Q1.

When a large object moves in air, there is a resistive force on it whose magnitude is given by: $F = 0.5\, D\, \rho\, B\, v^2$, where D is a dimensionless constant, ρ is the density of the air and v is the speed of the object. What are the dimensions of B?

A) L^2
B) M^2
C) T^2
D) ML^2
E) TM^2

Ans: $[B] = \left[\frac{F}{\rho v^2}\right] = \left(kg \cdot \frac{m}{s^2}\right) \cdot \left(\frac{kg}{m^3}\right)^{-1} \cdot \left(\frac{m^2}{s^2}\right)^{-1}$

$$= \frac{kg \cdot m}{s^2} \cdot \frac{m^3}{kg} \cdot \frac{s^2}{m^2} = m^2 \rightarrow L^2$$

Q2.

A cubic box has a side of length 1.00 ft. What is the volume of the box in cubic meters? (1 ft = 12.0 inch, 1 inch = 2.54 cm)

A) 0.0283
B) 0.843
C) 0.759
D) 0.227
E) 0.00100

Ans:

$$l = 1 ft \cdot \frac{12\ in}{1\ ft} \cdot \frac{2.54\ cm}{1\ in} \cdot \frac{1\ m}{100\ cm} = 0.3048\ m$$

$$V = l^3 = (0.3048)^3 = 0.0283\ m^3$$

Q3.

A car is travelling along a straight line. It travels at 40.0 km/h for 2.00 h, then at 50.0 km/h for 1.00 h, and finally at 20.0 km/h for 0.500 h. What is the average speed of the car?

A) 40.0 km/h
B) 36.7 km/h
C) 55.0 km/h
D) 45.0 km/h
E) 31.6 km/h

Ans:

$$\left.\begin{aligned} d_1 &= 40 \times 2 = 80\ km \\ d_2 &= 50 \times 1 = 50\ km \\ d_3 &= 20 \times \tfrac{1}{2} = 10\ km \end{aligned}\right\} \begin{aligned} d &= 80 + 50 + 10 = 140\ km \\ t &= 2 + 1 + \tfrac{1}{2} = 3.5\ h \end{aligned}$$

$$S_{avg} = \frac{d}{t} = \frac{140}{3.5} = 40\ km/h$$

Q4.

In one dimensional motion, a particle is 5.00 m east of the origin and is moving west with a speed of 2.00 m/s. Five seconds later, it is 11.0 m east of the origin. What is its acceleration? Assume that the acceleration is constant.

A) 1.28 m/s^2
B) – 0.320 m/s^2
C) 2.08 m/s^2
D) 1.68 m/s^2
E) 0.781 m/s^2

Ans: $x_1 = +5\ \text{m};\ v_1 = -2\ \text{m/s}$

$x_2 = +11\ \text{m};\ t = 5.0\ \text{s}$

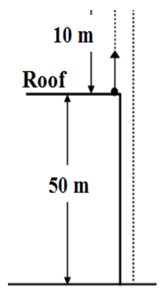
$$x_2 - x_1 = v_1 t + \frac{1}{2}at^2$$

$$11 - 5 = -10 + 12.5\ a \Longrightarrow a = \frac{16}{12.5} = 1.28\ \text{m/s}^2$$

Q5.

An object is thrown vertically upward from the roof of a building that is 50 m high. It rises to a maximum height of 10 m above the roof (**Figure 1**). When is it 20 m below the roof?

Figure 1



A) 3.9 s
B) 5.2 s
C) 4.9 s
D) 3.2 s
E) 6.1 s

Ans: Throw → max height: $v^2 = v_0^2 - 2g(y - y_0)$

$$0 = v_0^2 - 19.6(60 - 50) \Longrightarrow v_0 = 14\ \text{m/s}$$

Throw → requested point:

$$y - y_0 = v_0 t - \frac{1}{2}gt^2$$

$$30 - 50 = 14t - 4.9t^2$$

$$4.9\ t^2 - 14t - 20 = 0$$

$$t = \frac{14 \pm \sqrt{196 + (4 \times 20 \times 4.9)}}{9.8} = 3.9\ \text{s}$$

Q6.

At time t = 3.0 s, the velocity of a particle, moving along the x-axis with constant acceleration, is v = + 4.0 m/s. At t = 7.0 s, its velocity is v = –12 m/s. Find the velocity at t = 0.

