Question 5. 11. A truck starts from rest and accelerates uniformly at 2.0 ms^{-2}. At t = 10 s, a stone is dropped by a person standing on the top of the truck (6 m high from the ground). What are the

(a) velocity, and

(b) acceleration of the stone at t = 11s? (Neglect air resistance.)

Answer:

$u = 0$, $a = 2\ ms^{-2}$, t 10 s

Using equation, $v = u + at$, we get

$v = 0 + 2 \times 10 = 20\ ms^{-1}$

(a) Let us first consider horizontal motion. The only force acting on the stone is force of gravity which acts vertically downwards.

Its horizontal component is zero. Moreover, air resistance is to be neglected. So, horizontal motion is uniform motion.

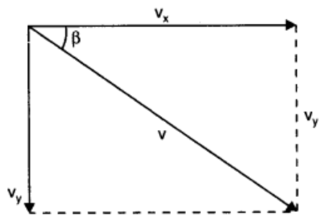
$\therefore v_x = v = 20\ ms^{-1}$

Let us now consider vertical motion which is controlled by force of gravity.

$u=0$, $a = g = 10\ ms^{-2}$, $t = (11 - 10)\ s = 1\ s$

Using $v = u + at$, $v_y = 0 + 10 \times 1 = 10\ ms^{-1}$

Resultant velocity,



$$v = \sqrt{v_x^2 + v_y^2}$$

$$\Rightarrow \quad v = \sqrt{20^2 + 10^2}\ ms^{-1}$$

$$= \sqrt{500}\ ms^{-1}$$

$$= 22.36\ ms^{-1}.$$

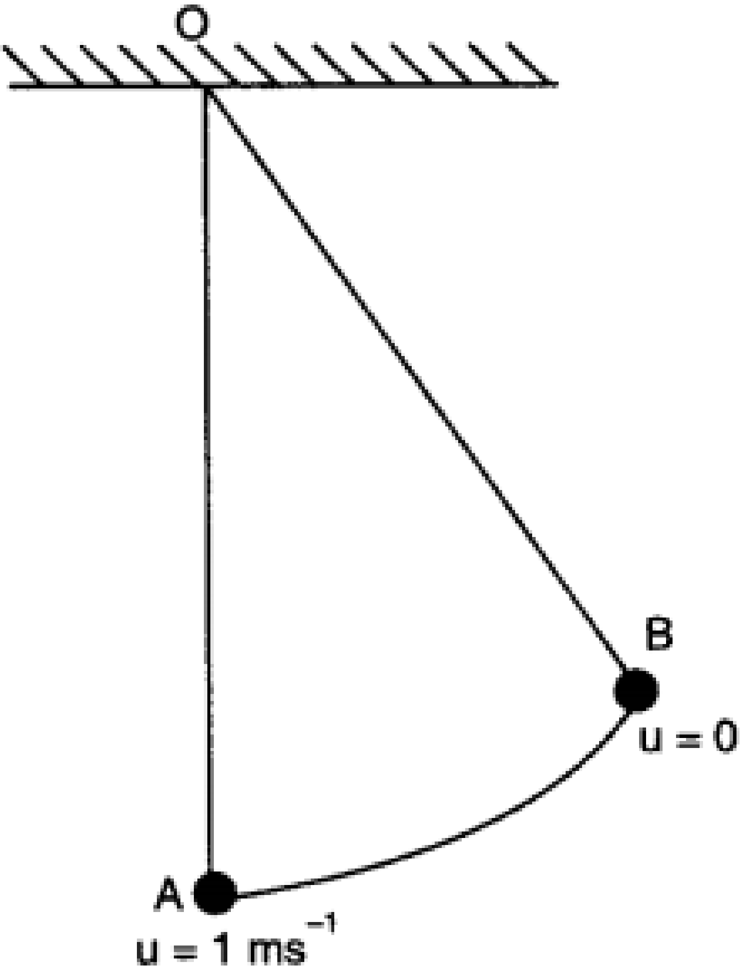
$$\tan\beta = \frac{v_y}{v_x} = \frac{10}{20} = \frac{1}{2} = 0.5$$

or $\beta = \tan^{-1}(0.5) = 26.56°$

or $\beta = 26° 34'$. This angle is with the horizontal.

(b) The moment the stone is dropped from the car, horizontal force on the stone is zero. The only acceleration of the stone is that due to gravity. This gives a vertically downward acceleration of 10 ms-2. This is also the net acceleration of the stone.

