Q1.

A car accelerates at 2.0 m/s^2 along a straight road. It passes two marks that are 30 m apart at times t = 4.0 s and t = 5.0 s. Find the car's velocity at t = 0.

A) 21 m/s
B) 34 m/s
C) 16 m/s
D) 11 m/s
E) 48 m/s

Ans:

$$x_5 - x_4 = v_4 t + \frac{1}{2} at^2$$

$$30 = v_4(1) + \frac{1}{2}(2)(1)^2$$

$$v_4 = 29 m/s \Rightarrow 29 = v_0 + a(4) \Rightarrow v_0 = 21\ m/s$$

Q2.

Two vectors are given by $\vec{A} = 1.00\hat{i} + 2.00\hat{j}$ and $\vec{B} = 1.00\hat{i} + 3.00\hat{j}$. Find the angle that the vector $\vec{A} - 2\vec{B}$ makes with the positive y-axis.

A) 166°
B) 100°
C) 133°
D) 111°
E) 173°

Ans:

$$\vec{C} = \vec{A} - 2\vec{B} = -\hat{i} - 4\hat{j}$$

$$\Rightarrow \tan^{-1}\theta = \frac{1}{4} \Rightarrow \theta = 14°$$

$$\text{Angle from } y - \text{axis} = 180° - 14° = 166°$$

Q3.

A projectile's launch speed is 4 times its speed at maximum height. Find the launch angle from the horizontal.

A) 75.5°
B) 70.6°
C) 45.3°
D) 32.0°
E) 49.2°

Ans:

$$\text{At maximum height } v_y = 0 \Rightarrow v = v_x = v_{0x}$$

$$v_0 = 4\ v_{0x} \Rightarrow v_0 = 4v_0\cos\theta_0$$

$$\Rightarrow \theta = 75.5°$$

Q4.

A particle moves at constant speed in a circular path. The instantaneous velocity and instantaneous acceleration vectors are both:

A) Perpendicular to each other
B) Perpendicular to the circular path
C) tangent to the circular path
D) Opposite to each other
E) Parallel to each other

Ans:

In uniform circular motion, the acceleration is perpendicular to velocity at each instant.

Q5.

An elevator initially moving upward is slowing down at a rate of 1.50 m/s^2. If the tension in the cable is 3.20×10^3 N then find the weight of the elevator.

A) 3.78×10^3 N
B) 1.53×10^4 N
C) 5.20×10^5 N
D) 1.72×10^3 N
E) 5.92×10^3 N

Ans:

$$T - W = -ma$$

$$\Rightarrow W = T + \left(mg \cdot \frac{a}{g}\right)$$

$$\Rightarrow W = \frac{T}{1 - a/g} = \frac{3.2 \times 10^3}{1 - \frac{1.5}{9.8}} = 3.78 \times 10^3 \text{N}$$

Q6.

A 12 N horizontal force is applied to a 4.1 kg block initially at rest on a rough horizontal surface. If the coefficients of friction are μ_s = 0.5 and μ_k = 0.4. Find the magnitude of the frictional force on the block.

A) 12 N
B) 16 N
C) 10 N
D) 20 N
E) 8.0 N

Ans:

$$f_{smax} = \mu_s F_n = \mu_s mg$$

$$= (0.5)(4.1)(9.8) = 20.1 \text{ N}$$

$$F < f_{smax} \rightarrow \text{No motion}$$

$$f_s \equiv F = 12 \text{ N}$$

Q7.

A single force *F* acts on a block of mass *m* = 3.0 kg from *t* = 0 s to *t* = 4.0 *s*. If the position of the block is given by $x = t^3 - 5.2t$ then find the work done on the block by *F*.

A) 2.7×10^3 J
B) 5.4×10^3 J
C) 4.2×10^3 J
D) 6.7×10^3 J
E) 1.2×10^3 J

Ans:

$$v = \frac{dx}{dt} = 3t^2 - 5.2 \;\Rightarrow v(4) = \; 42.8\ \text{m/s};\; v(0) = -5.2\ \text{m/s}$$

$$W = \; \Delta K = \frac{1}{2}\,m(v_4^2 - v_0^2) = 2707.2\ \text{J} = 2.7\times10^3\ \text{J}$$

Q8.

