Q1.
The air resistance force on a falling object can be expressed as $\boldsymbol{F} = \boldsymbol{a}\, \boldsymbol{v}^2$, where $\boldsymbol{a}$ is a constant, and $\boldsymbol{v}$ is the speed of the object. The dimension of $\boldsymbol{a}$ is

A) M/L
B) ML
C) L/M
D) M/L^2
E) ML^2

Answer:

$$a = \frac{F}{v^2} = kg.\frac{m}{s^2}\frac{s^2}{m^2} = \frac{kg}{m} \rightarrow ML^{-1}$$

Q2.
Assume it takes 6.00 minutes to fill a 30.0-gallon tank. Calculate the rate at which the tank is filled in cubic meters per second. [1 gallon = 231 inch^3, 1 inch = 2.54 cm]

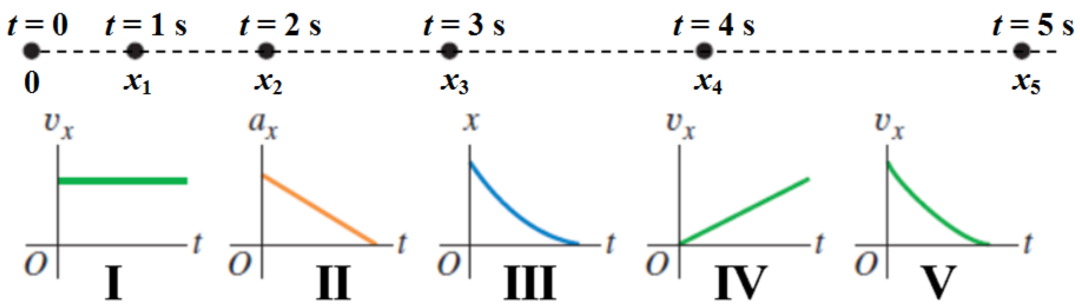
A) 3.15×10^{-4}
B) 4.89×10^{-5}
C) 5.25×10^{-5}
D) 1.89×10^{-2}
E) 1.05×10^{-5}

Answer:

$$V = 30\ gal\,\frac{231\ in^3}{1\ gal} = \frac{(2.54)^3 cm^3}{1\ in^3}\cdot\frac{1\ m^3}{10^6\ cm^3} = 0.11356\, m^3$$

$$rate = \frac{V}{t} = \frac{0.11356}{360} = 3.15\times\ 10^{-4}$$

Q3.
The top diagram in **Figure 1** represents a series of the locations of a particle moving along a straight line from left to right. The dots are taken every one second. Which of the lower graphs represents the motion of the particle?



A) IV
B) I
C) II

D) III
E) V

Answer:

The distance between adjacent dots increases. Thus, the speed is increasing.

Q4.
The position of a particle moving along the x axis is given by: $x(t) = 1.5\,t^2 - 0.050\,t^3$, where x in meters and t is in seconds. Calculate the average acceleration of the particle during the interval from $t = 2.0$ s to $t = 4.0$ s.

A) 2.1 m/s^2
B) 1.7 m/s^2
C) 0.45 m/s^2
D) 9.6 m/s^2
E) 5.4 m/s^2

Answer:

$$v = \frac{dx}{dt} = 3t - 0.15t^2$$
$$v_2 = 6 - 0.6 = 5.4\ m/s$$

$$v_4 = 12 - 2.4 = 9.6\ m/s$$
$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_4 - v_2}{4 - 2} = \frac{9.6 - 5.4}{2} = 2.1\ m/s^2$$

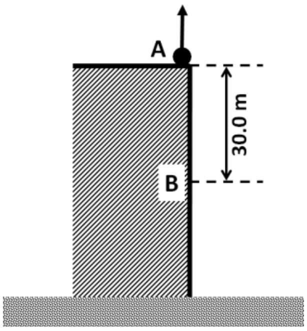
Q5.
A car travels in a straight line a distance of 40 m in 8.0 s while slowing down at constant deceleration to a final speed of 2.5 m/s. Find its initial speed.