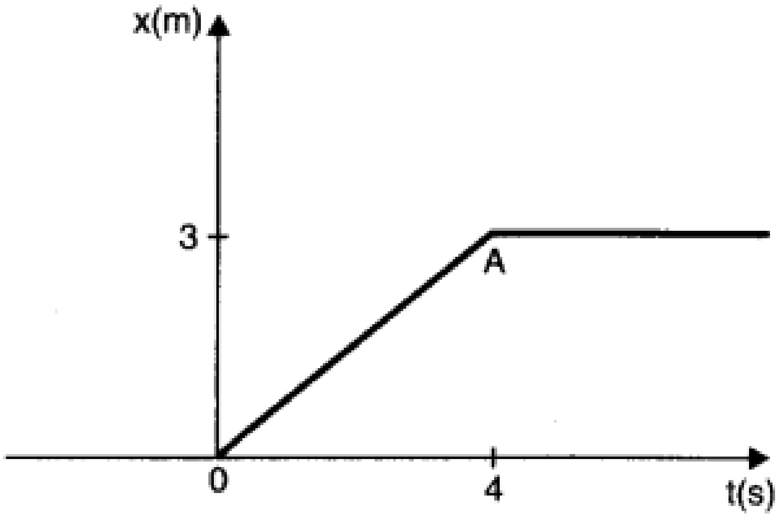
Question 5. 12. A bob of mass 0.1 kg hung from the ceiling of a room by a string 2 m long is set into oscillation. The speed of the bob at its mean position is 1 ms^{-1}. What is the trajectory of the bob if the string is cut when the bob is (a) at one of its extreme positions, (b) at o its mean position ?



Answer: Let the bob be oscillating as shown in the figure.
(a) When the bob is at its extreme position (say B), then its velocity is zero. Hence on cutting the string the bob will fall vertically downward under the force of its weight F = mg.
(b) When the bob is at its mean position (say A), it has a horizontal velocity of $v = 1\ ms^{-1}$ and on cutting the string it will experience an acceleration $a = g = 10\ ms^{-2}$ in vertical downward direction. Consequently, the bob will behave like a projectile and will fall on ground after describing a parabolic path.

Question 5. 13. A man of mass 70 kg, stands on a weighing machine in a lift, which is moving
(a) upwards with a uniform speed of $10\ ms^{-1}$.
(b) downwards with a uniform acceleration of $5\ ms^{-2}$.
(c) upwards with a uniform acceleration of $5\ ms^{-2}$. What would be the readings on the scale in each case?
(d) What would be the reading if the lift mechanism failed and it hurtled down freely under gravity?
Answer: Here, m = 70 kg, $g = 10\ m/s^2$
The weighing machine in each case measures the reaction R i.e., the apparent weight.
(a) When the lift moves upwards with a uniform speed, its acceleration is zero.
R = mg = 70 x 10 = 700 N
(b) When the lift moves downwards with $a = 5\ ms^{-2}$
R = m (g - a) = 70 (10 - 5) = 350 N
(c) When the lift moves upwards with $a = 5\ ms^{-2}$
R = m (g + a) = 70 (10 + 5) = 1050 N
(d) If the lift were to come down freely under gravity, downward acc. a = g
∴ R = m(g -a) = m(g-g) = Zero.

Question 5. 14. Figure shows the position-time graph of a particle of mass 4 kg. What is the (a) force on the particle for $t < 0$, $t > 4$ s, $0 < t < 4$ s? (b) impulse at $t = 0$ and $t = 4$ s? (Consider one-dimensional motion only).



Answer:

(a) When $t < 0$. As this part is horizontal, thus it can be concluded that distance covered by the particle is zero and hence force on the particle is zero.

When $0 < t < 4$s. As OA has a constant slope, hence in this interval, particle moves with constant velocity $\left(\frac{3}{4} = 0.75 \text{ ms}^{-1}\right)$. Hence force on the particle is zero.

When $t > 4$s. As this portion shows that particle always remains at a distance of 3 m from the origin *i.e.*, the particle is at rest. Hence force on the particle is zero.

(b) Impulse at $t = 0$. Here $u = 0$, $v = 0.75 \text{ ms}^{-1}$, $M = 4$ kg

$$\therefore \quad \text{Impulse} = \text{total change in momentum} = Mv - Mu$$
$$= M(v - u) = 4(0.75 - 0) = 3 \text{ kg ms}^{-1}$$

Impulse at $t = 4$s. Here $u = 0.75 \text{ ms}^{-1}$, $v = 0$

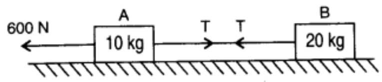
$$\therefore \quad \text{Impulse} = M(v - u) = 4(0 - 0.75) = -3 \text{ kg ms}^{-1}.$$

Question 5. 15. Two bodies of masses 10 kg and 20 kg respectively kept on a smooth, horizontal surface are tied to the ends of a tight string. A horizontal force F = 600 N is applied to (i) A, (ii) B along the direction of string. What is the tension in the string in each case?

