KD EDUCATION ACADEMY [9582701166]

Time : 6 Hour | Physics | Total Marks : 450

kd 90+ ch-4 laws of motion

*** Choose The Right Answer From The Given Options.[1 Marks Each] [32]**

1. A cricket ball of mass 150g has an initial velocity $\mathrm{u} = (3\hat{\mathrm{i}} + 4\hat{\mathrm{j}})\mathrm{m\ s^{-1}}$ and a final velocity $\mathrm{v} = -(3\hat{\mathrm{i}} + 4\hat{\mathrm{j}})\mathrm{m\ s^{-1}}$ after being hit. The change in momentum (final momentum-initial momentum) is (in kg m s^1):

(A) zero

(B) $-(0.45\hat{\mathrm{i}} + 0.6\hat{\mathrm{j}})$

(C) $-(0.9\hat{\mathrm{i}} + 1.2\hat{\mathrm{j}})$

(D) $-5(\hat{\mathrm{i}} + \hat{\mathrm{j}})$

Ans. :

c. $-(0.9\hat{\mathrm{i}} + 1.2\hat{\mathrm{j}})$

Explanation:

According to the problam, $\mathrm{u} = (3\hat{\mathrm{i}} + 4\hat{\mathrm{j}})\mathrm{m\ s^{-1}}$ and $\mathrm{v} = -(3\hat{\mathrm{i}} + 4\hat{\mathrm{j}})\mathrm{m\ s^{-1}}$ mass of the ball = 150g = 0.15kg.

Chang in momentum will be

$\overrightarrow{\Delta \mathrm{p}} = \overrightarrow{\mathrm{p_f}} - \overrightarrow{\mathrm{p_I}}$

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

$= \mathrm{m\hat{v}} - \mathrm{m\hat{u}}$

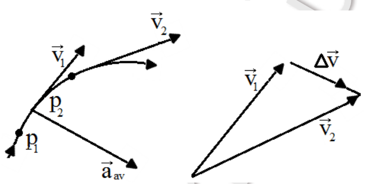
$= (0.15)[-3\mathrm{i} + 4\mathrm{j} - (3\hat{\mathrm{i}} + 4\hat{\mathrm{j}})]$

$= (0.15)[-6\hat{\mathrm{i}} - 8\hat{\mathrm{j}}]$

$= -[0.15 \times 6\hat{\mathrm{i}} + 0.15 \times 8\hat{\mathrm{j}}]$

$= -[0.9\hat{\mathrm{i}} + 1.2\hat{\mathrm{j}}]$

Hence, $\overrightarrow{\Delta \mathrm{p}} = -[0.9\hat{\mathrm{i}} + 1.2\hat{\mathrm{j}}]$



2. A bomb at rest explodes into 3 parts of the same mass. The momentum of 2 parts are $-2\hat{\mathrm{i}}$ and $\mathrm{p}\hat{\mathrm{j}}$. The momentum of the third part will have a magnitude of,

(A) p (B) $\sqrt{3}\mathrm{p}$ (C) $\sqrt{3\mathrm{p}}$ (D) zero

Ans. :

c. $\sqrt{3\mathrm{p}}$.

3. A particle of mass m moving with a velocity v strikes a stationary particle of mass 2m and stickes to it. The speed of the system will be,

(A) $\frac{\mathrm{v}}{2}$

(B) $2\mathrm{v}$

(C) $\frac{\mathrm{v}}{3}$

(D) $3\mathrm{v}$

Ans. :

c. $\frac{\mathrm{v}}{3}$

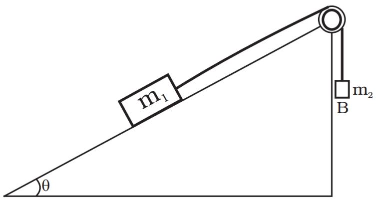
Explanation:

Applying principle of conservation of linear momentum,

(m + 2m)V = m × v + 2m × 0

$\mathrm{V} = \frac{\mathrm{v}}{3}$

4. Mass m_1 moves on a slope making an angle θ with the horizontal and is attached to mass m_2 by a string passing over a frictionless pulley as shown in The co-efficient of friction between m_1 and the sloping surface is μ. Which of the following statements are



true?

(A) If $m_2 > m_1 \sin\theta,$ the body will move up the plane.

(B) If $m_2 > m_1 (\sin\theta + \mu\cos\theta)$, the body will move up the plane.

(C) If $m_2 < m_1 (\sin\theta + \mu\cos\theta)$, the body will move up the plane.

(D) If $m_2 < m_1 (\sin\theta - \mu\cos\theta)$, the body will move down the plane.

Ans. :

b. If $m_2 > m_1 (\sin\theta + \mu\cos\theta)$, the body will move up the plane.

d. If $m_2 < m_1 (\sin\theta - \mu\cos\theta)$, the body will move down the plane.

Explanation:

Case I: Normal reaction $\mathrm{N} = \mathrm{m_1 g}\cos\theta$

$\mathrm{f} = \mu\mathrm{N} = \mu\mathrm{m_1 g}\cos\theta$

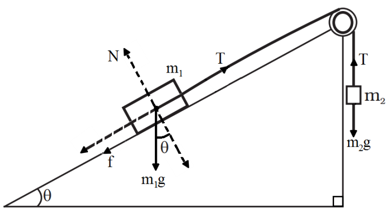
$\therefore$ Above equation becomes $\mathrm{T} - \mathrm{m_1 g}\sin\theta - \mathrm{m_1 g}\cos\theta = \mathrm{m_1 g}$

m_1 will up and m_2 down when $\mathrm{m_2 g} - (\mathrm{m_1 g})\cos\theta + \mathrm{f} > 0$

$\mathrm{m_2 g} - \mathrm{m_1 g}\sin\theta - \mathrm{g}\mu\mathrm{m_1 g}\cos\mathrm{g}\theta > 0$

$\mathrm{m_2 g} > \mathrm{m_1 g}(\sin\theta + \mu\cos\theta)$

or $\mathrm{m_2} > \mathrm{m_1}(\sin\theta + \mu\cos\theta)$



Case II: If body m_1 moves down and m_2 up then, direct of f becomes upward(opp. tomotion).

$$-\mathrm{f}+\mathrm{m_1 g}\sin\theta>\mathrm{m_2 g}$$
$$=\mu\mathrm{m_1 g}\cos\theta+\mathrm{m_1 g}\sin\theta>\mathrm{m_2 g}$$
$$\mathrm{m_1}(-\mu\cos\theta+\sin\theta)>\mathrm{m_2}$$
$$\mathrm{m_2}<\mathrm{m_1}(\sin\theta-\mu\cos\theta)$$

5. A body of mass 2kg travels according to the law x(t) = pt + qt^2 rt^3 where p = 3m s^{-1}, q = 4m s^{-2} and r = 5m s^{-3}. The force acting on the body at t = 2 seconds is.

(A) 136N (B) 134N (C) 158N (D) 68N

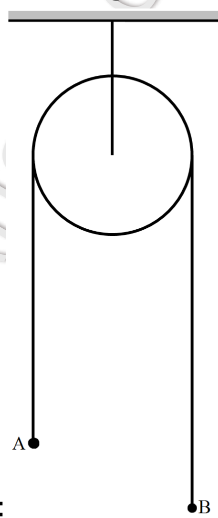
Ans. :

a. 136N

Expanation:

$$\vec{\mathrm{F}}=\mathrm{m}\vec{\mathrm{a}}=\mathrm{m}.\frac{\mathrm{d^2x}}{\mathrm{dt^2}}$$
$$\because\ \mathrm{x(t)=pt+qt^2+rt^3,\ p=3ms^{-1},\ q=4ms^{-2},\ r=5ms^{-3}}$$
$$\mathrm{x(t)=3t+4t^2+5t^3}$$
$$\frac{\mathrm{dx(t)}}{\mathrm{dt}}=3+8\mathrm{t}+15\mathrm{t}^2$$
$$\frac{\mathrm{d^2x(t)}}{\mathrm{dt^2}}=0+8+30t$$
$$\left[\frac{\mathrm{d^2x(t)}}{\mathrm{dt^2}}\right]_{\text{t-2}}=8+30\times2=68\mathrm{ms^{-2}}$$
$$\therefore\ \vec{\mathrm{F}}=2\times68=136\mathrm{N}.$$

6. The pulley in the diagram is smooth and light. The masses of A and B are 5kg and 2kg.



The acceleration of the system is:

(A) g (B) $\frac{7}{3}$g (C) $\frac{3}{7}$g (D) $\frac{1}{7}$g

Ans. :

c. $\frac{3}{7}$g

7. A trolley is carrying a box on its surface having coefficient of static friction equal to 0.3. Now the trolley starts moving with increasing acceleration. Find the maximum acceleration of the trolley so that the box does not slide back on the trolley.

(A) 2ms^{-2} (B) 3ms^{-2} (C) 4ms^{-2} (D) 5ms^{-2}

Ans. :

b. $3ms^{-2}$

Explanation:

As trolley accelerates forward, a pseudo force acts on the box in reverse. It prevents its slippage in backward direction, as friction starts acting on it. But as friction can be increased to a maximum value of u mg. So maximum acceleration that is possible for block before it starts slipping $= \mu g = 0.0 \times 10 = 3ms^{-2}$.

8. A particle of man 2kg is moving on a circular path of radius 10m with a speed of 5ms and its speed is increasing at rate of $3ms^{-1}$. Find the force acting on the particle.

(A) 5N (B) 10N (C) 12N (D) 14N

Ans. :

a. 5N

Explanation:

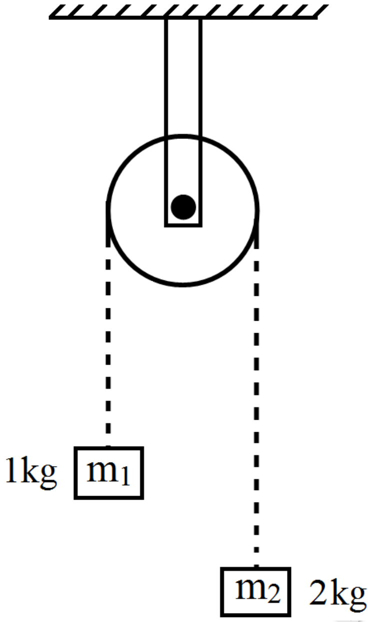
Radial acceleration (centripetal acceleration),

$= \frac{v^2}{r} = \frac{5 \times 5}{10} = 2.5ms^{-2}$

Force acting = mass X acceleration,

= 2 × 2.5 = 5N

9. Two masses m_1= 1kg and m_2 = 2kg are connected by a light inextensible string and suspended by means of a weightless pulley as shown in figure,



Assuming that both the masses start from rest, the distance travelled by 2kg mass in 2s is:

(A) $\frac{20}{9}$m (B) $\frac{40}{9}$m

(C) $\frac{20}{3}$m (D) $\frac{1}{3}$m

Ans. :

c. $\frac{20}{3}$m

Explanation:

Given, m_1 = 1kg, m_2 = 2kg and g = $10ms^{-2}$

Acceleration, $a = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)g$

$= \left(\frac{2-1}{1+2}\right)10 = \frac{10}{3}$

$\left[\because s = ut + \frac{1}{2}at^2 \text{ and } u = 0ms^{-1}\right]$

Distance, $s = \frac{1}{2} \times a \times t^2$

$= \frac{1}{2} \times \frac{10}{3} \times 4\frac{20}{3}m$

10. If a car is moving in uniform circular motion, then what should be the value of velocity of a car, so that car will not moving away from the circle,

(A) $v < \sqrt{\mu_s \ Rg}$

(B) $v \leq \sqrt{\mu_s \ Rg}$

(C) $v < \sqrt{\mu_k \ Rg}$

(D) None of these.

Ans. :

b. $v \leq \sqrt{\mu_s \ Rg}$

Explanation:

For car moving in circle of radius R, with velocity v, mass = m, centripetal force required = Frictional force $\leq \mu_s N$.

11. The dimension of Impulse is:

(A) MLT^{-2} (B) MLT^{-1} (C) MLT^{-3} (D) MLT

Ans. :

b. MLT^{-1}

12. A body with mass 5kg is acted upon by a force $F = (-3\hat{i} + 4\hat{j})N$. If its initial velocity at t = 0 is $v = (6\hat{i} - 12\hat{j})m\ s^{-1}$, the time at which it will just have a velocity along the y-axis is:

(A) never (B) 10s (C) 2s (D) 15s

Ans. :

b. 10s

Explanation:

According to the problam, mass m = 5kg

Force which is acting uppon the block $\vec{F} = (-3\hat{i} + 4\hat{j})N$

Inital velocity at $t = 0,\ \vec{u} = (6\vec{i} - 12\vec{j})m/s$

Retardation, $\vec{a} = \frac{\vec{F}}{m} = \left(-\frac{3\vec{i}}{5} + \frac{4\vec{j}}{5}\right)m/s^2$

And when final veocity is along y-axis only, its x-componet must be zero.

We have to apply kinematic wquations seprately for x-component only. then we get

$v_x = u_x + a_x t$

$0 = 6\vec{i} - \frac{3\vec{i}}{5}t$

$t = \frac{5\times6}{3} = 10\ s$

13. A particle of mass 10kg is moving in a straight line. If its displacement, x with time t is given by x = (t^3 - 2t - 10)m, then the force acting on it at the end of 4 seconds is:

(A) 24N
(B) 240N
(C) 300N
(D) 1200N

Ans. :

b. 240N.

Explanation:

$\mathrm{m} = 10\mathrm{kg}$

$\mathrm{x} = (\mathrm{t}^3 - 2\mathrm{t} - 10)\mathrm{m}$

$\frac{\mathrm{dx}}{\mathrm{dt}} = \mathrm{v} = 3\mathrm{t}^2 - 2$

$\frac{\mathrm{d}^2\mathrm{x}}{\mathrm{dt}^2} = \mathrm{a} = 6\mathrm{t}$

At the end of 4 sec, $\mathrm{a} = 6 \times 4 = 24\ \mathrm{m/s}^2$

$\mathrm{F} = \mathrm{ma} = 10 \times 24 = 240\mathrm{N}$

14. A particle is moving on a circular path of 10m radius. At any instant of time, its speed is $5ms^{-1}$ and the speed is increasing at a rate of $2ms^{-2}$. The magnitude of net acceleration at this instant is:

(A) $5ms^{-2}$
(B) $2ms^{-2}$
(C) $3.2ms^{-2}$
(D) $4.3ms^{-2}$

Ans. :

c. $3.2ms^{-2}$

15. A machine gun fires a bullet of mass 40gm with a velocity 1200m/ s. The man holding it can exert a maximum force of 144N on the gun. How many bullets can he fire per second at the most?

(A) Only one.
(B) Three.
(C) He can fire any number of bullets.
(D) 144 × 48

Ans. :

b. Three.

16. An insect is crawling up on the concave surface of a fixed hemispherical bowl of radius R. If the coefficient of friction is $\frac{1}{3}$ then the height up to which the insect can crawl is nearly:

(A) 5% of R.
(B) 6% of R.
(C) 6.5% of R.
(D) 7.5% of R.

Ans. :

a. 5% of R.

17. Two forces $\mathrm{F}_1 = 3\hat{\mathrm{i}} - 4\hat{\mathrm{j}}$ and $\mathrm{F}_2 = 2\hat{\mathrm{i}} - 3\hat{\mathrm{j}}$ are acting upon a body of mass 2kg. Find the force F, which when acting on the body will make it stable.

(A) $5\hat{\mathrm{i}} + 7\hat{\mathrm{j}}$
(B) $-5\hat{\mathrm{i}} - 7\hat{\mathrm{j}}$
(C) $-5\hat{\mathrm{i}} + 7\hat{\mathrm{j}}$
(D) $5\hat{\mathrm{i}} - 7\hat{\mathrm{j}}$

Ans. :

c. $-5\hat{i}+7\hat{j}$

18. A force of 200N is required to push a car of mass 500kg slowly at constant speed on a level road. If a force of 500N is applied, the acceleration of the car (in ms^{-2}) will be:

(A) Zero. (B) 0.2 (C) 0.6 (D) 1.0

Ans. :

c. 0.6

19. 25N force is required to raise 75kg mass from a pulley. If rope is pulled 12m, then the load is lifted to 3m, the efficiency of pulley system will be,

(A) 25% (B) 33.3% (C) 75% (D) 90%

Ans. :

c. 75%

Explanation:

$\eta=\frac{\text{Output}}{\text{Input}}=\frac{75\times3}{25\times12}$

$=\frac{75\times3}{25\times12}=\frac{75}{100}=\frac{75}{100}\times100\%=75\%$

20. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. Force P is applied at one end of the rope. The force which the rope exerts on the block is:

(A) $\frac{\mathrm{P}}{\mathrm{M-m}}$ (B) $\frac{\mathrm{PM}}{\mathrm{m+M}}$ (C) $\frac{\mathrm{P}}{\mathrm{M(m+M)}}$ (D) $\frac{\mathrm{Pm}}{\mathrm{M-m}}$

Ans. :

b. $\frac{\mathrm{PM}}{\mathrm{m+M}}$

21. Physical independence of force is a consequence of:

(A) Third law of motion.

(B) Second law of motion.

(C) First law of motion.

(D) All of these laws.

Ans. :

c. First law of motion.

22. A shell is fired from a cannon, it explodes in mid air, its total:

(A) Momentum increases.

(B) Momentum decreases.

(C) K.E. increases.

(D) K.E. decreases.

Ans. :

c. K.E. increases.

Explanation:

On explosion, K.E. increases, as chemical energy of explosives is converted into K.E.

23. A body of mass 10kg is acted upon by two perpendicular forces, 6N and 8N. The resultant acceleration of the body is:

(A) 1m s^{-2} at an angle of 1 4 $\tan^{-1}\left(\frac{4}{3}\right)$ w.r.t. 6N force.

(B) 0.2m s^{-2} at an angle of $\tan^{-1}\left(\frac{4}{3}\right)$ w.r.t. 6N force.

(C) 1m s^{-2} at an angle of $\tan^{-1}\left(\frac{4}{3}\right)$ w.r.t.8N force.

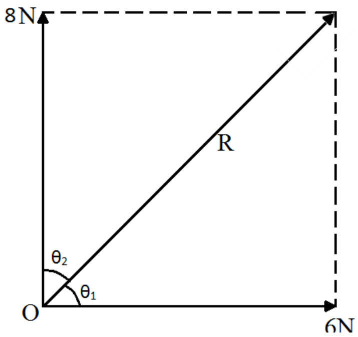
(D) 0.2m s^{-2} at an angle of $\tan^{-1}\left(\frac{4}{3}\right)$ w.r.t.8N force.

Ans. :

a. 1m s^{-2} at an angle of 1 4 $\tan^{-1}\left(\frac{4}{3}\right)$ w.r.t. 6N force.

c. 1m s^{-2} at an angle of $\tan^{-1}\left(\frac{4}{3}\right)$ w.r.t.8N force.

Expanation:



$$\mathrm{R} = \sqrt{8^2 + 6^2} = \sqrt{64 + 36} = \sqrt{100}$$
$$\mathrm{R} = 10\ \mathrm{N}$$
$$\mathrm{F} = \mathrm{ma} \Rightarrow \alpha = \frac{\mathrm{F}}{\mathrm{m}} = \frac{\mathrm{R}}{\mathrm{m}} = \frac{10}{10} = 1\mathrm{ms} - 2 \ldots (\mathrm{i})$$
$$\tan\theta_1 = \frac{8}{6} = \frac{4}{3} \Rightarrow \theta_1 = \tan^{-1}\left(\frac{4}{3}\right) \ldots (\mathrm{ii})$$
$$\tan\theta_2 = \frac{6}{8} = \frac{3}{4} \Rightarrow \theta_2 = \tan^{-1}\left(\frac{3}{4}\right) \ldots (\mathrm{iii})$$

(i),(ii) verifies option (a) and (i),(iii) verifies option (c).

Acceleration $\alpha \neq 0.2\ \mathrm{ms}^{-2}$, rejects the option (b) and (d).

24. A 7kg object is subjected to two forces (in Newton) $\vec{\mathrm{F}}_1 = 20\hat{\mathrm{i}} + 30\hat{\mathrm{j}}$ and $\vec{\mathrm{F}}_2 = 8\hat{\mathrm{i}} - 5\hat{\mathrm{j}}$ The magnitude of resulting acceleration in ms^{-2} will be:

(A) 5 (B) 4 (C) 3

Ans. :

c. 3

Explanation:

Resultant force, $\vec{\mathrm{F}} = \vec{\mathrm{F}}_1 + \vec{\mathrm{F}}_2$

$$= (20\hat{\mathrm{i}} + 30\hat{\mathrm{j}}) + (8\hat{\mathrm{i}} - 5\hat{\mathrm{j}})$$
$$\vec{\mathrm{F}} = 28\hat{\mathrm{i}} + 25\hat{\mathrm{j}}$$
$$\therefore\ \mathrm{F} = \sqrt{28^2 + 25^2}$$
$$= \sqrt{784 + 625} = \sqrt{1409} = 37.5\mathrm{N}$$
$$\mathrm{a} = \frac{\mathrm{F}}{\mathrm{m}} = \frac{37.5}{7} = 5.3\ \mathrm{ms}^{-2}$$

25. The coefficient of friction between tyres and the road is 0.1. Find the maximum speed allowed by traffic police for cars to cross a circular turn of radius 10m to prevent accident.

(A) $\sqrt{10}\,\mathrm{ms}^{-1}$ (B) $\sqrt{20}\,\mathrm{ms}^{-1}$

(C) $5\mathrm{ms}^{-1}$

Ans. :

a. $\sqrt{10}\,\mathrm{ms}^{-1}$

26. A particle of mass 5 kg is pulled along a smooth horizontal surface by a horizontal string. The acceleration of the particle is 10 ms $^{-2}$. The tension in the string is

(A) 2N (B) 50N (C) 15N

Ans. :

b. 50N.

27. When a car is taking a circular turn on a horizontal road, the centripetal force is the force of:

(A) Friction.

(B) Weight of the car.

(C) Weight of the tyres.

Ans. :

a. Friction.

28. A 60kg man pushes a 40kg man by a force of 60N. The 40kg man has pushed the other man with a force of:

a. 40N
b. 0N
c. 60N
d. 20N

Ans. :

c. 60N

Explanation:

According to Newton's third law, which states that an action-reaction pair of forces are equal in magnitude, the man who weighs 40kg will push the other man with the same force of 60N.

29. A neutron exerts a force on a proton which is:

a. Gravitational.
b. Electromagnetic.
c. Nuclear.
d. Weak.

Ans. :

a. Gravitational

c. Nuclear

Explanation:

A neutron exerts both the gravitational and nuclear forces on a proton.

The gravitational force can be seen between a neutron and a proton. However, its strength is negligible. The nuclear force is exerted only if the interacting particles are neutrons or protons or both. A neutron cannot exert electromagnetic force, because it is a neutral particle.

30. If all matters were made of electrically neutral particles such as neutrons:

a. There would be no force of friction.
b. There would be no tension in the string.
c. It would not be possible to sit on a chair.
d. The earth could not move around the sun.

Ans. :

a. There would be no force of friction.
b. There would be no tension in the string.
c. It would not be possible to sit on a chair.

Explanation:

For the existence of friction between two bodies and tension in a string, electromagnetic force is needed. Electromagnetic force exists only between charged particles. For sitting on a chair, we need fractional force. A neutral particle can exert gravitational force on other neutral particles. So, even if all the matters were made up of electrically neutral particles, the earth will still move around the sun.

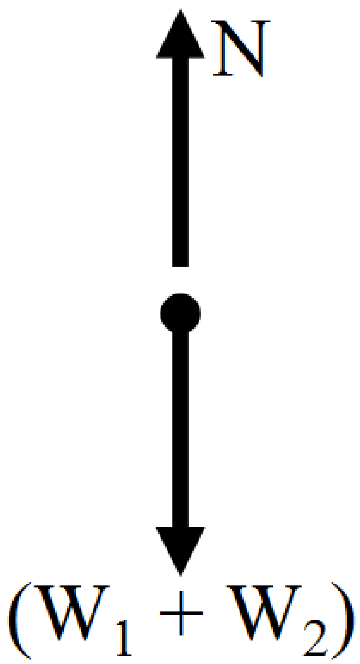
31. A body of weight w_1 is suspended from the ceiling of a room through a chain of weight w_2. The ceiling pulls the chain by a force:

a. w_1
b. w_2
c. $w_1 + w_2$
d. $\frac{w_1+w_2}{2}$

Ans. :

c. $w_1 + w_2$

Explanation:



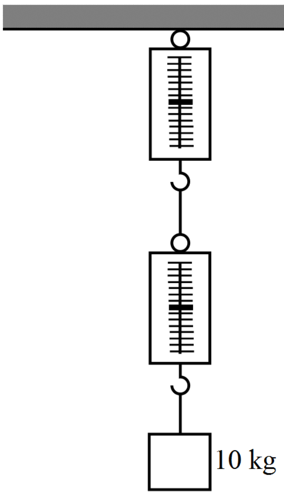
From the free-body diagram,

$(w_1 + w_2) - N = 0$

$N = w_1 + w_2$

The ceiling pulls the chain by a force $(w_1 + w_2)$.

32. A block of mass 10kg is suspended through two light spring balances as shown in figure:

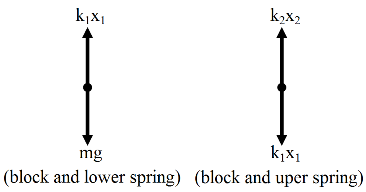


a. Both the scales will read 10kg.
b. Both the scales will read 5kg.
c. The upper scale will read 10kg and the lower zero.
d. The readings may be anything but their sum will he 10kg.

Ans. :

a. Both the scales will read 10kg.

Explanation:



From the free-body diagram,

$K_1x_1 = mg = 10 \times 9.8 = 98N$

$K_2x_2 = K_1x_1$

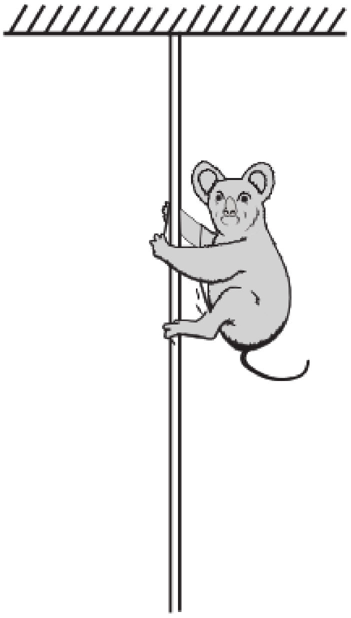
So, $K_1x_1 = K_2x_2 = 98N$

* **Answer The Following Questions In One Sentence.[1 Marks Each]** **[11]**

33. A batsman hits back a ball straight in the direction of the bowler without changing its initial speed of $12ms^{-1}$. If the mass of the ball is $0.15kg$, determine the impulse imparted to the ball. (Assume linear motion of the ball)

Ans. : Change in momentum
$= 0.15 \times 12-(-0.15\times12)$
$= 3.6$ N s,
Impulse = 3.6 N s,
in the direction from the batsman to the bowler. This is an example where the force on the ball by the batsman and the time of contact of the ball and the bat are difficult to know, but the impulse is readily calculated.