A) 7.5 m/s
B) 13 m/s
C) 2.5 m/s
D) 4.2 m/s
E) 6.8 m/s

Answer:
$$x = v_i t - \frac{1}{2}at^2$$
$$v_{f=} v_i - at$$
$$2.5 = v_i - 8a \implies a = \frac{v_i - 2.5}{8}$$
$$\implies 40 = 8v_i - \frac{1}{2} \times \frac{v_i - 2.5}{8} \times 64 \implies 40 = 8v_i - 4v_i + 10$$
$$30 = 4v_i \implies v_i = 7.5\ m/s$$

Q6.

A rock is thrown vertically upward from point A at the roof of a building (see **Figure 2**). It reaches point B, which is 30.0 m below point A, in a time of 5.00 s after it is thrown. What is the initial speed of the rock? Ignore air resistance.



A) 18.5 m/s
B) 30.5 m/s
C) 24.2 m/s
D) 49.0 m/s
E) 39.8 m/s

Answer:

Take the roof to be the reference and y to be (+) upward.

$y - y_0 = v_i t - \frac{1}{2} g t^2$

$-30 = 5v_i - (4.9 \times 25)$

$-30 = 5v_i - 122.5 \Longrightarrow 5v_i = 92.5 \Longrightarrow v_i = 18.5\ m/s$

Q7.

If two vectors have the same magnitude, what should be the angle between them for their resultant to have the same magnitude as any of them?

A) 120^{o}
B) 60^{o}
C) 45^{o}
D) 30^{o}
E) 150^{o}

Answer:

$R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

$R^2 = A^2 + B^2 + 2AB\cos\theta$

$A^2 = A^2 + A^2 + 2A^2\cos\theta$

$2A^2\cos\theta = -A^2$

$\cos\theta = -\frac{1}{2} \Longrightarrow \theta = 120°$

Q8.

A person moves 180 m straight west, then 270 m at 30.0° east of north. What third displacement would bring him back to the starting point?

A) 238 m at 79.1° south of east
B) 392 m at 10.9° north of east
C) 194 m at 25.7° west of north
D) 169 m at 29.3° west of south
E) 248 m at 36.3° east of south

Answer:

$\vec{d}_1 = -180\,\hat{\imath}$
$\vec{d}_2 = 270\;\cos 60\,\hat{\imath} + 270\sin 60\;\hat{\jmath}$

$= 135\,\hat{\imath} + 233.8\,\hat{\jmath}$

$\vec{d}_{net} = \vec{d}_1 + \vec{d}_2 + \vec{d}_3$

$0 = \;\vec{d}_1 + \;\vec{d}_2 \;+\; \vec{d}_3$

$\Rightarrow \vec{d}_3 = -(\vec{d}_1 + \vec{d}_2)$

$= +\,45\,\hat{\imath} - 233.8\,\hat{\jmath}$

$d_3 = \sqrt{45^2 + 233.8^2} = 238\,m$

Q9.

Two vectors $\vec{A}$ and $\vec{B}$ lie in the *xy* planes. Their magnitudes and angles measured counterclockwise from the positive *x*-axis are: A = 5.0, θ_A = 58°, B = 4.0, θ_B = 28°. A third vector $\vec{C}$ has magnitude 6.0 and points along the positive *z*-axis. Find $(\vec{B}\times\vec{A}).\vec{C}$.

A) + 60
B) – 34
C) – 60
D) zero
E) + 34

Answer:

$Let\ \theta\ be\ the\ angle\ between\ \vec{A}\ and\ \vec{B}\ \ \Rightarrow \theta = 58 - 28 = 30^0$
$|\vec{A}\times\vec{B}| = A.B.\sin\theta = 5\times 4\ \times\frac{1}{2} = 10$
$\vec{B}\times\vec{A}\ is\ in\ the\ (+)\ z\ direction$
$\therefore\ angle\ between\ (\vec{A}\times\vec{B})\ and\ \vec{C}\ is = 180 - 35 = 145^0$
$(\vec{B}\times\vec{A}).\vec{C} = 10\times 6\times\cos 0 = +60$

Q10.

