old Ch. 5

NCERT PHYSICS SOLUTIONS

CHAPTER : LAWS OF MOTION CLASS : XI

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Example 5.1

An astronaut - - - - - - - the spaceship?

Answer :

Assuming that there are no nearby stars to exert gravitational force and the small spaceship exerts negligible gravitational force on the astronaut.

The moment he gets out of the ship, there is no external force on him. By the first law of motion, the acceleration of the astronaut is zero.

Example 5.2

A bullet of mass 0.04 Kg moving - - - - - - - - - - - by the block on the bullet?

Solution:

Given,

Mass of bullet $m = 0.04$ kg

Speed of the bullet $u = 90\ ms^{-1}$

distance $s = 60$ cm $= 0.6$ m

Resistive force exerted by block $F = ?$

by, $v^2 = u^2 + 2as$

here $v = 0$ as bullet stopped, so

$$a = -\frac{u^2}{2s} \quad \text{(-ve sign for retardation)}$$

$$= -\frac{90 \times 90}{2 \times 0.6} = -\frac{8100}{1.2} = -6750\ ms^{-2}$$

or $a = -6750\ ms^{-2}$

By $F = ma$
$= 0.04 \times (-6750)$
$F = -270\ N$
-ve sign is due to retarding force.
Thus the average resistive force by the block on the bullet is 270 N Ans

Example 5.3
The motion of a particle ---- on the particle.
Solution:
We have
$$y = ut + \frac{1}{2}gt^2$$
on differentiating w.r.to t, we get
$$v = \frac{dy}{dt} = \frac{d}{dt}\left(ut + \frac{1}{2}gt^2\right)$$
or $V = u + 2.\frac{1}{2}gt$ $\quad \left[\because \frac{d}{dx}x^n = nx^{n-1}\right]$

or $V = u + gt$
Now
$$a = \frac{dv}{dt} = \frac{d}{dt}(u+gt)$$
or $a = 0 + g$
or $a = g$
which means the motion of particle is under the acceleration due to gravity. Therefore
$F = ma = mg$

Example 5.4

A batsman hits - - - - - - - to the ball.

Solution:

Given

Initial speed of the ball $u = 12\ m/s$

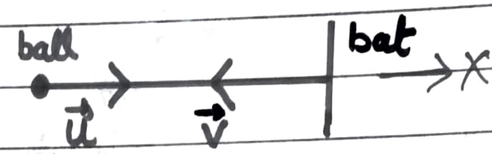
Final speed of the ball $v = 12\ m/s$ (opp. to u)

Mass of the ball $m = 0.15\ kg$.