34. A monkey of mass 40kg climbs on a rope (Fig.) which can stand a maximum tension of 600 N. In which of the following cases will the rope break: the monkey,



a. Climbs up with an acceleration of $6ms^{-2}$.
b. Climbs down with an acceleration of $4ms^{-2}$.
c. Climbs up with a uniform speed of $5ms^{-1}$.
d. Falls down the rope nearly freely under gravity?

(Ignore the mass of the rope).

Ans. : <u>Case</u> (a)

Mass of the monkey, m = 40kg

Acceleration due to gravity, g = 10m/s

Maximum tension that the rope can bear, T_{max} = 600N

Acceleration of the monkey, a = $6m/s^2$ upward

Using Newton's second law of motion, we can write the equation of motion as:

T - mg = ma

$\therefore$ T = m(g + a)

= 40(10 + 6)

= 640N

Since T > T_{max}, the rope will break in this case.

<u>Case</u> (b)

Acceleration of the monkey, a = $4m/s^2$ downward

Using Newton's second law of motion, we can write the equation of motion as:

mg - T = ma

$\therefore$ T = m (g - a)

= 40(10 - 4)

= 240N

Since T < T_{max}, the rope will not break in this case.

<u>Case</u> (c)

The monkey is climbing with a uniform speed of 5 m/s. Therefore, its acceleration is zero, i.e., a = 0.

Using Newton's second law of motion, we can write the equation of motion as:

T - mg = ma

T - mg = 0

$\therefore$ T = mg

= 40 × 10

= 400 N

Since $T < T_{max}$, the rope will not break in this case.

Case (d)

When the monkey falls freely under gravity, its will acceleration become equal to the acceleration due to gravity, i.e., a = g

Using Newton's second law of motion, we can write the equation of motion as:

mg - T = mg

$\therefore$ T = m(g - g) = 0

Since $T < T_{max}$, the rope will not break in this case.

35. Two objects having different masses have same momentum.Which one of them will move faster?

Ans. : Object with smaller mass.

36. Two masses are in the ratio 1 : 5. What is the ratio of their inertia?

Ans. : Mass is a measure of inertia.

$\therefore\ 1:5.$

37. What is the acceleration of a train travelling at $50ms^{-1}$ as it goes round a curve of 250m radius?

Ans. : Given, velocity, v = $50ms^{-1}$

Radius, r = 250m

Centripetal acceleration, $\mathrm{a}=\frac{\mathrm{v}^2}{\mathrm{r}}$

$\mathrm{a}=\frac{50\times50}{250}=10\mathrm{ms}^{-2}$

38. Calculate the force acting on a body whose linear momentum changes from $20kg\ ms^{-1}$ to $40kg\ ms^{-1}$ in 10s.

Ans. : Force = rate of change of linear momentum $=\frac{20}{10}=2\mathrm{N}.$

39. What is the apparent weight of a man of mass 60kg who is standing on a lift which is moving up with a uniform speed? ($g = 10ms^{-2}$)

Ans. : When lift moves with uniform speed acceleration is zero.

Apparent weight = mg = 60 × 10 = 600N

40. A ball moving with a momentum of $5kg\ ms^{-1}$ strikes against a wall at an angle of 45° and is reflected at the same angle and with same speed. Find the change in momentum of the ball.

Ans. : $\Delta \mathrm{p}=2 \mathrm{~mv} \cos \theta$
$=2 \times 5 \times \cos 45^{\circ}$
$=5 \sqrt{2} \mathrm{~kg} \mathrm{~m} / \mathrm{s}$

41. A heavy point mass tied to the end of string is whirled in a horizontal circle of radius 20cm with a constant angular speed. What is angular speed if the centripetal acceleration is 980cm/ s^{-2}?

Ans. : Here, radius r = 20cm

Centripetal acceleration, = 980cm/ s^{-2}

We know that centripetal acceleration, $\mathrm{a}=\mathrm{r} \omega^{2}$

$\omega=\sqrt{\frac{\mathrm{a}}{\mathrm{r}}}=\sqrt{\frac{980}{20}}$
$\omega=\sqrt{49}=7 \mathrm{rad} / \mathrm{s}$

42. A body of mass 25g is moving with a constant velocity of 5m/ sec on a horizontal frictionless surface in vacuum. What is the force acting on the body?

Ans. : Zero.

43. A stone is fastened to one end of a string and is whirled in a vertical circle of radius R. Find the minimum speed the stone can have at the highest point of the circle.

Ans. : At the highest point of a vertical circle

$\frac{\mathrm{mv}^{2}}{\mathrm{R}}=\mathrm{mg}$
$\Rightarrow \mathrm{v}^{2}=\mathrm{Rg} \Rightarrow \mathrm{v}=\sqrt{\mathrm{Rg}}$

* **Given Section consists of questions of 2 marks each.** **[28]**

44. A bullet of mass $0.04 kg$ moving with a speed of $90 m s^{-1}$ enters a heavy wooden block and is stopped after a distance of $60 cm$. What is the average resistive force exerted by the block on the bullet?

Ans. : The retardation ' a ' of the bullet (assumed constant) is given by
$a=\frac{-u^{2}}{2 s}=\frac{-90 \times 90}{2 \times 0.6} m s^{-2}=-6750 m s^{-2}$
The retarding force, by the second law of motion, is
$=0.04\ kg\ 6750\ m s^{-2}=270 N$
The actual resistive force, and therefore, retardation of the bullet may not be uniform. The answer therefore, only indicates the average resistive force.

45. Define centripetal force. A cyclist speeding at 18km/ hr on a level road takes a sharp circular turn of radius 3m without reducing the speed. The coefficient of static friction is 0.1. Will the cyclist slip while taking the turn?

Ans. : The force on the body towards the centre while it is moving is a circular path.

The condition for the cyclist not to slip is

$\mathrm{V}^{2} \leq \mu_{\mathrm{s}} \times \mathrm{R} \times \mathrm{g}$
$\mathrm{V}^{2} \leq 0.1 \times 3 \times 9.8$

$V^2 = 2.94 m^2/s^2$

But the speed of the cyclist is

$18 km/hr = 5 m/s$

$\therefore V^2 = 25 m^2/s^2$

$\therefore$ The condition is not obeyed

$\therefore$ The cyclist will slip.

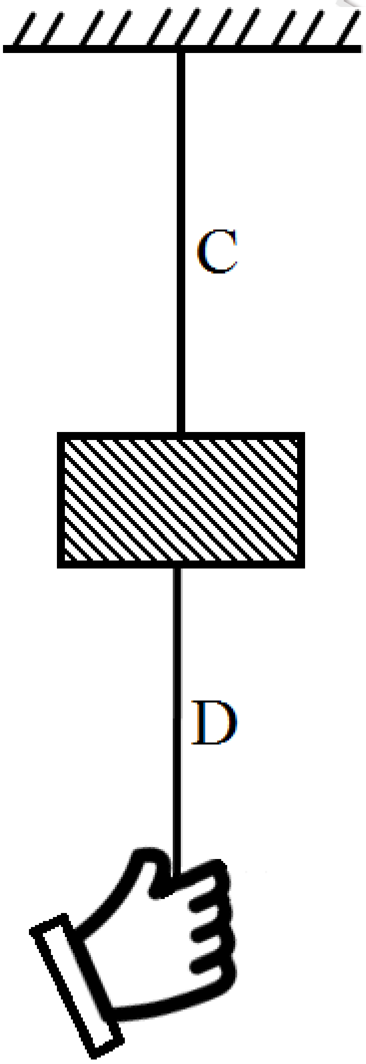
46. A car of mass 1000kg moving with a speed of $30ms^{-1}$ collides with the back of a stationary lorry of mass 9000kg. (Fig.). Calculate the speed of the vehicles immediately after the collision if they remain jammed together.

Ans. : Using conservation of momentum,

$(1000 + 9000)v = 1000 \times 30 + 9000 \times 0$ or

$V = \frac{1000\times30}{10000} m/s^{-1} = 3ms^{-1}$.

47. A block is supported by a cord C from a rigid support, and another cord D is attached to the bottom of the block. If you give a sudden jerk to D, it will break. But if you pull on D



steadily, C will break. Why?

Ans. : String C breaks because C is stretched more than D. This is because C was already in stretched state due to large weight. When D is given a jerk, the load will receive only a small acceleration due to its large mass. Thus, C will not be further stretched but D will exceed the safe limit and break.

48. A hammer of mass 1kg strikes on the head of a nail with a velocity of 10m s^{-1}7.It drives the nail 1cm into a wooden block. Calculate the force applied by the hammer and the time of impact.

Ans. : Here mass of hammer M = 1kg, when hammer strikes the nail with a velocity of 10ms^{-1} and as mass of nail is extremely small, hence nail also starts moving with same velocity. Thus, for nail u = 10ms^{-1}, v = 0 and s = 1cm = 0.01m.

Using the relation $v^2 - u^2 = 2$ as, we get

$(0)^2 - (10)^2 = 2 \times a \times (0.01)$

$\Rightarrow a = -\frac{10 \times 10}{2 \times 0.01} = -5 \times 10^3 ms^{-2}$

and using relation v = u + at, we have

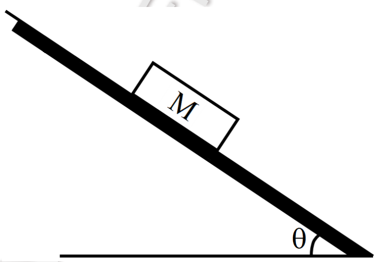
$0 = 10 - 5 \times 10^{-3}. t$

$\Rightarrow t = \frac{10}{5 \times 10^3} = 2 \times 10^{-3}s$ or $2ms$

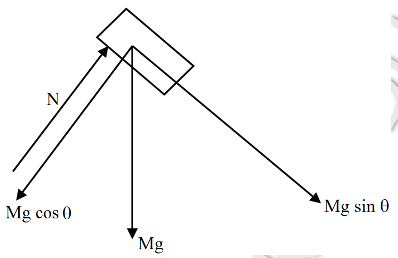
$\therefore$ Force exerted by the hammer on the nail $\frac{\Delta p}{\Delta t} = \frac{Mu - 0}{\Delta t}$

$= \frac{1 \times 10}{2 \times 10^{-3}} = 5 \times 10^3 N.$

49. A block of mass M is placed on a frictionless, inclined plane of angle θ, as shown in the figure. Determine the acceleration of the block after it is released. What is force exerted by the incline on the block?



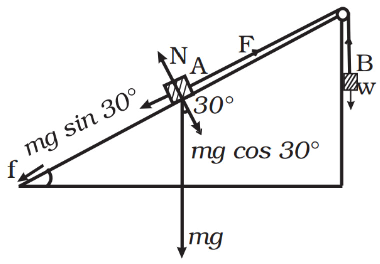
Ans. : When the block is released, it will move down the incline. Let its acceleration be a. As the surface is frictionless, so the contact force will be normal to the plane. Let it be N. Here, for the block we can apply equation for motion along the plane and equation for equilibrium perpendicular to the plane.



i.e., $Mg \sin\theta = Ma \Rightarrow a = g \sin\theta$

Also, $Mg \cos\theta - N = 0 \Rightarrow N = Mg \cos\theta.$

50. Block A of weight 100N rests on a frictionless inclined plane of slope angle 30° A flexible cord attached to A passes over a frictonless pulley and is connected to block B of weight W. Find the weight W for which the system is in equilibrium.



Ans. : Main concept used: On balanced condition i.e., no motion then no frictional force or f = 0

Explanation:

During equilibrium of A or B

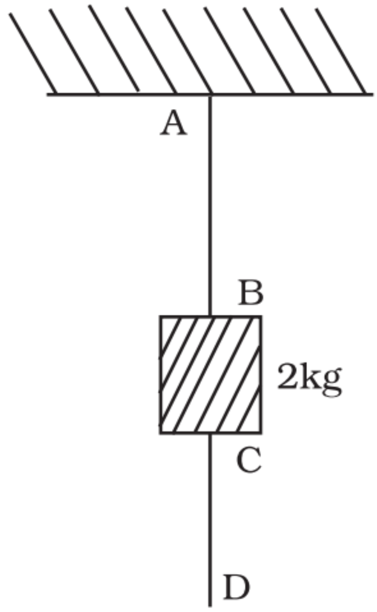
$\mathrm{mg}\sin 30^\circ = \mathrm{f}$

$\frac{1}{2}\mathrm{mg} = \mathrm{F}\ [\because \mathrm{mg} = 100\ \mathrm{N}]$

$\therefore \mathrm{F} = \frac{1}{2} \times 100 = 100 = 50$

For B is at rest W = F =50N.

51. A mass of 2kg is suspended with thread AB Thread CD of the same type is attached to the other end of 2kg mass. Lower thread is pulled gradually, harder and harder in the downward directon so as to apply force on AB. Which of the threads will break and why?



Ans. : Thread AB will break. Force on CD is equal to the force (f) applied at D downward, but the force on thread AB is equal to the force F along with force due to mass 2kg downward. so the force on AB is 2kg more than applied force at D.Hence the thread AB will break up.

52. A person of mass 50kg stands on a weighing scale on a lift. If the lift is descending with a downward acceleration of 9m s^{-2}, what would be the reading of the weighing scale? (g = 10m s^{-2})

Ans. : When lift is descending with acceleration a, the apparent weight decreases on weighing scale

$\therefore \mathrm{W}' = \mathrm{R} = (\mathrm{mg} - \mathrm{ma}) = \mathrm{m}(\mathrm{g} - \mathrm{a})$

Apparent weight due to reaction force by the lift on weighing scale.

$\therefore W' = 50(10-9) = 50N$

Reading of weighing scale $= \frac{R}{g} = \frac{50}{10} = 5kg$

53. A woman throws an object of mass 500g with a speed of 25m s^1. What is the impulse imparted to the object?

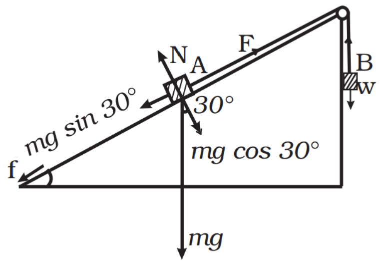
Ans. : Mass of object m = 500 g = 0.5kg

u = 0, v = 25m/ s

Impulse $\vec{F}.dt = \frac{d\vec{p}}{dt} = d\vec{p} = m\vec{v} - m\vec{u}$

$I = \Delta\vec{p} = m(\vec{v} - \vec{u}) = 0.5(25.5)N - s$

54. Block A of weight 100N rests on a frictionless inclined plane of slope angle 30° A flexible cord attached to A passes over a frictonless pulley and is connected to block B of weight W. Find the weight W for which the system is in equilibrium.



Ans. : Main concept used: On balanced condition i.e., no motion then no frictional force or f = 0

Explanation:

During equilibrium of A or B

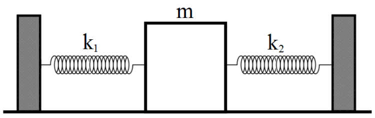
$mg\sin 30^\circ = f$

$\frac{1}{2}mg = F\ [\because mg = 100\ N]$

$\therefore F = \frac{1}{2} \times 100 = 100 = 50$

For B is at rest W = F =50N.

55. Both the springs shown in figure are unstretched. If the block is displaced by a distance x and released, what will be the initial acceleration?



Ans. : Let, the block m towards left through displacement x.

$F_1 = k_1x$ (compressed)

$F_2 = k_2x$ (expanded)

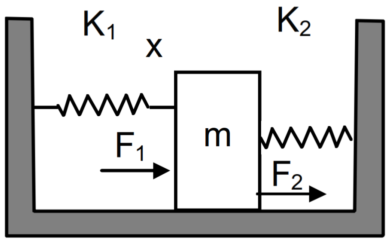
They are in same direction.

Resultant $F = F_1 + F_2$

⇒ $F = k_1x + k_2\,x$

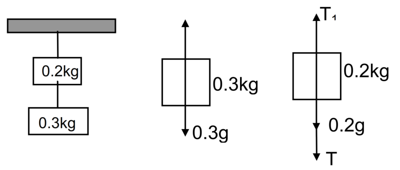
⇒ $F = x(k_1 + k_2)$

So, a = acceleration $= \frac{F}{m} = \frac{x(k_1+k_2)}{m}$ opposite to the displacement.



56. A block of mass 0.2kg is suspended from the ceiling by a light string. A second block of mass 0.3kg is suspended from the first block through another string. Find the tensions in the two strings. Take g = 10m/s^2.

Ans. :



g = 10m/s^2

T - 0.3g = 0

⇒ T = 0.3g = 0.3 × 10 = 3N

⇒ T_1 - (0.2g + T) = 0

⇒ T = 0.2g + T = 0.2 × 10 + 3 = 5N

∴ Tension in the two strings are 5N & 3N respectively.

57. A car moving at 40km/h is to be stopped by applying brakes in the next 4.0m. If the car weighs 2000kg, what average force must be applied on it?

Ans. : $\mathrm{u} = 40\mathrm{km/hr} = \frac{40000}{3600} = 11.11\mathrm{m/s}.$

$\mathrm{m} = 20000\mathrm{kg}; \mathrm{v} = 0; \mathrm{s} = 4\mathrm{m}$

acceleration 'a' $= \frac{\mathrm{v}^2 - \mathrm{u}^2}{2\mathrm{s}} = \frac{0^2 - (11.11)^2}{2 \times 4} = -\frac{123.43}{8}$

$= -15.42\mathrm{m/s}^2(\text{deceleration})$

So, braking force = F = ma = 2000 × 15.42 = 30840 = 3.08 × 10^{4}N

*** Given Section consists of questions of 3 marks each. [129]**

58. See Fig. 4.11. A mass of 4 kg rests on a horizontal plane. The plane is gradually inclined until at an angle θ = 15° with the horizontal, the mass just begins to slide. What is the coefficient of static friction between the block and the surface ?

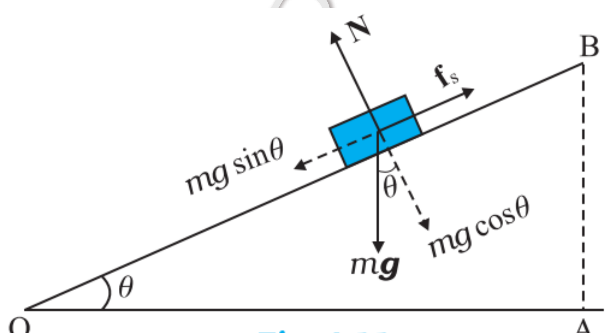


Fig. 4.11

Ans. : The forces acting on a block of mass m at rest on an inclined plane are (i) the weight mg acting vertically downwards (ii) the normal force N of the plane on the block, and (iii) the static frictional force f_s opposing the impending motion. In equilibrium, the resultant of these forces must be zero. Resolving the weight mg along the two directions shown, we have

$$mg\sin\theta = f_s, \quad mg\cos\theta = N$$

As θ increases, the self-adjusting frictional force f_s increases until at $\theta = \theta_{\max}$, f_s achieves its maximum value, $(f_s)_{\max} = \mu_s N$.

Therefore,

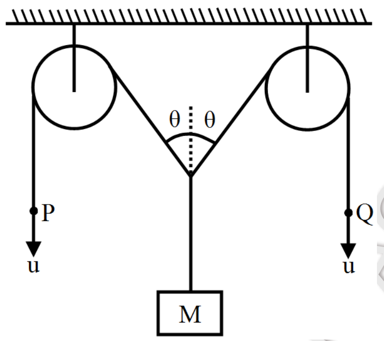
$$\tan\theta_{\max} = \mu_s \text{ or } \theta_{\max} = \tan^{-1}\mu_s$$

When θ becomes just a little more than $\theta_{\max}$, there is a small net force on the block and it begins to slide. Note that $\theta_{\max}$ depends only on μ_s and is independent of the mass of the block.

For

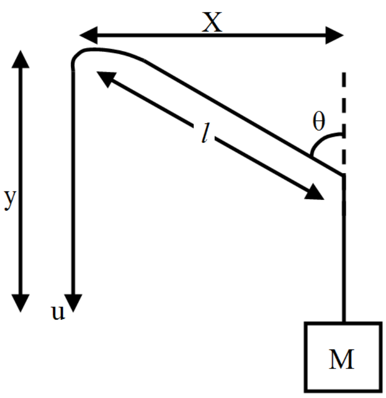
$$\begin{aligned}\theta_{\max} &= 15^\circ \\ \mu_s &= \tan 15^\circ \\ &= 0.27\end{aligned}$$

59. In the given arrangement, if the points P and Q move down with a velocity u, find the velocity of M?



Ans. : Using Pythagoras theorem, $l^2 = x^2 + y^2$.

Differentiating both sides, (w.r.t. time)



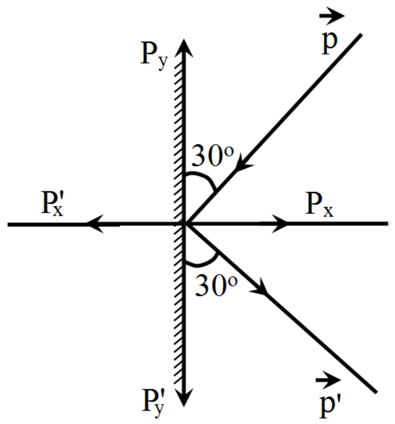
$2l\frac{dl}{dt} = 2y\frac{dy}{dt}$ since x is constant.

$\frac{dy}{dt} = \frac{l}{y}\frac{dl}{dt} = \frac{1}{\cos\theta}.\mathbf{u}$

$\therefore$ Velocity of M going up $= \frac{u}{\cos\theta}$

60. A ball moving with a momentum of 15kg ms^{-1} strikes against the wall at an angle of 30° and is reflected with the same momentum at the same angle. Calculate impulse.

Ans. : Initial momentum $\vec{P} = 15\text{kg m/s}$



Resolving it into two components

$\mathrm{p_y = p\cos 30^\circ,\ p_x = p\sin 30^\circ}$

Final momentum $\overrightarrow{\mathrm{p'}} = 15\text{kg m/s}$

$\therefore\ \vec{\mathrm{p}} = -\overrightarrow{\mathrm{p'}}$

Resolving $\vec{\mathrm{p}}$ into two components

$\mathrm{p'_y = p'\cos 30^\circ, p'_x = p'\sin 30^\circ}$

The two x-components are in opposite direction so they cancel out.

$\therefore$ Impulse = change in momentum

$= \mathrm{p_y + p'_y = 2 \times p\cos 30^\circ}$

$= 30 \times \frac{\sqrt{3}}{2} = 15\sqrt{3}\text{kg m/s}$

61. A cricket ball of mass 150g is moving with a velocity of 12ms^{-1} and is hit by a bat so that the ball is turned back with a velocity of 20ms^{-1}. The force of the blow acts for 0.01s. Find the average force exerted on the ball by the bat.

Ans. : The impulse of the force exerted by the bat is given by the change in the momentum of the ball. Now,

Initial momentum of the ball $= \frac{150}{1000} \times 12\text{kg/ ms}^{-1}$

Final momentum of the ball $= -\frac{150}{1000} \times 20\text{kg/ ms}^{-1} = -3.0\text{kg/ ms}^{-1}$

Change in the momentum of the ball $= [1.8 - (-3.0)]\text{kg/ ms}^{-1}$

$= 4.8\text{kg/ ms}^{-1}$

This equals the impulse of the force exerted by the bat. Since

Impulse = force × time

We have,

Average force exerted $= \frac{\text{Impulse}}{\text{time}} = \frac{4.8\text{kg/ ms}^{-1}}{0.01\text{s}}$

$= 480\text{kg/ ms}^{-2} = 480\text{N}.$

62. A bomb at rest explodes into three parts of the same mass. The moments of the two parts is –2p_i and p_j. What will be the momentum of the third part?

Ans. : Since initial momentum is zero, the final momentum should also be zero. Let the momentum of third part be p_3.

$$\therefore \quad -2p_i + p_j + p_3 = 0$$
$$\Rightarrow \; P_3 = 2p_i - p_j$$
$$\Rightarrow \; |p_3| = p\sqrt{2^2 + (-1)^2}$$
$$= \sqrt{5}p$$

and is directed at an angle $\theta = \tan^{-1}\left(\frac{-1}{2}\right)$ with the x-axis.

63. A body of mass 2kg is being dragged with a uniform velocity of $2ms^{-1}$ on a rough horizontal plane. The coefficient of friction between the body and the surface is 0.2. Calculate the amount of heat generated per second. Take g = $9.8ms^{-2}$ and J = 4.2J/ cal^{-1}.

Ans. : Given, $m = 2kg, u = 2ms^{-1}, \mu = 0.2$

Force of friction, $F = \mu R$

$$F = \mu mg \; [\because R = mg]$$
$$F = 0.2 \times 2 \times 9.8$$
$$F = 3.92N$$

Distance moved per second s = ut,

$$s = 2 \times 1 = 2$$

Work done by friction per second, W = Fs

$$W = 3.92 \times 2 = 7.84J$$

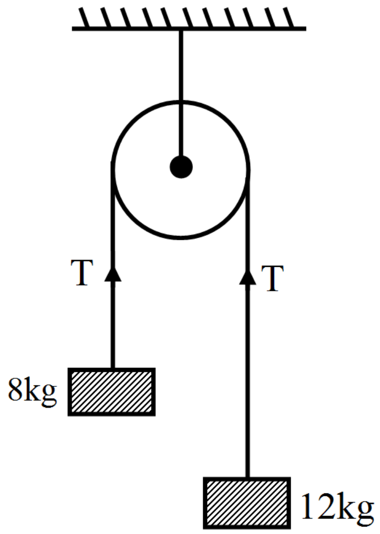
Heat produced, $H = \frac{W}{J} \Rightarrow H = \frac{7.84}{4.2}$

$$h = 1.87cal.$$

64.

a. Explain the term impulse. Show that impulse of a variable force is equal to the area enclosed by the force-time curve.

b. Two masses 8kg and 12kg are connected at the two ends of a light inextensible string that passes over a frictionless pulley. Find the acceleration of the masses and tension in the string, when the masses are released.