A) + 16 m/s
B) + 20 m/s
C) – 16 m/s
D) – 20 m/s
E) + 5.0 m/s

Ans: $v = v_0 + at$

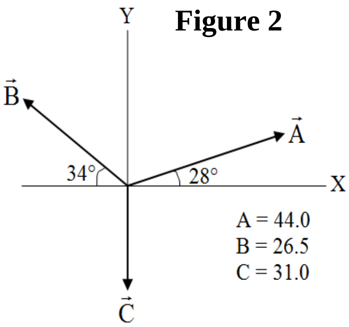
$$\begin{rcases} \text{(i)} \quad 4 = v_0 + 3a \\ \text{(ii)} \; -12 = v_0 + 7a \end{rcases}$$

$$\begin{rcases} \text{(i)} \times -7: -28 = -7v_0 - 21a \\ \text{(ii)} \times 3: -36 = 3v_0 + 21a \end{rcases} \xrightarrow{\oplus} -64 = -4v_0 \Rightarrow v_0 = +16\ m/s$$

Q7.

For the three vectors $(\vec{A}, \vec{B}, \vec{C})$ shown in **Figure 2**, find $\vec{C}\times(\vec{A}\times\vec{B})$.

Figure 2



A) $-3.19\times10^{4}\,\hat{\mathbf{i}}$
B) $-6.27\times10^{4}\,\hat{\mathbf{i}}$
C) $+2.67\times10^{4}\,\hat{\mathbf{i}}$
D) $+3.67\times10^{4}\,\hat{\mathbf{i}}$
E) zero

Ans: ϕ angle between $\vec{A}, \vec{B} = 118°$

$$|\vec{A}\times\vec{B}| = 44 \times 26.5 \times sin118° = 1029.5 \rightarrow \hat{k}$$

$$\vec{C}\times(\vec{A}\times\vec{B})\ is\ along\ (-x)\ by\ right-hand\ rule$$

$$|\vec{C}\times(\vec{A}\times\vec{B})| = 31.0 \times 1029.5 \times sin90° = 3.19 \times 10^4$$

Q8.

What is the angle between two vectors $\vec{A} = 20\hat{\mathbf{i}}$ and $\vec{B} = -25\hat{\mathbf{i}} + 30\hat{\mathbf{j}}$?

A) 130°
B) 150°
C) 160°
D) 140°
E) 110°

Ans: $\vec{A}$ *is along the x − axis*

Angle between $\vec{B}$ and is (+) x axis is $\phi = 180 - tan^{-1}\left(\frac{30}{25}\right) = 130°$

Q9.

A body moves from a position with coordinates (1.0, 2.0) m to (– 4.0, 2.0) m. Its displacement vector is given by

A) 5.0 m at 180°
B) 5.0 m at 135°
C) 1.7 m at 297°
D) 5.0 m at 0°
E) 5.2 m at 108°

Ans:

$$\left.\begin{matrix}\vec{r}_1 = \hat{\imath} + 2\hat{\jmath} \\ \vec{r}_2 = -4\hat{\imath} + 2\hat{\jmath}\end{matrix}\right\} \vec{d} = \vec{r}_2 - \vec{r}_1 = -5\hat{\imath}\ (m)$$

$\Rightarrow \vec{d}$ *makes an angle of* 180° *and has a magnitude of* $5.0\ m.$

Q10.

At time $t = 0$, a particle leaves the origin with a velocity of 9.0 m/s in the positive y-direction and moves in the xy plane with a constant acceleration of $(2.0\hat{\mathbf{i}} - 4.0\hat{\mathbf{j}})$ m/s^2. What is the speed of the particle when its x-coordinate is + 15 m?

A) 10 m/s
B) 16 m/s
C) 12 m/s
D) 14 m/s
E) 26 m/s

Ans:

$$x = v_{0x}t + \frac{1}{2}a_x t^2$$

$$15 = 0 + \left(\frac{1}{2} \times 2\right)t^2 \Rightarrow t = \sqrt{15} = 3.87\ s$$

$$v_x = v_{0x} + a_x t = 0 + (2)(\sqrt{15}) = 7.75\ m/s$$

$$v_y = v_{0y} + a_y t = 9 + (-4)(\sqrt{15}) = -6.49\ m/s$$

$$\text{Speed} = \sqrt{v_x^2 + v_y^2} = 10\ m/s$$

Q11.

A projectile is launched from the ground at time $t = 0$. When $t = 5.00$ s, its velocity is given as: $\vec{v} = 25.0\hat{\mathbf{i}} - 30.0\hat{\mathbf{j}}$ (m/s). Find the maximum height of the projectile.

