LAWS OF MOTION

NCERT Exercise Solution

Q.1 Give the magnitude and direction of the net force acting on:

Sol^n. (a) As the rain drop is falling with constant speed, $a = 0$, hence $F = ma = 0$ [law of inertia]

(b) As the cork is floating on water its weight is balanced by upthrust due to water.
So net force $= 0$ [law of inertia]

(c) As kite is held stationary so according to Newton's first law, $F_{net} = 0$
All forces (tension in string, wind force, gravity) are balanced.

(d) As car is moving with constant velocity, $a = 0$
ie $F_{net} = 0$ [law of inertia]
(Engine force balances the friction)

(e) As no force is acting on electron in space, $F_{net} = 0$

Q.2. A pebble of mass 0.05 kg - - - - - - - on the pebble.

Given,

$m = 0.05\,kg$, Take $g = 10\,m/s^2$

In all parts force due to gravity acts downward:

$F = mg$
$= 0.05 \times 10 = 0.5\,N$ downward

(a) During upward motion, net force
$F = 0.5\,N$, vertically downward.

(b) During its upward motion, net force
$F = 0.5\,N$, vertically downward.

(c) At highest point, $v = 0$ and $a = g = 10\,m/s^2$
So net force, $F = 0.5\,N$, vertically downward

Yes, the force remains same even if the pebble is thrown at an angle of 45° because it has a constant horizontal component of velocity throughout its motion.

Q.3. Give the magnitude and direction of the net force acting on the stone of mass 0.1 kg.

Sol^n. (a) In this situation F = weight of the stone

$$F = mg = 0.1 \times 10$$
$$= 1\ N \quad (\text{downward})$$

(b) Since, no force is applied on the stone due to uniform motion of train, so

$$F = mg = 0.1 \times 10$$
$$= 1\ N \quad (\text{downward})$$

(c) When stone is dropped from the train, the horizontal direction force will not be active and only force due to gravity will act on the stone.

Therefore the net force $F = 0.1 \times 10$
$$= 1\ N \quad (\text{downward})$$

* force at an instant depends on the situation at that instant, not on history

(d) When stone is lying on the floor of the train which has accelaration $a = 1\ m/s^2$ then there is a Pseudo force

$$F = ma$$
$$= 0.1 \times 1$$
$$= 0.1\ N$$

weight of stone is balanced by the normal reaction

Direction → In the direction of motion of train. (horizontal direction)

[Pseudo force: A fictitious force which is introduced in non inertial (accelerating) frame of reference.]

Q.4. One end of the string - - - - - towards the centre is (I) T (II) $T - \frac{mv^2}{r}$ (III) $T + \frac{mv^2}{r}$ (IV) 0

Sol.ⁿ Since tension T in the string is the only force acting toward the centre and this provides the centripetal force, so

$$T = \frac{mv^2}{l} \quad [r = l]$$

i.e $F_{net} = T$

correct option (i) T Ans

Q.5. A constant retarding - - - - - - take to stop.

Solⁿ Given,

$$F = -50\,N, \; m = 20\,kg, \; u = 15\,m/s$$

$$v = 0, \; t = ?$$

Now, $a = \frac{F}{m} = -\frac{50}{20} = -2.5\,m/s^2$

$$a = -2.5\,m/s^2$$

From

$$v = u + at$$

$$0 = 15 + (-2.5)t$$

$$\Rightarrow t = \frac{150}{25} = 6\,s \text{ Ans}$$

Q.6. A constant force - - - - - of the force?

Solⁿ Given, $u = 2\,m/s$, $v = 3.5\,m/s$ $t = 25\,s$

by $v = u + at$

$$3.5 = 2 + a \times 25$$

$$25a = 3.5 - 2$$

$$25a = 1.5$$

or $a = \frac{1.5}{25} = 0.06\ m/s^2$

i.e $a = 0.06\ m/s^2$ Ans

Q.7 A body of mass - - - — — - - . of the body.

Soln: Given, $m = 5\ kg$, $F_1 = 8N$, $F_2 = 6N$

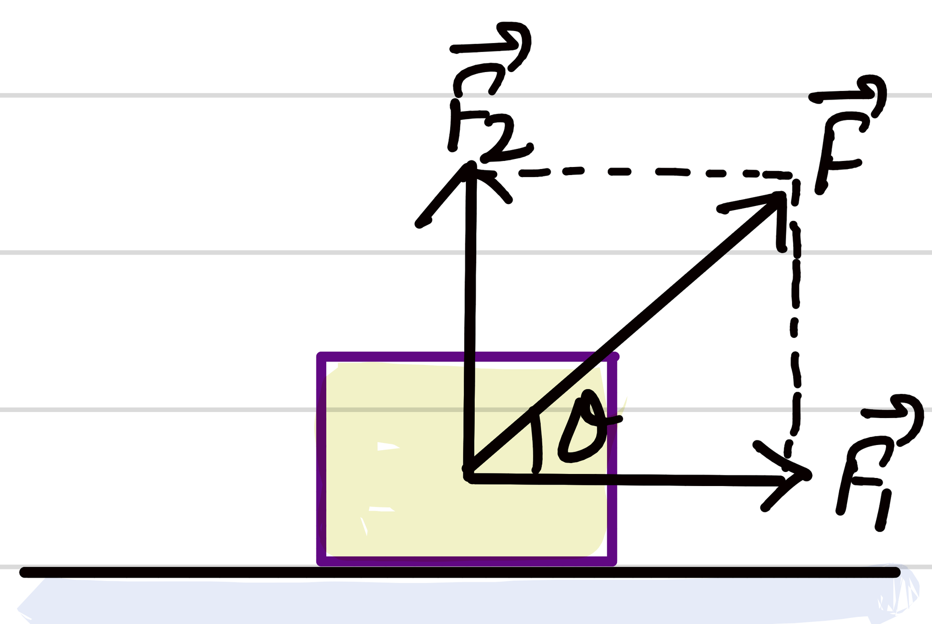
$a = ?$

Resultant force

$$\vec{F} = \vec{F_1} + \vec{F_2}$$

F_1 and F_2 are perpendicular to each other.