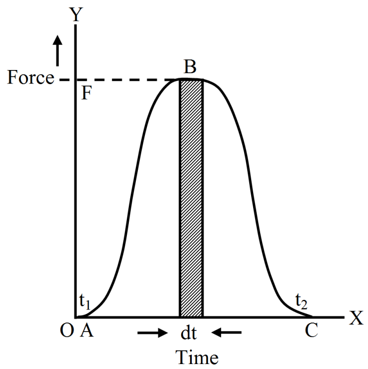


Ans. :

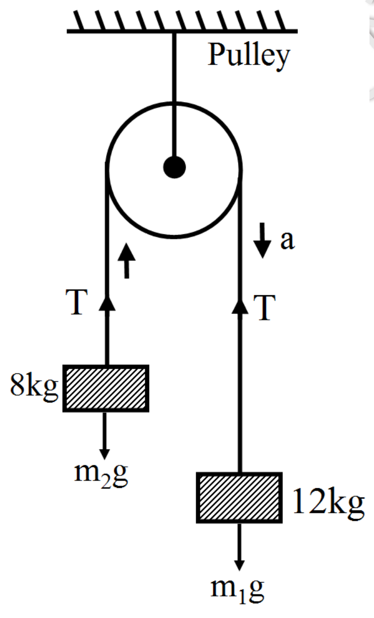
a. The product of the force and the time interval on which it acts or change in momentum is called impulse.

$$\vec{\mathrm{I}} - \vec{\mathrm{F}}_{\mathrm{av}} \times \mathrm{t} = \mathrm{dp} = \mathrm{F.dt} = \text{Area of shaded portion}$$

$$\text{Net impulse} = \int_{t_1}^{t_2} \vec{\mathrm{F}} \times \mathrm{dt} = \text{area under graph ABC and time axis.}$$



b. Consider two masses m_1 and m_2 are connected to the ends of an inextensible string passing over a smooth frictionless pulley.



Let T be the tension in the string which is uniform throughout.

The heavier mass m_1 moves downward with an acceleration a.

The resultant downward force while considering the heavier mass m, is given by

m_1g - T = m_1a ...(i)

The resultant upward force while considering the lighter mass m_2 is given by

T - m_2g = m_2a ...(ii)

Adding (i) and (ii), we have

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

$\Rightarrow \ \mathrm{a} = \left(\frac{\mathrm{m}_1 - \mathrm{m}_2}{\mathrm{m}_1 + \mathrm{m}_2}\right)\mathrm{g} \ldots \text{(iii)}$

Putting the value of a in (i) and simplifying we get

$\mathrm{T} = \frac{2\mathrm{m}_1\mathrm{m}_2}{\mathrm{m}_1 + \mathrm{m}_2}\mathrm{g} \ldots \text{(iv)}$

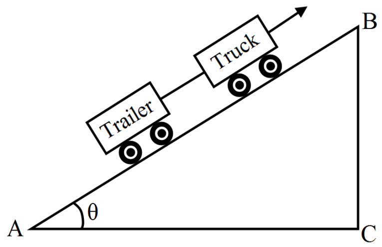
Substituting the given values, we have

$\Rightarrow \ \mathrm{a} = \left(\frac{12-8}{12+8}\right) \times 9.8 = 1.96\mathrm{ms}^{-2}$

$\mathrm{T} = \frac{2 \times 12 \times 8 \times 9.8}{12+8} = \frac{1881.6}{20}$

$= 64.08\mathrm{N}$

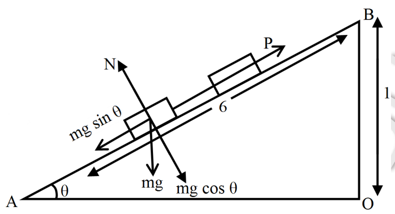
65. A truck tows a trailer of mass 1200kg at a speed of $10ms^{-1}$ on a level road. The tension in the coupling is 1000N. What is the power extended on the trailer? Find the tension in the coupling when the truck ascends a road having an inclination of 1 in 6. Assume that the frictional resistance on the inclined plane is the same as that on the level road.



Ans. : Force applied by the truck = 1000N

Power or work done per second

$= \frac{\mathrm{F} \times \mathrm{S}}{\mathrm{t}} = 1000 \times \frac{10}{1} = 10^4\mathrm{W}$



When the truck ascends a road having an inclination of 1 in 6, i.e., if OB = 1, AB = 6, then it has to apply not only a forward force of 1000N to overcome friction, but also will have to overcome downward component of weight, i.e., $\mathrm{mg} \ \sin\theta$.

$\therefore$ Tension in the coupling,

P = forward force $= 1000 + \mathrm{mg}\sin\theta$

$= 1000 + 1200 \times 9.8 \times \frac{1}{6}$

or P = 2960N

Thus, the required tension in the coupling is 2960N.

66. A constant retarding force of 50N is applied to a body of mass 20kg moving initially with a speed of $15ms^{-1}$. How long does the body take to stop?

Ans. : Retarding force, F = –50N

Mass of the body, m = 20kg

Initial velocity of the body, u = 15m/s

Final velocity of the body, v = 0

Using Newton's second law of motion, the acceleration (a) produced in the body can be calculated as:

F = ma

–50 = 20 × a

$\therefore \mathrm{a} = \frac{-50}{20} = -2.5\mathrm{ms}^{-2}$

Using the first equation of motion, the time (t) taken by the body to come to rest can be calculated as:

v = u + at

$\therefore \mathrm{t} = \frac{-\mathrm{u}}{\mathrm{a}} = \frac{-15}{-2.5} = 6\mathrm{s}$

67. A man of mass 70kg stands on a weighing scale in a lift which is:

a. Moving upwards with a uniform speed of 10m/ s.

b. Moving down with a uniform acceleration of 5m/ s^2.

c. Freely falling under gravity.

What would be reading on the scale in each case?

Ans. : m = 70kg

a. Uniform speed of $10ms^{-1}$.

Since a = 0, weight = mg = 700N.

b. For uniform downward acceleration,

N = mg - ma.

∴ Weight = mg - ma = 700 - 70 × 5 = 350N.

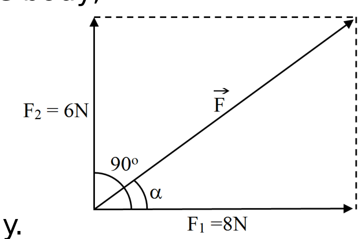
c. Force free fall N = 0.

∴ Weight felt is zero.

68. Two mutually perpendicular forces of 8N and 6N acts on the same body of mass 10kg. Calculate

i. Net force acting on the body,

ii. Magnitude of the acceleration of the body,



iii. Direction of acceleration of the body.

Ans. : Here $\mathrm{m} = 10\mathrm{kg}, \mathrm{F}_1 = 8\mathrm{N}$,

$\mathrm{F}_2 = 6\mathrm{N}, \theta = 90^\circ$

i. Net force action on the body is,

$$F = \left[F_1^2 + F_2^2 + 2F_1F_2\cos\theta\right]^{\frac{1}{2}}$$

$$= \left[F_1^2 + F_2^2\right]^{\frac{1}{2}} \; [\because \cos\theta = \cos 90^\circ = 02]$$

$$= \left[8^2 + 6^2\right]^{\frac{1}{2}} = 10 \text{ or } F = 10N$$

ii. Now, $F = m, a$

$$\therefore a = \frac{F}{m} = \frac{10N}{10kg} = 1ms^{-2}$$

iii. Let α be the angle made by resultant force (F) or the acceleration with F_1

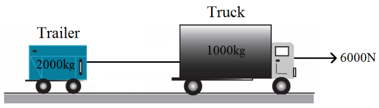
$$\therefore \tan\alpha = \frac{F_2}{F_1} = \frac{6}{8} = \frac{3}{4} = 0.7500$$

$$\alpha = 36^\circ 53'$$

$\therefore$ Magnitude of acceleration = $1ms^{-2}$ and it makes an angle of 36º 53' with 8N force.

69. A truck of mass 1000kg is pulling a trailer of mass 2000kg as shown. The retarding (frictional) force on the truck is 500N and that on the trailer is 1000N. The truck engine exerts a force of 6000N. Calculate:

   i. The acceleration of the truck and the trailer.
   ii. The tension in the connecting rope.



Ans. :

i. The net force f_1 exerted on the trailer in the direction of f_1 = (T - 1000)N, where T is tension in the connecting rope.

$\therefore$ T - 1000 = 2000a ...(i)

Similarly, the net force f_2 exerted by the engine of the truck is given by,

f_2 = (6000 - 500 - T) = 1000a

or 5500 - T = 1000a ...(ii)

Adding (i) and (ii), we have

4500 = 3000a

$$\text{or } a = \frac{4500}{3000} = 1.5 \text{ ms}^{-2}$$

ii. Putting the value of 'a' in (i) we have,

T = 1000 + 2000a

= 1000 + 2000 × 1.5

= 4500N

70. A man of mass 70kg stands on a weighing scale in a lift which is moving. Upwards with a uniform acceleration of $5ms^{-2}$. What would be the readings on the scale in each case?

Ans. : Mass of the man, m = 70kg

Acceleration, a = $5m/s^2$ upward

Using Newton’s second law of motion, we can write the equation of motion as:

R - mg = ma

R = m(g + a)

= 7(10 + 5) = 70 × 15

= 1050N

∴ Reading on the weighing scale $= \frac{1050}{\mathrm{g}} = \frac{1050}{10} = 105\mathrm{kg}$

71. See Fig. 4.8. A mass of $6kg$ is suspended by a rope of length $2m$ from the ceiling. A force of $50N$ in the horizontal direction is applied at the midpoint P of the rope, as shown. What is the angle the rope makes with the vertical in equilibrium? (Take $g = 10ms^{-2}$). Neglect the mass of the rope.

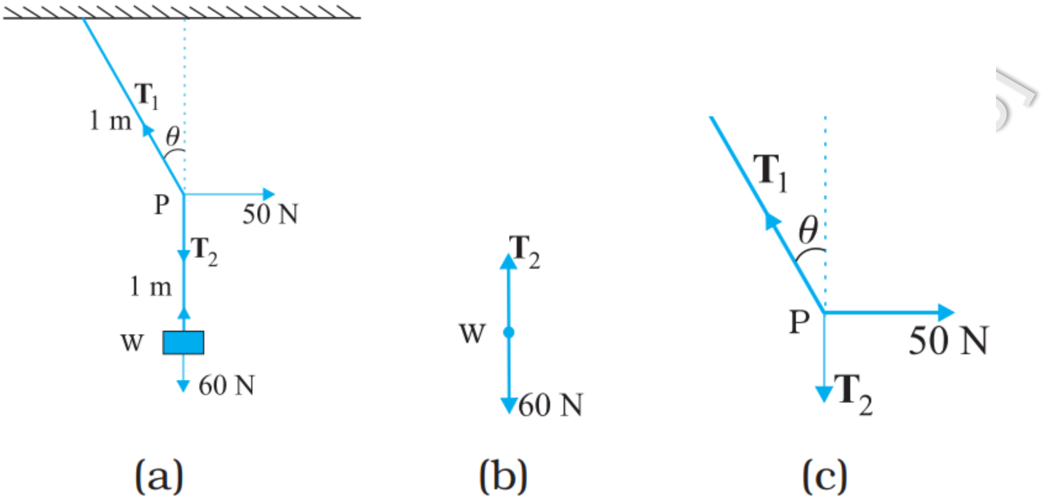


Fig. 4.8

Ans. : Figures 4.8(b) and 4.8(c) are known as free-body diagrams. Figure 4.8(b) is the free-body diagram of W and Fig. 4.8(c) is the free-body diagram of point P. Consider the equilibrium of the weight W. Clearly, $T_2 = 6 \times 10 = 60N$. Consider the equilibrium of the point P under the action of three forces - the tensions T_1 and T_2, and the horizontal force $50N$. The horizontal and vertical components of the resultant force must vanish separately :

$T_1 \cos\theta = T_2 = 60N$

$T_1 \sin\theta = 50N$

which gives that

$\tan\theta = \frac{5}{6}$ or $\theta = \tan^{-1}\left(\frac{5}{6}\right) = 40^\circ$

Note the answer does not depend on the length of the rope (assumed massless) nor on the point at which the horizontal force is applied.

72. A man of mass 70kg stands on a weighing scale in a lift which is moving. What would be the reading if the lift mechanism failed and it hurtled down freely under gravity?

Ans. : When the lift moves freely under gravity, acceleration a = g

Using Newton's second law of motion, we can write the equation of motion as:

R + mg = ma

R = m(g – a)

= m(g - g) = 0

∴ Reading on the weighing scale $\frac{0}{\mathrm{g}} = 0\mathrm{kg}$

The man will be in a state of weightlessness.

73. A rocket with a lift-off mass 20,000kg is blasted upwards with an initial acceleration of $5.0ms^{-2}$. Calculate the initial thrust (force) of the blast.

Ans. : Given:

Mass of the rocket, m = 20,000kg

Initial acceleration, $a = 5m/s^2$

Acceleration due to gravity, $g = 10m/s^2$

Using Newton's second law of motion, the net force (thrust) acting on the rocket is given by the relation:

(F - mg) = ma

F = m(g + a)

$= (20000 \times (10 + 5)) = (20000 \times 15) = 3 \times 10^5 N$

74. A bob of mass 0.1kg hung from the ceiling of a room by a string 2m long is set into oscillation. The speed of the bob at its mean position is $1ms^{-1}$. 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 its mean position.

Ans. :

a. **Vertically downward:** At the extreme position, the velocity of the bob becomes zero. If the string is cut at this moment, then the bob will fall vertically on the ground.

b. **Parabolic path:** At the mean position, the velocity of the bob is 1m/s. The direction of this velocity is tangential to the arc formed by the oscillating bob. If the bob is cut at the mean position, then it will trace a projectile path having the horizontal component of velocity only. Hence, it will follow a parabolic path.

75. A constant retarding force of 50N is applied to a body of mass 20kg moving initially with a speed of $15ms^{-1}$. How long does the body take to stop?

Ans. : Retarding force, F = –50N

Mass of the body, m = 20kg

Initial velocity of the body, u = 15m/s

Final velocity of the body, v = 0

Using Newton's second law of motion, the acceleration (a) produced in the body can be calculated as:

F = ma

–50 = 20 × a

$\therefore \mathrm{a} = \frac{-50}{20} = -2.5\mathrm{ms}^{-2}$

Using the first equation of motion, the time (t) taken by the body to come to rest can be calculated as:

v = u + at

$\therefore \mathrm{t} = \frac{-\mathrm{u}}{\mathrm{a}} = \frac{-15}{-2.5} = 6\mathrm{s}$

76. A man of mass 70kg stands on a weighing scale in a lift which is moving. Upwards with a uniform acceleration of $5ms^{-2}$. What would be the readings on the scale in each case?

Ans. : Mass of the man, m = 70kg

Acceleration, a = 5m/s^2 upward

Using Newton’s second law of motion, we can write the equation of motion as:

R - mg = ma

R = m(g + a)

= 7(10 + 5) = 70 × 15

= 1050N

∴ Reading on the weighing scale $= \frac{1050}{\mathrm{g}} = \frac{1050}{10} = 105\mathrm{kg}$

77. A cricket ball of mass 150g is moving with a velocity of 12ms^{-1}, and is hit by a bat, so that the ball is turned back with a velocity of 20ms^{-1}. The force of the blow acts for 0.01s on the ball. Find the average force exerted by the bat on the ball.

Ans. : Mass of the ball, m = 0.15kg

Initial velocity, u = 12ms^{-1}

final velocity v = -20ms^{-1}, t = 0.01s

Initial momentum of the ball

= 0.15 × 12 = 1.8kg ms^{-1}

Final momentum of the ball

= 0.15 × (-20) = -3.0kg ms^{-1}

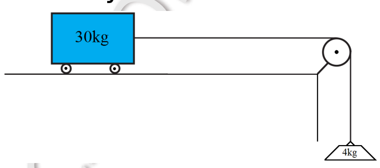
Change in momentum

= 4.8kg ms^{-1}

Average force exerted by the bat on the ball

$= \frac{4.8\mathrm{kg\ ms^{-1}}}{0.01\mathrm{s}} = 480\mathrm{N}$

78. Compute the acceleration of the block and trolley system as shown. If the coefficient of kinetic friction between the trolley and the surface is 0.04, what is the tension in the



string? [Take g = 10ms^{-2}]

Ans. : Let a be the acceleration produced in the block-trolley system. Considering forces acting on the weight 30kg

30 - T = 4a ...(i)

Kinetic friction, F$_k$ = μ(mass of trolley) × g

= 0.04 × 30 × 10 = 12N

Considering forces acting on trolley of mass 30kg, we have

T - F$_1$ = 30a

or T - 12 = 30a ...(ii)

Adding (i) and (ii), we get

28 = 34a

or $\mathrm{a} = \frac{28}{34} = 0.82\ \mathrm{ms}^{-2}$

Putting this value in (i), we get

T = 30 - 4 × 0.82

= 30 - 3.28

= 26.72N

79. The barrel of a gun is 1m long and it fires a bullet of mass 0.05kg with a muzzle velocity of 400ms^{-1}. Find:

a. The acceleration,

b. The force, and

c. The impulse given to the bullet by the gun.

Ans. : Here mass of bullet, m = 0.05kg, initial velocity of bullet before firing u = 0, length of barrel of gun, moving through which the bullet is accelerated s = 1m, final muzzle velocity of bullet v = 400ms^{-1}.

a. Using the relation v^2 - u^2 =2as, we have,

$(400)^2 - (0)^2 = 2 \times \mathrm{a} \times 1$,

$\Rightarrow \mathrm{a} = \frac{400 \times 400}{2 \times 1} = 8 \times 10^4 \mathrm{ms}^{-2}$,

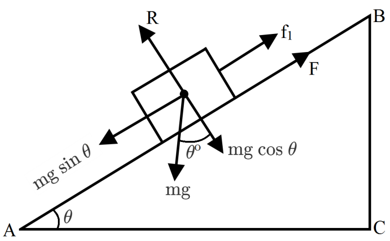
b. Force $\mathrm{F} = \mathrm{ma} = 0.05 \times 8 \times 10^4 = 4000\mathrm{N}$

c. Impulse given to the bullet by the gun, J = change in momentum of bullet

$= \mathrm{m}(\mathrm{v} - \mathrm{u}) = 0.05 \times (400 - 0) = 20\mathrm{Ns}.$

80. Define the term 'coefficient of limiting friction' between two surfaces. A body of mass 10kg is placed on an inclined surface of angle 30°. If the coefficient of limiting friction is $\frac{1}{\sqrt{3}}$ find the force required to just push the body up the inclined surface. The force is being applied parallel to the inclined surface.

Ans. : Coefficient of limiting friction between two surfaces in contact is defined as the ratio of force of limiting friction and normal reaction between them.



$\mathrm{m} = 10\mathrm{kg}$

$\theta = 30^\circ$

$\mu = \frac{1}{\sqrt{3}}.$

$\mathrm{R} = \mathrm{mg}\cos\theta$

Force of friction $\mathrm{F} = \mu\mathrm{R} = \mu\ \mathrm{mg}\ \cos\theta$

$= \frac{1}{\sqrt{3}} \times 10 \times 9.8 \times \cos 30^\circ$

$= \frac{1}{\sqrt{3}} \times 98 \times \frac{\sqrt{3}}{2} = 49\mathrm{N}$

$\mathrm{mg}\ \sin\theta = 10 \times 9.8 \times \sin 30^\circ$

$= 49\mathrm{N}$

Force required to push the body up inclined surface = (49 + 49) = 98N.

81. Define impulse. A cricket ball of mass 150gm moving with speed of 12m/ s is hit by a bat so that the ball is turned back with a velocity of 20m/ s. Calculate the impulse received by the ball.

Ans. : The product of force and the time on which it acts or change in momentum is called Impulse.

Momentum before the hit = $150 \times 12 \times 10^{-3}$

= 1.8kg ms^{-1}

Momentum after the hit = $150 \times 10^{-3} \times -20$

= -3kg ms^{-1}

$\therefore$ Impulse = change in momentum

= -4.8kg ms^{-1}

82. State law of conservation of momentum and prove it using third law of motion.

Ans. : When no external force acts on the body, the momentum remains conserved. According to third law, for every action there is an equal and opposite reaction. So if dp_1 and dp_2 are change in momentum of two masses m_1 and m_2 then,

$\frac{\mathrm{dp_1}}{\mathrm{dt}} = -\frac{\mathrm{dp_2}}{\mathrm{dt}},$

Since $F_1 = -F_2$

$\therefore \quad -\frac{\mathrm{d}}{\mathrm{dt}}(\mathrm{p_1} + \mathrm{p_2}) = 0,$

i.e., $p_1 + p_2$ = constant.

83. A motor car is travelling at 30m/ s on a circular road of radius 500m. It is increasing its speed at the rate of 2ms^2. What is the acceleration?

Ans. : Speed is 30m/ s, radius = 500m

Tangential acceleration $a_t = 2\text{m/ s}^2$

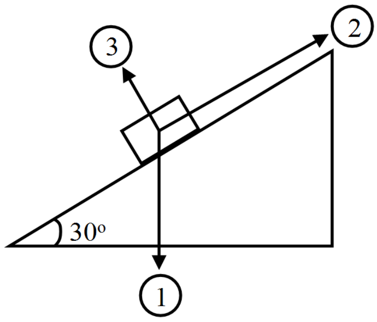
Centripetal acceleration,

$\mathrm{a_r} = \frac{\mathrm{v^2}}{\mathrm{r}} = \frac{900}{500} = 1.8\mathrm{ms}^{-2}$

Net acceleration $= \sqrt{\mathrm{a_r^2} + \mathrm{a_t^2}}$

$= \sqrt{2^2 + (1.8)^2} = 2.7\mathrm{m/s^2}$

84. A block of wood of mass 3kg is resting on the surface of a rough inclined surface,



inclined at an angle θ as shown in the figure:

a. Name the forces (1, 2, 3).

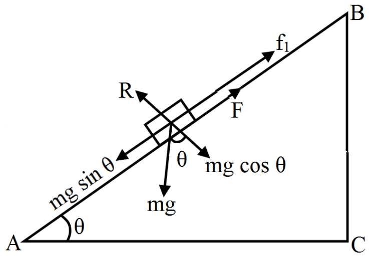
b. If the coefficient of static friction is 0.2, calculate the value of all the three forces. (may use $g = 10\text{m/ s}^2$)

Ans. :

a. Force 1 = weight = mg

Force 2 = force of limiting friction

Force 3 = Normal Reaction R



b. $\mu = 0.2,\ \mathrm{m} = 3\mathrm{kg}, \theta = 30^{\circ}$

Force 1 = weight = mg

= 3 × 10 = 30N

$\mathrm{Force}\ 2 = \mathrm{f}_1 = \mathrm{mg} \sin \theta - \mathrm{F}$

$\therefore\ \mathrm{mg} \sin \theta = 3 \times 10 \times \sin 30^{\circ} = 15\mathrm{N}$

And force of friction $\mathrm{F} = \mu \mathrm{R}$

$= \mu \mathrm{mg} \cos \theta$

$= 0.2 \times 3 \times 10 \cos 30^{\circ} = 3\sqrt{3}\mathrm{N}$

then force $2 = \mathrm{f}_1 = 15 - 3\sqrt{3} \approx 9.8\mathrm{N}$

Force 3 = Normal reaction R

$\therefore\ \mathrm{R} = \mathrm{mg} \cos \theta = 3 \times 10 \cos 30^{\circ}$

$= 15\sqrt{3}\mathrm{N}$

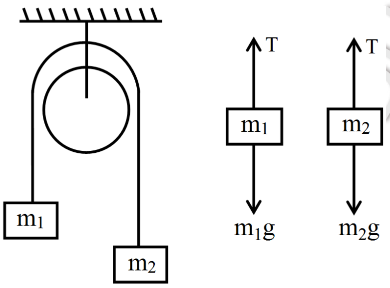
85. Two masses m_1 and m_2 are connected to the ends of a string passing over a pulley. Find the tension and acceleration associated.

Ans. : The pulley is frictionless, massless and fixed. The free body diagram for the two masses are shown along with the equation.

$\mathrm{m}_2 \mathrm{g} - \mathrm{T} = \mathrm{m}_2 \mathrm{a},$

$\mathrm{T} - \mathrm{m}_1 \mathrm{g} = \mathrm{m}_1 \mathrm{a}$

Solve the equations to get,



$\mathrm{a} = \frac{(\mathrm{m}_2 - \mathrm{m}_1)\mathrm{g}}{(\mathrm{m}_2 + \mathrm{m}_1)}$

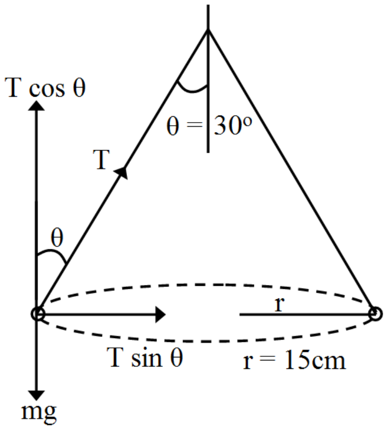
and $\mathrm{T} = \frac{2\mathrm{m}_1 \mathrm{m}_2 \mathrm{g}}{(\mathrm{m}_1 + \mathrm{m}_2)}$.

86. A cyclist goes round a circular track of 440 metres length in 20 seconds. Find the angle that the cycle makes with the vertical.

Ans. : Length of the track = 440m

$\therefore$ Radius $= \frac{440}{2\pi}$m

Speed $= \frac{2\pi r}{t} = \frac{440}{20} = 22\ ms^{-1}$



$\tan\theta = \frac{v^2}{rg}$

$\therefore\ \theta = \tan^{-1}\left[\frac{(22)^2}{\frac{440}{2\pi}\times g}\right] = 35^\circ 12'$

87. A woman throws an object of mass 500g with a speed of 25m s^1. If the object hits a wall and rebounds with half the original speed, what is the change in momentum of the object?

Ans. : $m = 0.5kg\ \ u = +25ms^{-1}$(Forword)

$v = \frac{-25}{2}ms^{-1}$ (as backward)

$\therefore \Delta p = m(v - u) = 0.5\left[\frac{-25}{2} - 25\right]$

$= 0.5[-12.5 - 25] = 0.5 \times (-37.5)$

$\Delta p = -18.75kg\ ms^{-1}$ or N-s

Hence, the Δp or $\frac{\Delta p}{\Delta t}$ or force is opposite to the initial velocity of ball.

88. The displacement vector of a particle of mass m is given by $r(t) = \hat{i}A\cos\omega t + \hat{j}B\sin\omega t$. Show that the trajectory is an ellipse.

Ans. : The Main concept used: To plot the graph (r - t) or trajectory we relate x and y coordinates.

$\vec{r}(t) = \hat{i}A\cos\omega t + \hat{j}B\sin\omega t$

$x = A\cos\omega t$ and $y = \sin\omega t$

$\frac{x}{A} = \cos\omega t \ldots(i)\ \frac{y}{B} = \sin\omega t \ldots(ii)$

Squaring and adding (i), (ii)

$\frac{x^2}{A^2} + \frac{y^2}{B^2} = \cos^2\omega t + \sin^2\omega t$

$\frac{x^2}{A^2} + \frac{y^2}{B^2} = 1$ it is the equation of an ellipse. So the trajectory is an ellipse.