Answer:

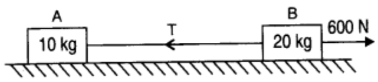
$$\text{Acceleration} = \frac{600 \text{ N}}{10 \text{ kg} + 20 \text{ kg}} = 20 \text{ ms}^{-2}$$

(*i*) When force is applied on 10 kg mass



$$600 - T = 10 \times 20 \quad \text{or}$$
$$T = 400 \text{ N}$$

(*ii*) When force is applied on 20 kg mass,



$$600 - T = 20 \times 20 \quad \text{or}$$
$$T = 200 \text{ N}$$

Question 5. 16. Two masses 8 kg and 12 kg are connected at the two ends of a light in extensible string that goes over a friction less pulley. Find the acceleration of the masses, and the tension in the string when the masses are released.

Answer:

For block $m_2 \rightarrow m_2 g - T = m_2 a$ ...(*i*)

and for block $m_1 \rightarrow T - m_1 g = m_1 a$ ...(*ii*)

Adding (*i*) and (*ii*), we obtain

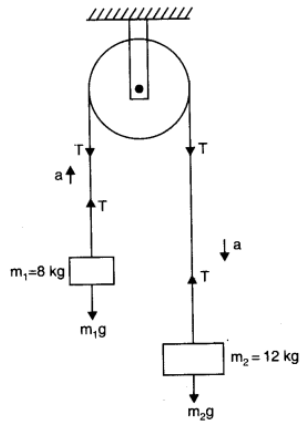
$$(m_2 - m_1) g = (m_2 + m_1) a$$

or

$$a = \left(\frac{m_2 - m_1}{m_2 + m_1}\right) g$$
$$= \frac{12 - 8}{12 + 8} \times 10$$
$$= \frac{4 \times 10}{20} = 2 \text{ ms}^{-2}$$

Substituting value of a in equation (*ii*), we obtain

$$T = m_1 (g + a)$$
$$= 8 \times (10 + 2)$$
$$= 8 \times 12 = 96 \text{ N}.$$



Question 5. 17. A nucleus is at rest in the laboratory frame of reference. Show that if it disintegrates into two smaller nuclei the products must move in opposite directions.
Answer: Let m_1, m_2 be the masses of products and v_1,v_2 be their respective velocities. Therefore, total linear momentum after disintegration = $m_1v_1 + m_2 v_2$. Before disintegration, the nucleus is at rest.
Therefore, its linear momentum before disintegration is zero.
According to the principle of conservation of linear momentum,

$$m_1\vec{v}_1 + m_2\vec{v}_2 = 0 \quad \text{or} \quad \vec{v}_2 = -\frac{m_1\vec{v}_1}{m_2}$$

Negative sign shows that v_1 and v_2 are in opposite directions.

Question 5. 18. Two billiard balls, each of mass 0.05 kg, moving in opposite directions with speed 6 ms^{-1} collide and rebound with the same speed. What is the impulse imparted to each ball due to the other?
Answer:
Initial momentum of each ball before collision
= 0.05 x 6 kg ms^{-1} = 0.3 kg ms^{-1}
Final momentum of each ball after collision
= - 0.05 x 6 kg ms^{-1} = - 0.3 kg ms^{-1} Impulse imparted to each ball due to the other
= final momentum - initial momentum = 0.3 kg m s-1 - 0.3 kg ms^{-1}
= - 0.6 kg ms^{-1} = 0.6 kg ms^{-1} (in magnitude)
The two impulses are opposite in direction.

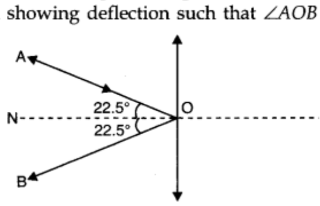
Question 5. 19. A shell of mass 0.020 kg is fired by a gun of mass 100 kg. If the muzzle speed of the shell is 80 ms^{-1} what is the recoil speed of the gun?
Answer: m = 0.02 kg, M = 100 kg, v = 80 ms^{-1}, V = ?

$$V = -\frac{mv}{M} = -\frac{0.020\ \text{kg} \times 80\ \text{m s}^{-1}}{100\ \text{kg}}$$
$$= -0.016\ \text{m s}^{-1} = -\mathbf{1.6\ cm\ s^{-1}}$$

Negative sign indicates that the gun moves in a direction opposite to the direction of motion of the bullet.

Question 5. 20. A batsman deflects a ball by an angle of 45° without changing its initial speed which is equal to 54 km/h. What is the impulse imparted to the ball? (Mass of the ball is 0.15 kg.)
Answer:
Suppose the point O as the position of bat. AO line shows the path along which the ball strikes the bat with velocity u and OB is the path showing deflection such that $\angle AOB$ = 45°. Now initial momentum of ball

$$= mu\cos\theta$$
$$= \frac{0.15 \times 54 \times 1000 \times \cos 22.5}{3600}$$
$$= 0.15 \times 15 \times 0.9239 \text{ along } NO$$



Final momentum of ball = $mu\cos\theta$ along ON

Impulse = change in momentum = $mu\cos\theta - (-mu\cos\theta)$
$= 2mu\cos\theta = 2 \times 0.15 \times 15 \times 0.9239 = 4.16$ kg m^{-1}.

*********** END **********