Magnitude of $\vec{F}$



$$F = \sqrt{F_1^2 + F_2^2}$$
$$= \sqrt{8^2 + 6^2}$$
$$= \sqrt{64 + 36}$$
$$= \sqrt{100} = 10N$$

Acceleration $a = \frac{F}{m} = \frac{10}{5} = 2\ m/s^2$ (in the dirn of $\vec{F}$)

If $\vec{F}$ makes an angle θ with $\vec{F_1}$, then

$$\tan\theta = \frac{F_2}{F_1} = \frac{6}{8} = \frac{3}{4} = 0.75$$

or $\theta = \tan^{-1}(0.75)$

$\Rightarrow \theta = 36.86° \simeq 37°$ (with force of 8N)

Q.8 The driver of a three - - - —— driver is 65 kg.

Soln: Given, $u = 36\ km/h$

$$= \cancel{36}^{2} \times \frac{5}{\cancel{18}} = 10\ m/s$$

$v = 0$, $t = 4$ sec

we get, $0 = 10 + a \times 4$

or $4a = -10$

or $a = -\frac{10}{4} = -2.5\ m/s^2$

Total mass of the driver and the three wheeler

$M = 65 + 400$

$= 465\ kg$

Retarding force

$F = ma$

$= 465 \times (-2.5)$

$= -1162.5\ N$

$= -1.16 \times 10^3 \approx 1.2 \times 10^3\ N$ Ans

Q.9. A rocket with a - - - - - - - of the blast.

Soln: Given,

$m = 20,000\ kg$

$a = 5\ m/s^2$

Here, total acceleration

$a' = (g + a)$

$a' = 9.8 + 5$

$= 14.8\ m/s^2$

so, thrust of blast of rocket $= ma'$

$= 20000 \times 14.8$

$= 2.96 \times 10^5 N \approx 3 \times 10^5 N$ Ans

Q.10. A body of mass 0.40 kg - - - - - - - at $t = -5s, 25s, 100s$.

Soln: Given,

Mass of the body, $m = 0.40\ kg$

Initial speed $u = 10\ m/s$ due north

Force acting on the body, $F = -8.0\ N$

Acceleration, $a = \frac{F}{m}$

$= \frac{-8.0}{0.40} = -20\ m/s^2$

At $t = -5\,s$

Acceleration, $a = 0$ and $u = 10\ m/s$

$$S = ut + \frac{1}{2}a't^2$$

$$= 10 \times (-5) = -50\,m \quad \underline{\text{Ans}}$$

At $t = 25\,s$

Acceleration, $a = -20\ m/s^2$, $u = 10\ m/s^2$

$$S = ut + \frac{1}{2}at^2$$

$$= 10 \times 25 + \frac{1}{\cancel{2}} \times (\overset{-10}{\cancel{-20}}) \times 25^2$$

$$= 250 - 6250$$

$$= -6000\ m = -6\ Km \quad \underline{\text{Ans}}$$

At $t = 100\,s$

First motion up to 30 sec $\rightarrow 0 \leqslant t \leqslant 30$

$$a = -20\ m/s^2$$

$$u = 10\ m/s$$

$$S_1 = ut + \frac{1}{2}at^2$$

$$= 10 \times 30 + \frac{1}{\cancel{2}} \times (\overset{-10}{\cancel{-20}}) \times 30^2$$

$$= 300 - 9000$$

$$S_1 = -8700\ m \quad \underline{\text{Ans}}$$

at $t = 30$ sec, $v = 10 - 20 \times 30$ $[v = u + at,\ a = -20\ m/s^2]$

$$= -590\ m/s$$

This final velocity for 0 to 30 s is the initial velocity for motion 30 to 100 s i.e for $t = 70\,s$.

So for motion between 30 to 100 s

$$S_2 = -590 \times 70 = -41300\ m$$

So the total distance,

$$S = S_1 + S_2$$

$$S = -87000 - 41300$$
$$= -50000\ m = -50\ km \quad (\text{-ve displacement})$$

Q.11. A truck starts — — — — — — — — - - - at $t = 11 s$?

Solⁿ: Given,

$u = 0$, $a = 2 m/s^2$, $t = 10\ s$

(a) velocity of car at $t = 10 s$

$$v = 0 + 2 \times 10 \qquad [v = u + at]$$
$$v = 20\ m/s$$

The final velocity of truck and hence of the stone is 20 m/s.