89. The gravitational force acting on a particle of 1g due to a similar particle is equal to 6.67 × 10^{-17}N. Calculate the separation between the particles.

Ans. : Mass of the particle m = 1 $\mathrm{gm} = \frac{1}{1000}\mathrm{kg}$

Let the distance between the two particles be r.

Gravitational force between the particle, F = 6.67 × 10^{-17}N

Also, $\mathrm{F} = \frac{\mathrm{Gm_1m_2}}{\mathrm{r^2}}$

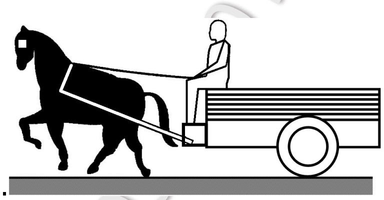
Substituting the respective values in the above formula, we get:

$$6.67 \times 10^{-17} = \frac{6.67 \times 10^{-11} \times \left(\frac{1}{10000}\right) \times \left(\frac{1}{10000}\right)}{\mathrm{r}^2}$$

$$\Rightarrow \mathrm{r}^2 = \frac{6.67 \times 10^{-6} \times 10^{-11}}{6.67 \times 10^{-17}}$$

$$\Rightarrow \frac{10^{-17}}{10^{-17}} = 1$$

$$\Rightarrow \mathrm{r} = \sqrt{1} = 1\mathrm{m}$$

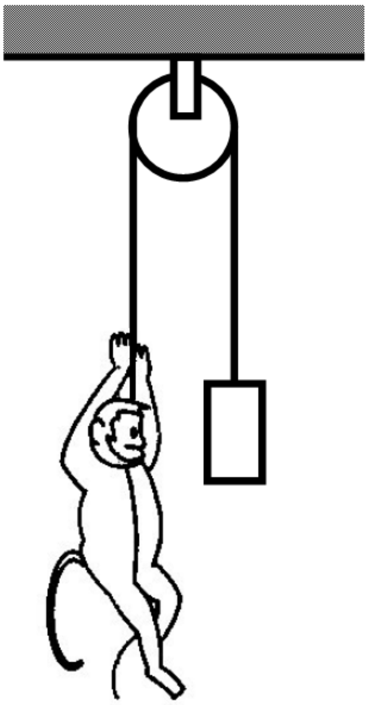


90. Figure shows a cart. Complete the table shown.

Ans. :

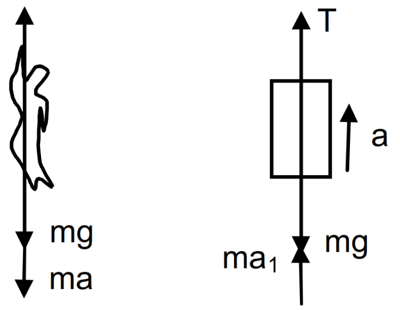
Force on	Force by	Nature	Direction
cart	gravity(weight)	gravitational	downward
	friction(road)	mechanical	backward
	pull (horse)	mechanical	forward
horse	cart(weight)	gravitational	downward
	pull(cart)	mechanical	backward
driver	pull (cart)	mechanical	forward

91. A monkey is climbing on a rope that goes over a smooth light pulley and supports a block of equal mass at the other end figure. Show that whatever force the monkey exerts on the rope, the monkey and the blockmove in the same direction with equal acceleration. If initially both were at rest, their separation will not change as time



passes.

Ans. :



Suppose the monkey accelerates upward with acceleration 'a' & the block, accelerate downward with acceleration a_1. Let Force exerted by monkey is equal to 'T'

From the free body diagram of monkey

$\therefore$ T - mg - ma = 0 ...(i)

$\Rightarrow$ T = mg + ma.

Again, from the FBD of the block,

T = ma_1 - mg = 0.

$\Rightarrow$ mg + ma + ma_1 - mg = 0 [From (i)]

$\Rightarrow$ ma = -ma_1

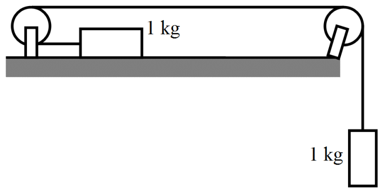
$\Rightarrow$ a = a_1.

Acceleration '-a' downward i.e. 'a' upward.

$\therefore$ The block & the monkey move in the same direction with equal acceleration.

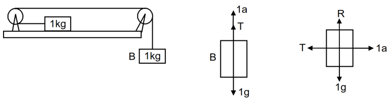
If initially they are rest (no force is exertied by monkey) no motion of monkey of block occurs as they have same weight (same mass). Their separation will not change as time passes.

92. Calculate the tension in the string shown in figure. The pulley and the string are light



and all surfaces are frictionless. Take g = $10 m/s^2$.

Ans. :



T + 1a = 1g ...(i)

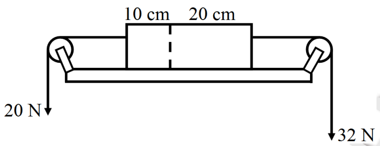
T - 1a = 0 ⇒ T = 1a ...(ii)

From eqn (i) and (ii), we get

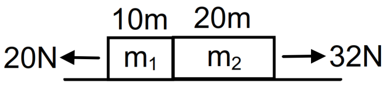
1a + 1a = 1g ⇒ 2a = g $\Rightarrow \mathrm{a} = \frac{\mathrm{g}}{2} = \frac{10}{2} = 5\mathrm{m/s}^2$

From (ii) T = 1a = 5N.

93. Figure shows a uniform rod of length 30cm having a mass of 3.0kg. The strings shown in the figure are pulled by constant forces of 20N and 32N. Find the force exerted by the 20cm part of the rod on the 10cm part. All the surfaces are smooth and the strings and the pulleys are light.



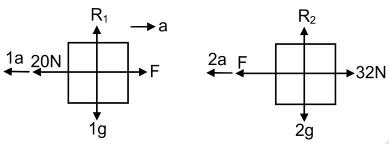
Ans. : Mass per unit length $\frac{3}{30}\frac{\mathrm{kg}}{\mathrm{cm}} = 0.10\frac{\mathrm{kg}}{\mathrm{cm}}$.



Mass of 10cm part = m_1 = 1kg

Mass of 20cm part = m_2 = 2kg.

Let, F = contact force between them.



From the free body diagram

F - 20 - 10 = 0 ...(i)

And, 32 - F - 2a = 0 ...(ii)

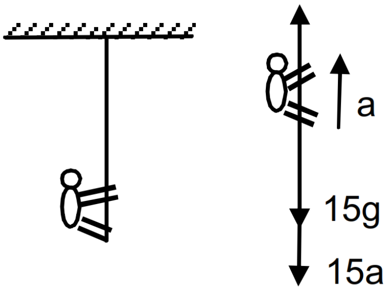
From eqa (i) and (ii)

$3\mathrm{a} - 12 = 0 \Rightarrow \mathrm{a} = \frac{12}{3} = 4\mathrm{m/s}^2$

Contact force F = 20 + 1a = 20 + 1 × 4 = 24N.

94. A monkey of mass 15kg is climbing on a rope with one end fixed to the ceiling. If it wishes to go up with an acceleration of $1 m/s^2$, how much force should it apply to the rope? If the rope is 5m long and the monkey starts from rest, how much time will it take to reach the ceiling?

Ans. :



m = 15kg of monkey.

a = 1m/s^2.

From the free body diagram

$\therefore$ T - [15g + 15(1)] = 0

⇒ T = 15(10 + 1)

⇒ T = 15 × 11

⇒ T = 165N.

The monkey should apply 165N force to the rope.

Initial velocity u = 0 ; acceleration a = 1m/s^2; s = 5m.

$\therefore \mathrm{s} = \mathrm{ut} + \frac{1}{2}\mathrm{at}^2$

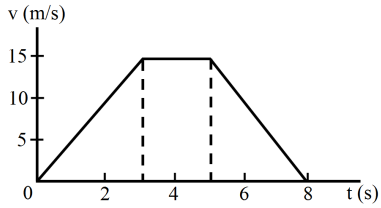
$5 = 0 + \left(\frac{1}{2}\right)1\mathrm{t}^2$

$\Rightarrow \mathrm{t}^2 = 5 \times 2$

$\Rightarrow \mathrm{t} = \sqrt{10}\ \mathrm{sec.}$

Time required is $\sqrt{10}\mathrm{sec.}$

95. A particle of mass 50g moves on a straight line. The variation of speed with time is shown in figure. Find the force acting on the particle at t = 2, 4 and 6 seconds.



Ans. : m = 50g = 5 × 10^{-2}kg

As shown in the figure,

Slope of OA $= \tan\theta \frac{\mathrm{AD}}{\mathrm{OD}} = \frac{15}{3} = 5\mathrm{m/s}^2$

So, at t = 2sec acceleration is 5m/s^2

Force = ma = 5 × 10^{-2} × 5 = 0.25N along the motion

At t = 4sec slope of AB = 0, acceleration = 0 [tan0^o=0]

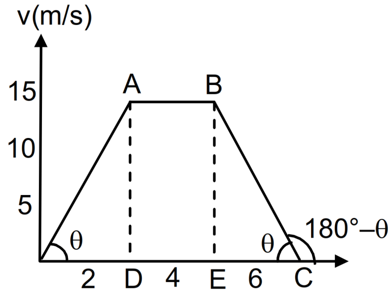
$\therefore$ Force = 0

At t = 6sec, acceleration = slope of BC.

In $\triangle\mathrm{BEC} = \tan\theta = \frac{\mathrm{BE}}{\mathrm{EC}} = \frac{15}{3} = 5.$

Slope of $\mathrm{BC} = \tan(180^\circ - \theta) = -\tan\theta = -5\mathrm{m/s}^2(\mathrm{deceleration})$

Force = ma = 5 × 5 × 10^{-2} = 0.25N. Opposite to the motion.



96. A block of 2kg is suspended from the ceiling through a massless spring of spring constant k = 100N/m. What is the elongation of the spring? If another 1kg is added to the block, what would be the further elongation?

Ans. : Given, m = 2kg, k = 100N/m

From the free body diagram, kl - 2g = 0 ⇒ kl = 2g

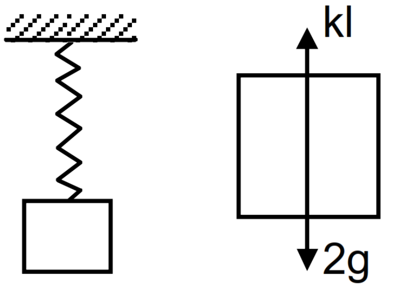
$$\Rightarrow \mathrm{I}=\frac{2\mathrm{g}}{\mathrm{k}}=\frac{2\times 9.8}{100}=\frac{19.6}{100}=0.196=0.2\mathrm{m}$$

Suppose further elongation when 1kg block is added be x,

Then k(1 + x) = 3g

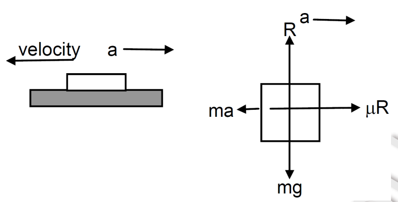
$$\Rightarrow \mathrm{kx}=3\mathrm{g}-2\mathrm{g}=\mathrm{g}=9.8\mathrm{N}$$

$$\Rightarrow \mathrm{x}=\frac{9.8}{100}=0.098=0.1\mathrm{m}$$



97. A block is projected along a rough horizontal road with a speed of 10m/s. If the coefficient of kinetic friction is 0.10, how far will it travel before coming to rest?

Ans. :



Due to friction the body will decelerate

Let the deceleration be ‘a’

$$\mathrm{R}-\mathrm{mg}=0 \Rightarrow \mathrm{R}=\mathrm{mg}\ldots(1)$$

$\mathrm{ma}-\mu\mathrm{R}=0 \Rightarrow \mathrm{ma}=\mu\mathrm{R}=\mu\mathrm{mg}$ (from(1))

$$\Rightarrow \mathrm{a}=\mu\mathrm{g}=0.1\times 10=1\mathrm{m/s}^2$$

Initial velocity u = 10m/s

Final velocity v = 0m/s

$$\mathrm{a}=-1\mathrm{m/s}^2$$

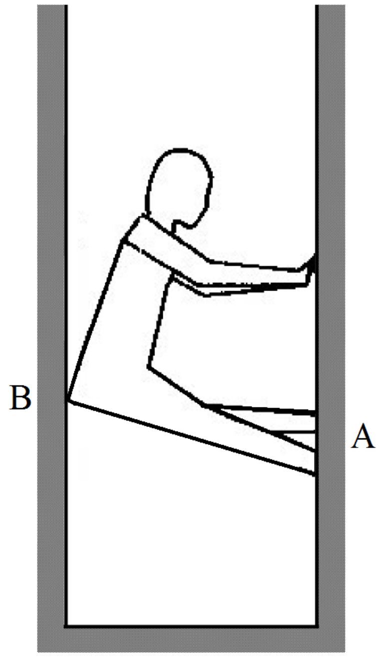
$$\mathrm{S}=\frac{\mathrm{v}^2-\mathrm{u}^2}{2\mathrm{a}}=\frac{0-10^2}{2(-1)}=\frac{100}{2}=50\mathrm{m}$$

It will travel 50m before coming to rest.

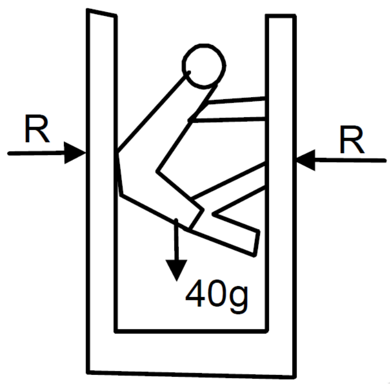
98. A person (40kg) is managing to be at rest between two vertical walls by pressing one wall A by his hands and feet and the other wall B by his back. Assume that the friction coefficient between his body and the walls is 0.8 and that limiting friction acts at all the contacts.

a. Show that the person pushes the two walls with equal force.

b. Find the normal force exerted by either wall on the person. Take g = $10 m/s^2$.



Ans. :



a. Mass of man = 50kg.

g = $10 m/s^2$

Frictional force developed between hands, legs & back side with the wall the wt of man. So he remains in equilibrium.

He gives equal force on both the walls so gets equal reaction R from both the walls. If he applies unequal forces R should be different he can’t rest between the walls.

Frictional force $2\mu R$ balance his wt.

From the free body diagram

$\mu R + \mu R = 40g$

$\Rightarrow 2\mu R = 40 \times 10 \Rightarrow R = \frac{40 \times 10}{2 \times 0.8} = 250N$

b. The normal force is 250N.

99. A simple pendulum is suspended from the ceiling of a car taking a turn of radius 10m at a speed of 36km/ h. Find the angle made by the string of the pendulum with the vertical if this angle does not change during the turn. Take g= 10m/s^2.

Ans. :

A pendulum is suspended from the ceiling of a car taking a turn

r = 10m, v = 36km/ hr = 10m/ sec, g = 10m/ sec^2

From the figure

$$\mathrm{T}\sin\theta = \frac{\mathrm{mv}^2}{\mathrm{r}} \ \ldots(1)$$
$$\mathrm{T}\cos\theta = \mathrm{mg} \ \ldots(2)$$
$$\Rightarrow \frac{\sin\theta}{\cos\theta} = \frac{\mathrm{mv}^2}{\mathrm{rmg}}$$
$$\Rightarrow \tan\theta = \frac{\mathrm{v}^2}{\mathrm{rg}}$$
$$\Rightarrow \theta = \tan^{-1}\left(\frac{\mathrm{v}^2}{\mathrm{rg}}\right)$$
$$\Rightarrow \theta = \tan^{-1}\frac{100}{10\times10} = \tan^{-1}(1)$$
$$\Rightarrow \theta = 45^\circ$$

100. A particle moves in a circle of radius 1.0cm at a speed given by v = 2.0t where v is in cm/s and t in seconds.

a. Find the radial acceleration of the particle at t = 1s.
b. Find the tangential acceleration at t = 1s.
c. Find the magnitude of the acceleration at t = 1s.

Ans. : V = 2t, r = 1cm

a. Radial acceleration at t = 1sec.

$$\mathrm{a} = \frac{\mathrm{v}^2}{\mathrm{r}} = \frac{2^2}{1}$$
$$= 4\mathrm{cm/sec}^2$$

b. Tangential acceleration at t = 1sec.

$$\mathrm{a} = \frac{\mathrm{dv}}{\mathrm{dt}} = \frac{\mathrm{d}}{\mathrm{dt}}(2\mathrm{t})$$
$$= 2\mathrm{cm/sec}^2$$

c. Magnitude of acceleration at t = 1sec.

$$\mathrm{a} = \sqrt{4^2 + 2^2}$$
$$= \sqrt{20}\,\mathrm{cm/sec}^2$$

*** Given Section consists of questions of 5 marks each. [230]**

101. Explain why,

a. A horse cannot pull a cart and run in empty space.
b. Passengers are thrown forward from their seats when a speeding bus stops suddenly.
c. It is easier to pull a lawn mower than to push it.
d. A cricketer moves his hands backwards while holding a catch.

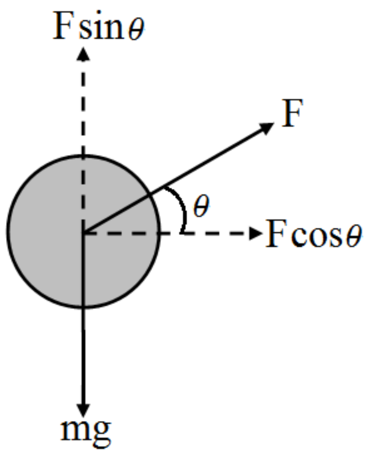
Ans. :

a. While trying to pull a cart, ahorse pushes the ground backward with some force. The ground in turn exerts an equal and opposite reaction force upon the feet of the horse. This reaction force causes the horse to move forward.

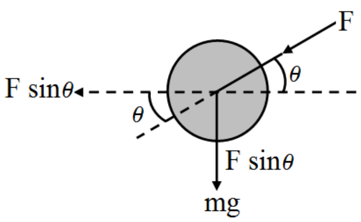
An empty space is devoid of any such reaction force. Therefore, a horse cannot pull a cart and run in empty space.

b. This is due to inertia of motion. When a speeding bus stops suddenly, the lower part of a passenger's body, which is in contact with the seat, suddenly comes to rest. However, the upper part tends to remain in motion (as per the first law of motion). As a result, the passenger's upper body is thrown forward in the direction in which the bus was moving.

c. While pulling a lawn mower, a force at an angle θ is applied on it, as shown in the following figure.



The vertical component of this applied force acts upward. This reduces the effective weight of the mower. On the other hand, while pushing a lawn mower, a force at an angle θ is applied on it, as shown in the following figure.



In this case, the vertical component of the applied force acts in the direction of the weight of the mower. This increases the effective weight of the mower.

Since the effective weight of the lawn mower is lesser in the first case, pulling the lawn mower is easier than pushing it.

d. According to Newton's second law of motion, we have the equation of motion:

$$\mathrm{F} = \mathrm{ma} = \frac{\mathrm{m}\triangle \mathrm{v}}{\triangle \mathrm{t}} \ldots (\mathrm{i})$$

Where,

F = Stopping force experienced by the cricketer as he catches the ball

m = Mass of the ball

$\triangle \mathrm{t}$ = Time of impact of the ball with the hand

It can be inferred from equation (i) that the impact force is inversely proportional to the impact time, i.e.,

$$\frac{\mathrm{F}\propto 1}{\triangle \mathrm{t}} \ldots (\mathrm{ii})$$

Equation (ii) shows that the force experienced by the cricketer decreases if the time of impact increases and vice versa.

While taking a catch, a cricketer moves his hand backward so as to increase the time of impact $(\triangle \mathrm{t})$. This is turn results in the decrease in the stopping force, thereby preventing the hands of the cricketer from getting hurt.

102. A stream of water flowing horizontally with a speed of $15 ms^{-1}$ gushes out of a tube of cross-sectional area $10^{-2} m^2$, and hits a vertical wall nearby. What is the force exerted on the wall by the impact of water, assuming it does not rebound?

Ans. : Speed of the water stream, v = 15m/s

Cross-sectional area of the tube, $A = 10^{-2} m^2$

Volume of water coming out from the pipe per second,

V = Av

$= 15 \times 10^{-2} m^3/s$

Density of water, $p = 10^3 kg/m^3$

Mass of water flowing out through the pipe per second = p × V = 150kg/s

The water strikes the wall and does not rebound.

Therefore, according to Newton's second law of motion,

Force exerted by the water on the wall,

F = Rate of change of momentum $= \frac{\Delta \mathrm{p}}{\Delta \mathrm{t}}$

$= \frac{\mathrm{mv}}{\mathrm{t}}$

150×15

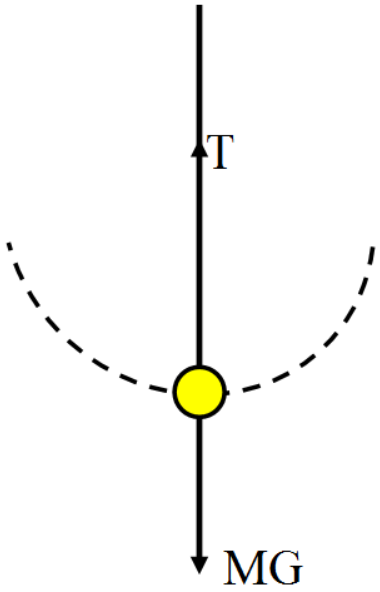
$= 2250 \mathrm{N}$

103. A stone of mass m tied to the end of a string revolves in a vertical circle of radius R. The net forces at the lowest and highest points of the circle directed vertically downwards are: [Choose the correct alternative]

	Lowest Point	**Highest Point**
(a)	$mg - T_1$	$mg + T_2$
(b)	$mg + T_1$	$mg - T_2$
(c)	$mg + T_1 - (mv_1^2)/R$	$mg - T_2 + (mv_1^2)/R$
(d)	$mg - T_1 - (mv_1^2)/R$	$mg + T_2 + (mv_1^2)/R$

T_1 and v_1 denote the tension and speed at the lowest point. T_2 and v_2 denote corresponding values at the highest point.

Ans. : The free body diagram of the stone at the lowest point is shown in the figure below:

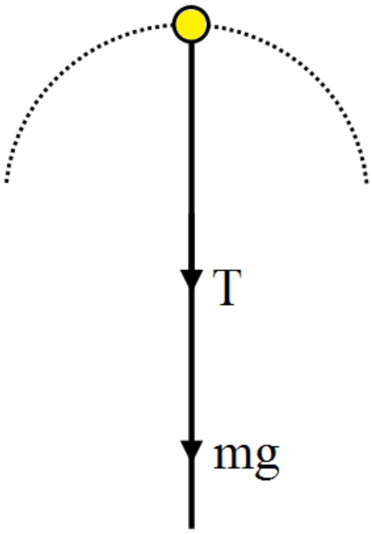


According to Newton's second law of motion, the net force acting on the stone at this point is equal to the centripetal force.

i.e., F_{net} = T - mg $\frac{mv_1^2}{R}$ $\ldots.(i)$

where, v_1 is the velocity at the lowest point.

The free body diagram of the stone at the highest point is shown in the following figure.



Using Newton's second law of motion,

$T + mg = \frac{mv_2^2}{R} \ldots.(ii)$

Where, v_2 is the velocity at the highest point.

From equations (i) and (ii),

Net force acting at the lowest = (T - mg)

Net force at the highest points = (T + mg).

104. A disc revolves with a speed of $33\frac{1}{3}\text{rev/min},$ and has a radius of 15cm. Two coins are placed at 4cm and 14cm away from the centre of the record. If the co-efficient of friction between the coins and the record is 0.15, which of the coins will revolve with the record?

Ans. : Coin placed at 4cm from the centre

Mass of each coin = m

Radius of the disc, $\mathrm{r = 15m = 0.15m}$

Frequency of revolution, $\mathrm{v} = \frac{100}{3}\mathrm{rev/min} = \frac{100}{3\times 60} = \frac{5}{9}\mathrm{rev/s}$

Coefficient of friction, $\mu = 0.15$

In the given situation, the coin having a force of friction greater than or equal to the centripetal force provided by the rotation of the disc will revolve with the disc. If this is not the case, then the coin will slip from the disc.

<u>Coin placed at 4cm</u>:

Radius of revolution, $\mathrm{r' = 4cm = 0.04m}$

Angular frequency, $\omega = 2\pi \mathrm{v} = 2 \times \frac{22}{7} \times \frac{5}{9} = 3.49\mathrm{s}^{-1}$

Frictional force, $\mathrm{f} = \mu \mathrm{mg} = 0.15 \times \mathrm{m} = 10 = 1.5\mathrm{mN}$

Centripetal force on the coin:

$$\mathrm{F_{cent}} = \mathrm{mr}, \omega^2$$
$$= \mathrm{m} \times 0.04 \times (3.49)^2$$
$$= 0.49\mathrm{mN}$$

Since f > $\mathrm{F_{cent}}$, the coin will revolve along with the record.

<u>Coin placed at 14cm</u>:

Radius, $\mathrm{r" = 14cm = 0.14m}$

Angular frequency, $\omega = 3.49\mathrm{s}^{-1}$

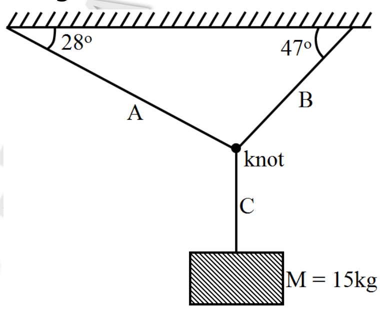
Frictional force, $\mathrm{f' = 1.5mN}$

Centripetal force is given as:

$$\mathrm{F_{cent}} = \mathrm{mr}, \omega^2$$
$$= \mathrm{m} \times 0.14 \times (3.49)^2$$
$$= 1.7\mathrm{mN}$$

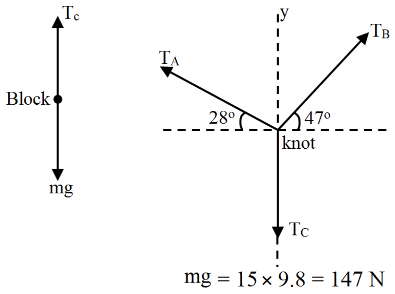
Since f < $\mathrm{F_{cent.}}$, the coin will slip from the surface of the record.