The Rotational inertia of an object does not depend upon:

A) Its angular velocity.
B) Its mass.
C) Its size and shape.
D) The location of the axis of rotation.
E) The distribution of its mass.

Ans:

I is independent of $\vec{L}$

Q9.

A uniform meter stick pivoted at 10.0 cm mark is oscillating. Find the period of oscillation.

A) 1.57 s
B) 2.32 s
C) 3.60 s
D) 4.15 s
E) 3.43 s

Ans:

$$T = \; 2\pi\sqrt{\frac{I}{mgh}} = 2\pi\sqrt{\frac{\frac{1}{12}\,mL^2 + mh^2}{m(9.8)(0.4)}}$$

$$= 2\pi\sqrt{\frac{m\left(\frac{1}{12} + (0.4)^2\right)}{m(9.8)(0.4)}} \; = \; 1.57\ \text{s}$$

Q10.

A thin uniform rod of length 1.5 m and mass 0.50 kg is suspended freely from one end. It is pulled to one side and then allowed to swing like a pendulum, passing through its lowest position with angular speed 5.0 rad/s. Neglecting friction and air resistance, find the rod's kinetic energy at its lowest position.

A) 4.7 J
B) 1.2 J
C) 9.4 J
D) 0.90 J
E) 7.8 J

Ans:

$$K = \frac{1}{2} Iw^2 = \frac{1}{2}\left(\frac{1}{3} mL^2\right) w^2$$

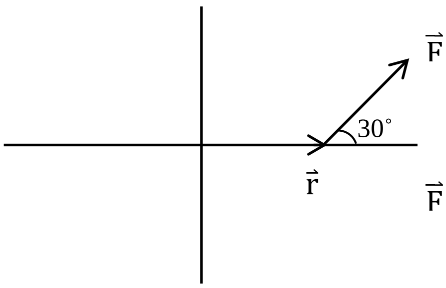
$$= \frac{1}{6} mL^2w^2 = \frac{1}{6}(0.5)(1.5)^2(5)^2$$

$K = 4.7\ \text{J}$

Q11.

A force of magnitude 10.0 N acts on a rigid body. The force lies in the *xy* plane. Its line of action passes through the point (0.500, 0.00) and makes an angle of 30.0^o with the positive *x*-axis. Find the torque of the force about the point (-0.300, 0.00).

A) $+4.00\ \hat{k}$ (N.m)
B) $-4.00\ \hat{k}$ ((N.m)
C) $+1.00\ \hat{k}$ ((N.m)
D) $-1.00\ \hat{k}$ ((N.m)
E) $+6.93\ \hat{i}$ ((N.m)



Ans:

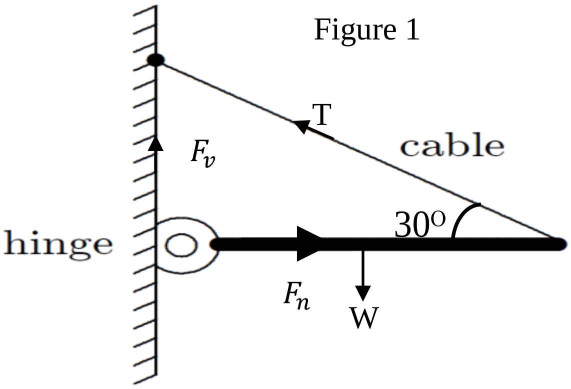
$$\tau = |r||F|\sin 30°$$

$$= (0.8)(10)\left(\frac{1}{2}\right) = 4.00\ \hat{k}\ (\text{N.m})$$

Q12.

A horizontal uniform beam of weight 1000 N is supported by a hinge at one end and by a cable at the other end, as shown in **Figure 1**. Find the magnitude of the force exerted on the beam by the hinge.