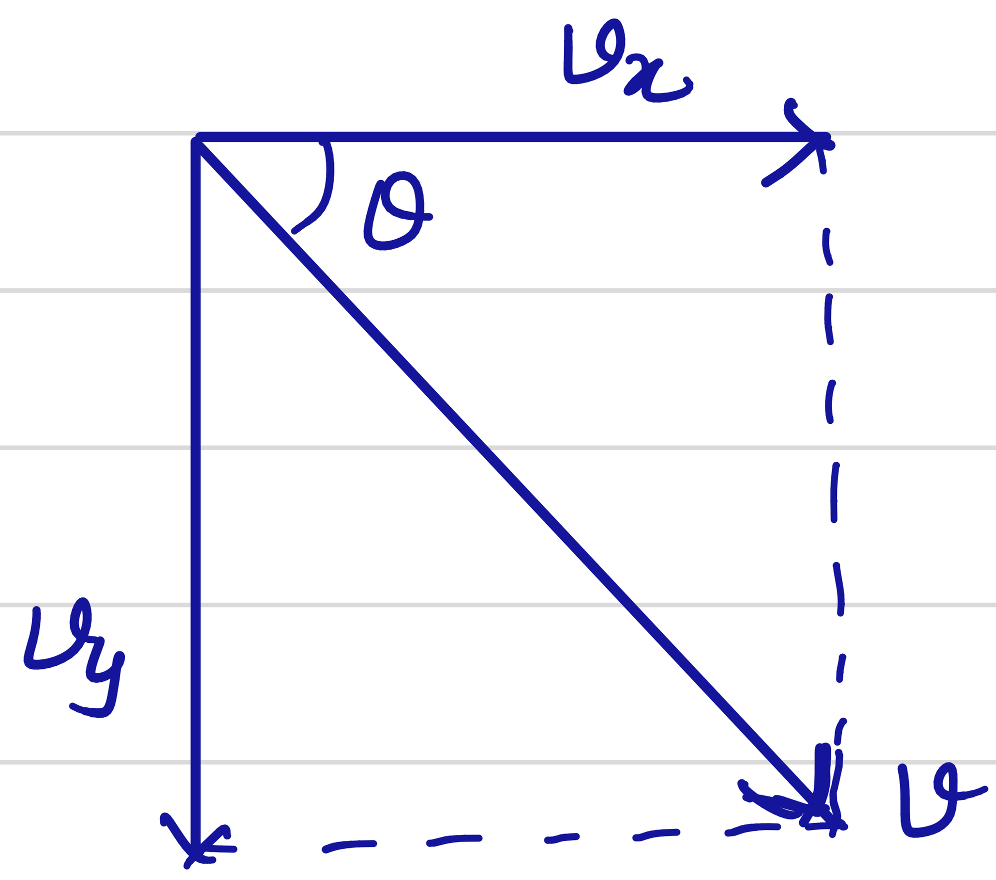
At $t = 11 s$, $v_x \rightarrow$ horizontal component remain unchanged.

i.e $v_x = 20\ m/s$

And $v_y \rightarrow$ vertical component,

$$v_y = u_y + a_y t \qquad \left[\because u_y = 0,\ a_y = g = 10\ m/s^2,\ t = 11 - 10 = 1\ s\right.$$
$$v_y = 0 + 10 \times 1$$
$$v_y = 10\ m/s$$

The resultant velocity,



$$v = \sqrt{v_x^2 + v_y^2}$$
$$= \sqrt{20^2 + 10^2}$$
$$= \sqrt{400 + 100}$$
$$= \sqrt{500}$$
$$= 10\sqrt{5}\ m/s$$
$$\simeq 10 \times 2.24$$
$$= 22.4\ m/s$$

Direction of v with v_x

$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{10}{20}\right) = \tan^{-1}(0.5)$$
$$= 26.57°$$

(b) Acceleration at $t = 11\ s$

When stone is dropped its horizontal velocity remain constant because $a_x = 0$.

The motion of stone is due to $a_y (= g)$ only.

Therefore acceleration $= g = 10\ m/s^2$ (downwards) Ans

Q.13. A man of 70 Kg — — — — — — — — under gravity.

Solⁿ: Given,

Mass of man $m = 70\ kg$

Here the weighing scale will read the reaction R, i.e apparent weight.

(a) Lift is moving upward with uniform speed.