105. A block of mass 15kg hangs from three chords as shown in figure. What are the tensions in the chords?

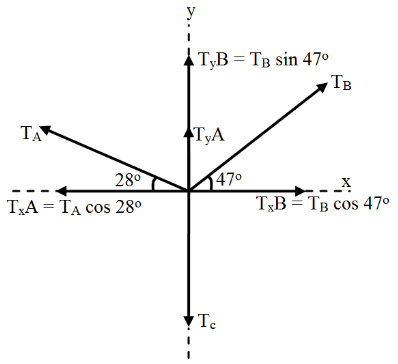


Ans. : The free-body diagram of the given problem is shown in the figure

a.



Since block is at rest, so T_C = mg =15 × 9.8 = 147 N



Resole T_A and T_B into x and y components. x- component of T_A is given by

$$\mathrm{T_{xA}} = -\mathrm{T_A}\cos 28^\circ = -\mathrm{T_A}$$
$$(0.8830) = -0.8830\mathrm{T_A}$$

y- component of T_A s given by

$$\mathrm{T_{yA}} = \mathrm{T_A}\sin 28^\circ = 0.4690$$

Similarly, x- component of T_B is given by

$$\mathrm{T_{xB}} = \mathrm{T_B}\cos 47^\circ = 0.6820\mathrm{T_B}$$

and y- component of T_B is give by

$$\mathrm{T_{yB}} = \mathrm{T_B}\sin 47^\circ = 07310\mathrm{T_B}.$$

These components are represented as shown in fig. (b).

Since the knot is in equilibrium, so

i. $\sum$ x-components of tensions = 0

i.e., $\mathrm{T_{xA}} + \mathrm{T_{xB}} = 0$

or $-0.8830\mathrm{T_A} + 0.6820\mathrm{T_B} = 0$

or $\mathrm{T_A} = \frac{0.6820}{0.8830}\mathrm{T_B} = 0.772...(\mathrm{i})$

ii. $\sum$ y- components of tensions = 0

i.e., $\mathrm{T_{yA}} + \mathrm{T_{yB}} - \mathrm{T_C} = 0$

or $0.4690\mathrm{T_A} + 0.7310\mathrm{T_B} - 147 = 0$

or $0.4690\mathrm{T_A} + 07310\mathrm{T_B} = 147$

Substituting the value of equation (i), we get

$$0.4690 \times 0.772\mathrm{T_B} + 0.7310\mathrm{T_B}$$
$$= \frac{147}{1.093} = 134.5\mathrm{N}$$

Now Substituting the values of T_B in eqn. (i),we get

$$\mathrm{T_A} = 0.772 \times 134.5\mathrm{N} = 103.8\mathrm{N}$$

Thus, $\mathrm{T_A} = 103.8\mathrm{N}; \mathrm{T_B} = 134.5\mathrm{N}$ and $147\mathrm{N}$.

106. A helicopter of mass 2000kg rises with a vertical acceleration of 15m s^{-2}. The total mass of the crew and passengers is 500kg. Give the magnitude and direction of the (g = 10m s^{-2})

a. Force on the floor of the helicopter by the crew and passengers.
b. Action of the rotor of the helicopter on the surrounding air.
c. Force on the helicopter due to the surrounding air.

Ans. : Mass (M) of helicopter = M = 2000kg Mass of the crew and passengers = m = 500kg. Acceleration of helicopter along with crew and passengers = 15ms^{-2}

a. Force on floor of helicopter by crew and passenger will be equal to apparent weight (left)

m(g + a) = 500(10 + 15)

F_1 = 500 × 25 = 12500N downward

b. The action of the rotor of the helicopter on surrounding air will be equal to the reaction force by Newton’s third law due to which helicopter along with crew and passenger rises up with acceleration on 15ms^{-1} (M + m)(g + a) So the action by rotor on surrounding air = (2000 + 500)(g + a)

F_2 = 2500 × (10 + 15) = 2500 × 25 = 62500N downward.

c. Force (F) acting on the helicopter by the reaction force by surrounding air.

so F_3 = -Action force (by Newton’s third law)

= -62500N downward

or F_3 = +62500N upward

107. State Newton's Second law of motion. Prove that second law is the real law of motion.

Ans. : Newton's II Law: The total unbalanced external force acting on a mass is the product of its mass (m) and acceleration (a), i.e,.

F = ma.

I Law and II Law: According to II law, force experienced is the product of mass and acceleration. When there is no force, the mass does not accelerate and retains the same status. So the view of I law, i.e., when there is no force the body maintains the status of motion.

III Law and II Law: Consider two masses m, and m, exerting force on each other (internal forces). If their change in momentum are dp_1 and dp_2 then, $dp_1 + dp_2 = 0$.

Since no external force acts on the system of two masses.

$\therefore \frac{dp_1}{dt} = -\frac{dp_2}{dt}$

i.e., $f_1 = -f_2$

i.e., force experienced by m_1 due to m_2 and by m_2 due to m_1 are equal and opposite, confirming action and reaction.

Since both laws can be derived from second law, so it is real law of motion.

108. A shell of mass 0.020kg is fired by a gun of mass 100kg. If the muzzle speed of the shell is 80ms^{-1}, what is the recoil speed of the gun?

Ans. : Mass of the gun, M= 100kg

Mass of the shell, m = 0.020kg

Muzzle speed of the shell, v = 80 m/s

Recoil speed of the gun = V

Both the gun and the shell are at rest initially.

Initial momentum of the system = 0

Final momentum of the system = mv - MV

Here, the negative sign appears because the directions of the shell and the gun are opposite to each other.

According to the law of conservation of momentum:

Final momentum = Initial momentum

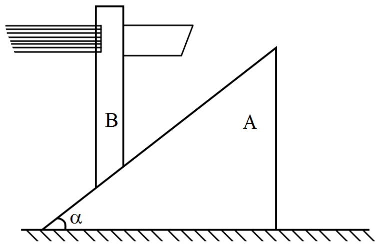
mv - MV = 0

$\therefore \mathrm{V}=\frac{\mathrm{mv}}{\mathrm{M}}$

$=\frac{0.020 \times 80}{100 \times 1000}$

$=0.016 \mathrm{m/s}$

109. Find the acceleration of rod B and wedge A in the arrangement shown in figure, if the ratio of the mass of wedge to that of rod equals n and there is no friction between any



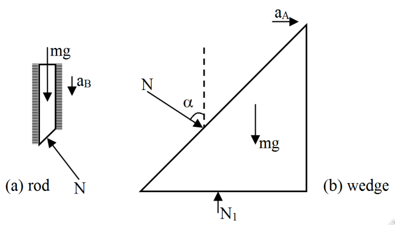
contact surfaces.

Ans. : Let m be the mass of rod B and M that of wedge.

Given, $\frac{\mathrm{M}}{\mathrm{m}}=\mathrm{n}$

If acceleration of rod B and A are a_A and a_B then,

$\mathrm{a_B}=\mathrm{a_A} \tan \alpha$



Writing equation for motion,

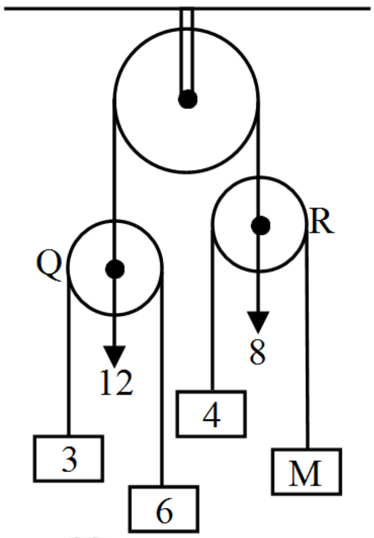
For rod, $\mathrm{mg}-\mathrm{N} \cos \alpha=\mathrm{ma_B} \ldots \mathrm{ii}$

For wedge, $\mathrm{N} \sin \alpha=\mathrm{Ma_A} \ldots(\mathrm{iii})$

Solving equation (i), (ii) and (iii)

$\mathrm{a_B}=\frac{\mathrm{g} \tan \alpha}{\tan \alpha+\mathrm{n} \cot \alpha}, \mathrm{a_A}=\frac{\mathrm{g}}{\tan \alpha+\mathrm{n} \cot \alpha}$

110. Two pulleys of masses 12kg and 8kg are connected by a fine string hanging over a fixed pulley as shown. Over the 8kg pulley is hung a fine string with masses 4kg and M. Over the 12kg pulley is hung another fine string with masses 3kg and 6kg. Calculate M



so that the string over the fixed pulley remains stationary.

Ans. : P is a fixed pulley. The pulleys Q and R have masses 12kg and 8kg respectively. The different tensions and accelerations are shown. Various equations can be written as,

$6g - T_1 = 6a_1$ ...(i) for pulley Q

$T_1 - 3g = 3a_1$ ....(ii) for pulley Q

$Mg - T_2 = Ma_2$ ....(iii) for pulley R

$T_2 - 4g = 4a_2$ ...(iv) for pulley R

$T = 2T_1 + 12g$ ...(v) for pulley Q

$T = 2T_2 + 8g$ ...(vi) for pulley R

∵ Pulley Q and R remain stationary.

From (i) and (ii), we get

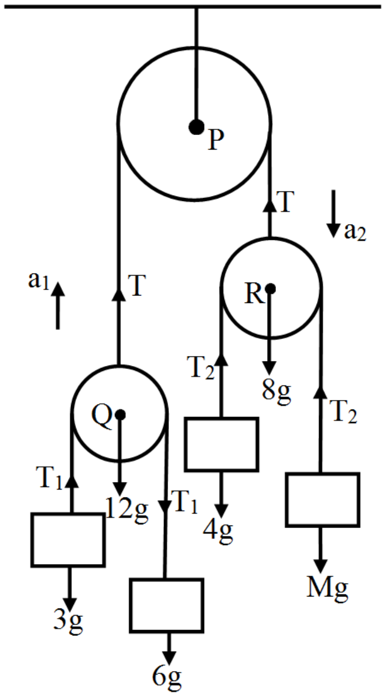
$6g - T_1 = 6a_1 = 2T_1 - 6g$

$3T_1 = 12g$

$T_1 = 4g$ ....(vii)

From (iii) and (iv) we have,

$a_2 = \left(\frac{M-4}{M+4}\right)g,$



$T_2 = \frac{2M \times 4 \times g}{M+4} \ldots (viii)$

From (v) and (vi) we have,

$2T_1 + 12g = 2T_2 + 8g$

$T_2 - T_1 = 2g$ ....(ix)

From (vii) and (viii), putting values of T_2 and T_1, we get

$\frac{8Mg}{M+4} - 4g = 2g$

$\frac{8Mg}{M+4} = 6g$

8M = 6(M + 4)

2M = 24

M = 12kg.

111. A machine gun has a mass of 20kg. It fires 35g bullets at the rate of 400 bullets per second with a speed of $400ms^{-1}$. What force must be applied to the gun to keep it in position?

Ans. : Let the mass of the machine gun,

M = 20kg

Mass of the bullet m = 35g = 0.035kg

Velocity of bullet v = $400ms^{-1}$

Velocity of recoil of the gun V = ?

By the law of conservation of momentum,

MV + mv = 0,

or $V = -\frac{mv}{M}$

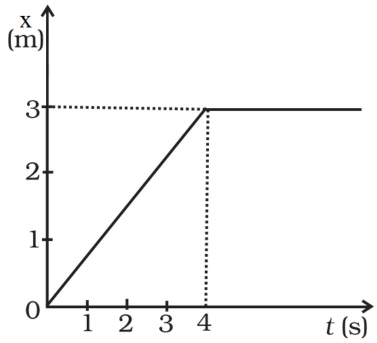
$= -\frac{0.035 \times 400}{20} = -0.7ms^{-1}$

-ve sign shows that the gun recoils.

∴ Force required to hold the gun in position

$$F = Ma = M\left(\frac{V-u}{t}\right)$$
$$= \frac{20 \times (0.7-0)}{\frac{1}{400}} = 5600N.$$

112. The position time graph of a body of mass 2kg is as given in What is the impulse on



the body at t = 0 s and t = 4s.

Ans. : Mass of body (m) = 2kg at t =0.. Initial velocity (v_1) is zero, V_1 = 0 from $t \geq 0 t o t \leq 4, (x - t)$ graph is straight line. So the velocity (v) of body is constant.

$v_2 = \tan\theta = \frac{3}{4} = 0.75 \text{ m/ l}$

$\text{At } t \geq 4$ the slope of the graph is zero so velocity $v_3 = 0$

Impulse $= \vec{F}.t = \frac{\overrightarrow{dp}}{dt}.dt = \overrightarrow{dp}$

Impulse=Change in momentum

Impulse at t = 0:

= 2[0.75 – 0] = 1.50kg ms^{-1} (increased)

Impulse at t = 4:

= m (v_3 - v_2) = 2[0 – 0.75]

Impulse at t = 4:

= -1.50kg ms^{-1}

So impulse at t = 0 increases by + 1.5kg ms^{-1} and at t = 4 it decreased by (- 1.5kg ms^{-1}).

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

Ans. : Horizontal force, F = 600N

Mass of body A, m_1 = 10kg

Mass of body B, m_2 = 20kg

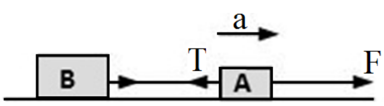
Total mass of the system, m = m_1 + m_2 = 30kg

Using Newton's second law of motion, the acceleration (a) produced in the system can be calculated as:

F = ma

$\therefore a = \frac{F}{m} = \frac{600}{30} = 20ms^{-2}$

When force F is applied on body A:



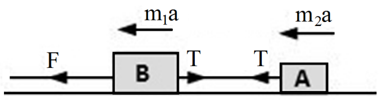
The equation of motion can be written as:

$F - T = m_1 a$

$\therefore T = F - m_1 a$

$= 600 - 10 \times 20 = 400N$ ......(i)

When force F is applied on body B:



The equation of motion can be written as:

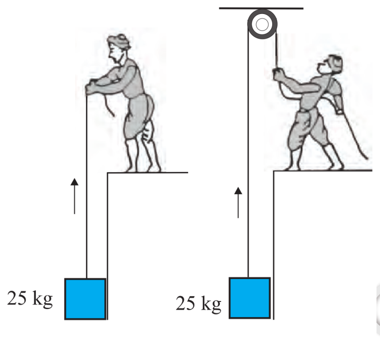
$F - T = m_2 a$

$T = F - m_2 a$

$\therefore T = 600 - 20 \times 20 = 200N$ ...(ii)

Which is different from value of T in case (i). Hence our answer depends on which mass end, the force is applied.

114. A block of mass 25kg is raised by a 50kg man in two different ways as shown in Fig. What is the action on the floor by the man in the two cases? If the floor yields to a normal force of 700N, which mode should the man adopt to lift the block without the



floor yielding? (a) (b)

Ans. : 750N and 250N in the respective cases; Method (b)

Mass of the block, m = 25kg

Mass of the man, M = 50kg

Acceleration due to gravity, $g = 10 m/s^2$

Force applied on the block, $F = 25 \times 10 = 250N$

Weight of the man, $W = 50 \times 10 = 500N$

Case (a): When the man lifts the block directly

In this case, the man applies a force in the upward direction. This increases his apparent weight.

$\therefore$ Action on the floor by the man = 250 + 500 = 750N

Case (b): When the man lifts the block using a pulley

In this case, the man applies a force in the downward direction. This decreases his apparent weight.

$\therefore$ Action on the floor by the man = 500 - 250 = 250N

If the floor can yield to a normal force of 700N, then the man should adopt the second method to easily lift the block by applying lesser force.

115. A disc revolves with a speed of $33\frac{1}{3}\mathrm{rev/min}$, and has a radius of 15cm. Two coins are placed at 4cm and 14cm away from the centre of the record. If the co-efficient of friction between the coins and the record is 0.15, which of the coins will revolve with the record?

Ans. : Coin placed at 4cm from the centre

Mass of each coin = m

Radius of the disc, $\mathrm{r} = 15\mathrm{m} = 0.15\mathrm{m}$

Frequency of revolution, $\mathrm{v} = \frac{100}{3}\mathrm{rev/min} = \frac{100}{3\times60} = \frac{5}{9}\mathrm{rev/s}$

Coefficient of friction, $\mu = 0.15$

In the given situation, the coin having a force of friction greater than or equal to the centripetal force provided by the rotation of the disc will revolve with the disc. If this is not the case, then the coin will slip from the disc.

<u>Coin placed at 4cm</u>:

Radius of revolution, $\mathrm{r}' = 4\mathrm{cm} = 0.04\mathrm{m}$

Angular frequency, $\omega = 2\pi\mathrm{v} = 2 \times \frac{22}{7} \times \frac{5}{9} = 3.49\mathrm{s}^{-1}$

Frictional force, $\mathrm{f} = \mu\mathrm{mg} = 0.15 \times \mathrm{m} = 10 = 1.5\mathrm{mN}$

Centripetal force on the coin:

$\mathrm{F}_{\mathrm{cent}} = \mathrm{mr}, \omega^2$

$= \mathrm{m} \times 0.04 \times (3.49)^2$

$= 0.49\mathrm{mN}$

Since f > F_{cent}, the coin will revolve along with the record.

<u>Coin placed at 14cm</u>:

Radius, $\mathrm{r}'' = 14\mathrm{cm} = 0.14\mathrm{m}$

Angular frequency, $\omega = 3.49\mathrm{s}^{-1}$

Frictional force, $\mathrm{f}' = 1.5\mathrm{mN}$

Centripetal force is given as:

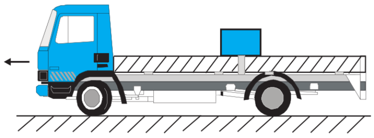
$\mathrm{F}_{\mathrm{cent}} = \mathrm{mr}, \omega^2$

$= \mathrm{m} \times 0.14 \times (3.49)^2$

$= 1.7\mathrm{mN}$

Since f < $F_{cent.}$, the coin will slip from the surface of the record.

116. The rear side of a truck is open and a box of 40kg mass is placed 5m away from the open end as shown in Fig. The coefficient of friction between the box and the surface below it is 0.15. On a straight road, the truck starts from rest and accelerates with $2\mathrm{ms}^{-2}$. At what distance from the starting point does the box fall off the truck? (Ignore the size of the box).



Ans. : Mass of the box, m = 40kg

Coefficient of friction, $\mu = 0.15$

Initial velocity, u = 0

Acceleration, a = 2m/s^2

Distance of the box from the end of the truck, s' = 5m

As per Newton's second law of motion, the force on the box caused by the accelerated motion of the truck is given by:

F = ma

= 40 × 2 = 80N

As per Newton's third law of motion, a reaction force of 80N is acting on the box in the backward direction. The backward motion of the box is opposed by the force of friction f, acting between the box and the floor of the truck. This force is given by:

$$\mathrm{f} = \mu \mathrm{mg}$$

= 0.15 × 40 × 10 = 60N

$\therefore$ Net force acting on the block:

F_{net} = 80 - 60 = 20N backward

The backward acceleration produced in the box is given by:

$$\mathrm{a_{back}} = \frac{\mathrm{F_{net}}}{\mathrm{m}} = \frac{20}{40} = 0.5\mathrm{ms}^{-2}$$

Using the second equation of motion, time t can be calculated as:

$$\mathrm{s}' = \mathrm{ut} + \left(\frac{1}{2}\right)\mathrm{a_{back}}\mathrm{t}^2$$

$$5 = 0 + \left(\frac{1}{2}\right) \times 0.5 \times \mathrm{t}^2$$

$$\therefore \mathrm{t} = \sqrt{20}\,\mathrm{s}$$

Hence, the box will fall from the truck after $\sqrt{20}$s from start.

The distance s, travelled by the truck in $\sqrt{20}$s is given by the relation:

$$\mathrm{s} = \mathrm{ut} + \left(\frac{1}{2}\right)\mathrm{at}^2$$

$$= 0 + \left(\frac{1}{2} \times 2 \times \left(\sqrt{20}\right)^2\right.$$

$$= 20\mathrm{m}$$

117. A helicopter of mass 1000kg rises with a vertical acceleration of 15ms^{-2}. The crew and the passengers weigh 300kg. Give the magnitude and direction of the,

a. Force on the floor by the crew and passengers.

b. Action of the rotor of the helicopter on the surrounding air.

c. Force on the helicopter due to the surrounding air.

Ans. : Mass of the helicopter, m_h = 1000kg

Mass of the crew and passengers, m_p = 300kg

Total mass of the system, m = 1300kg

Acceleration of the helicopter, a = 15m/s^2

a. Using Newton's second law of motion, the reaction force R, on the system by the floor can be calculated as:

R - m_pg = ma

= m_p(g + a)

= 300(10 + 15) = 300 × 25

= 7500N

Since the helicopter is accelerating vertically upward, the reaction force will also be directed upward. Therefore, as per Newton's third law of motion, the force on the floor by the crew and passengers is 7500N, directed downward.

Using Newton's second law of motion, the reaction force R', experienced by the helicopter can be calculated as:

R' - mg = ma

= m(g + a)

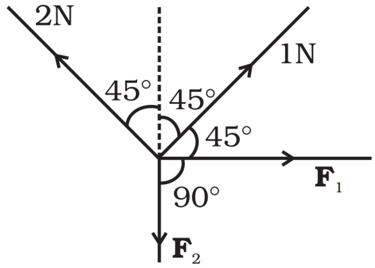
= 1300(10 + 15) = 1300 × 25

= 32500N

b. The reaction force experienced by the helicopter from the surrounding air is acting upward. Hence, as per Newton's third law of motion, the action of the rotor on the surrounding air will be 32500 N, directed downward.

c. The force on the helicopter due to the surrounding air is 32500N, directed upward.

118. There are four forces acting at a point P produced by strings as shown in which is at



rest. Find the forces F_1 and F_2.

Ans. : As the particle is rest or a = 0. So resultant force due to all forces will be zero.

∴ Net components along X and Y-axis will be zero.

Resolving all forces along X-axis

$$\mathrm{F_x} = 0$$

$$\mathrm{F_1} + 1\cos 45^\circ - 2\cos 45^\circ = 0 \text{ or } \mathrm{F_1} - 1\cos 45^\circ = 0$$

$$\mathrm{F_1} = \cos 45^\circ = \frac{1}{\sqrt{2}}\frac{\sqrt{2}}{\sqrt{2}} = \frac{\sqrt{2}}{2} = \frac{1.414}{2} = 0.707\mathrm{N}$$

Resolving all forces along Y-axis

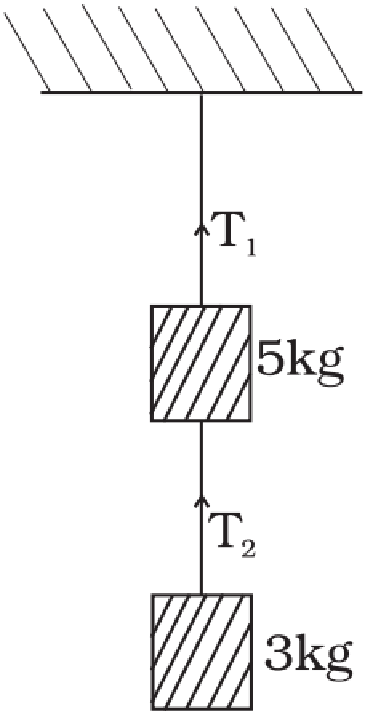
$$\mathrm{F_y} = 0$$

$$-\mathrm{F_2} + 1\cos 45^\circ + 2\cos 45$$

$$-\mathrm{F_2} = -3\cos 45^\circ$$

$$\mathrm{F_2} = 3.\frac{1}{\sqrt{2}} = \frac{3\sqrt{2}}{2} = \frac{3\times 1.414}{2} = 3 \times 0.707 = 2.121\mathrm{N}.$$

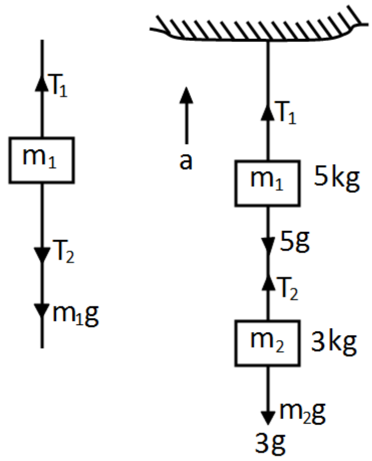
119. Two masses of 5kg and 3kg are suspended with help of massless inextensible strings as shown in Calculate T_1 and T_2 when whole system is going upwards with acceleration



= 2m s^2 (use g = 9.8m s^{-2}).

Ans. : As the whole system is going up with acceleration = a = 2ms^{-2}

$m_1 = 5kg \; m_2 = 3kg \; g = 9.8m/s^2$



Tension in a string is equal and opposite in all parts of a string.

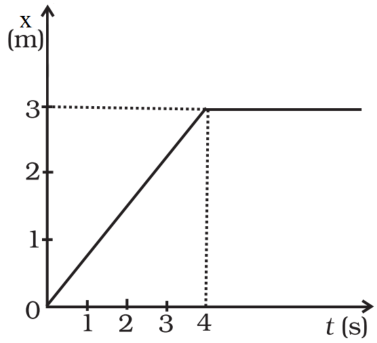
Forces on mass m_1

$$T_1 - T_2 - m_1g = m_1a$$
$$T_1 - T_2 - 5g + 5a$$
$$T_1 - T_2 = 5g + 5a$$
$$T_1 - T_2 = 5(9.8 + 2)$$
$$= 5 \times 11.8$$
$$T_1 - T_2 = 59.0 \text{ N}$$

Forces on mass m_2

$$T_2 - m_2g = m_2a$$
$$T_2 = m(g + a) = 3(9.8 + 2) = 3 \times 11.8$$
$$T_2 = 35.4$$
$$T_1 = T_2 + 59.0 \Rightarrow T_1 = 53.4 + 59.0 = 94.4 \text{ N}$$

120. The position time graph of a body of mass 2kg is as given in What is the impulse on



the body at t = 0 s and t = 4s.

Ans. : Mass of body (m) = 2kg at t =0.. Initial velocity (v_1) is zero, $V_1 = 0$ from $\mathrm{t} \geq 0 \mathrm{tot} \leq 4, (\mathrm{x}-\mathrm{t})$ graph is straight line. So the velocity (v) of body is constant.

$\mathrm{v}_2 = \tan\theta = \frac{3}{4} = 0.75\ \mathrm{m}/\ \mathrm{l}$

$\mathrm{At\ t} \geq 4$ the slope of the graph is zero so velocity $\mathrm{v}_3 = 0$

Impulse $= \vec{\mathrm{F}}.\mathrm{t} = \frac{\overrightarrow{\mathrm{dp}}}{\mathrm{dt}}.\mathrm{dt} = \overrightarrow{\mathrm{dp}}$

Impulse=Change in momentum

Impulse at t = 0:

= 2[0.75 – 0] = 1.50kg ms^{-1} (increased)

Impulse at t = 4:

= m (v_3 - v_2) = 2[0 – 0.75]

Impulse at t = 4:

= -1.50kg ms^{-1}

So impulse at t = 0 increases by + 1.5kg ms^{-1} and at t = 4 it decreased by (- 1.5kg ms^{-1}).