Here the batsman hits the ball back. So

$\vec{u} = 12\ m/s$

and $\vec{v} = -12\ m/s$



We know that

Impulse = Change in momentum

$\vec{I} = \vec{p}_f - \vec{p}_i$

$= m\vec{v} - m\vec{u}$

$= 0.15(-12 - 12)$

$\vec{I} = -3.6\ Ns$

$p_f \rightarrow$ final momentum

$p_i \rightarrow$ Initial momentum

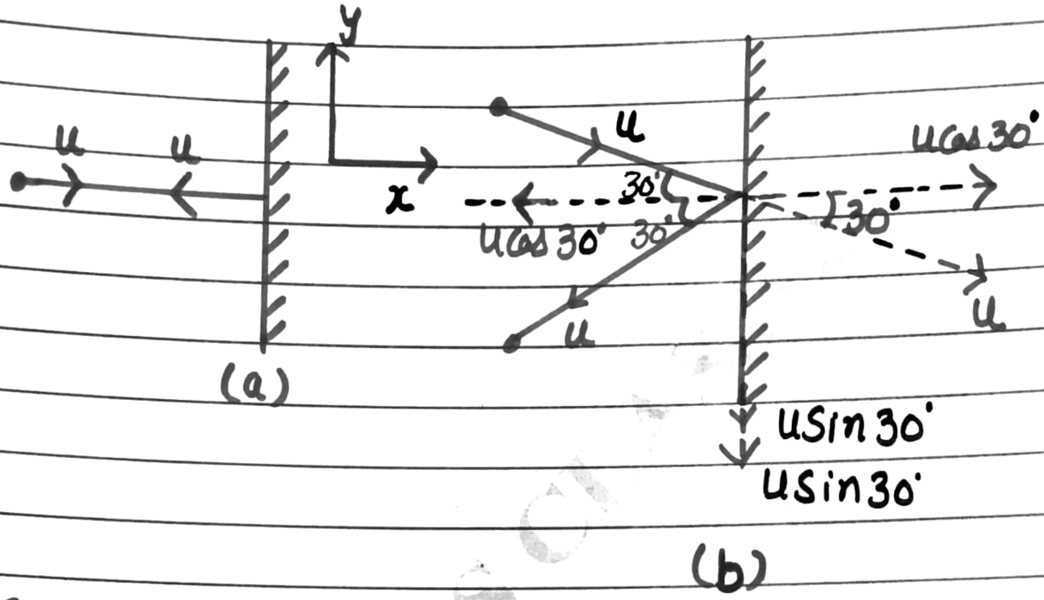
or $I = 3.6\ Ns$

Thus the impulse is 3.6 N in the direction from the batsman to the bowler.

Example 5.5

Two Identical billiard ball - - - - - - the wall ?

Solution:



Case (a)

Change in velocity $= -u - u$ (Along x-axis)

$= -2u$

So, change in momentum $= -2mu$ [$\because p = mv$]

or Δp for case (a) $= -2mu$ —(1)

(Along y-axis momentum $= 0$)

Case (b)

Change in velocity along x-axis

$= -u\cos 30° - u\cos 30°$

$= -2u\cos 30°$

$= -2u \times \frac{\sqrt{3}}{2}$

$= -\sqrt{3}u$

So, change in momentum along x-axis

$= -\sqrt{3}\, mu$

Now change in velocity along y-axis

$= -u\sin 30^\circ - (-u\sin 30^\circ)$

$= -u\sin 30^\circ + u\sin 30^\circ$

$= 0$

So, change in momentum along y axis

$= 0$

Thus the net change in momentum in case (b) -

Δp for case (b) $= -\sqrt{3}\, mu$ —(2)

(i) Direction of force

In case (a)

From fig (a) we can see,

Force by the ball on the wall along the +ve x-axis.

In case (b)

As Δp is along x-axis only, so direction of force is same as in case (a) i.e force on the wall is along the +ve x axis.

(ii) The ratio of the magnitudes of impulse imparted

For case (a)

$I_a = \Delta p = -2mu$ [from eq^n (1)]

and for case (b)

$I_b = \Delta p = -\sqrt{3}\, mu$ [from eq^n (2)]

Hence the ratio

$$\frac{I_a}{I_b} = \frac{-2mu}{-\sqrt{3}mu} = \frac{2}{\sqrt{3}}$$

or $$\frac{I_a}{I_b} = \frac{2}{\sqrt{3}} = \frac{2}{1.732} = 1.15$$

$$I_a : I_b = 2 : \sqrt{3}$$

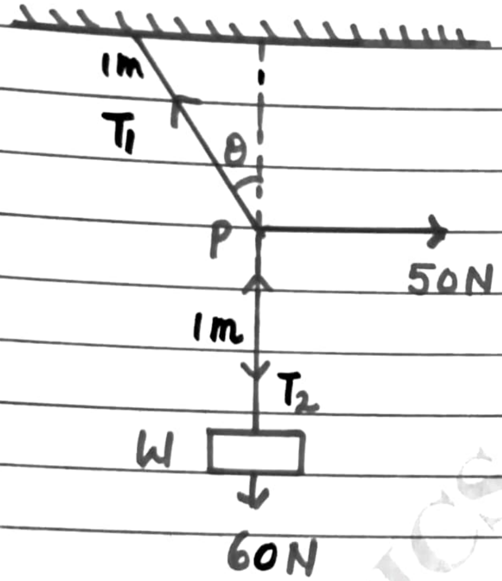
Ans.