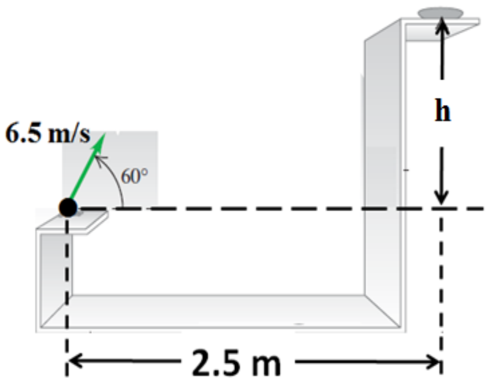
The position vector (in meters) of a particle is given by $\vec{r} = 2.50\, t^2\hat{i} + 5.00\, t\, \hat{j}$, where t is in seconds. At t = 2.00 s, what is the instantaneous speed (v) of the particle and the angle θ between $\vec{v}$ and the positive x axis measured counterclockwise?

A) v = 11.2 m/s, θ = 26.6°
B) v = 11.2 m/s, θ = 63.4°
C) v = 14.1 m/s, θ = 26.6°
D) v = 14.1 m/s, θ = 63.4°
E) v = 12.6 m/s, θ = 45.0°

Answer:

$$\vec{r} = 2.5t^2\hat{\imath} + 5t\,\hat{\jmath}$$
$$\vec{v} = 5t\,\hat{\imath} + 5\,\hat{\jmath}$$
$$\vec{v_2} = 10\,\hat{\imath} + 5\,\hat{\jmath}$$
$$v = \sqrt{100 + 25} = 11.2\ m/s$$
$$\theta = tan^{-1}\left(\frac{5}{10}\right) = 26.6°$$

Q11.
A small stone is thrown with an initial speed of 6.5 m/s at an angle of 60° above the horizontal and lands on a shelf that is a horizontal distance of 2.5 m from its launch point (see **Figure 3**). What is the height (h) of the shelf? Ignore air resistance.



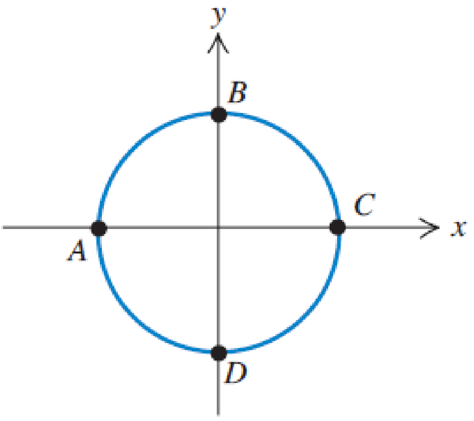
A) 1.4 m
B) 4.3 m
C) 5.7 m
D) 3.6 m
E) 2.9 m

Answer:

Take the launch point as the origin
$$x - motion:\ x = v_{ix}t$$
$$t = \frac{x}{v_{ix}} = \frac{x}{v_i\cos\theta_i} = \frac{2.5}{6.5 \times \frac{1}{2}} = 0.769\ s$$

$y - motion: \; y = v_{iy}t - \frac{1}{2}gt^2$
$= (6.5 \times \sin 60° \times 0.769) - [4.9 \times (0.769^2)]$
$= 4.3301 - 2.8994 = 1.43 \text{ m}$

Q12.
A particle executes uniform circular motion with it moves clockwise with a speed of 5.00 m/s around a circle of radius 50.0 m, as shown in **Figure 4**. What is the least time to go from point A to point B?



A) 15.7 s
B) 62.8 s
C) 31.4 s
D) 47.1 s
E) 39.2 s

Answer:
$T = \frac{2\pi R}{v}$
$\frac{T}{4} = \frac{\pi R}{2v}$
$= \frac{\pi \times 50}{2 \times 5}$
$= 5\pi$

Q13.
A car has a velocity of 15 m/s due south as it passes a train travelling with a velocity of 24 m/s due north. What is the velocity of the car relative to the train?