i.e $a = 0$

So $W = R = mg$

$= 70 \times 10$

$= 700\ N$

Reading on scale $= \frac{700}{10} = 70\ kg$

(b) Lift is moving downward with $a = 5 m/s^2 (\downarrow)$

So $W = R = m(g-a)$

$= 70(10-5)$

$= 70 \times 5$

$= 350\ N$

Reading is 35 kg

(c) Lift is moving upward with $a = 5 m/s^2 (\uparrow)$

So $W = R = m(g+a)$

$= 70(10+5)$

$= 70 \times 15$

$= 1050\ N$

Reading on scale = 105 kg

(d) Acceleration of the lift when it is falling freely under gravity, $a = g$

So

$$W = R = m(g-g)$$
$$= 0$$

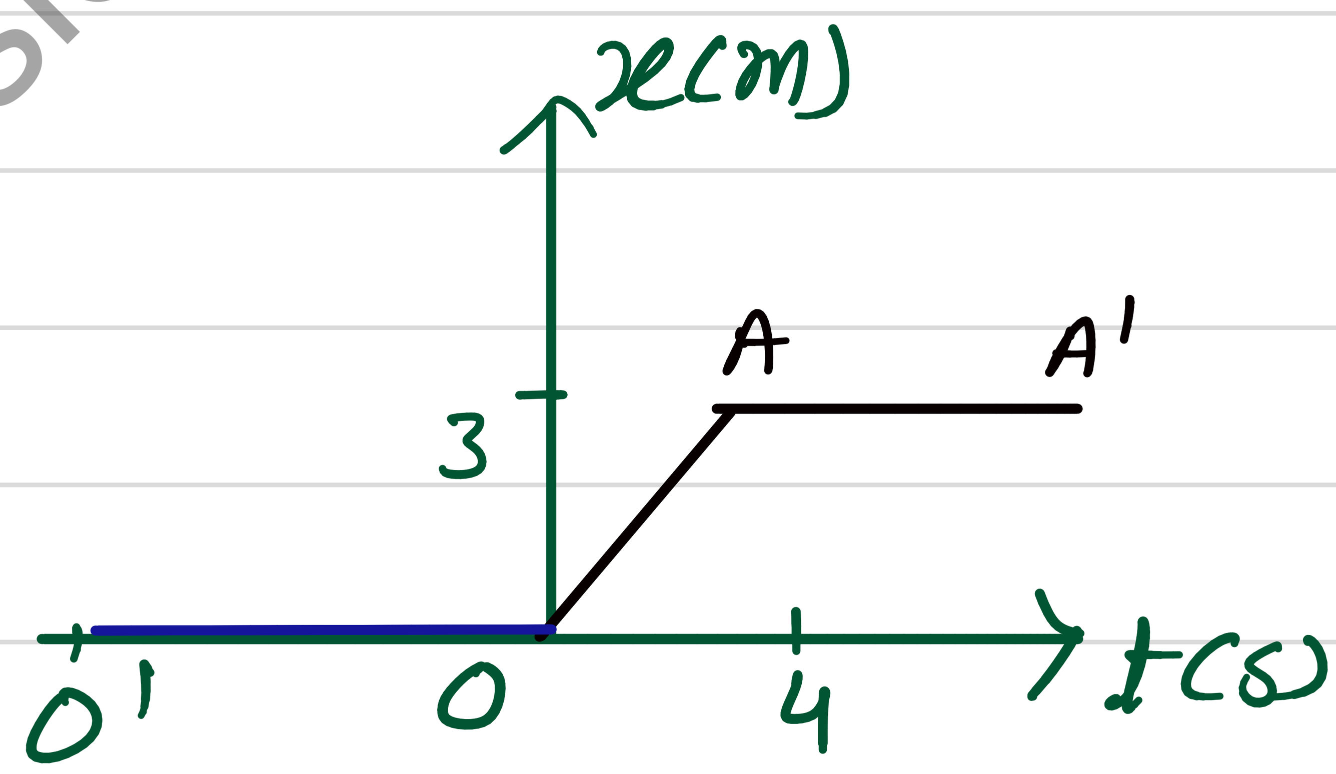
Reading on scale = 0

This is the state of weightlessness.

Q.14 Fig. below shows - - - - - - - - - - $t=0$ and $t=4$ s?

Sol: Given,

Mass of particle $m = 4$ kg



(a) (i) Force on the particle for $t<0$

For $t<0$, the x-t graph is OO' which means displacement $= 0$ i.e particle is at rest.

Hence $F=0$

(ii) For $t > 4$ s the x-t graph AA' is parallel to the time axis. i.e particle is at rest.

Hence $F=0$

(iii) For $0 < t < 4$ s

Particle is changing its position. The x-t graph shows uniform motion i.e. with constant velocity.

i.e $a=0$

Hence $F=0$

(b) Impulse at $t=0$

$$I = \text{change in momentum}$$
$$= mv - mu$$
$$I = m(v-u)$$

At $u=0$, v = slope of graph OA

$$v = \frac{3}{4}$$

so $I = mv = 4 \times \frac{3}{4} = 3 \text{ kgms}^{-1}$

At $t = 4$ s

At $t = 4$ s particle is at rest, i.e. $v = 0$

so $I = mv - mu$

$= 0 - 4 \times \frac{3}{4}$

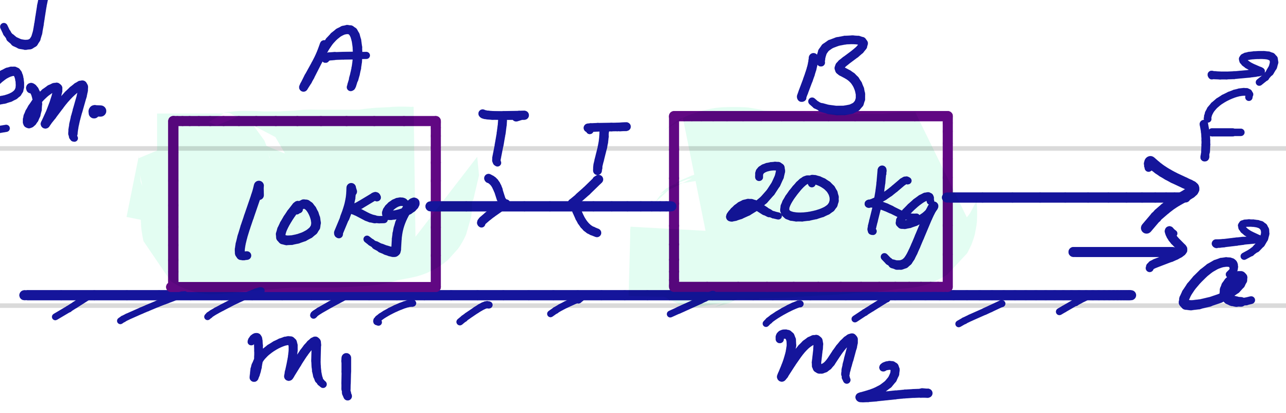
$= -3 \text{ kgms}^{-1}$ Ans

Q. 15. Two bodies A and B - - - - - - - - in each case?

Sol^n: Given,

$F = 600N$, $m_1 = 10kg$, $m_2 = 20kg$

Let 'T' is the tension in the string and 'a' is acceleration of the system.



(a) If 20 kg mass is pulled,

$m_2 a = F - T$

$20a = 600 - T$ —(1)

and $m_1 a = T$

$10a = T$ —(11)

from (1) and (2)

$20a = 600 - 10a$

or $30a = 600$

or $a = 20 \text{ m/s}^2$

Now from (2)

$10 \times 20 = T$

or $T = 200$ N

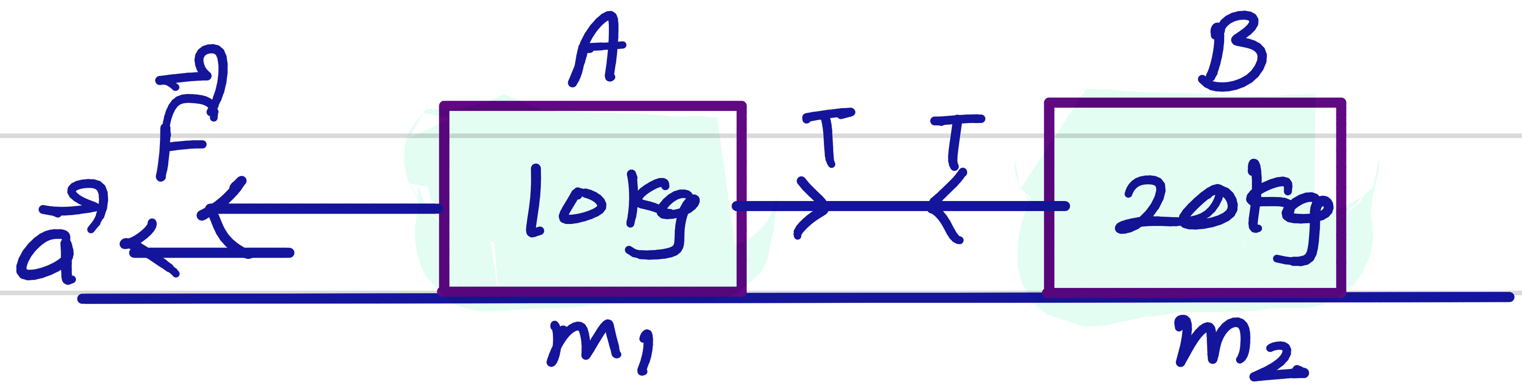
So, $a = 20 \text{ m/s}^2$ and $T = 200$ N Ans

