

$$v_y^2 = v_{0y}^2 - 2g\left(y - y_0\right) \Rightarrow v_{0y} = 19.6\ m/s \Rightarrow v_{0x} = 11.3\ m/s \Rightarrow t = \frac{x}{v_{0x}} = 4.4\ s$$

Q5.

As shown in **Figure 2**, a block with mass M = 3.00 kg is lying on a smooth surface and is attached to another block of mass m = 2.00 kg by means of a light, inextensible string which passes over a massless pulley. What force F acting on the block M at angle $\theta = 60^o$ above the horizontal will hold both objects at rest?

Figure 2



A) 39.2 N
B) 29.4 N
C) 19.6 N
D) 49.0 N
E) 9.80 N

Ans:

$$T - F\cos 60 = 0, \text{ and } T = mg \Rightarrow F = \frac{mg}{\cos 60} = 39.2\ N$$

Q6.

A car is moving on a flat horizontal circular track of radius R = 25.0 m. The coefficient of static friction between the car wheels and the track is $\mu_s = 0.350$. What is the speed at which the car starts sliding outside the track?

A) 9.26 m/s
B) 13.0 m/s
C) 14.5 m/s
D) 11.1 m/s
E) 5.44 m/s

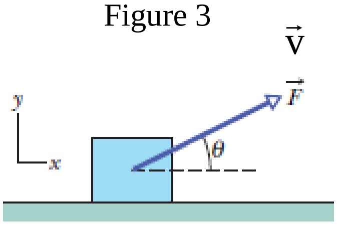
Ans:

$$m\frac{v^2}{R} = \mu mg \Rightarrow v = \sqrt{\mu Rg} = 9.26\ m/s$$

Q7.

A block of mass m = 5.00 kg slides on a horizontal rough surface under the action of a steady force F applied to the block at a constant angle of θ = 45° (**Figure 3**). The coefficient of kinetic friction between the block and the surface is 0.400. Find the maximum value of the force F for which the block will move only horizontally.

Figure 3



A) 69.3 N
B) 19.6 N
C) 50.0 N
D) 98.0 N
E) 150 N

Ans:

$$F_N = 0, F\sin\theta = mg$$

Q8.

A 100 kg parachute falls at a constant speed of 0.750 m/s. At what rate is energy being lost?

A) 735 W
B) 75.0 W
C) 56.3 W
D) 28.0 W
E) 147 W

Ans:

$$P = Fv$$

Q9.

A mass m = 1.00 kg is released from rest at point P (h = 6.00 m). It slides along the smooth track and reaches point O on the circular part of the track (R = 1.00 m) shown in **Figure 4**. What force does the track exert on the mass at point O?

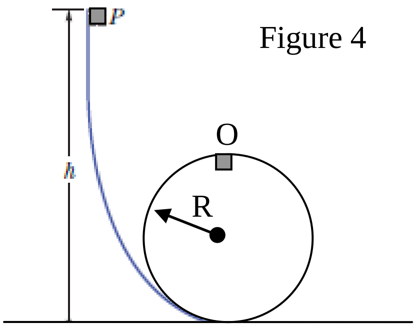


Figure 4

A) 68.6 N
B) 88.2 N
C) 98.0 N
D) 19.6 N
E) 49.0 N

Ans:

$$-N - mg = -m\frac{v^2}{R} \Rightarrow N = m\frac{v^2}{R} - mg, \text{ Note: } \tfrac{1}{2}mv^2 = mg\left(h - 2R\right)$$

Q10.

A stationary object of mass m = 24.0 kg explodes into two pieces of masses 14.0 kg and 10.0 kg. The velocity of the 10.0 kg mass is 6.00 m/s in the positive x-direction. The change in the kinetic energy of the object is:

A) 309 J
B) 511 J
C) 240 J
D) 180 J
E) 160 J

Ans:

$$0 = m_1 v_1 + m_2 v_2 \Rightarrow v_2 = -4.28\ m/s. \Delta K = \tfrac{1}{2} m_1 v^2{}_1 + \tfrac{1}{2} m_2 v^2{}_2 - 0 = 309\ J$$

Q11.

If the kinetic energy of a body is increased by a factor of 9, then the momentum of the body will increase by a factor of:

A) 3
B) 1
C) 9
D) 4
E) 2

Ans:

$$\frac{K_2}{K_1} = \frac{v_2^2}{v_1^2} = 9,\quad \frac{p_2}{p_1} = \frac{v_2}{v_1} = \sqrt{\frac{K_2}{K_1}} = \sqrt{9} = 3$$

Q12.