Figure 1



A) 1000 N
B) 1200 N
C) 780.0 N
D) 1500 N
E) 892.0 N

Ans:

$\Sigma\tau = 0$

$\Rightarrow W\left(\frac{L}{2}\right) = TL\left(\frac{1}{2}\right) \Rightarrow T = W = 1000\text{ N}$

$\Sigma F_x = 0 \Rightarrow F_n = T\cos\theta \Rightarrow (1000)\cos(30) = 0.75 \times 10^6\ N$

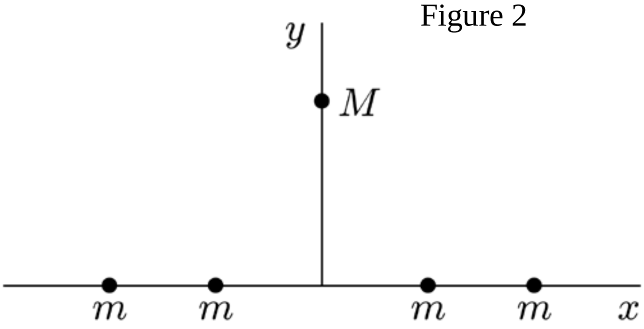
$\Sigma F_y = 0 \Rightarrow F_v = W - T\sin\theta = 0.5 \times 10^3\ N$

$F_{hinge} = \sqrt{F_n^2 + F_v^2} = 1000\text{ N}$

Q13.

Four particles, each with mass *m*, are arranged symmetrically about the origin on the *x* axis, as shown in **Figure 2**. A fifth particle, with mass *M*, is on the *y* axis. The direction of the gravitational force on *M* is:

Figure 2



A) Along the negative *y* axis
B) Along the positive *y* axis
C) Along the negative *x* axis
D) Along the positive *x* axis
E) Along the negative *z* axis

Ans:

Horizontal forces on M cancel out due to symmetry while vertical components are added in the y axis direction.

Q14.

A uniform solid sphere has a mass of 1.5×10^4 kg and a radius of 1.0 m. Find the magnitude of the gravitational force due to the sphere on a particle of mass *m* = 1.0 kg located at a distance of 0.75 m from the center of the sphere.

A) 7.5×10^{-7} N
B) 1.9×10^{-7} N
C) 3.6×10^{-7} N
D) 9.9×10^{-7} N
E) 0

Ans:

$$F = \frac{GMm'}{r^2} = \frac{GM}{r^2} \cdot \frac{r^3}{R^3} M = 7.5 \times 10^{-7} \text{ N}$$

$$m' = \rho V = \frac{M}{\frac{4}{3}\pi R^3} \cdot \frac{4\pi}{3} r^3 = \left(\frac{r}{R}\right)^3 M$$

Q15.

A planet has a mass of about 0.0558 times the mass of Earth and a diameter of about 0.381 times the diameter of Earth. The acceleration of a body falling near the surface of this planet is: (take acceleration due to gravity on earth to be 9.8 m/s^2)

A) 3.77 m/s^2
B) 1.50 m/s^2
C) 5.95 m/s^2
D) 9.80 m/s^2
E) 2.42 m/s^2

Ans:

$$g_E = \frac{GM}{R^2} \Rightarrow \frac{g_P}{g_E} = \frac{\frac{GM_P}{R_P^2}}{\frac{GM_E}{R_E^2}} = \frac{M_P}{M_E}\left(\frac{R_E}{R_P}\right)^2$$

$$\Rightarrow g_p = \frac{0.0558}{(0.381)^2} \times 9.8 = 3.77 \text{ m/s}^2$$

Q16.

Neglecting air resistance, a 1.0 kg projectile has an escape speed of about 11 km/s at the surface of Earth. Find the corresponding escape speed for a 2.0 kg projectile.