(b) If the 10 kg mass is pulled.

$$m_1 a = F - T$$
$$10a = 600 - T \quad -(1)$$

and $m_2 a = T$

$$20a = T \quad -(11)$$



From (1) and (2)

$$10a = 600 - 20a$$

or $30a = 600$

$$a = 20\ m/s^2$$

from eq^n (2)

$$20 \times 20 = T$$

or $T = 400\ N$

i.e $a = 20\ m/s^2$ and $T = 400\ N$ Ans

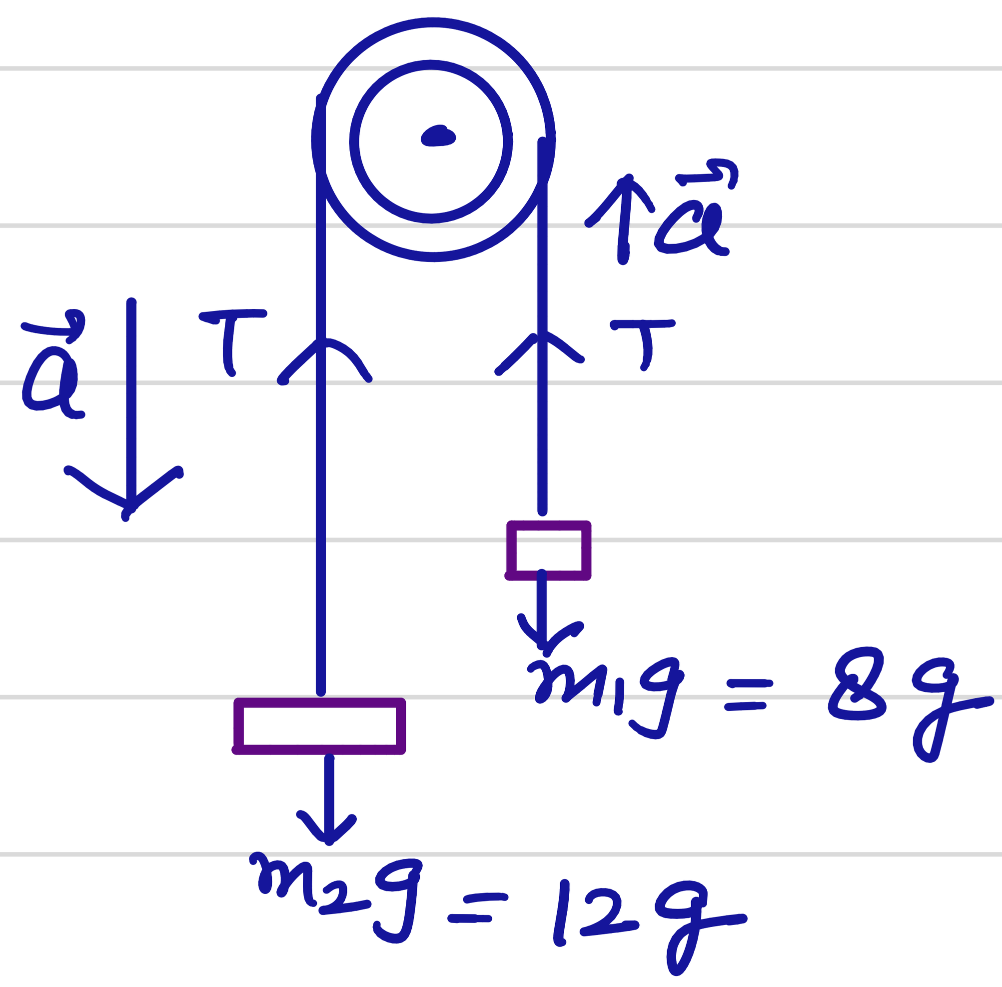
Q.16. Two masses 8 kg and 12 kg ———— . . . are released.

Sol^n: Given,

$m_1 = 8$ kg $m_2 = 12$ kg

T is tension in the string.

a is common acceleration



For m_1 and m_2

$$T - m_1 g = m_1 a$$
$$T - 8g = 8a \quad -(1)$$

and

$$m_2 g - T = m_2 a$$
$$12g - T = 12a \quad -(2)$$

From (1) and (2)

On adding

$$\cancel{T} - 8g = 8a$$
$$-\cancel{T} + 12g = 12a$$

$$4g = 20a$$

or $a = \frac{4g}{20} = \frac{g}{5} = \frac{10}{5} = 2\,m/s^2$

Put value of a in eqn (1)

$T - 8g = 8 \times 2$

or $T = 16 + 8g = 16 + 8 \times 10$

or $T = 16 + 80 = 96\,N$

So we get, $a = 2\,m/s^2$ and $T = 96\,N$ Ans

Q.17. A nucleus is - - - - - - - - - - in opposite directions

Soln: Let mass of nucleus at rest $= m$

Its initial velocity $u = 0$

Let m_1 and m_2 be the masses of the two smaller nuclei. v_1 and v_2 are velocities of m_1 and m_2 respectively

Initial momentum

$$\vec{p}_i = m\vec{u} = 0$$

and final momentum

$$\vec{p}_f = m_1\vec{v}_1 + m_2\vec{v}_2$$

By the law of conservation of linear momentum

$$p_i = p_f$$

$$0 = m_1\vec{v}_1 + m_2\vec{v}_2$$

$$\Rightarrow m_2\vec{v}_2 = -m_1\vec{v}_1$$

or $$\vec{v}_2 = \frac{-m_1\vec{v}_1}{m_2}$$

$-$ve sign show that $\vec{v}_1$ and $\vec{v}_2$ are in opposite directions. Ans

Q.18. Two billiard balls - - - - - - - - due to the other?