A) 39 m/s, due south
B) 39 m/s, due north
C) 9 m/s, due south
D) 9 m/s, due north
E) 15 m/s, due north

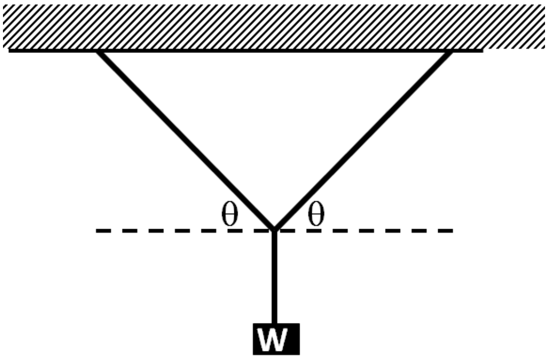
Answer:
g = ground, c = car, t = train
$v_{cg} = v_{ct} + v_{tg}$
$v_{ct} = v_{cg} - v_{tg} = -15 - 24 = -39\ m/s$

Q14.
Two cars A and B approach each other at an intersection. Car A is travelling due south at 20 m/s, while car B is travelling due east at 17 m/s. What is the speed of car A relative to car B?

A) 26 m/s
B) 37 m/s
C) 11 m/s
D) 21 m/s
E) 24 m/s

Answer:
$\vec{v}_{Ag} = \vec{v}_{AB} + \vec{v}_{Bg}$
$\vec{v}_{AB} = \vec{v}_{Ag} - \vec{v}_{Bg}$
$\vec{v}_{AB} = -20\,\hat{j} + 17\,\hat{\imath}$
Thus: $v_{AB} = [(20)^2 + (17)^2]^{1/2} = 26$ m/s

Q15.
A box of weight **W** hangs from two massless strings, as shown in **Figure 5**. Each string makes the same angle θ with the horizontal. The magnitudes of the weight of the box and tension in each string are equal ($T = W$) if the angle θ is



A) 30^o
B) 15^o
C) 45^o
D) 60^o
E) 75^o

Answer:
$y: 2T\sin\vartheta = W$
$2w\sin\vartheta = W$
$\sin\theta = \frac{1}{2}$

$\theta = 30°$

Q16.
A 4.8-kg box is pulled vertically upward with a tension of 72 N. What is the magnitude of the acceleration of the box?

A) 5.2 m/s^2
B) 25 m/s^2
C) 1.1 m/s^2
D) 2.7 m/s^2
E) 6.7 m/s^2

Answer:
True weight = $W = mg = 4.8 \times 9.8 = 47$ N
Since the tension is larger than W, the acceleration is upward.
Newton's second law: $ma = T - W = 72 - 47 = 25$ N
Thus: $a = 25/4.8 = 5.2$ m/s^2

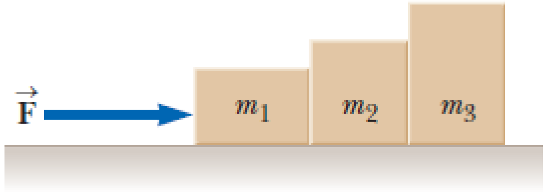
Q17.
A 2.50-kg object is subject to the gravitational force and another constant force. The object starts from rest and in 2.00 s experiences a displacement of $(3.00\hat{i} - 3.50\hat{j})$ (m), where the direction of $\hat{j}$ is the upward vertical direction. Determine the other force.

A) $3.75\hat{i} + 20.1\hat{j}$ (N)
B) $3.75\hat{i} - 4.38\hat{j}$ (N)
C) $3.75\hat{i} + 32.3\hat{j}$ (N)
D) $3.75\hat{i} - 32.3\hat{j}$ (N)
E) $3.75\hat{i} - 24.5\hat{j}$ (N)

Answer:

$$\vec{r} = \frac{1}{2}t^2\vec{a}$$
$$\vec{a} = \frac{2\vec{r}}{t^2} = \frac{6\,\hat{\imath} - 7\,\hat{\jmath}}{4} = 1.5\,\hat{\imath} - 1.75\,\hat{\jmath}\ (m/s^2)$$
$$\vec{F}_{net} = m\vec{a} = 3.75\,\hat{\imath} - 4.375\,\hat{\jmath}$$
$$\vec{F}_{net} = \vec{F}_g + \vec{F}_x$$
$$\vec{F}_x = \vec{F}_{net} - \vec{F}_g$$
$$\vec{F}_g = m\,\vec{g} = -24.5\,\hat{\jmath}$$
$$\vec{F}_x = 3.75\hat{\imath} - 4.375\hat{\jmath} + 24.5\hat{\jmath}$$
$$= 3.75\hat{\imath} + 20.1\hat{\jmath}$$