Example 5.6

See fig 5.8 A mass of - - - - - - - - - - mass of the rope.

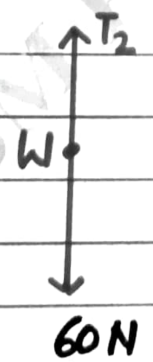
Solution:

Given length of the rope = 2 m
and $g = 10\ m/s^2$



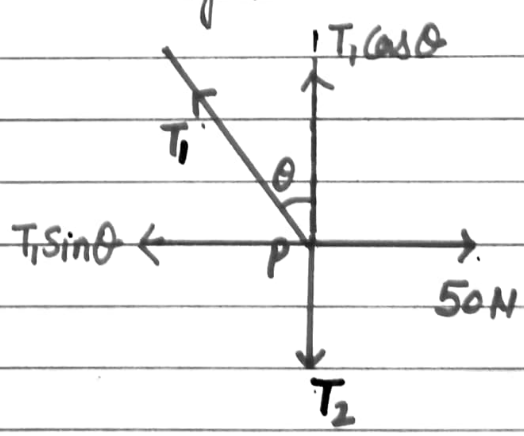
(a)

Free body diagram of W



(b)

Free body diagram of P



(c)

Cosider the equilibrium of weight W
Clearly

$$T_2 = 6 \times 10 = 60\,N \quad \text{[from fig (b)]}$$

Consider the equilibrium of point P

$$T_1 \cos\theta = T_2$$

or $T_1 \cos\theta = 60\,N$

and

$$T_1 \sin\theta = 50\,N$$

On dividing

$$\frac{T_1 \sin\theta}{T_1 \cos\theta} = \frac{50}{60}$$

or $\tan\theta = \frac{5}{6} = 0.833$

or $\tan\theta = 0.833 \simeq \tan 40^\circ$

or $\theta = 40^\circ$ Ans

* It is clear that θ is independent of length of rope (assumed massless).

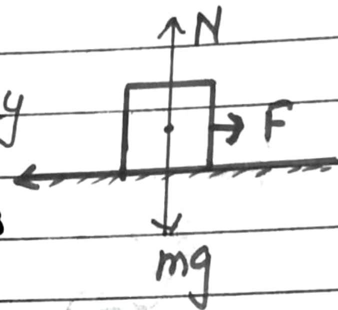
Example 5.7

Determine the - - - - - - - floor is 0.15

Solution:

Given $\mu_s = 0.15$

To remain the box stationary



$\therefore$

$F = f_s$

$m a_{max} = \mu_s N$

or

$$m a_{max} = \mu_s m g \quad [\because N = mg]$$

or

$$a_{max} = \mu_s g$$

$$= 0.15 \times 10$$

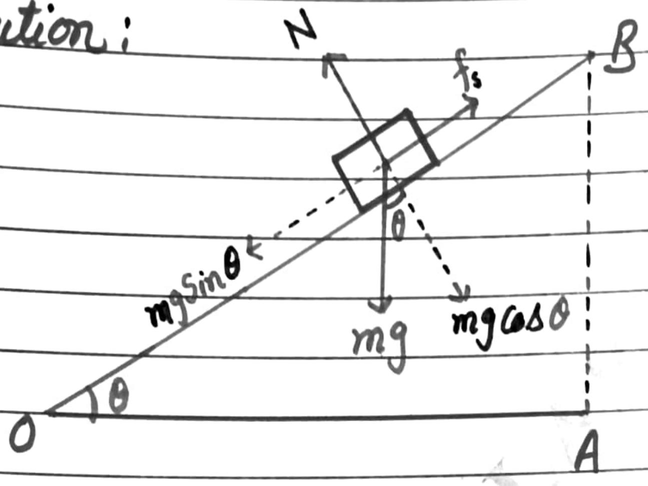
$$a_{max} = 1.5\ m/s^2$$

i.e the maximum acceleration of the train for which box remains in the rest is $1.5\ m/s^2$.