A) 11 km/s
B) 7.2 km/s
C) 15 km/s
D) 5.5 km/s
E) 22 km/s

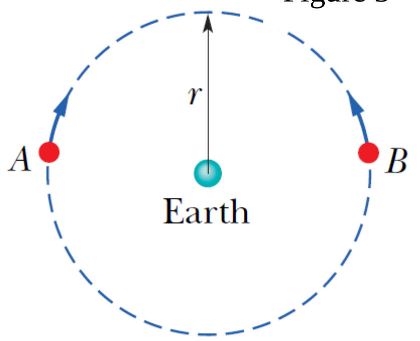
Ans:

Escape speed is mass independent.

Q17.

Two satellites *A* and *B* of same mass of 130 kg are shown in **Figure 3,** and move in the same circular orbit of radius $r = 7.77 \times 10^6$ m around earth but of opposite senses of rotation and therefore they are expected to collide. If the collision is completely inelastic, find the total mechanical energy immediately after collision.

Figure 3



A) -1.33×10^{10} J
B) -3.39×10^{10} J
C) -1.98×10^{8} J
D) -2.93×10^{10} J
E) 0

Ans:

$m_1 = m_2$

$\vec{v} = -\vec{v}_2 = \vec{v}_{com} = 0$

So after collision, KE = 0

$$\Rightarrow E = N = \frac{-2GmM}{r}$$

$$= \frac{-2 \times 6.67 \times 10^{-11} \times 130}{7.77 \times 10^6} = -1.33 \times 10^{10}\ \text{J}$$

Q18.

At a fixed depth within a fluid at rest, the pressure pushing upward is:

A) Equal to pressure pushing downward.
B) Zero, because pressure only pushes equal in all horizontal direction.
C) Zero, because the fluid above does not support the weight of the fluid below.
D) Greater than the pressure pushing downward.
E) Less than the pressure pushing downward.

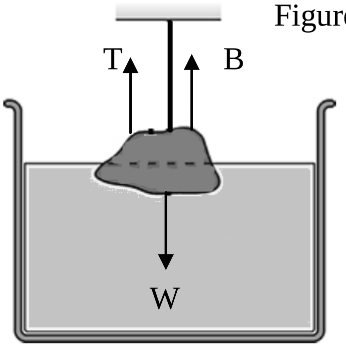
Ans:

Condition for fluid at rest.

Q19.

A 5.0 kg rock whose density is 4800 kg/m^3 is suspended by a string such that half of the rock's volume is under water (see **Figure 4**). Find the tension in the string.

Figure 4



A) 44 N
B) 73 N
C) 32 N
D) 68 N
E) 21 N

Ans:

$$T = W - B$$

$$= \rho_0 v_g - \rho_W \frac{v}{2} g$$

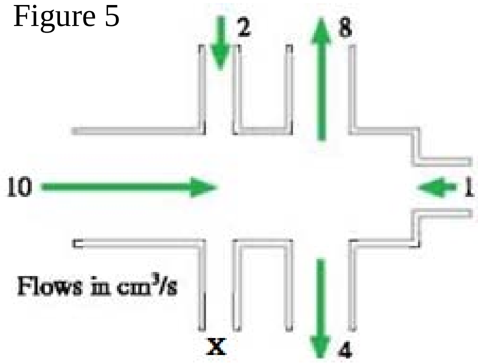
$$= \left(1 - \frac{\rho_W}{2\rho_0}\right) mg$$

$$= \left(1 - \frac{1000}{9600}\right)(5)(9.8) = 44\ \text{N}$$

Q20.

Figure 5 shows volume flow rates (in cm^3/s) of a fluid from all but one tube. Assuming steady flow of the fluid, find the volume flow rate through the **X** tube and its direction.

Figure 5



A) 1 cm^3/s flowing out
B) 7 cm^3/s flowing in
C) 5 cm^3/s flowing out
D) 3 cm^3/s flowing in
E) 4 cm^3/s flowing out

Ans:

in $\rightarrow$ +ve

out $\rightarrow$ −ve

$\rightarrow$ net flow rate = 0

$$\Rightarrow\ +2 + 10 + 1 - 8 - 4 + X = 0$$

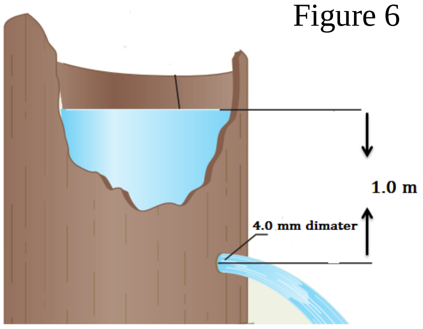
$$\Rightarrow\ X = -1$$

Q21.