121. A helicopter of mass 2000kg rises with a vertical acceleration of 15m s^{-2}. The total mass of the crew and passengers is 500kg. Give the magnitude and direction of the (g = 10m s^{-2})

a. Force on the floor of the helicopter by the crew and passengers.
b. Action of the rotor of the helicopter on the surrounding air.
c. Force on the helicopter due to the surrounding air.

Ans. : Mass (M) of helicopter = M = 2000kg Mass of the crew and passengers = m = 500kg. Acceleration of helicopter along with crew and passengers = 15ms^{-2}

a. Force on floor of helicopter by crew and passenger will be equal to apparent weight (left)

m(g + a) = 500(10 + 15)

F_1 = 500 × 25 = 12500N downward

b. The action of the rotor of the helicopter on surrounding air will be equal to the reaction force by Newton’s third law due to which helicopter along with crew and passenger rises up with acceleration on 15ms^{-1} (M + m)(g + a) So the action by rotor on surrounding air = (2000 + 500)(g + a)

F_2 = 2500 × (10 + 15) = 2500 × 25 = 62500N downward.

c. Force (F) acting on the helicopter by the reaction force by surrounding air.

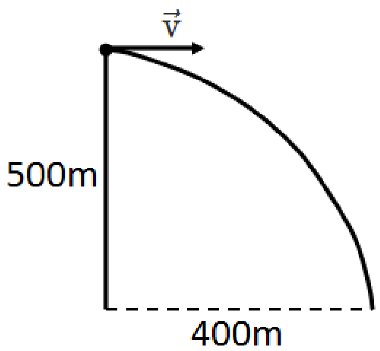
so F_3 = -Action force (by Newton’s third law)

= -62500N downward

or F_3 = +62500N upward

122. A 100kg gun fires a ball of 1kg horizontally from a cliff of height 500m. It falls on the ground at a distance of 400m from the bottom of the cliff. Find the recoil velocity of the gun. (acceleration due to gravity = 10m s^{-2})

Ans. :



Main concept used: Speed of recoil of the gun can be find out by the velocity of the ball by projectiles formulae.

Solution: Let the horizontal speed of the ball is μms^{-1} its vertical component will be zero. Consider the motion of ball vertically downward

$\mu = 0,\ s = h = 500m,\ g = 10sm^{-2}$

$s = \mu t + \frac{1}{2}at^2$

$500 = a \times t + \frac{1}{2} \times 10t^2 \Rightarrow t^2 = \frac{500}{5} = 100$

$t = \sqrt{100} = 10\,sec$

Horizontal range $= \mu \times 10$

$400 = u \times 10 \Rightarrow u = 40m/\,sec$

By the law of conservation of momentum

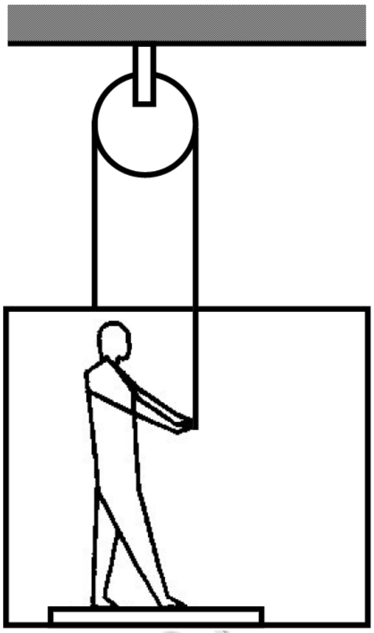
$m_b u_b + M_G u_g = m_b v_b + M_G v_G$ [Here m_b = mass of ball, M_g = Mass of gun, u_b = initial velocity of ball, v_b = final velocity of ball, v_g = final velocity of gun]

$\Rightarrow m_b \times 0 + M_G \times 0 = 1 \times 40 + 100v_G$

$100v_G = -40$

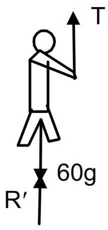
Recoil velocity of Gun $= \frac{-40}{100}ms^{-1} = \frac{-2}{5}ms^{-1} = -0.4ms^{-1}$ i.e opposite to the speed of ball.

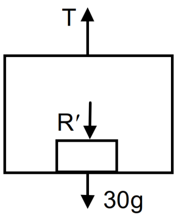
123. Figure shows a man of mass 60kg standing on a light weighing machine kept in a box of mass 30kg. The box is hanging from a pulley fixed to the ceiling through a light rope, the other end of which is held by the man himself. If the man manages to keep the box at rest, what is the weight shown by the machine? What force should he exert on the



rope to get his correct weight on the machine?

Ans. :





i. Given, Mass of man = 60kg.

Let R' = apparent weight of man in this case.

Now, R' + T - 60g = 0 [From FBD of man]

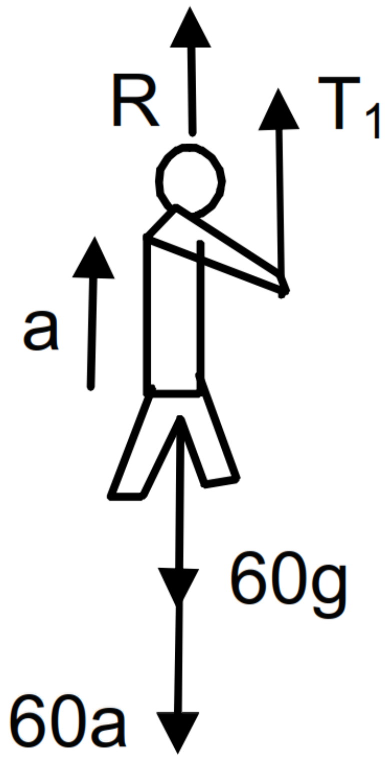
⇒ T = 60g - R' ...(i)

T - R' - 30g = 0 ...(ii) [From FBD of box]

⇒ 60g - R' - R' - 30g = 0 [From (i)]

⇒ R' = 15g The weight shown by the machine is 15kg.

ii. To get his correct weight suppose the applied force is 'T' and so, acclerates upward with 'a'. In this case, given that correct weight = R = 60g, where g = 10 due to gravity

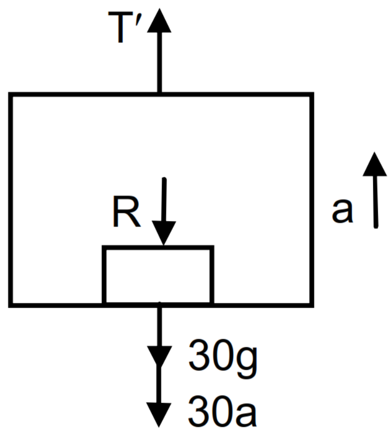


From the FBD of the man

$T^1 + R - 60g - 60a = 0$

$\Rightarrow T^1 - 60a = 0$ [$\therefore R = 60g$]

$\Rightarrow T^1 = 60a$ ...(i)



From the FBD of the box

$T_1 - R - 30g - 30a = 0$

$\Rightarrow T^1 - 60g - 30g - 30a = 0$

$\Rightarrow T^1 - 30a = 90g = 900$

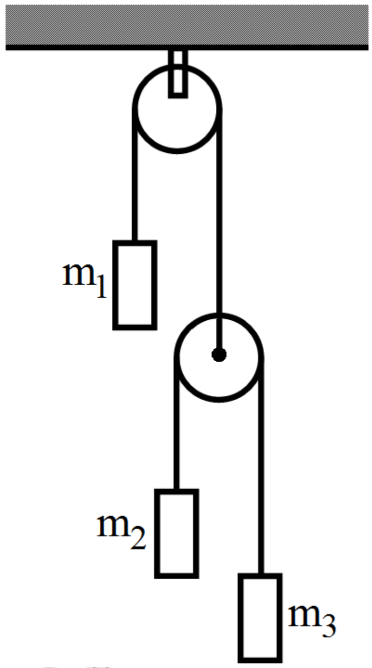
$\Rightarrow T^1 = 30a - 900$ ...(ii)

From eqn (i) and eqn (ii) we get

$T^1 = 2T^1 - 1800 \Rightarrow T^1 = 1800N$.

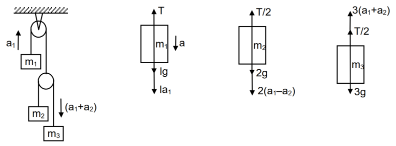
$\therefore$ So, he should exert 1800N force on the rope to get correct reading.

124. Let $m_1 = 1kg$, $m_2 = 2kg$ and $m_3 = 3kg$ in figure. Find the accelerations of m_1, m_2 and m_3. The string from the upper pulley to m_1 is 20cm when the system is released from



rest. How long will it take before m, strikes the pulley?

Ans. :



Let the block m+1+ moves upward with acceleration a, and the two blocks m_2 an m_3 have relative acceleration a_2 due to the difference of weight between them. So, the actual acceleration at the blocks m_1, m_2 and m_3 will be a_1.

(a_1 - a_2) and (a_1 + a_2) as shown

T = 1g - 1a_2 = 0 ...(i) from fig. (2)

$\frac{T}{2} - 2g - 2(a_1 - a_2) = 0 \ldots (ii)$ from fig. (3)

$\frac{T}{2} - 3g - 3(a_1 + a_2) = 0 \ldots (iii)$ from fig. (4)

From eqn (i) and eqn (ii), eliminating T

we get, 1g + 1a_2 = 4g + 4(a_1 + a_2) ⇒ 5a_2 - 4a_1 = 3g (iv)

From eqn (ii) and eqn (iii),

we get 2g + 2(a_1 - a_2) = 3g - 3(a_1 - a_2) ⇒ 5a_1 + a_2 = (v)

Solving (iv) and (v) $a_1 = \frac{2g}{29}$ and $a_2 = g - 5a_1 = g - \frac{10g}{29} = \frac{19g}{29}$

So, $a_1 - a_2 = \frac{2g}{29} - \frac{19g}{29} = -\frac{17g}{29}$

$a_1 + a_2 = \frac{2g}{29} + \frac{19g}{29} = \frac{21g}{29}$ acceleration of m_1, m_2, m_3 ae

$\frac{19g}{29}(up)\frac{17g}{29}(down)\frac{21g}{29}(down)$ respectively.

Again, for m_1, u = 0, s = 20cm = 0.2m and $a_2 = \frac{19}{29}g$ [g = 10m/s^2]

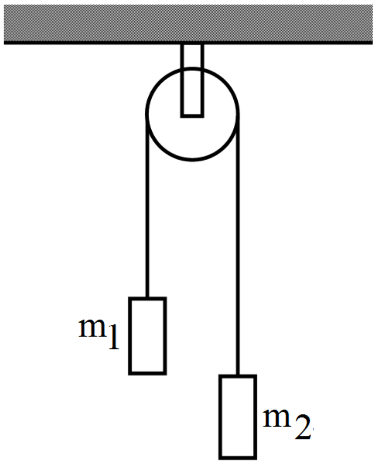
$\therefore S = ut + \frac{1}{2}at^2 = 0.2 = \frac{1}{2} \times \frac{19}{29}gt^2 \Rightarrow t = 0.25\,sec.$

125. In a simple Atwood machine, two unequal masses m_1 and m_2 are connected by a string going over a clamped light smooth pulley. In a typical arrangement m_1 = 300g and m_2 = 600g. The system is released from rest.

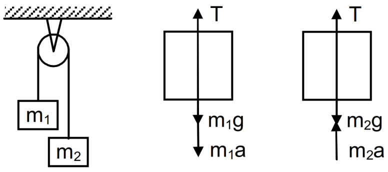
a. Find the distance travelled by the first block in the first two seconds.

b. Find the tension in the string.

c. Find the force exerted by the clamp on the pulley.



Ans. :



$m_1 = 0.3kg$, $m_2 = 0.6kg$

$T - (m_1g + m_1a) = 0$ ...(i)

$\Rightarrow T = m_1g + m_1a$

$T + m_2a - m_2g = 0$ ...(ii)

$\Rightarrow T = m_2g - m_2a$

From equation (i) and equation (ii)

$m_1g + m_1a + m_2a - m_2g = 0$, from (i)

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

$$\Rightarrow a = f\left(\frac{m_2 - m_1}{m_1 - m_2}\right) = 9.8\left(\frac{0.6 - 0.3}{0.6 + 0.3}\right) = 3.266ms^{-2}.$$

a. t = 2 sec acceleration = 3.266 ms^{-2}

Initial velocity u = 0

So, distance travelled by the body is,

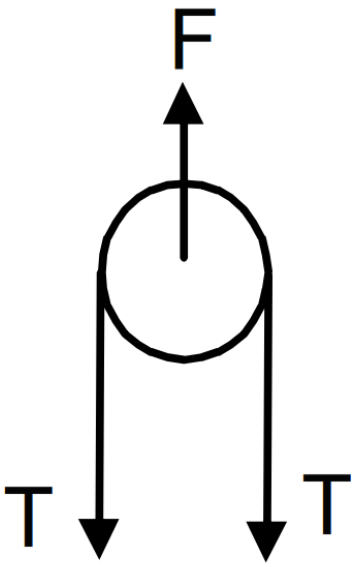
$$S = ut + \frac{1}{2}at^2 \Rightarrow 0 + \frac{1}{2}(3.266)2^2 = 6.5m$$

b. From (i) $T = m_1(g + a) = 0.3(9.8 + 3.26) = 3.9N$

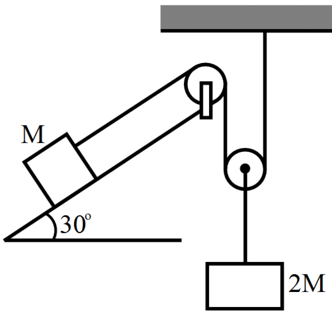
c. The force exerted by the clamp on the pully is given by

$F - 2T = 0$

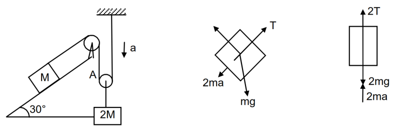
$F = 2T = 2 \times 3.9 = 7.8N$.



126. Find the acceleration of the block of mass M in the situation shown in figure. All the surfaces are frictionless and the pulleys and the string are light.



Ans. :



$2\text{Ma} + \text{Mg}\ \sin\theta - \text{T} = 0$

$\Rightarrow \text{T} = 2\text{Ma} + \text{Mg}\ \sin\theta \ldots \text{(i)}$

$2\text{T} + 2\text{Ma} - 12\text{Mg} = 0$

$\Rightarrow 2(2\text{Ma} + \text{Mg}\sin\theta) + 2\text{Ma} - 2\text{Mg} = 0$ [From (i)]

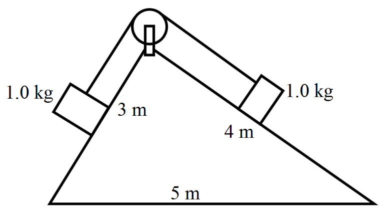
$\Rightarrow 4\text{Ma} + 2\text{Mg}\ \sin\theta + 2\text{Ma} - 2\text{Mg} = 0$

$\Rightarrow 6\text{Ma} + 2\text{Mg}\ \sin 30^\circ - 2\text{Mg} = 0$

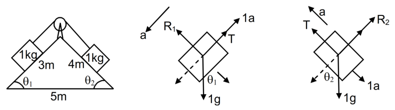
$\Rightarrow 6\text{Ma} = \text{Mg} \Rightarrow \text{a} = \frac{\text{g}}{6}.$

Acceleration of mass M is $2\text{a} = \text{s} \times \frac{\text{g}}{6} = \frac{\text{g}}{3}$ up the plane.

127. Consider the situation shown in figure. All the surfaces are frictionless and the string and the pulley are light. Find the magnitude of the acceleration of the two blocks.



Ans. :



$\sin\theta_1 = \frac{4}{5}$

$\sin\theta_2 = \frac{3}{5}$

$\mathrm{g}\sin\theta_1 - (\mathrm{a} + \mathrm{T}) = 0$

$\Rightarrow \mathrm{g}\sin\theta_1 = \mathrm{a} + \mathrm{T} \ldots (\mathrm{i})$

$\Rightarrow \mathrm{T} + \mathrm{a} - \mathrm{g}\sin\theta_1 = 0$

$\mathrm{T} - \mathrm{g}\sin\theta_2 - \mathrm{a} = 0$

$\Rightarrow \mathrm{T} = \mathrm{g}\sin\theta_2 + \mathrm{a} \ldots (\mathrm{ii})$

$\Rightarrow \mathrm{T} + \mathrm{a} - \mathrm{g}\sin\theta_1 = 0$

From eqn (i) and (ii)

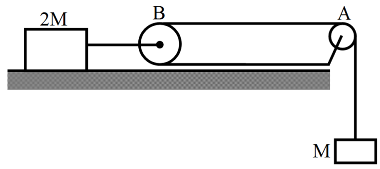
$\mathrm{g}\sin\theta_2 + \mathrm{a} + \mathrm{a} - \mathrm{g}\sin\theta_1 = 0$

$\Rightarrow 2\mathrm{a} = \mathrm{g}\sin\theta_1 - \mathrm{g}\sin\theta_2 = \mathrm{g}\left(\frac{4}{5} - \frac{3}{5}\right) = \frac{\mathrm{g}}{5}$

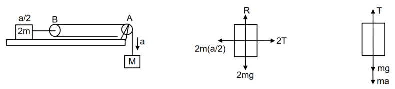
$\Rightarrow \mathrm{a} = \frac{\mathrm{g}}{5} \times \frac{1}{2} = \frac{\mathrm{g}}{10}$

128. Consider the situation shown in figure. Both the pulleys and the string are light and all the surfaces are frictionless.

a. Find the acceleration of the mass M.
b. Find the tension in the string.
c. Calculate the force exerted by the clamp on the pulley A in the figure.



Ans. :



$\mathrm{Ma} - 2\mathrm{T} = 0$

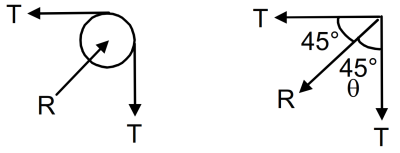
$\Rightarrow \mathrm{Ma} = 2\mathrm{T} \Rightarrow \mathrm{T} = \frac{\mathrm{Ma}}{2}.$

$\mathrm{T} + \mathrm{Ma} - \mathrm{Mg} = 0$

$\Rightarrow \frac{\mathrm{Ma}}{2} + \mathrm{ma} = \mathrm{Mg}. \left(\text{because} = \mathrm{T} = \frac{\mathrm{Ma}}{2}\right)$

$\Rightarrow 3\mathrm{Ma} = 2\mathrm{Mg} \Rightarrow \mathrm{a} = \frac{2\mathrm{g}}{3}$

a. acceleration of mass M is $\frac{2\mathrm{g}}{3}$.
b. Tension $\mathrm{T} = \frac{\mathrm{Ma}}{2} = \frac{\mathrm{M}}{2} = \frac{2\mathrm{g}}{3} = \frac{\mathrm{Mg}}{3}$
c. Let, R^1 = resultant of tensions = force exerted by the clamp on the pulley



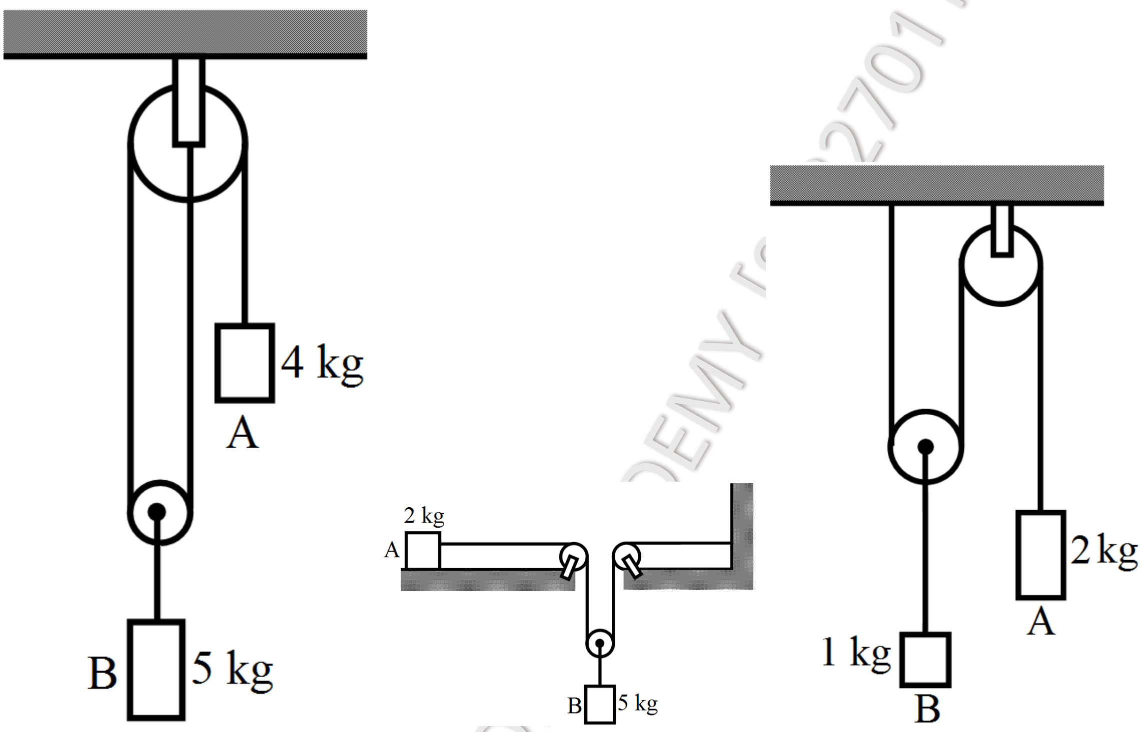
$$R^1 = \sqrt{T^2 + T^2} = \sqrt{2}T$$

$\therefore R = \sqrt{2}T = \sqrt{2}\frac{Mg}{3} = \frac{\sqrt{2}Mg}{3}$

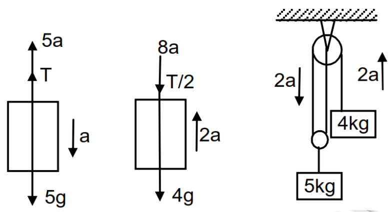
Again, $\tan\theta = \frac{T}{T} = 1 \Rightarrow \theta = 45^\circ.$

So, it is $\frac{\sqrt{2}Mg}{3}$ at an angle of 45° with horizontal.

129. Find the acceleration of the blocks A and B in the three situations shown in figure.



Ans. :



a. $5a + T - 5g = 0 \Rightarrow T = 5g - 5a \ldots (i)$ (From FBD - 1)

Again $\left(\frac{1}{2}\right) - 4g - 8a = 0 \Rightarrow T = 8g - 16a \ldots (ii)$ (From FBD - 2)

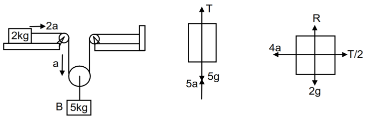
From equn (i) and (ii), we get

$5g - 5a = 8g + 16a \Rightarrow 21a = -3g \Rightarrow a = -\frac{1}{7}g$

So, acceleration of 5kg mass is $\frac{g}{7}$ upward and that of 4kg mass is

$2a = \frac{2g}{7}$ (downward).

b.



$4a - \frac{t}{2} = 0 \Rightarrow 8a - T = 0 \Rightarrow T = 8a \ldots (ii)$ [from FBD - 4]

Again, $T + 5a - 5g = 0 \Rightarrow 8a + 5a - 5g = 0$

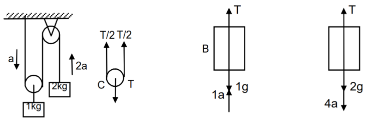
$\Rightarrow 13a - 5g = 0 \Rightarrow a = \frac{5g}{13}$ downward. (from FBD - 3)

Acceleration of mass

A. $\text{kg is } 2a = \frac{10}{13}(g)\ \&\ 5\text{kg}$

B. is $\frac{5g}{13}$.

c.



$T + 1a - 1g = 0 \Rightarrow T = 1g - 1a \ldots (i)$ [From FBD - 5]

Again, $\frac{T}{2} - 2g - 4a = 0 \Rightarrow T - 4g - 8a = 0 \ldots (ii)$ [From FBD - 6]

$\Rightarrow 1g - 1a - 4g - 8a = 0$ [From (i)]

$\Rightarrow a = -\left(\frac{g}{3}\right)$ downward.

Acceleration of mass 1kg(b) is $\frac{g}{3}(\text{up})$

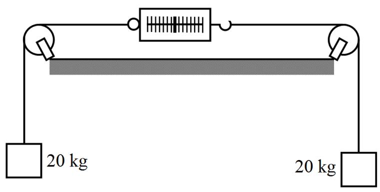
Acceleration of mass 2kg(A) is $\frac{2g}{3}$ (downward).

130. Figure shows a light spring balance connected to two blocks of mass 20kg each. The graduations in the balance measure the tension in the spring.

a. What is the reading of the balance?

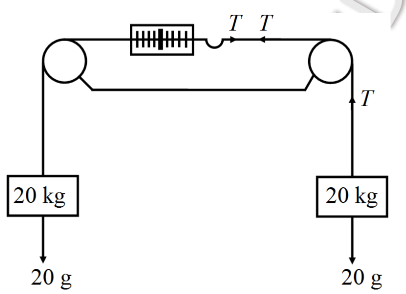
b. Will the reading change if the balance is heavy, say 2.0kg?

c. What will happen if the spring is light but the blocks have unequal masses?



Ans. :

a.



The reading of the balance = Tension in the string

And tension in the string = 20g

So, the reading of the balance = 20g = 200N

b. If the balance is heavy, the reading will not change because the weight of spring balance does not affect the tension in the string.

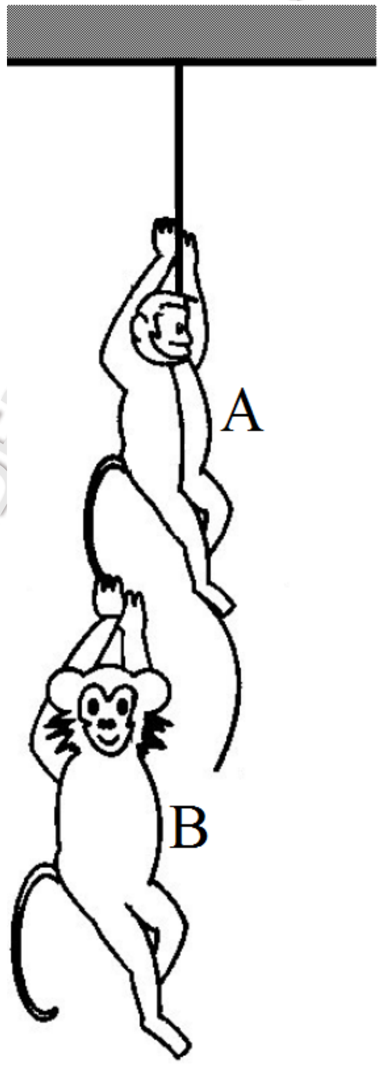
c. If the blocks have unequal masses, the spring balance will accelerate towards the heavy block with an acceleration a. Then the reading will be equal to the tension in the string.