A) 18.4 m
B) 15.6 m
C) 32.9 m
D) 65.8 m
E) 49.4 m

Ans:

$$v_y = v_{0y} - gt$$

$$-30 = v_{0y} - (9.8 \times 5) \Rightarrow v_{0y} = 19\ \text{m/s}$$

launch $\rightarrow$ max. height:

$$v_y^2 = v_{0y}^2 - 2g(y - y_0)$$

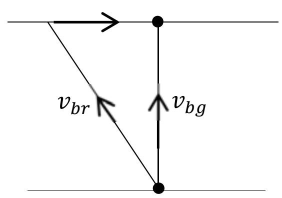
$$0 = (19)^2 - (19.6)(H - 0)$$

$$\Rightarrow H = 18.4\ \text{m}$$

Q12.

A river, of width 150 m, flows with a uniform speed of 4.0 m/s toward the east. It takes 20 s for a boat to cross the river from a point on the south side to the opposite point on the north side. What is the speed of the boat relative to the water?

A) 8.5 m/s
B) 9.1 m/s
C) 5.7 m/s
D) 7.0 m/s
E) 6.4 m/s



Ans:

r $\longrightarrow$ river, g $\rightarrow$ ground, b $\rightarrow$ boat

$$v_{rg} = 4.0\ \text{m/s}$$

$$v_{bg} = \frac{150}{20} = 7.5\ \text{m/s}$$

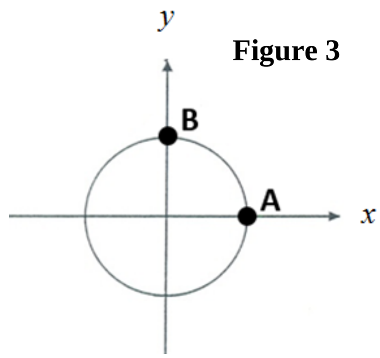
$$v_{br} = \sqrt{v_{bg}^2 + v_{rg}^2} = \sqrt{(4)^2 + (7.5)^2} = 8.5\ \text{m/s}$$

Q13.

A particle undergoes counterclockwise uniform circular motion around a circle of radius 5.0 m with a period of 3.2 s, as shown in **Figure 3**. In a quarter of a period, as the particle moves from A to B, what is the magnitude of the average velocity of the particle?

A) 8.8 m/s
B) 9.8 m/s
C) 4.9 m/s
D) 7.8 m/s
E) zero

Figure 3



Ans:

$$\left.\begin{aligned}\vec{r}_i &= 5.0\hat{\imath}\\ \vec{r}_f &= 5.0\hat{\jmath}\end{aligned}\right\} \begin{aligned}&\Delta\vec{r} = 5.0\hat{\jmath} - 5.0\hat{\imath}\ (m)\\ &\Delta t = \frac{T}{4} = \frac{3.2}{4} = 0.8\ s\end{aligned}$$

$$\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t} = \frac{5.0\hat{\jmath} - 5.0\hat{\imath}}{0.8} = -6.25\hat{\imath} + 6.25\hat{\jmath}\ \text{(m/s)}$$

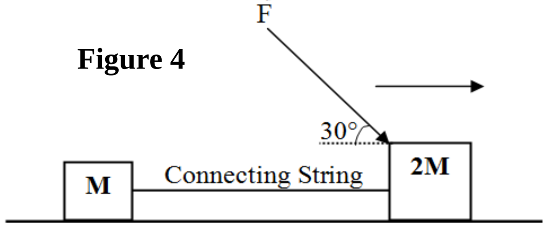
$$v_{avg} = \sqrt{2} \times 6.25 = 8.8\ m/s$$

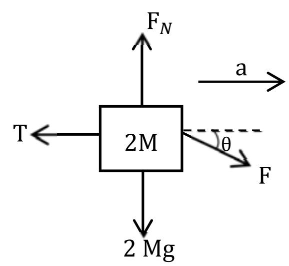
Q14.

In **Figure 4**, the force $\vec{F}$ acts to move the two blocks on a horizontal frictionless surface. Find the magnitude of the tension in the massless connecting string. Take F = 15 N, M = 1.5 kg.

A) 4.3 N
B) 5.9 N
C) 5.1 N
D) 3.8 N
E) 6.2 N

Figure 4





Ans:

$$2M:\ 2\,Ma = F\cos\theta - T \longrightarrow (1)$$

$$M:\ Ma = T \longrightarrow (2)$$

Adding(1) an (2) we get, 3 Ma = Fcosθ

$$\Rightarrow a = \frac{F\cos\theta}{3M}$$

Back to (1):

$$T = F\cos\theta - 2Ma = F\cos\theta - (2M)\left(\frac{F\cos\theta}{3M}\right)$$

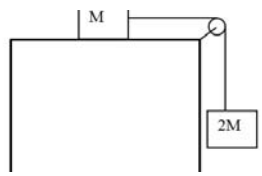
$$= \frac{1}{3}F\cos\theta = \frac{1}{3} \times 15 \times \cos 30° = 4.3\ \text{N}$$

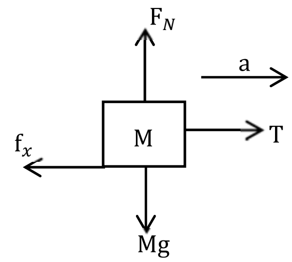
Q15.