Soln: Given, mass of each ball, $m = 0.05$ Kg

speed, $v = 6\,m/s$

Initial momentum of each ball $= m\vec{v}$

$= 0.05 \times 6$

$= 0.30\ kg\ ms^{-1}$

After collision final momentum of each ball $= m(-\vec{v})$

$= 0.05 \times (-6)$

$= -0.30\ kg\ ms^{-1}$

Impulse imparted to each ball,

$$p_f - p_i = -0.30 - 0.30$$
$$= -0.60\ kg\ ms^{-1}.$$

The two impulses are equal and opposite. Ans

Q.19. A shell of mass - - - - - - - - speed of the gun?

Given,

mass of gun $m_g = 100\ kg$

mass of shell $m_s = 0.02\ kg$

velocity of shell $v_s = 80\ ms^{-1}$

Initially gun and shell are at rest.

So total initial momentum $= 0$

Total final momentum = momentum of bullet + momentum of gun

$$= m_s v_s + m_g v_g$$

By principle of conservation of momentum

Total initial momentum = Total final momentum

$$0 = m_s v_s + m_g v_g$$

or $m_s v_s = -m_g v_g$

or $v_g = -\dfrac{m_s v_s}{m_g}$

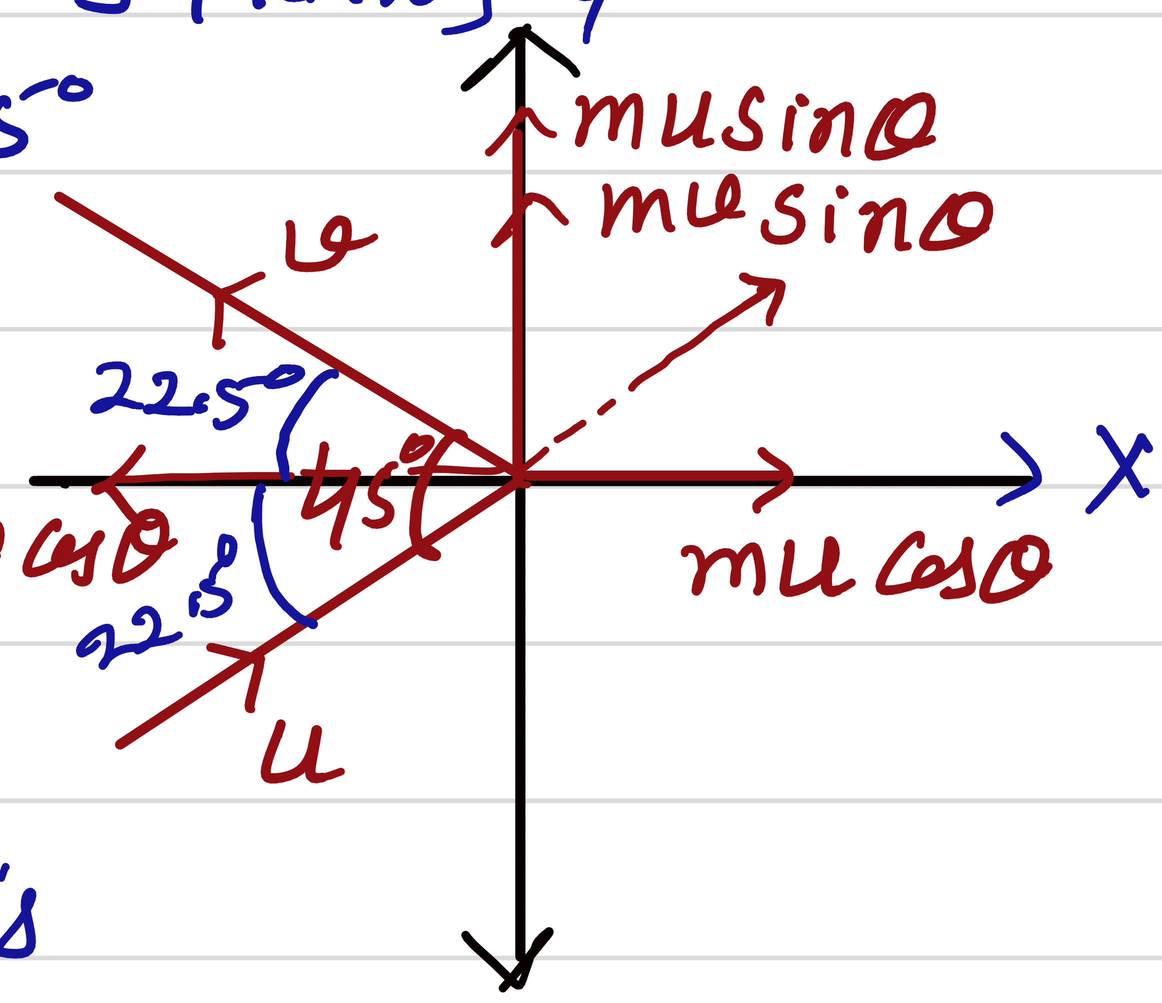
or $v_g = \dfrac{0.02 \times 80}{10000} = \dfrac{160}{10^4} = 160 \times 10^{-4}$

i.e recoil speed of gun, $v_g = 0.016\ m/s$ Ans

Q.20. A batsman deflects - - - - - - - - ball is 0.15 Kg.