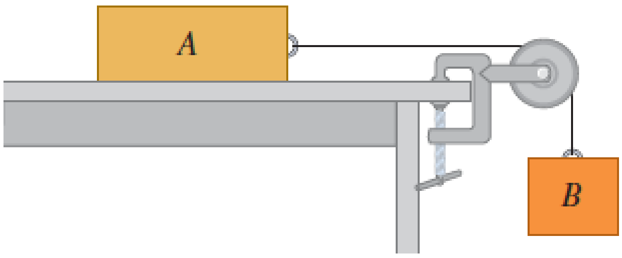
Q18.
Three blocks are in contact with one another on a frictionless horizontal surface, as shown in **Figure 6**. Take m_1 = 3.00 kg, m_2 = 4.00 kg, and m_3 = 5.00 kg. A horizontal force $\vec{F}$, of magnitude 18.0 N, is applied to m_1 as shown. What is the magnitude of the contact force between blocks m_1 and m_2?



A) 13.5 N
B) 4.50 N
C) 22.5 N
D) 6.00 N
E) 11.6 N

Answer:
$a = \frac{F}{M} = \frac{18}{12} = 1.5\ m/s^2$
$m_1 a = F - F_{12}$
$\Longrightarrow F_{12} = F - m_1 a$
$= 18 - (3 \times 1.5) = 13.5\ N$

Q19.
As shown in **Figure 7**, block A (mass 2.3 kg) rests on a horizontal rough surface (μ_k = 0.45). It is connected by a horizontal cord passing over a massless frictionless pulley to block B (mass 1.3 kg). What is the magnitude of the acceleration of the system?



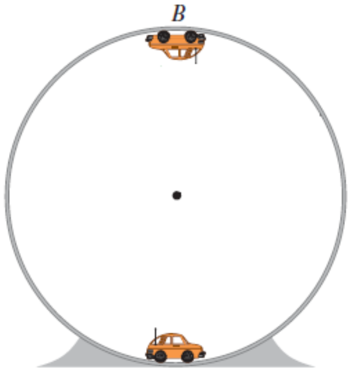
A) 0.72 m/s^2
B) 0.15 m/s^2
C) 0.65 m/s^2
D) 0.38 m/s^2
E) 0.34 m/s^2

Answer:
$A : m_A = T - \mu m_A g$
$B : m_B = T - m_B g - T$
$\oplus\ Ma = (m_B - \mu m_A) g$
$a = \frac{m_B - \mu m_A}{M} g = \frac{1.3 - (0.45 \times 2.3)}{3.6} \times 9.8 = 0.721\ m/s^2$

$v^2 + 2a\,x \Longrightarrow v = \sqrt{2ax} = \sqrt{2 \times 0.721 \times 0.03} = 0.21\ m/s^2$

Q20.

A small car of mass 0.750 kg travels at constant speed on the inside of a track that is a vertical circle, as shown in **Figure 8**. If the normal force exerted by the track on the car when it is at the top of the track (point B) is 5.50 N, what is the magnitude of the normal force at the bottom of the track (point A)?



A) 20.2 N
B) 9.20 N
C) 7.40 N
D) 14.7 N
E) 12.9 N

Answer:

$B : \dfrac{m\,v^2}{R} = F_{NB} + mg \longrightarrow \dfrac{m\,v^2}{R} = 5.5 + mg$

$A : \dfrac{m\,v^2}{R} = F_{NA} - mg$

$5.5 + mg = F_{NA} - \mathrm{mg}$

$\Longrightarrow F_{NA} = 5.5 + 2mg$

$= 5.5 + (2 \times 0.75 \times 9.8)$

$= 20.2\ N$