Example 5.8

See fig 5.11. A mass of - - - - - - - - the surface?

Solution:



The forces acting on the block are -

(I) The weight of the block $mg\downarrow$ (downwards)

(II) The normal reaction N (perpendicular to the plane)

(III) The static friction f_s (opp. to the impending motion)

In equilibrium

$$f_s = mg\sin\theta \quad -(1)$$

$$\text{and} \quad N = mg\cos\theta \quad -(2)$$

$$\text{here} \quad \theta = \theta_{max}$$

$$\text{and} \quad (f_s)_{max} = \mu_s N$$

$(1) \div (2)$

$$\frac{\mu_s N}{\cancel{N}} = \tan\theta$$

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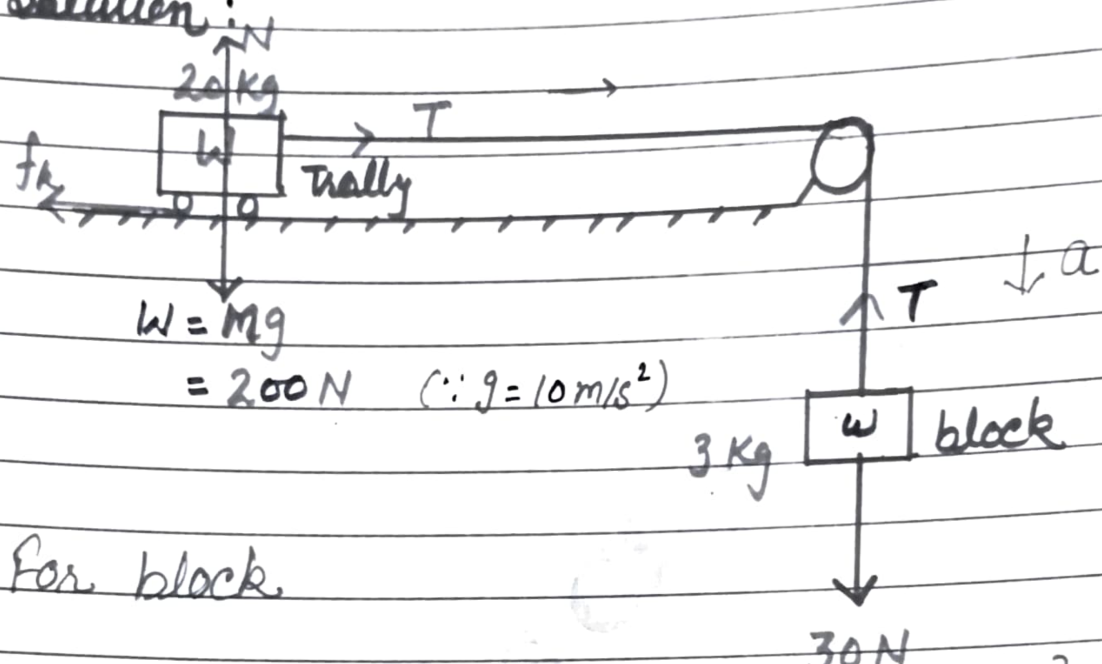
or $\mu_s = \tan\theta$

here $\theta = 15°$

$\mu_s = \tan 15°$

or $\mu_s \doteq 0.27$ Ans

Example 5.9
What is the acceleration - - - - - of the string?
Solution :



$W = Mg$
$= 200\,N \quad (\because g = 10\,m/s^2)$

For block

$30 - T = ma$ [m → mass of block]
$30 - T = 3a$ —(1)

For trolly

$T - f_k = Ma$ [M → mass of trolly]
$T - \mu_k N = Ma$
$T - \mu_k Mg = Ma$

$T - 0.04 \times 20 \times 10 = 20 \times a$
or $T - 8 = 20a$ —(2)

(1) + (2), we get
$22 = 23a$

or $a = \frac{22}{23}$

$= 0.96 \ m/s^2$

Now from $eq^n (2)$

$T - 8 = 20a$

$T - 8 = 20 \times 0.96$

or $T = 19.2 + 8$

or $T = 27.2 \ N$

Thus $a = 0.96 \ m/s$
and $T = 27.2 \ N$ } Ans

Example 5.10

A cyclist speeding - - - - - - - taking the turn?