A 4.0 mm diameter hole is 1.0 m below the surface of a large tank of water as shown in **Figure 6**. Find water volume flow rate through the hole.

A) 5.6×10^{-5} m^3/s
B) 3.1×10^{-5} m^3/s
C) 7.8×10^{-5} m^3/s
D) 1.5×10^{-6} m^3/s
E) 4.7×10^{-6} m^3/s

Figure 6



Ans:

$$\frac{1}{2}\rho v_2^2 = \rho g\,(Y_1 - Y_2)$$

$$\Rightarrow v_2 = \sqrt{2g\,(Y_1 - Y_2)} = 4.43\ \text{m/s}$$

$$R_v = A \cdot v = \pi r^2 v = 5.6 \times 10^{-5} \text{m}^3/\text{s}$$

Q22.

For an object undergoing a simple harmonic motion. Only one statement is correct

A) The object has varying acceleration.
B) The object has varying amplitude.
C) The object has varying period.
D) The object has varying frequency.
E) The object has varying total mechanical energy.

Ans:

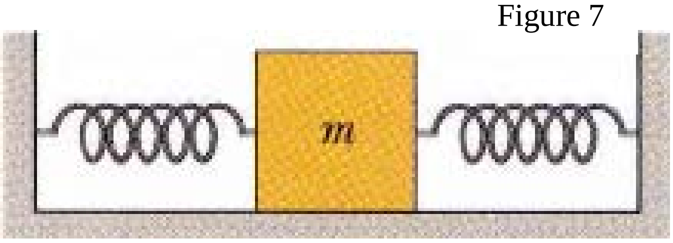
In SHM acceleration it is time dependent

Q23.

As shown in **Figure 7**, two identical springs of spring constant 7.00×10^3 N/m are attached to a block that is sitting on a frictionless floor. If the frequency of oscillation is 30.0 Hz, find the mass of the block.

A) 0.394 kg
B) 0.126 kg
C) 0.328 kg
D) 0.200 kg
E) 0.175 kg

Figure 7



Ans:

$$f = \frac{w}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{2k}{m}}$$

$$m = \frac{2k}{f^2 4\pi^2} = 0.394\ \text{kg}$$

Q24.

A 3.000 kg block, attached to a spring, executes simple harmonic motion. The position of the block is given as: $x = 2.000\cos(50.00t)$ where x is in meters and t is in seconds. Find the spring constant of the spring:

A) 7500 N/m
B) 6800 N/m
C) 9000 N/m
D) 2560 N/m
E) 4700 N/m

Ans:

$$k = mw^2$$

$$= (3)(50)^2 = 7500\ \mathrm{N/m}$$

Q25.

A 50 kg boy stands on frictionless level ice floor. He kicks a 0.10 kg stone lying near his feet if the velocity of the stone is (1.1 m/s)$\hat{i}$, find the velocity of the boy just after kicking the stone.

A) (-2.2×10^{-3} m/s)$\hat{i}$
B) (2.0×10^{-3} m/s)$\hat{i}$
C) (1.1×10^{-3} m/s)$\hat{i}$
D) (-1.2×10^{-3} m/s)$\hat{i}$
E) 0

Ans:

$$\vec{P}_{before} = \vec{P}_{after}$$

$$0 = v_{fs}m_s + v_{fb}m_b$$

$$= (1.1\ \hat{\imath})(0.1) + v_{fb}(50)$$

$$\Rightarrow \vec{v}_{boy} = (-2.2 \times 10^{-3}\mathrm{m/s})\ \hat{\imath}$$