Suppose $m_1 > m_2$.

Then tension in the string,

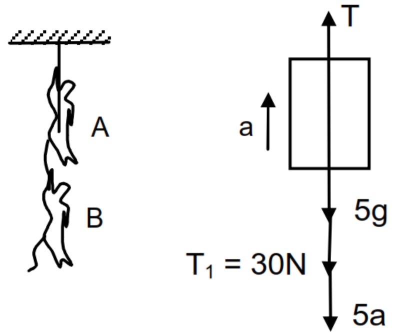
$T = \frac{2m_1m_2g}{m_1+m_2}$

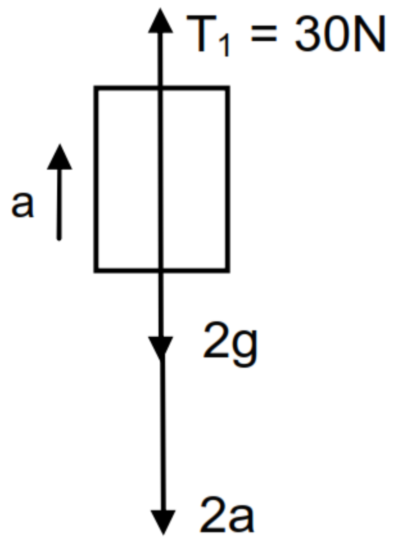
131. The monkey B shown in figure is holding on to the tail of the monkey A which is climbing up a rope. The masses of the monkeys A and B are 5kg and 2kg respectively. If A can tolerate a tension of 30N in its tail, what force should it apply on the rope in order



to carry the monkey B with it? Take $g = 10 m/s^2$

Ans. : Suppose A move upward with acceleration a, such that in the tail of A maximum tension 30N produced.





T - 5g - 30 - 5a = 0 ...(i)

⇒ T = 50 + 30 + (5 × 5) = 105N (max)

30 - 2g - 2a = 0 ...(ii)

⇒ 30 - 20 - 2a = 0 ⇒ a = 5m/s^2

So, A can apply a maximum force of 105N in the rope to carry the monkey B with it.

For minimum force there is no acceleration of monkey 'A' and B. ⇒ a = 0

Now equation (ii) is T'_1 - 2g = 0 ⇒ T'_1 = 20N (wt. of monkey B)

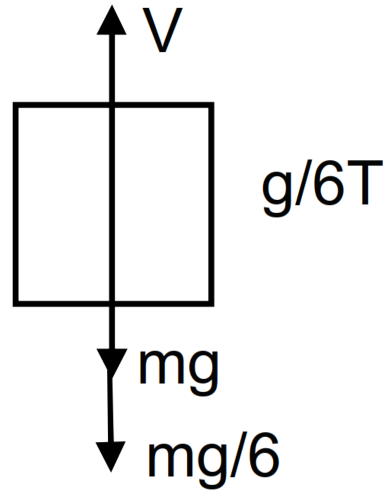
Equation (i) is T - 5g - 20 = 0 [As T'_1 = 20N]

⇒ T = 5g + 20 = 50 + 20 = 70N.

∴ The monkey A should apply force between 70N and 105N to carry the monkey B with it.

132. An empty plastic box of mass m is found to accelerate up at the rate of $\frac{g}{6}$ when placed deep inside water. How much sand should be put inside the box so that it may accelerate down at the rate of $\frac{g}{6}$?

Ans. : When the box is accelerating upward,



$$U-mg-m\left(\frac{g}{6}\right)=0$$

$$\Rightarrow U=mg+\frac{mg}{6}=m\left\{g+\left(\frac{g}{6}\right)\right\}=7\frac{mg}{7}\ \ldots(i)$$

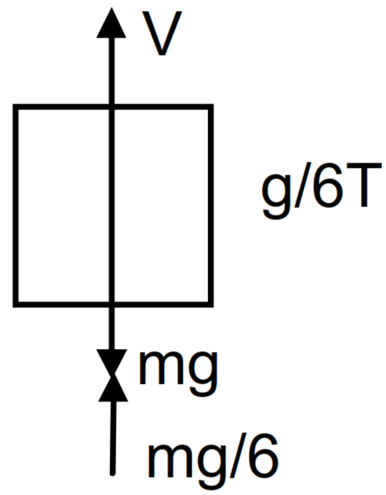
$$\Rightarrow m=\frac{6U}{7g}.$$

When it is accelerating downward, let the required mass be M.

$$U-Mg+\frac{Mg}{6}=0$$

$$\Rightarrow U=\frac{6Mg-Mg}{6}=\frac{5Mg}{6}\Rightarrow M=\frac{6U}{5g}$$

Mass to be added $=M-m=\frac{6U}{5g}-\frac{6U}{7g}=\frac{6U}{g}\left(\frac{1}{5}-\frac{1}{7}\right)$



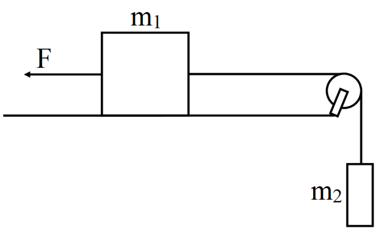
$$=\frac{6U}{g}\left(\frac{2}{35}\right)=\frac{12}{35}\left(\frac{U}{g}\right)$$

$=\frac{12}{35}\left(\frac{7mg}{6}\times\frac{1}{g}\right)$ from (i)

$$=\frac{2}{5}m.$$

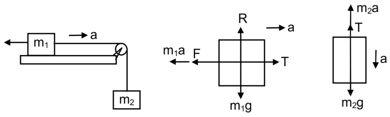
$\therefore$ The mass to be added is $\frac{2m}{5}$.

133. A constant force $F=\frac{m_2 g}{2}$ is applied on the block of mass m_1 as shown in figure. The string and the pulley are light and the surface of the table is smooth. Find the



acceleration of m_1.

Ans. :



From the above Free body diagram

$\mathrm{M_1a + F - T = 0 \Rightarrow T = m_1a + F \ldots (i)}$

From the above Free body diagram

$\mathrm{m_2a + T - m_2g = 0 \ldots (ii)}$

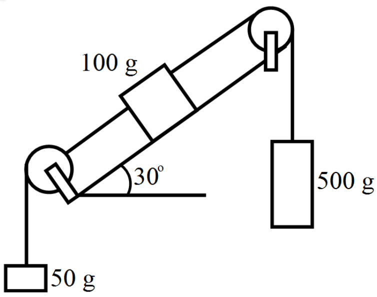
$\Rightarrow \mathrm{m_2a + m_1a + F - m_2g = 0}$ (from (i))

$\Rightarrow \mathrm{a(m_1 + m_2) + \frac{m_2g}{2} - m_2g = 0} \left\{\text{because f } = \frac{\mathrm{m^2g}}{2}\right\}$

$\Rightarrow \mathrm{a(m_1 + m_2) - m_2g = 0}$

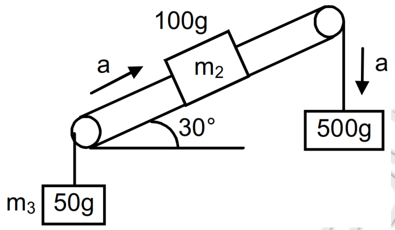
$\Rightarrow \mathrm{a(m_1 + m_2) = \frac{m_2g}{2} \Rightarrow a\frac{m_2g}{2(m_1 = m_2)}}$

Acceleration of mass m_1 is $\frac{\mathrm{m_2g}}{2(\mathrm{m_1 = m_2})}$ towards right.



134. Find the acceleration of the 500g block in figure.

Ans. :



m_1 = 100g = 0.1kg

m_2 = 500g = 0.5kg

m_3 = 50g = 0.05kg.

T + 0.5a - 0.5g = 0 ...(i)

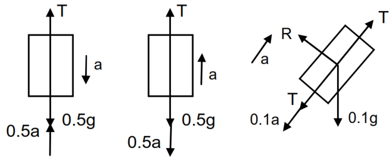
T_1 - 0.5a - 0.05g = a ...(ii)

T_1 + 0.1a - T + 0.05g = 0 ...(iii)

From equn (ii) T_1 = 0.05g + 0.05a ...(iv)

From equn (i) T_1 = 0.5g - 0.5a ...(v)

Equn (iii) becomes $T_1 + 0.1a - T + 0.05g = 0$

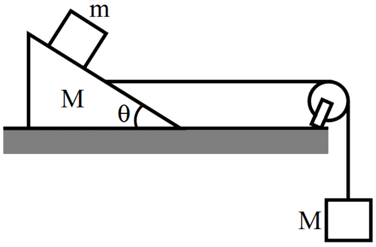


$\Rightarrow 0.05g + 0.05a + 0.1a - 0.5g + 0.5a + 0.05g = 0$ [From (iv) and (v)]

$\Rightarrow 0.65a = 0.4g \Rightarrow a = \frac{0.4}{0.65} = \frac{40}{65}g = \frac{8}{13}g$ downward

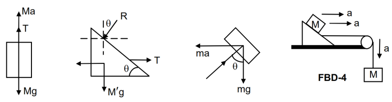
Acceleration of 500gm block is $\frac{8g}{13g}$ downward

135. Find the mass M of the hanging block in figure which will prevent the smaller block from slipping over the triangular block. All the surfaces are frictionless and the strings



and the pulleys are light.

Ans. :



As the block 'm' does not slinover M', ct will have same acceleration as that of M' From the freebody diagrams.

$\mathrm{T} + \mathrm{Ma} - \mathrm{Mg} = 0 \ldots (\mathrm{i})$ (From FBD - 1)

$\mathrm{T} - \mathrm{M'a} - \mathrm{R}\sin\theta = 0 \ldots (\mathrm{ii})$ (From FBD - 2)

$\mathrm{R}\sin\theta - \mathrm{ma} = 0 \ldots (\mathrm{iii})$ (From FBD - 3)

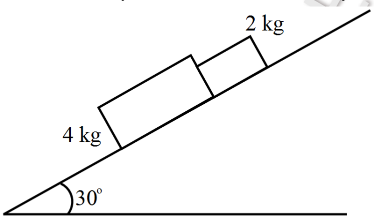
$\mathrm{R}\cos\theta - \mathrm{mg} = 0 \ldots (\mathrm{iv})$ (From FBD - 4)

Eliminating T, R and a from the above equation, we get $\mathrm{M} = \frac{\mathrm{M'+m}}{\cot\theta - 1}$

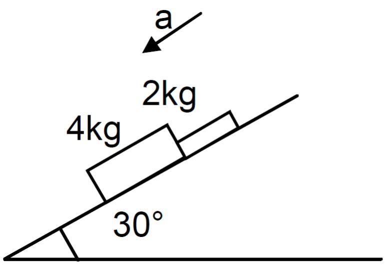
136. Figure shows two blocks in contact sliding down an inclined surface of inclination 30°. The friction coefficient between the block of mass 2.0kg and the incline is μ_1, and that between the block of mass 4.0kg and the incline is μ_2. Calculate the acceleration of the 2.0kg block if:

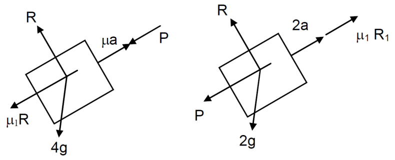
a. $\mu_1 = 0.20$ and $\mu_2 = 0.30$

b. $\mu_1 = 0.30$ and $\mu_2 = 0.20$ Take $g = 10\mathrm{m/s^2}$.



Ans. :





a. From the free body diagram

$\mathrm{R} = 4\mathrm{g}\cos 30^\circ = 4 \times 10 \times \frac{\sqrt{3}}{2} = 20\sqrt{3} \ldots \mathrm{(i)}$

$\mu_2\mathrm{R} + 4\mathrm{a} - \mathrm{P} - 4\mathrm{g}\sin 30^\circ = 0$

$\Rightarrow 0.3(40)\cos 30^\circ + 4\mathrm{a} - \mathrm{P} - 40\sin 20^\circ = 0 \ldots \mathrm{(ii)}$

$\mathrm{P} + 2\mathrm{a} + \mu_1\mathrm{R}_1 - 2\mathrm{g}\sin 30^\circ = 0 \ldots \mathrm{(iii)}$

$\mathrm{R}_1 = 2\mathrm{g}\cos 30^\circ = 2 \times 10 \times \frac{\sqrt{3}}{2} = 10\sqrt{3} \ldots \mathrm{(iv)}$

Equn. (ii) $6\sqrt{3} + 4\mathrm{a} - \mathrm{P} - 20 = 0$

Equn (iv) $\mathrm{P} + 2\mathrm{a} + 2\sqrt{3} - 10 = 0$

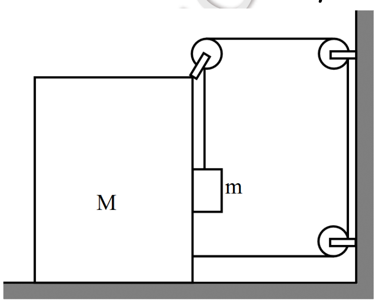
From Equn (ii) & (iv) $6\sqrt{3} + 6\mathrm{a} - 30 + 2\sqrt{3} = 0$

$\Rightarrow 6\mathrm{a} = 30 - 8\sqrt{3} = 30 - 13.85 = 16.15$

$\Rightarrow \mathrm{a} = \frac{16.15}{6} = 2.69 = 2.7\mathrm{m/s}^2$

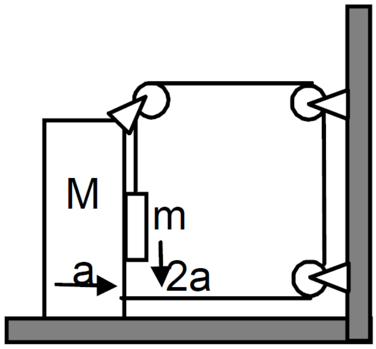
b. can be solved. In this case, the 4kg block will travel with more acceleration because, coefficient of friction is less than that of 2kg. So, they will move separately. Drawing the free body diagram of 2kg mass only, it can be found that, a = 2.4m/s^2.

137. Find the acceleration of the block of mass M in the situation of figure. The coefficient of friction between the two blocks is μ_1 and that between the bigger block and the



ground is μ_2.

Ans. : Let the acceleration of block M is 'a' towards right. So, the block 'm' must go down with an acceleration '2a'.



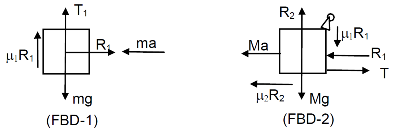
As the block ‘m’ is in contact with the block ‘M’, it will also have acceleration ‘a’ towards right. So, it will experience two inertia forces as shown in the free body diagram-1.

From free body diagram-1

$\mathrm{R_1 - ma = 0 \Rightarrow R_1 = ma \ldots (i)}$

Again, $\mathrm{2ma + T - mg + \mu_1 R_1 = 0}$

$\mathrm{\Rightarrow T = mg - (2 - \mu_1)ma \ldots (ii)}$



From free body diagram-2

$\mathrm{T + \mu_1 R_1 + mg - R_2 = 0}$

$\mathrm{\Rightarrow R_2 = T + \mu_1 ma + Mg}$ [Putting the value of R_1 from (i)]

$\mathrm{= (mg - 2ma - \mu_1 ma) + \mu_1 ma + Mg}$ [Putting the value of T from (ii)]

$\mathrm{\therefore R_2 = Mg + mg - 2ma \ldots (iii)}$

Again, form the free body diagram-2

$\mathrm{T + T - R - Ma - \mu_2 R_2 = 0}$

$\mathrm{\Rightarrow 2T - MA - mA - \mu_2(Mg + mg - 2ma) = 0}$ [Putting the values of R_1 and R_2 from (i) and (iii)]

$\mathrm{\Rightarrow 2T = (M + m) + \mu_2(Mg + mg - 2ma) \ldots (iv)}$

From equation (ii) and (iv)

$\mathrm{2T = 2mg - 2(2 + \mu_1)mg}$

$\mathrm{= (M + m)a + \mu_2(Mg + mg - 2ma)}$

$\mathrm{\Rightarrow 2mg - \mu_2(M + m)g}$

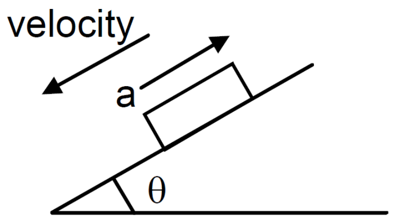
$\mathrm{= \ a(M + m - 2\mu_2 m + 4m + 2\mu_1 m)}$

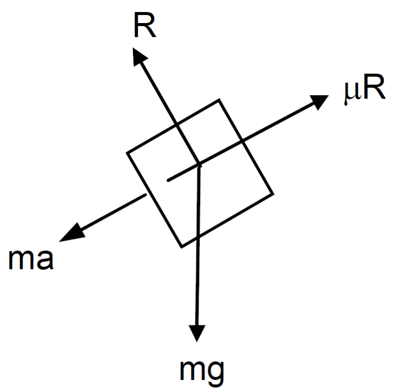
$\mathrm{\Rightarrow a = \frac{[2m - \mu_2(M + m)]g}{M + m[5 + 2(\mu_1 - \mu_2)]}}$

138. The friction coefficient between a road and the tyre of a vehicle is $\frac{4}{3}$. Find the maximum incline the road may have so that once hard brakes are applied and the wheel starts skidding, the vehicle going down at a speed of 36km/hr is stopped within 5m.

Ans. :

$\theta \rightarrow$ the max. angle





$s = 5\text{m},\ \mu = \frac{4}{3}, g = 10\text{m/s}^2$

$u = 36\text{km/h} = 10\text{m/s},\ v = 0,$

$a = \frac{v^2 - u^2}{2s} = \frac{0 - 10^2}{2 \times 5} = -10\text{m/s}^2$

From the freebody diagrams,

$R - mg\cos\theta = 0; g = 10\text{m/s}^2$

$\Rightarrow R = mg\cos\theta \ldots (i); \mu = \frac{4}{3}.$

Again, $ma + mg\sin\theta - \mu R = 0$

$\Rightarrow ma + mg\sin\theta - \mu mg\cos\theta = 0$

$\Rightarrow a + g\sin\theta - mg\cos\theta = 0$

$\Rightarrow 10 + 10\sin\theta - \left(\frac{4}{3}\right) \times 10\cos\theta = 0$

$\Rightarrow 30 + 30\sin\theta - 40\cos\theta = 0$

$\Rightarrow 3 + 3\sin\theta - 4\cos\theta = 0$

$\Rightarrow 4\cos\theta - 3\sin\theta = 3$

$\Rightarrow 4\sqrt{1 - \sin^2\theta} = 3 + 3\sin\theta$

$\Rightarrow 16(1 - \sin^2\theta) = 9 + 9\sin^2\theta + 18\sin\theta$

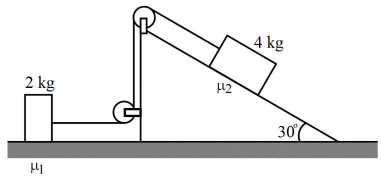
$\sin\theta = \frac{-18 \pm \sqrt{18^2 - 4(25)(-7)}}{2 \times 25}$ [Taking +ve sign only]

$= \frac{-18 \pm 32}{50} = \frac{14}{50} = 0.28$

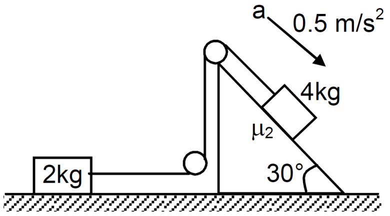
$\Rightarrow \theta = \sin^{-1}(0.28) = 16^\circ$

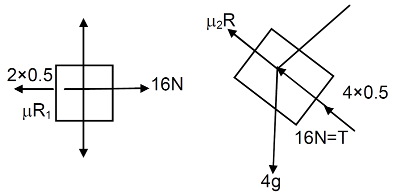
Maximum incline is $\theta = 16^\circ$

139. If the tension in the string in figure is 16N and the acceleration of each block is 0.5m/s^2, find the friction coefficients at the two contacts with the blocks.



Ans. :





From the free body diagram

$\mu_1 \mathrm{R} + 1 - 16 = 0$

$\Rightarrow \mu_1(2\mathrm{g}) + (-15) = 0$

$\Rightarrow \mu_1 = \frac{15}{20} = 0.75$

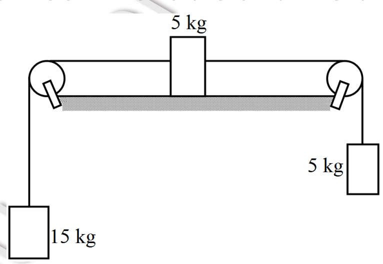
$\mu_2 \mathrm{R}_1 + 4 \times 0.5 + 16 - 4\mathrm{g}\sin 30^\circ = 0$

$\Rightarrow \mu_2\left(\frac{20}{\sqrt{3}}\right) + 2 + 16 - 20 = 0$

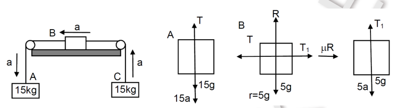
$\Rightarrow \mu_2 = \frac{2}{20\sqrt{3}} = \frac{1}{17.32} = 0.057 \approx 0.06$

$\therefore$ Co-efficient of friction $\mu_1 = 0.75$ and $\mu_2 = 0.06$

140. The friction coefficient between the table and the block shown in figure is 0.2. Find the tensions in the two strings.



Ans. :



From the free body diagram

$\mathrm{T} + 15\mathrm{a} - 15\mathrm{g} = 0$

$\Rightarrow \mathrm{T} = 15\mathrm{g} - 15\mathrm{a} \ldots (1)$

$\mathrm{T} - (\mathrm{T}_1 + 5\mathrm{a} + \mu\mathrm{R}) = 0$

$\Rightarrow \mathrm{T} - (5\mathrm{g} + 5\mathrm{a} + 5\mathrm{a} + \mu\mathrm{R}) = 0$

$\Rightarrow \mathrm{T} = 5\mathrm{g} + 10\mathrm{a} + \mu\mathrm{R} \ldots (\mathrm{ii})$

$\mathrm{T}_1 - 5\mathrm{g} - 5\mathrm{a} = 0$

$\Rightarrow T_1 = 5g + 5a \ldots (iii)$

From (i) & (ii)

$15g - 15a = 5g + 10a + 0.2\,(5g)$

$\Rightarrow 25a = 90 \Rightarrow a = 3.6 m/s^2$

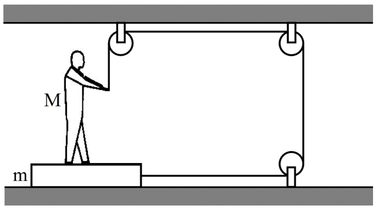
Equation (ii)

$\Rightarrow T = 5 \times 10 + 10 \times 3.6 + 0.2 \times 5 \times 10$

$\Rightarrow 96N$ in the left string

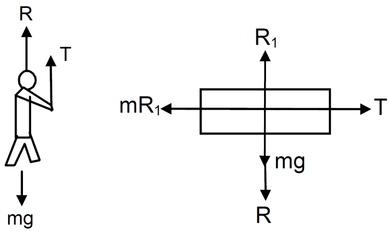
Equation (iii) $T_1 = 5g + 5a = 5 \times 10 + 5 \times 3.6 = 68N$ in the right string.

141. The friction coefficient between the board and the floor shown in figure is μ. Find the maximum force that the man can exert on the rope so that the board does not slip on



the floor.

Ans. :



Let, the max force exerted by the man is T.

From the free body diagram

$R + T - Mg = 0$

$\Rightarrow R = Mg - T \ldots (i)$

$R_1 - R - mg = 0$

$\Rightarrow R_1 = R + mg \ldots (ii)$

And $T - \mu R_1 = 0$

$\Rightarrow T - \mu(R + mg) = 0$ [From equn. (ii)]

$\Rightarrow T - \mu R - \mu mg = 0$

$\Rightarrow T - \mu(Mg + T) - \mu mg = 0$ [from (i)]

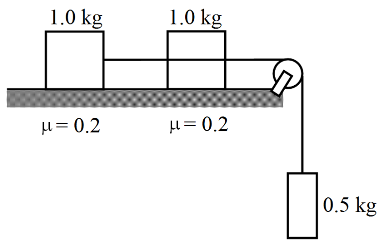
$\Rightarrow T(1 + \mu) = \mu Mg + \mu mg$

$\Rightarrow T = \frac{\mu(M + m)g}{1+\mu}$

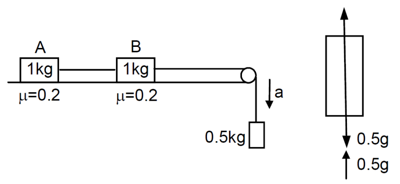
Maximum force exerted by man is $\frac{\mu(M + m)g}{1+\mu}$

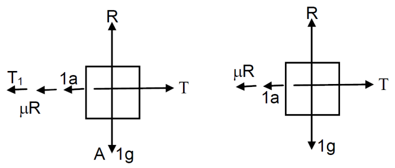
142. Consider the situation shown in figure. Calculate:

a. The acceleration of the 1.0kg blocks.
b. The tension in the string connecting the 1.0kg blocks.
c. The tension in the string attached to 0.50kg.