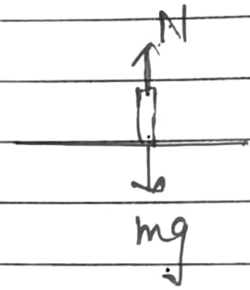
Solution:

On an unbanked road the centripetal force is provided by the friction force.
The condition of cyclist not to slip while taking circular turn is given by.

Centripetal force $\leq$ friction force

$$f_c \leq f$$

$$\frac{mv^2}{R} \leq \mu_s N$$



or $$\frac{\cancel{m}v^2}{R} \leq \mu_s \cancel{m}g$$

or $$\frac{v^2}{R} \leq \mu_s g$$

or $$v^2 \leq R\mu_s g$$

Here $v = 18\ Km/H$

$= 18 \times \frac{5}{18}\ m/s$ $\left[\because 1\ Km/H = \frac{100\cancel{0}}{6\cancel{0} \times 6\cancel{0}}\ m/s = \frac{5}{18}\ m/s\right.$

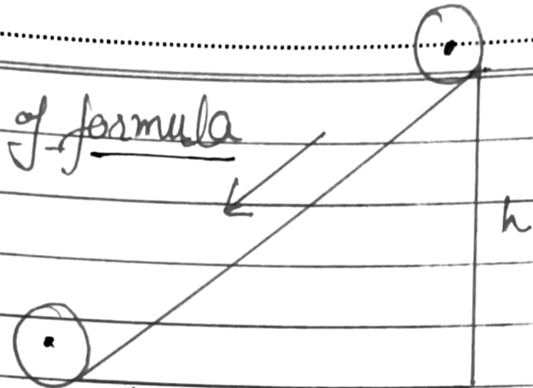
$v = 5\ m/s$

and $R = 3\ m$

$\mu_s = 0.1$

$g = 9.8\ m/s^2$

<u>Derivation of formula</u>



by the conservation of energy

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}Mk^2\left(\frac{v}{r}\right)^2 \quad \left[\begin{array}{l} I = Mk^2 \\ v = r\omega \end{array}\right.$$

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}\frac{mv^2k^2}{r^2}$$

$$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2\left[1 + \frac{k^2}{r^2}\right]$$

$$2gh = v^2\left[1 + \frac{k^2}{r^2}\right]$$

or $$v^2 = \frac{2gh}{1 + k^2/r^2}$$

$$v = \sqrt{\frac{2gh}{1 + k^2/r^2}}$$

Now

$$v^2 = 5^2$$
$$= 25\ m^2/s^2$$

and

$$\mu_s R g = 0.1 \times 3 \times 9.8$$
$$= 2.94\ m^2/s^2$$

i.e $v^2 > \mu_s R g$

Hence the cyclist will slip while taking turn.

Example 5.11

A circular racetrack - - - - avoid slipping?

Solution:

Given

$$R = 300\ m$$
$$\theta = 15°$$
$$\mu_s = 0.2$$
$$g = 9.8\ m/s^2$$

(a) Optimum speed

$$V_o = \sqrt{Rg\tan\theta}$$
$$= \sqrt{300 \times 9.8 \times \tan 15°}$$
$$= \sqrt{300 \times 9.8 \times 0.27}$$
$$= \sqrt{81 \times 9.8}$$

$$V_0 = \sqrt{81 \times 9.8}$$

$$= 9 \times \sqrt{9.8}$$

$$= 9 \times 3.13$$

$$= 28.17 \text{ m/s}$$

$$\begin{array}{r|l} & 3.13 \\ 3 & 9.80 \\ & 9 \\ 61 & 80 \\ & 61 \\ 623 & 1900 \end{array}$$