The two blocks shown in **Figure 5** are released from rest and are observed to have an acceleration of 1.5 m/s^2. What is the magnitude of the frictional force on the block that slides horizontally? Assume the pulleys and strings are massless, and take M = 1.4 kg.

A) 21 N
B) 46 N
C) 11 N
D) 37 N
E) 29 N

Figure 5

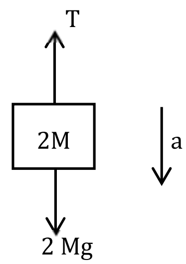




Ans:

$$\left.\begin{aligned} Ma &= T - f_k \\ 2Ma &= 2Mg - T \end{aligned}\right\} \oplus \rightarrow 3Ma = 2Mg - f_k$$

$$\Rightarrow f_k = (2g - 3a)M = (19.6 - 4.5)(1.4) = 21\ \text{N}$$



Q16.

An 80-kg man stands in an elevator that has a downward acceleration of 1.5 m/s^2. The magnitude of the force exerted by the man on the floor of the elevator is

A) 664 N
B) 784 N
C) 904 N
D) 388 N
E) zero

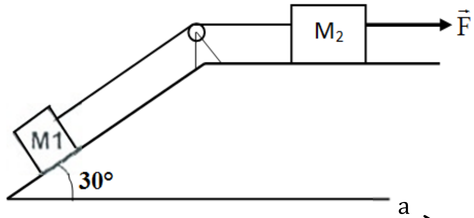
Ans:

$$-Ma = F_N - Mg$$

$$\Rightarrow F_N = M(g - a) = (80)(9.8 - 1.5) = 664\ \text{N}$$

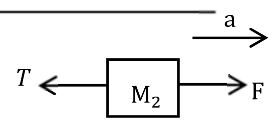
Q17.

Two blocks with masses M_1 = 3.0 kg and M_2 = 5.0 kg are connected by a light rope and move on a frictionless surface, as shown in **Figure 6**. A force F = 20 N acts on M_2 as shown in the figure. Find the magnitude of the acceleration of the system.



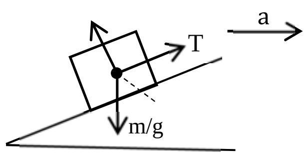
A) 0.66 m/s^2
B) 2.6 m/s^2
C) 1.8 m/s^2
D) 4.3 m/s^2
E) 0.86 m/s^2

Ans:



$$M_1a = T - M_1 g\sin\theta \longrightarrow (1)$$

$$M_2a = F - T \longrightarrow (2)$$



Adding (1) and (2) we get

$$(M_1 + M_2)a = F - M_1 g\sin\theta$$

$$a = \frac{F - M_1 g\sin\theta}{M_1 + M_2} = \frac{20 - \left(3 \times 9.8 \times \frac{1}{2}\right)}{8} = 0.66\ \text{m/s}^2$$

Q18.

A car moves on a level horizontal road in a circle of radius 40 m. The coefficient of static friction between tires and road is 0.50. The maximum speed with which this car can round this curve without sliding is

A) 14 m/s
B) 12 m/s
C) 16 m/s
D) 10 m/s
E) 18 m/s

Ans:

$$ma = F_{net}$$

$$\frac{mv^2}{R} = f_s$$

$$\frac{mv_{max}^2}{R} = f_{s,max} = \mu_s F_N = \mu_s mg$$

$$\Rightarrow v_{max} = \sqrt{\mu_s \cdot R \cdot g} = \sqrt{0.5 \times 40 \times 9.8} = 14\ m/s$$

Q19.

Which of the following statements is **TRUE**?

A) A particle can be in equilibrium and yet moving.
B) A stone that has been thrown vertically upward reverses its acceleration as it reaches the top of its trajectory.
C) Two vectors of unequal magnitudes can add up to zero.
D) On a displacement-time graph, a straight line with positive slope indicates motion at increasing speed.
E) The action and reaction forces act on the same object.

Ans:

A

Q20.

Which of the following statements is **TRUE**?

A) A car can be accelerating while moving at constant speed.
B) If an object is released from rest, it falls 9.8 m during the first second of its motion.
C) The velocity of a projectile equals its initial velocity added to a constant horizontal velocity.
D) A particle can move with uniform velocity along a circular path.
E) The velocity of a projectile at the top of its trajectory is zero.

Ans:

A