A solid spherical ball of mass *M* = 0.40 kg and radius *R* = 5.0 cm is rotating about its fixed central axis with angular speed of 4.0 rad/s. It was brought to a stop in 6.0 s. The work done to stop the ball is:

A) – 3.2 x 10–3 J
B) – 4.8 x 10–3 J
C) – 5.4 x 10–3 J
D) – 1.8 x 10–3 J
E) – 2.8 x 10–3 J

Ans:

$$W = \tau\theta = I\alpha\theta = \tfrac{2}{5} mR^2 \left(\frac{\omega^2 - \omega_0{}^2}{2\theta} \right) \theta$$

Q13.

An electric fan is turned off, and its angular velocity decreases uniformly from 500 rev/min to 250 rev/min in 4.00 s. Find the number of revolutions made by the motor in the 4.00 s interval.

A) 25.0
B) 10.0
C) 15.0
D) 20.0
E) 30.0

Ans:

$$\theta = \left(\frac{\omega + \omega_0}{2}\right)t$$

Q14.

A 0.20 kg stone attached to a string is rotating with a constant angular speed of 3.0 rev/s in a horizontal circle of radius 0.75 m. The magnitude of the angular momentum of the stone relative to the center of the circle is:

A) 2.1 kg.m2/s
B) 4.2 kg.m2/s
C) 3.2 kg.m2/s
D) 0.44 kg.m2/s
E) 1.6 kg.m2/s

Ans:

$$l = I\omega = mr^2\omega$$

Q15.

A hoop rolls down an inclined plane. The ratio of its rotational kinetic energy to it its total kinetic energy is:

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

Ans:

$$\frac{K_R}{K_R + K_T} = \frac{\frac{1}{2}I\omega^2}{\frac{1}{2}I\omega^2 + \frac{1}{2}mv^2} = \frac{mR^2\omega^2}{mR^2\omega^2 + mR^2\omega^2} = \frac{1}{2}$$

Q16.

A small sphere is made of a material with a bulk modulus of 1.90 x 10^9 Pa. The volume of the sphere shrinks by 0.20 % when submerged in a fluid at a depth of 400 m. What is the density of this fluid? Assume the pressure on the sphere at this depth is the same from all directions.

A) 970 kg/m3
B) 1200 kg/m3
C) 990 kg/m3
D) 1000 kg/m3
E) 1100 kg/m3

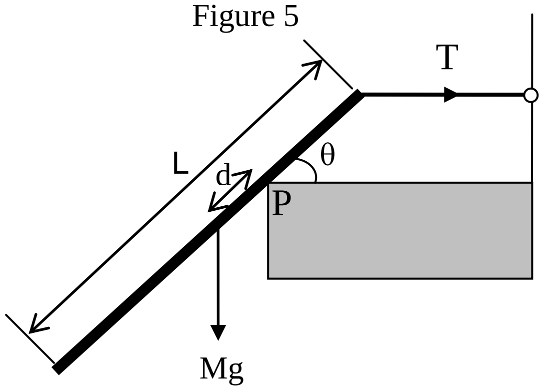
Ans:

$$P = B\frac{\Delta V}{V} = 3.8\times10^6\ Pa, P = \rho gh \Rightarrow \rho = 970\ \text{kg/m}^3$$

Q17.

Figure 5 shows a uniform rod (mass M = 5.0 kg, length L = 1.2 m) dangling over a frictionless edge at point P, but secured by a horizontal rope with tension T = 5.0 N. If the angle θ= 30^o, then what is the distance *d* needed to keep the rod in equilibrium.

Figure 5



A) 3.3 cm
B) 2.6 cm
C) 4.7 cm
D) 2.0 cm
E) 5.8 cm

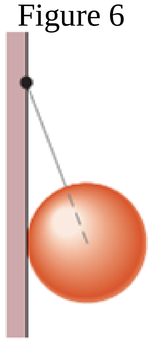
Ans:

$$Mgd\cos\theta - T\left(\frac{L}{2} - d\right)\sin\theta = 0$$

Q18.

The uniform sphere in **Figure 6** has a mass m = 2.0 kg and is held in place by a massless rope of length L = 20 cm, touching a rough wall. Find the force of friction between the sphere and the wall if the tension in the rope is 10 N, and the angle θ = 30^o.