Solⁿ: The ball struck by the bat and deflected bat at 45°. [Given, $m = 0.15\,kg$, $u = 54\,kmh^{-1}$]

So with horizontal, angle $= 22.5°$



Change in momentum along y-axis

Both components are in same dirⁿ

so, $\Delta p_y = mv\sin\theta - mu\sin\theta$
$= 0$

Change in momentum, along x-axis

$\Delta p_x = mv\cos\theta - (-mu\cos\theta)$
$= 2mu\cos\theta$ [$\because u = v$]

We know

Impulse = change in momentum

$= \Delta p_x$

$= 2mu\cos\theta$

$= 2 \times 0.15 \times \overset{3}{\cancel{54}} \times \frac{5}{\cancel{18}} \cos 22.5°$ [$\because 1\,kmh^{-1} = \frac{5}{18}\,m/s$]

$= 0.30 \times 15 \times 0.9239$ [$\cos 22.5 = 0.9239$]

$= 4.5 \times 0.9239$

$= 4.157$

i.e Impulse $\simeq 4.2\,kg\,ms^{-1}$ Ans

Q.21. A stone of mass 0.25 Kg - - - - - - - tension of 200N?

Solⁿ: Given,

Frequency $\nu = 40\,rev/min$

$= \frac{40}{60}\,rev/s = \frac{2}{3}\,rev/s$

mass of stone, $m = 0.25\,kg$

radius, $r = 1.5\,m$

We know

$$\omega = 2\pi\nu$$

$$= 2\pi \times \frac{2}{3} = \frac{4\pi}{3} \text{ rad s}^{-1}$$

Now for tension T (tension in string)

Given $T_{max} = 200$ N

[needed to move on circular path, i.e. provides centripetal force $\frac{mv^2}{r}$]

$$T = \frac{mv^2}{r} = mr\omega^2$$

or $T = 0.\cancel{25}_{\cancel{100}\,4} \times \frac{1.5}{10} \times \left(\frac{4\pi}{3}\right)^2$

$$= \frac{1}{\cancel{4}} \times \frac{15.5}{10} \times \frac{\cancel{16}^{4}\pi^2}{\cancel{9}_3}$$

$$= \frac{2\cancel{0} \times 9.86}{3\cancel{0}} = \frac{19.72}{3}$$

or $T = 6.58$ N $\simeq 6.6$ N

As the string stand with a maximum tension of 200 N,

$$T_{max} = \frac{mv_{max}^2}{r}$$

$$v_{max} = \sqrt{\frac{r\,T_{max}}{m}}$$

$$= \sqrt{\frac{1.5 \times 200}{0.\cancel{25}} \times \cancel{100}^{4}}$$

$$= 20\sqrt{3}$$

$$= 20 \times 1.732 = 34.64 \text{ m/s}$$

i.e. $v_{max} \simeq 35$ m/s Ans

Q.22 If in Q.21 the speed - - - - - - - - - - the string breaks.

Ans. Correct option (b)

The velocity always acts tangentially to the circle at each point in the circular motion. At the time string breaks, the particle continues to move in the tangential direction according to Newton's first law of motion.

Q.23. Explain why: - - - - - - - - holding a catch.

Ans. (a) A horse cannot pull a cart and run in empty space.

Because to pull the cart, horse pushes the ground backwards with a certain force at an angle. The ground offers an equal reaction in opposite direction on the feet of horse. The forward component of this reaction is responsible for the motion of cart.

i.e No reaction force → no forward motion (Newton's 3rd law)

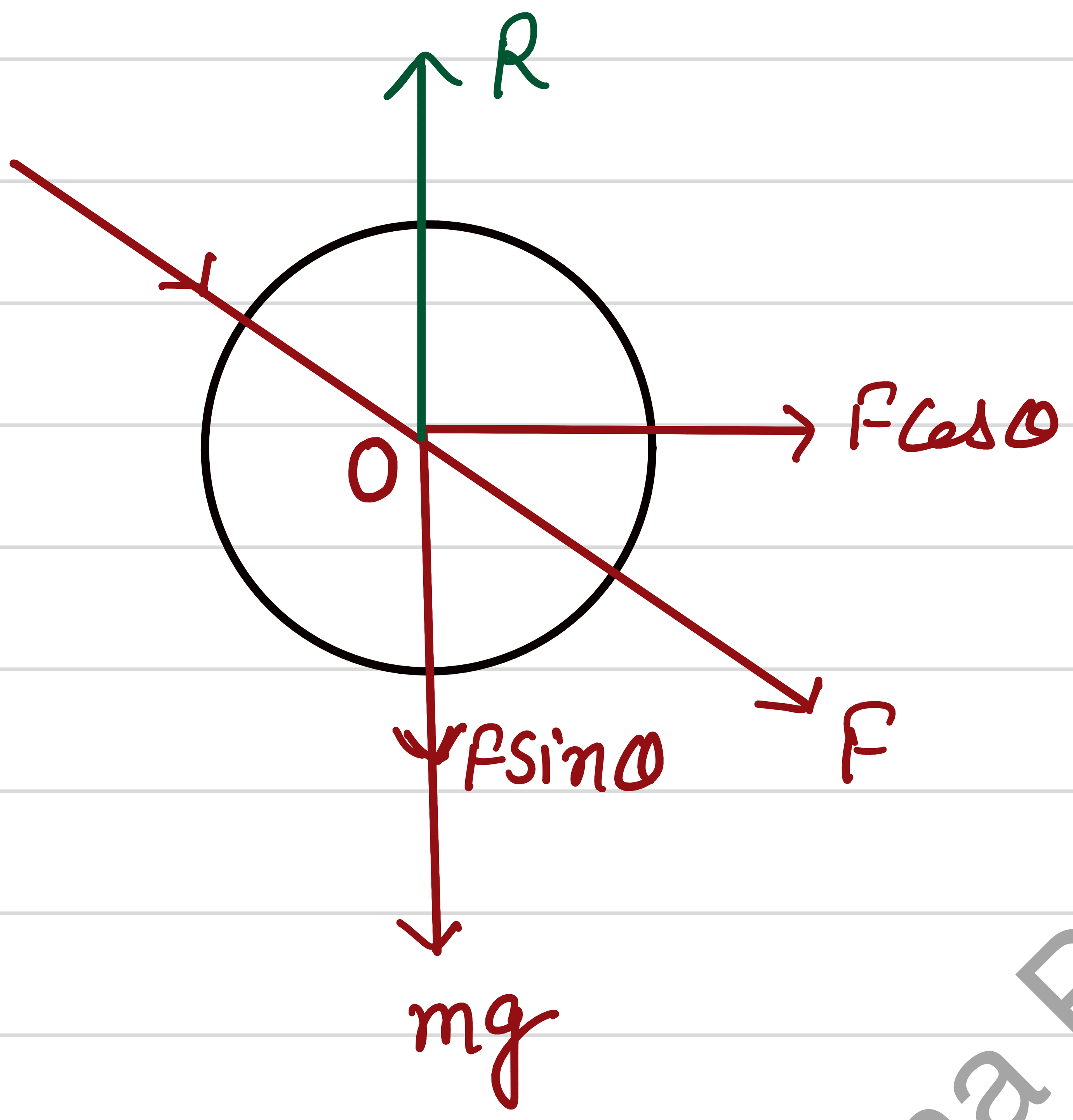
(b) Passengers are thrown forward from their seats when a speeding bus stops suddenly.