(b)

$$V_{max} = \sqrt{Rg\left(\frac{\mu_s + \tan\theta}{1 - \mu_s \tan\theta}\right)}$$

$$= \sqrt{300 \times 9.8\left(\frac{0.2 + \tan 15}{1 - 0.2 \tan 15}\right)}$$

$$= \sqrt{300 \times 9.8\left(\frac{0.2 + 0.27}{1 - 0.2 \times 0.27}\right)}$$

$$= \sqrt{300 \times 9.8\left(\frac{0.47}{1 - 0.054}\right)}$$

$$= \sqrt{\frac{300 \times 9.8 \times 0.47}{0.946}}$$

$$= \sqrt{\frac{3 \times 9.8 \times 47}{0.946}}$$

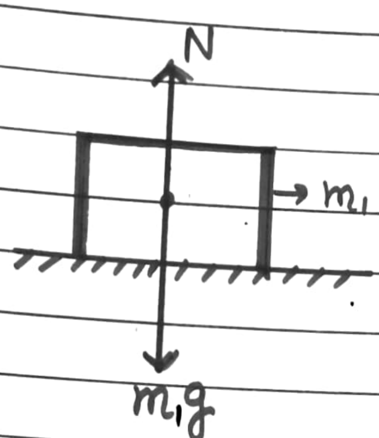
$$= \sqrt{\frac{1381.8}{0.946}} = \sqrt{1454.5}$$

$$V_{max} = 38.13 \text{ m/s}$$

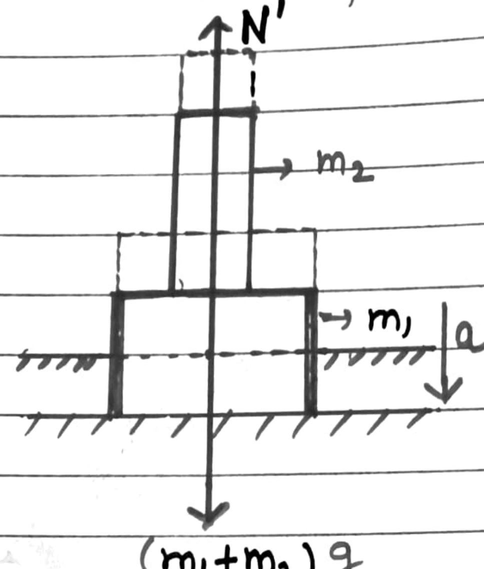
Example 5.12

A wooden block of - - - - - - in the problem.

Solution:



(1)



(II)

We are given

$m_1 = 2$ kg , $m_2 = 25$ kg

$g = 10 m/s^2$, $a = 0.1 m/s^2$

(a) Before floor yield

from fig (1)

$$N = m_1 g$$

$$N = 2 \times 10$$

or $N = 20$ newton

(b) After floor yield

from fig (II)

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

$$(2+25)\times 10 - N' = (2+25)\times 0.1$$

or $27 \times 10 - N' = 27 \times 0.1$

or $270 - N' = 2.7$

or $N' = 270 - 2.7$

$N' = 267.3$ newton

So

$N = 20$ newton

and $N' = 267.3$ newton

Action - reaction pairs

For fig (i) { A → Action, R → Reaction

(i) (A) • Force of gravity on the block by the earth.
(R) • Force of gravity on the earth by the block.

(ii) (A) • force on the floor by the block.
(R) • Force on the block by the floor.

For fig (ii)

(i) (A) • The force of gravity on the system by the earth.
(R) • The force of gravity on the earth by the system.

(ii) (A) • The force on the floor by the system.
(R) • The force on the system by the floor.

(iii) (A) • The force on the block by the cylinder.
(R) • The force on the cylinder by the block.