Figure 6



A) 11 N
B) 7.0 N
C) 8.0 N
D) 18 N
E) 4.5 N

Ans:

$$mg = T + f_s$$

Q19.

Planet Pluto has a radius 20% of the earth radius and a mass only 0.2% that of earth. If an astronaut can jump 0.5 m high on earth, then how high can he jump on Pluto? (assume the astronaut jumps on both planets with the same velocity)

A) 10 m
B) 20 m
C) 0.5 m
D) 5.0 m
E) 0.05

Ans:

$$a = \frac{GM}{r^2} = \frac{G(0.002M_E)}{(0.2R_E)^2} = \frac{0.002}{(0.2)^2} g = 0.05g$$

$$v_E = v_P \Rightarrow 2gh_E = 2ah_P \Rightarrow h_P = 10 \text{ m}$$

Q20.

A satellite orbits a planet of unknown mass in a circle of radius 2.0 x 10^7 m. The magnitude of the gravitational force on the satellite is 80 N. What is the kinetic energy of the satellite in this orbit?

A) 80 x 107 J
B) 2.5 x 105 J
C) 40 x 107 J
D) 1.6 x 107 J
E) 32 x 107 J

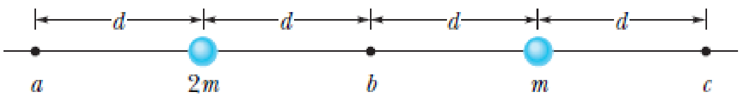
Ans:

$$K = \frac{U}{2} = \tfrac{1}{2} rF$$

Q21.

Figure 7 shows two particles of masses, m and 2m fixed in their positions. A particle of mass m is to be brought from an infinite distance to one of the three locations, a, b and c. Rank these three locations according to the magnitude of the net work done by the gravitational force on this particle due to the fixed particles, greatest first.

Figure 7



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

Ans:

$$\Delta U_a = G\left(\frac{2m}{d} + \frac{m}{3d}\right),\ \Delta U_b = G\left(\frac{2m}{d} + \frac{m}{d}\right),\ \Delta U_c = G\left(\frac{2m}{3d} + \frac{m}{d}\right)$$

Q22.

Which one of the following statements concerning Kepler's laws is FALSE?

A) Satellites in the same orbit around the earth but with different masses will have different periods.
B) Satellites with the same masses but in different orbits having different radii around the earth will have different periods.
C) The angular momentum is conserved for planets rotating about the sun.
D) The planets move faster when they are close to the sun.
E) Planets in their orbits sweep equal areas in equal times.

Ans:

A

Q23.

The volume flow rate of water through a horizontal pipe is 2.0 m^3/min. Calculate the speed of flow at a point where the radius of the pipe is 10 cm.

A) 1.1 m/s
B) 3.2 m/s
C) 0.55 m/s
D) 2.5 m/s
E) 4.0 m/s

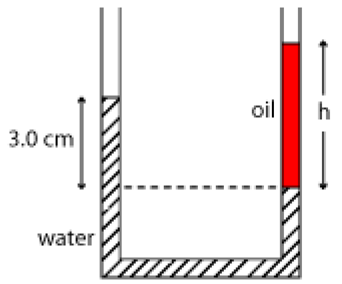
Ans:

$$Av = R \Rightarrow v = \frac{R}{\pi r^2}$$

Q24.

A uniform U-tube is partially filled with water. Oil, of density 0.75 g/cm^3, is poured into the right arm as shown in **Figure 8**. The length of the oil column (h) is then:

Figure 8



A) 4.0 cm
B) 8.0 cm
C) 6.0 cm
D) 2.0 cm
E) 10 cm

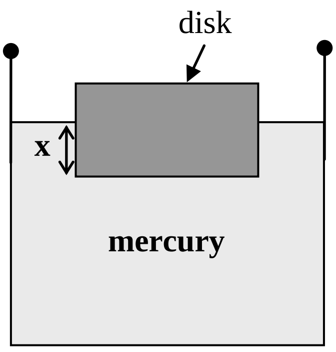
Ans:

$$\rho_w g h_w = \rho_o g h_o \Rightarrow h_o = \frac{\rho_w}{\rho_o} h_w$$

Q25.

A disk made of lead (diameter = 5.0 cm, height = 3.0 cm, density = 11.3 x 10^3 kg/m^3) floats in a container of mercury (density = 13.6 x 10^3 kg/m^3). What is the depth x (see **Figure 9**) by which the disk sinks in mercury.