Due to inertia, the lower body stops with bus but upper body keeps moving forward. That's why passengers are thrown ahead.

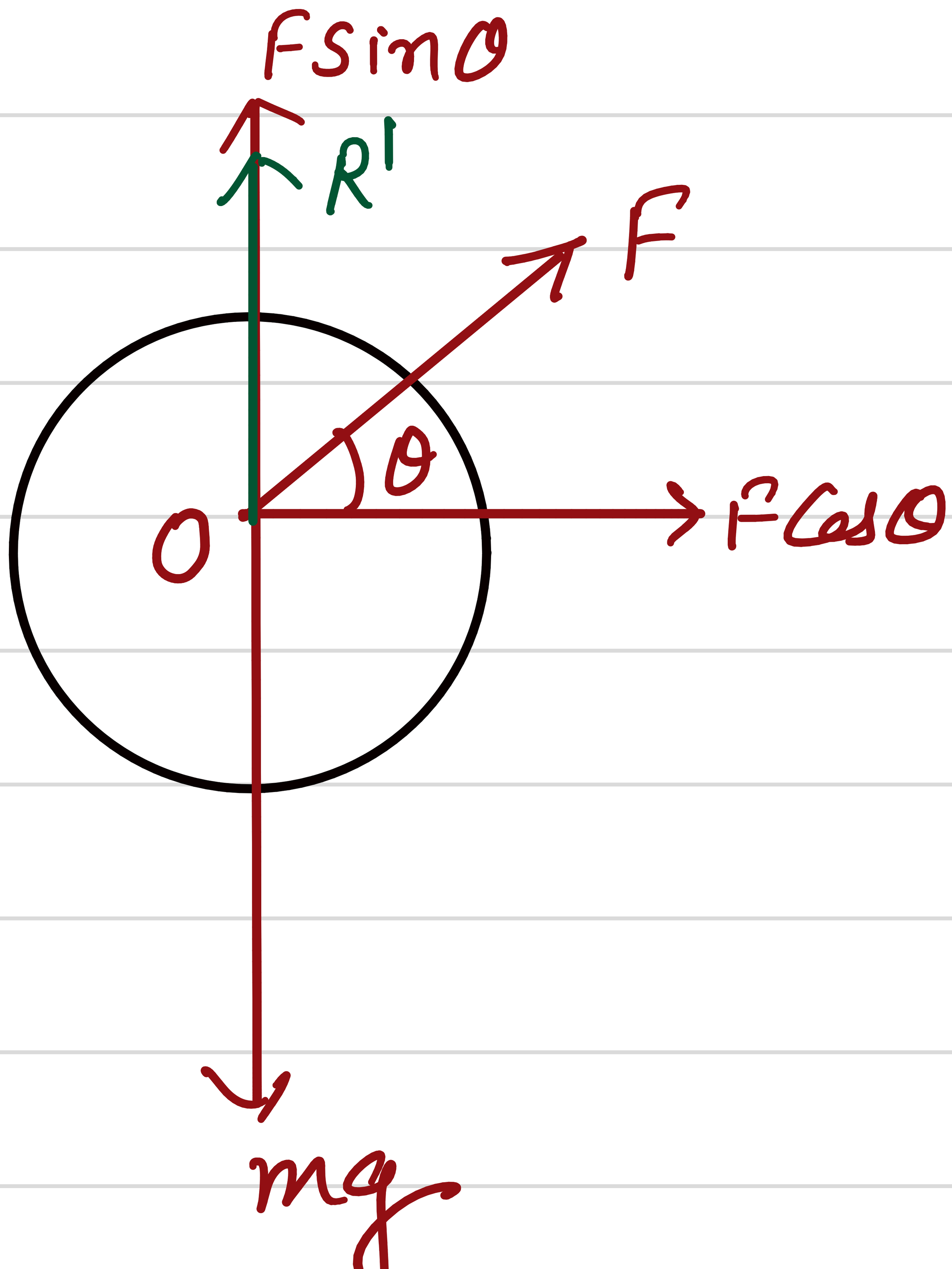
(c) It is easier to pull a lawn mower than to push it.

When pulling, the vertical part of the force helps reduce normal force - less friction.

When pushing, vertical force add to weight - more friction ⇒ Pulling is easier than pushing.



Pushing



Pulling

$R = mg + F\sin\theta$

Force of friction

$f = \mu R$

$f = \mu(mg + F\sin\theta)$

$R' = mg - F\sin\theta$

Friction

$f' = \mu R'$

$f' = \mu(mg - F\sin\theta)$

Clearly $f' < f$ therefore pulling is easier than pushing.

(d) A cricketer moves his hand backwards when holding a catch.

By moving hands back, he increases the time duration to reduce force, as

Impulse = Force × time

This prevents injury and gives a soft catch.