Figure 9



A) 2.5 cm
B) 1.3 cm
C) 2.0 cm
D) 2.8 cm
E) 1.7 cm

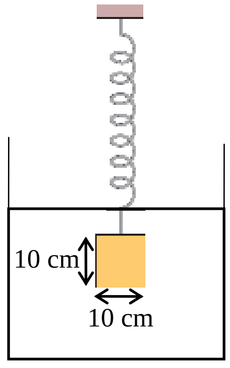
Ans:

$$F_B = mg \Rightarrow \rho_m V_m = \rho_l V_l \Rightarrow \rho_m Ax = \rho_l Ah \Rightarrow x = \frac{\rho_l}{\rho_m} h$$

Q26.

The edge length of the cube in **Figure 10** is 10 cm and its mass is 2.0 kg. It hangs from a spring and is fully submerged in water. If the spring constant is 98 N/m, by how much does the spring stretch from its equilibrium length.

Figure 10



A) 10 cm
B) 20 cm
C) 15 cm
D) 5.0 cm
E) 25 cm

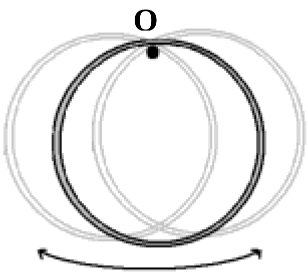
Ans:

$$kx + F_B - mg = 0$$

Q27.

A simple pendulum of length 12 cm is to be replaced by a hoop in one of the old O'clocks. See **Figure 11**. What should be the radius of the hoop needed to produce the same period as that of the pendulum, while oscillating about point O?

Figure 11



A) 6.0 cm
B) 4.0 cm
C) 3.0 cm
D) 12 cm
E) 24 cm

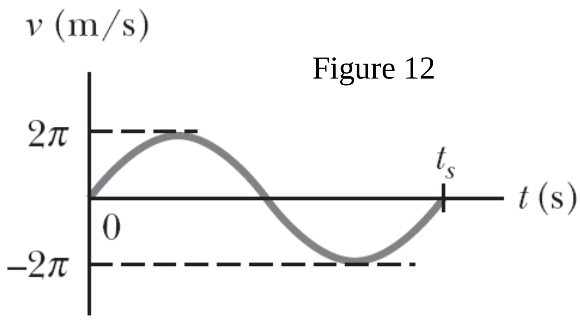
Ans:

$$T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{I}{mgh}} \Rightarrow \sqrt{\frac{L}{g}} = \sqrt{\frac{MR^2 + MR^2}{MgR}} \Rightarrow \sqrt{L} = \sqrt{2R} \Rightarrow R = \frac{L}{2}$$

Q28.

The velocity versus time plot for a block-spring system performing a simple harmonic motion is shown in **Figure 12**. The horizontal scale is set by t_s = 0.2 s. Find the acceleration of the system at t = 0.1 s.

Figure 12



A) 200 m/s2
B) 100 m/s2
C) 80 m/s2
D) 10 m/s2
E) 60 m/s2

Ans:

At t=0.1, the acceleration is maximum. $a = x_m\omega^2 = v_m\left(\frac{2\pi}{T}\right)$

Q29.

A block-spring system is in simple harmonic motion and its displacement as a function of time is given by the equation:

$$x = (5.0\text{ m})\cos[(\pi/3\text{ rad/s})t - \pi/4\text{ rad}],$$

The mass of the block is 3.0 kg. Find the speed of the block when the kinetic energy is one-fourth the total energy.

A) 2.6 m/s
B) 4.7 m/s
C) 3.3 m/s
D) 5.0 m/s
E) 1.5 m/s

Ans:

$$K = \tfrac{1}{2}mv^2 = \tfrac{1}{4}\left(\tfrac{1}{2}kx_m^2\right) \Rightarrow v = \tfrac{1}{2}x_m\sqrt{\frac{k}{m}} = \tfrac{1}{2}x_m\omega$$

Q30.

A mass m_1 = 1.0 kg is connected to a spring (with spring constant equal to k) and oscillates on a horizontal frictionless table with a period of 1.0 s. When m_1 is replaced with another unknown mass m_2, the period changes to 2.0 s. Find the value of m_2.

A) 4.0 kg
B) 3.0 kg
C) 2.0 kg
D) 0.50 kg
E) 1.0 kg

Ans:

$$T = 2\pi\sqrt{\frac{m}{k}}$$