Ans. :





From the free body diagram

$\mathrm{T} + 0.5\mathrm{a} - 0.5\mathrm{g} = 0 \ldots (1)$

$\mu\mathrm{R} + 1\mathrm{a} + \mathrm{T}_1 - \mathrm{T} = 0 \ldots (2)$

$\mu\mathrm{R} + 1\mathrm{a} - \mathrm{T}_1 = 0$

$\mu\mathrm{R} + 1\mathrm{a} = \mathrm{T}_1 \ldots (3)$

From (2) & (3)

$\Rightarrow \mu\mathrm{R} + \mathrm{a} = \mathrm{T} - \mathrm{T}_1$

$\therefore \mathrm{T} - \mathrm{T}_1 = \mathrm{T}_1$

$\Rightarrow \mathrm{T} = 2\mathrm{T}_1$

Equation (2) becomes

$\mu\mathrm{R} + \mathrm{a} + \mathrm{T}_1 - 2\mathrm{T}_1 = 0$

$\Rightarrow \mu\mathrm{R} + \mathrm{a} - \mathrm{T}_1 = 0$

$\Rightarrow \mathrm{T}_1 = \mu\mathrm{R} + \mathrm{a} = 0.2\mathrm{g} + \mathrm{a} \ldots (4)$

Equation (1) becomes

$2\mathrm{T}_1 + \frac{0}{5\mathrm{a}} - 0.5\mathrm{g} = 0$

$\Rightarrow \mathrm{T}_1 = \frac{0.5\mathrm{g} - 0.5\mathrm{a}}{2} = 0.25\mathrm{g} - 0.25\mathrm{a} \ldots (5)$

From (4) & (5) $0.2\mathrm{g} + \mathrm{a} = 0.25\mathrm{g} - 0.25\mathrm{a}$

$\Rightarrow \mathrm{a} = \frac{0.05}{1.25} \times 10 = 0.04/10 = 0.4\mathrm{m/s}^2$

a. Accln of 1kg blocks each is $0.4\mathrm{m/s}^2$
b. Tension $T_1 = 0.2g + a + 0.4 = 2.4N$
c. $T = 0.5g - 0.5a = 0.5 \times 10 - 0.5 \times 0.4 = 4.8N$

143. A motorcycle has to move with a constant speed on an overbridge which is in the form of a circular arc of radius R and has a total length L. Suppose the motorcycle starts from the highest point.

a. What can its maximum velocity be for which the contact with the road is not broken at the highest point?

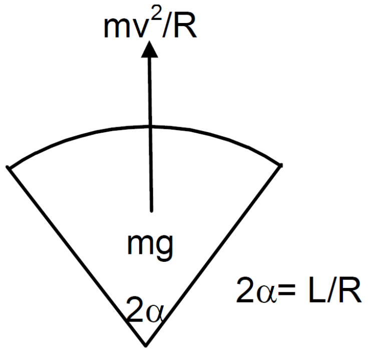
b. If the motorcycle goes at speed $\frac{1}{\sqrt{2}}$ times the maximum found in part (a), where will it lose the contact with the road?

c. What maximum uniform speed can it maintain on the bridge if it does not lose contact anywhere on the bridge?

Ans. : R = radius of the bridge.

L = total length of the over bridge.

a.



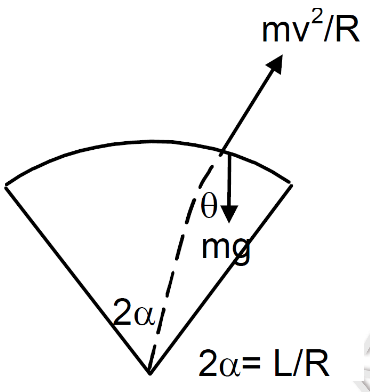
At the highest pt.

$\mathrm{mg} = \frac{\mathrm{mv}^2}{\mathrm{R}}$

$\Rightarrow \mathrm{v}^2 = \mathrm{Rg}$

$\Rightarrow \mathrm{v} = \sqrt{\mathrm{Rg}}$

b.



Given, $\mathrm{v} = \frac{1}{\sqrt{2}}\sqrt{\mathrm{Rg}}$

suppose it loses contact at B. So, at B, $\mathrm{mg}\cos\theta = \frac{\mathrm{mv}^2}{\mathrm{R}}$

$\Rightarrow \mathrm{v}^2 = \mathrm{Rg}\cos\theta$

$\Rightarrow \left(\sqrt{\frac{\mathrm{Rv}}{2}}\right)^2 = \mathrm{Rg}\cos\theta$

$\Rightarrow \frac{\mathrm{Rg}}{2} = \mathrm{Rg}\cos\theta$

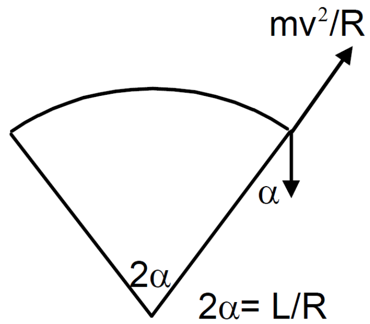
$\Rightarrow \cos\theta = \frac{1}{2}$

$\Rightarrow \theta = 60^\circ = \frac{\pi}{3}$

$\theta = \frac{\ell}{\mathrm{r}} \rightarrow \ell = \mathrm{r}\theta = \frac{\pi\mathrm{R}}{3}$

So, it will lose contact at distance $\frac{\pi\mathrm{R}}{3}$ from highest point.

c.



Let the uniform speed on the bridge be v.

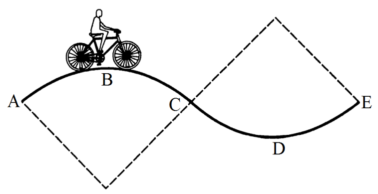
The chances of losing contact is maximum at the end of the bridge for which $\alpha = \frac{L}{2R}$.

So, $\frac{mv^2}{R} = mg\cos\alpha$

$\Rightarrow v = \sqrt{gR\cos\left(\frac{L}{2R}\right)}$

144. A track consists of two circular parts ABC and CDE of equal radius 100m and joined smoothly as shown in figure. Each part subtends a right angle at its centre. A cycle weighing 100 kg together with the rider travels at a constant speed of 18km/h on the track.

a. Find the normal contact force by the road on the cycle when it is at B and at D.
b. Find the force of friction exerted by the track on the tyres when the cycle is at B, C and D.
c. Find the normal force between the road and the cycle just before and just after the cycle crosses C.
d. What should be the minimum friction coefficient between the road and the tyre, which will ensure that the cyclist can move with constant speed? Take g= 10m/s^2.



Ans. : Radius of the curves = 100m

Weight = 100kg

Velocity = 18km/hr = 5m/sec Cl

a. $AT\ B = mg - \frac{mv^2}{R} = N \Rightarrow N = (100 \times 10) - \frac{100 \times 25}{100} = 1000 - 25 = 975N$

$AT\ D, N = mg - \frac{mv^2}{R} = 1000 + 25 = 1025N$

b. At B and D the cycle has no tendency to slide. So at B & D, frictional force is zero.

$At\ C, mg\sin\theta = F \Rightarrow F = 1000 \times \frac{1}{\sqrt{2}} = 707N$

c.

i. Before C $mg\cos\theta - N = \frac{mv^2}{R} \Rightarrow N = mg\cos\theta - \frac{mv^2}{R} = 707 - 25 = 683N$

ii. $\mathrm{N} - \mathrm{mg}\cos\theta = \frac{\mathrm{mv}^2}{\mathrm{R}} \Rightarrow \mathrm{N} = \frac{\mathrm{mv}^2}{\mathrm{R}} + \mathrm{mg}\cos\theta = 25 + 707 = 732\mathrm{N}$

To find out the minimum desired coefficient of friction, we have to consider a point just before C. (where N is minimum)

Now, $\mu\mathrm{N} = \mathrm{mg}\sin\theta \Rightarrow \mu \times 682 = 707 \Rightarrow \mu = 1.037$

145. A turn of radius 20m is banked for the vehicles going at a speed of 36 km/h. If the coefficient of static friction between the road and the tyre is 0.4, what are the possible speeds of a vehicle so that it neither slips down nor skids up?

Ans. : In the question it is given radius of turn r = 20m and banked with angle θ for speed

$v = \frac{36\mathrm{km}}{\mathrm{h}} = \frac{36\times5}{18} = 10\mathrm{m/\ sec}$

And coefficient of friction $\mu = 0.4$

From here we can find the value of $\tan\theta$

We know $\tan\theta = \frac{v^2}{\mathrm{rg}}$

$\Rightarrow \tan\theta = \frac{10^2}{20\times10} = \frac{1}{2}\ldots(1)$

We assume two conditions one when a vehicle moves with maximum speed in this condition the vehicle may skid up if speed will increase.

In this situation friction between road and tyre is opposite to skidding direction as shown in figure

We mark all forces on vehicle as shown in figure and dividing them in their component

From figure clearly see that if vehicle is in equilibrium so the force acting on vehicle are equal along the road and perpendicular to the road

Force along the road

$\Rightarrow \mathrm{mg}\sin\theta + \mu\mathrm{N} = \frac{\mathrm{m}v^2}{\mathrm{r}}\cos\theta$

Rearranging this equation

$\Rightarrow \mu\mathrm{N} = \frac{\mathrm{m}v^2}{\mathrm{r}}\cos\theta - \mathrm{mg}\sin\theta\ldots(2)$

Now take forces perpendicular to road

$\Rightarrow \mathrm{N} = \mathrm{mg}\cos\theta + \frac{\mathrm{m}v^2}{\mathrm{r}}\sin\theta\ldots(3)$

Divide (2) by (3)

$\Rightarrow \mu = \frac{\frac{\mathrm{m}v^2}{\mathrm{r}}\cos\theta - \mathrm{mg}\sin\theta}{\mathrm{mg}\cos\theta + \frac{\mathrm{m}v^2}{\mathrm{r}}\sin\theta}$

Solving this equation we get

$\Rightarrow \mu = \frac{v^2\cos\theta - \mathrm{r}\sin\theta}{\mathrm{rg}\cos\theta + v^2\sin\theta}$

Right hand side divided by $\cos\theta$

$\Rightarrow \mu(\mathrm{rg} + \mathrm{v}^2\tan\theta) = \mathrm{v}^2 - \mathrm{rg}\tan\theta$

Solving this we can find value of vv maximum velocity of vehicle where it will not skid

$\Rightarrow v = \sqrt{\frac{\mathrm{rg}\tan\theta + \mu\mathrm{rg}}{1 - \mu\tan\theta}}$

Put the given values in this equation

$\Rightarrow v=\sqrt{\frac{20\times10\times\frac{1}{2}+0.4\times20\times10}{1-0.4\times\frac{1}{2}}}$

$\Rightarrow v=\sqrt{225}$

$v=15\mathrm{m/\ sec}$

Convert into $\mathrm{km/\ h}$

Maximum speed $\mathrm{v}=54\mathrm{km/\ h}$

Now we take the minimum speed case in this case friction applied in upward direction along the road as shown in figure.

Equate Forces along road

$\Rightarrow \mu\mathrm{N}=\frac{\mathrm{m}v^2}{\mathrm{r}}\cos\theta=\mathrm{mg}\sin\theta$

$\Rightarrow \mu\mathrm{N}=\mathrm{mg}\sin\theta-\frac{\mathrm{m}v^2}{\mathrm{r}}\cos\theta\ldots(4)$

Forces perpendicular to road

$\Rightarrow \mathrm{N}=\mathrm{mg}\cos\theta-\frac{\mathrm{m}v^2}{\mathrm{r}}\sin\theta\ldots(5)$

Divide (4) by (5)

$\Rightarrow \mu=\frac{\mathrm{mg}\ \sin\theta-\frac{\mathrm{m}v^2}{\mathrm{r}}\cos\theta}{\mathrm{mg}\ \cos\theta+\frac{\mathrm{m}v^2}{\mathrm{r}}\sin\theta}$

Solving this we get

$\Rightarrow \mu=\frac{\mathrm{rg}\ \sin\theta-v^2\ \cos\theta}{\mathrm{rg}\ \cos\theta-v^2\ \sin\theta}$

Divide right hand side by $\cos\theta$

$\Rightarrow \mu=\frac{\mathrm{rg}\ \tan\theta-v^2}{\mathrm{rg}-v^2\ \tan\theta}$

Further solving it we get

$\Rightarrow \mu=\sqrt{\frac{\mathrm{rg}\ \tan\theta-\mu\mathrm{rg}}{\mu\ \tan\theta+1}}$

Putting given values in above equation

$\Rightarrow v=\sqrt{\frac{20\times10\times\frac{1}{2}+0.4\times20\times10}{0.4\times\frac{1}{2}+1}}$

By solving this

$\Rightarrow v=\sqrt{16.66}$

Minimum speed

$\therefore \mathrm{v}=4.08\mathrm{m/\ sec}$

Convert into $\mathrm{km/\ h}$

$v=4.08\times\frac{18}{5}=14.68\mathrm{km/\ h}$

Hence the minimum speed is $14.7\mathrm{km/\ h}$

146. A car moving at a speed of 36 km/hr is taking a turn on a circular road of radius 50m. A small wooden plate is kept on the seat with its plane perpendicular to the radius of the circular road (figure In). A small block of mass 100g is kept on the seat which rests against the plate. The friction coefficient between the block and the plate is $\mu=0.58$.

a. Find the normal contact force exerted by the plate on the block.

b. The plate is slowly turned so that the angle between the normal to the plate and the radius of the road slowly increases. Find the angle at which the block will just start sliding on the plate.

Ans. : v = Velocity of car = 36km/hr = 10m/s

r = Radius of circular path = 50m

m = mass of small body = 100g = 0.1kg.

μ = Friction coefficient between plate & body = 0.58

a. The normal contact force exerted by the plate on the block,

$$\mathrm{N}=\frac{\mathrm{mv}^2}{\mathrm{r}}=\frac{0.1\times 100}{50}=0.2\mathrm{N}$$

b. The plate is turned so the angle between the normal to the plate & the radius of the road slowly increases,

$$\mathrm{N}=\frac{\mathrm{mv}^2}{\mathrm{r}}\cos\theta\ \ldots(1)$$

$$\mu\,\mathrm{N}=\frac{\mathrm{mv}^2}{\mathrm{r}}\cos\theta\ \ldots(2)$$

Putting value of N from (1),

$$\mu\frac{\mathrm{mv}^2}{\mathrm{r}}\cos\theta=\frac{\mathrm{mv}^2}{\mathrm{r}}\sin\theta$$

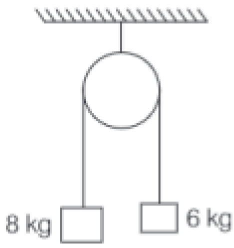
$$\Rightarrow \mu=\tan\theta$$

$$\Rightarrow \theta=\tan^{-1}\mu$$

$$\Rightarrow \theta=\tan^{-1}(0.58)=30^\circ$$

* Case study based questions [20]

147. Read the passage given below and answer the following questions from (i) to (v). Force of Friction on Connected Bodies When bodies are in contact, there are mutual contact forces satisfying the third law of motion. The component of contact force normal to the surfaces in contact is called normal reaction. The component parallel to the surfaces in



contact is called friction In the above figure, 8 kg and 6 kg are hanging stationary from a rough pulley and are about to move. They are stationary due to roughness of the pulley.

i. Which force is acting between pulley and rope?

   a. Gravitational force

   b. Tension force

   c. Frictional force

   d. Buoyant force

ii. The normal reaction acting on the system is

   a. 8g

   b. 6g

c. 2g
d. 4g

iii. The tension is more on side having mass of:
a. 8kg
b. 6kg
c. Same on both
d. Nothing can be said

iv. The force of friction acting on the rope is:
a. 20N
b. 30N
c. 40N
d. 50N

v. Coefficient of friction of the pulley is
a. $\frac{1}{6}$
b. $\frac{1}{7}$
c. $\frac{1}{5}$
d. $\frac{1}{4}$

Ans. :

i. (c) Frictional force

Explanation:

Frictional force acts between pulley and rope.

ii. (d) 4g

Explanation:

The reaction force is

R = T_1 + T_2 = (8 + 6)g = 14g

iii. (a) 8kg

Explanation:

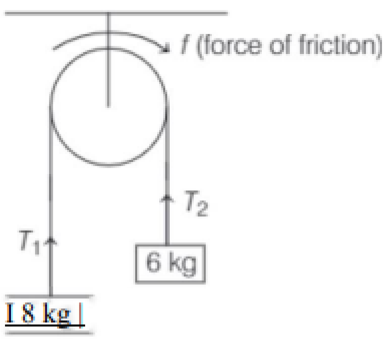
As, tension, T = mg

$\Rightarrow \mathrm{T} \propto \mathrm{M}$

So, the side having 8 kg mass will have more tension.

iv. (a) 20N

Explanation:



Due to friction, tension at all points of the thread is not alike.

T_1 - T_2 = f

⇒ f = 8g - 6g = 2g

= 28N

v. (b) $\frac{1}{7}$

Explanation:

As, UR = f = 20N

$$\mathrm{u}=\frac{20}{\mathrm{R}}=\frac{20}{14\times10}=\frac{1}{7}$$

148. Read the passage given below and answer the following questions from (i) to (v).

Momentum and Newton's Second Law of Motion Momentum of a body is the quantity of motion possessed by the body. It depends on the mass of the body and the velocity with which it moves. When a bullet is fired by a gun, it can easily pierce human tissue before coming to rest resulting in casualty. The same bullet fired with moderate speed will not cause much damage. The greater the change in momentum in a given time, the greater is the force that needs to be applied. The second law of motion refers to the general situation, where there is a net external force rating on the body.

i. A satellite in force-free space sweeps stationary interplanetary dust at a rate $\frac{\mathrm{dM}}{\mathrm{dt}}=\mathrm{dv},$ where M is the mass, v is the dt velocity of satellite and a is a constant. What is the deceleration of the satellite?

a. $\frac{-2\mathrm{av}^2}{\mathrm{M}}$

b. $\frac{-\mathrm{av}^2}{\mathrm{M}}$

c. $-\mathrm{av}^2$

d. $\frac{\mathrm{av}^2}{\mathrm{M}}$

ii. A body of mass 5 kg is moving with velocity of $\mathrm{v}=(2\hat{\mathrm{i}}+6\hat{\mathrm{j}})$ ms^{-1} at t = 0s. After time t = 2s, velocity of body is $(10\hat{\mathrm{i}}+6\hat{\mathrm{j}})$ ms^{-1}, then change in momentum of body is:

a. $40\hat{\mathrm{i}}\ \mathrm{kg}-\mathrm{ms}^{-1}$

b. $20\hat{\mathrm{i}}\ \mathrm{kg}-\mathrm{ms}^{-1}$

c. $30\hat{\mathrm{i}}\mathrm{kg}-\mathrm{ms}^{-1}$

d. $(50\hat{\mathrm{i}}+30\hat{\mathrm{j}})$ Kg - ms^{-1}

iii. A cricket ball of mass 0.25kg with speed 10m/ s collides with a bat and returns with same speed with in 0.01s. The force acted on bat is:

a. 25N

b. 50N

c. 250N

d. 500N

iv. A stationary bomb explodes into three pieces. One piece of 2 kg mass moves with a velocity of 8 ms" 1 at right angles to the other piece of mass 1 kg moving with a velocity of 12 ms -1 . If the mass of the third piece is 0.5 kg, then its velocity is:

a. $10ms^{-1}$

b. $20ms^{-1}$

c. $30ms^{-1}$

d. $AOms^{-1}$

v. A force of 10 N acts on a body of mass 0.5kg for 0.25s starting from rest. What is its momentum now?
   a. 0.25 N/ s
   b. 2.5 N/ s
   c. 0.5 N/ s
   d. 0.75 N/ s

Ans. :

i. (d) $\frac{av^2}{M}$

Explanation:

Force, $F=\frac{dq}{dt}=v\left[\frac{dM}{dt}\right]=\alpha v^2$

$\Rightarrow a=\frac{F}{M}=\frac{\alpha v^2}{M}$

ii. (a) $40\hat{i}\ kg-ms^{-1}$

Explanation:

Given, mass, m = 5 kg

Change in velocity, $\triangle v=v_f-v_i$

$=\left[(10-2)\hat{i}+(6-6)\hat{j}\right]$

Change in momentum

$=m\triangle v=5\left[8\hat{i}\right]$

$=40\hat{i}\ kg-ms^{-1}$

iii. (d) 500N

Explanation:

Momentum, $\triangle p=2mv=2\times 0.25\times 10=15kg\text{-}m/s$

Force, $F=\frac{\triangle p}{\triangle t}$

$=\frac{5}{0.01}=500N$

iv. (d) AOms^{-1}

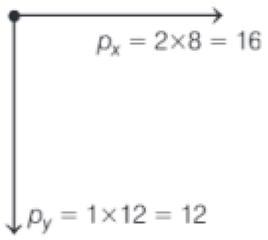
Explanation:

Momentum of third piece,

$p=\sqrt{p_x^2+p_y^2}=\sqrt{(16)^2+(12)^2}$

$=20\ kg-m/s$

$v=\frac{p}{m}=\frac{20}{0.5}=40m/s$



v. (b) 0.75 N/s

Explanation:

Given, F = 10 N, v_i = 0,

m = 0.5 kg, At = 0.25s

Change in momentum, Ap = p_f - p_t ...(i)

Also,$\triangle \mathrm{p} = \mathrm{F}.\triangle \mathrm{t}....(ii)$

From Eqs. (i) and (ii), we get

FM = pf - pi or 10 x 0.25 = pf -mvi

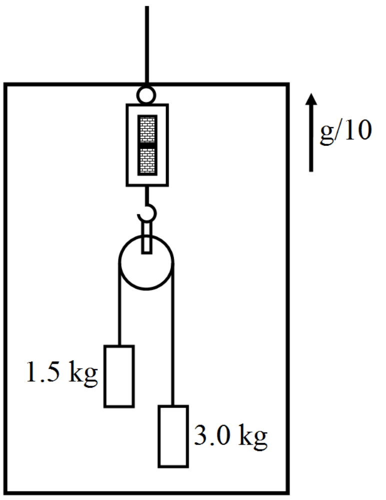
25 = pf — 0.5 x 0

⇒ pf = 2.5N/s

149. A person is standing on a weighing machine placed on the floor of an elevator. The elevator starts going up with some acceleration, moves with uniform velocity for a while and finally decelerates to stop. The maximum and the minimum weights recorded are 72kg and 60kg. Assuming that the magnitudes of the acceleration and the deceleration are the same, find:

a. The true weight of the person.

b. The magnitude of the acceleration. Take g = 9.9m/s^2.



Ans. : When the elevator is accelerating upwards, maximum weight will be recorded.

R - (W + ma) = 0

⇒ R = W + ma = m(g + a) max.wt.

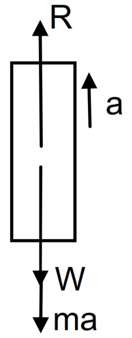
When decelerating upwards, maximum weight will be recorded.

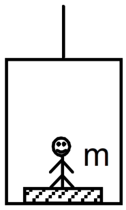
R + ma - W = 0

⇒ R = W - ma = m(g - a)

So, m(g + a) = 72 × 9.9 ...(1)

m(g - a) = 60 × 9.9 ...(2)





Now, mg + ma = 72 × 9.9 ⇒ mg - ma = 60 × 9.9

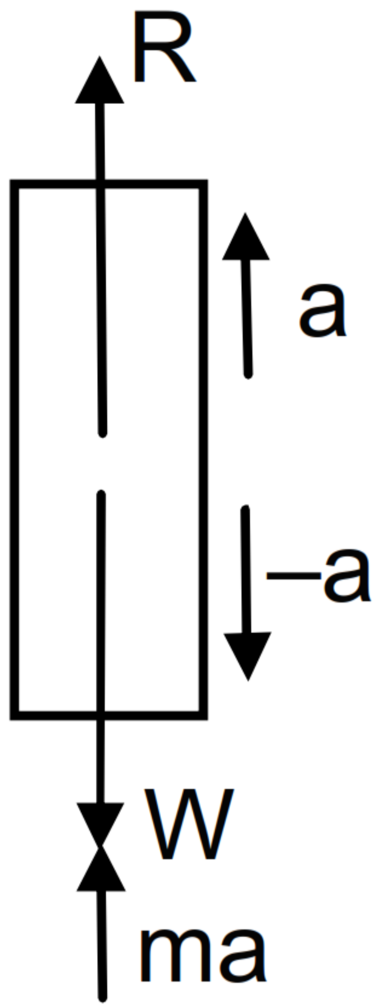
$\Rightarrow$ 2mg = 1306.8

$\Rightarrow \mathrm{m} = \frac{1306.8}{2 \times 9.9} = 66\mathrm{kg}$

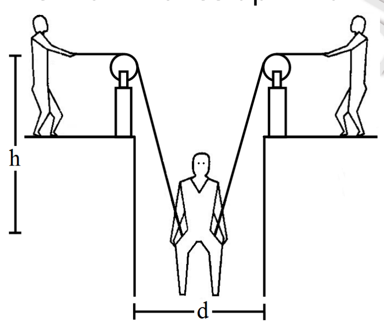
So, the true weight of the man is 66kg.

Again, to find the acceleration, mg + ma = 72 × 9.9

$\Rightarrow \mathrm{a} = \frac{72 \times 9.9 - 66 \times 9.9}{66} = \frac{9.9}{11} = 0.9\mathrm{m/s}^2.$



150. A man has fallen into a ditch of width d and two of his friends are slowly pulling him out using a light rope and two fixed pulleys as shown in figure. Show that the force (assumed equal for both the friends) exerted by each friend on the road increases as the man moves up. Find the force when the man is at a depth h.



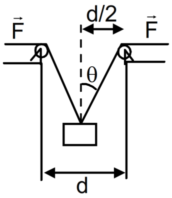
Ans. :

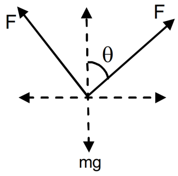
a. At any depth let the ropes make angle θ with the vertical From the free body diagram

$$\mathrm{F}\cos\theta + \mathrm{F}\cos\theta - \mathrm{mg} = 0$$

$\Rightarrow 2F\cos\theta = mg \Rightarrow F = \frac{mg}{2\cos\theta}$

As the man moves up. θ increases i.e. $\cos\theta$ decreases. Thus F increases.

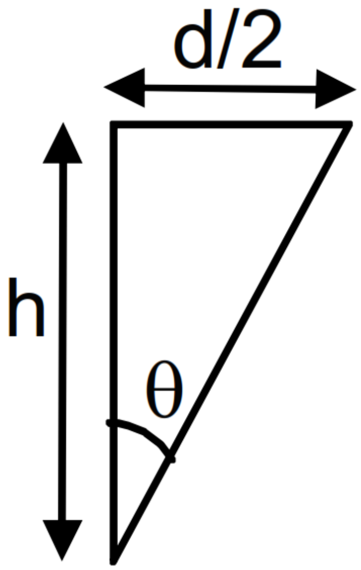




b. When the man is at depth h

$$\cos\theta = \frac{h}{\sqrt{\left(\frac{d}{2}\right)^2 + h^2}}$$

$$\text{Force} = \frac{mg}{\frac{h}{\sqrt{\frac{d^2}{4}+h^2}}} = \frac{mg}{4h}\sqrt{d^2 + 4h^2}$$



151. A small coin is placed on a record rotating at $33\frac{1}{3}$ rev/ minute. The coin does not slip on the record. Where does it get the required centripetal force from?

Ans. : The frictional force between coin and record would not let the coin slip away from the record as the record is at low revolution speed thus frictional force is grater than centrifugal force.

----- जब भी कोई काम करो तो उसे ऐसे करो कि काम को गर्व हो की तुमने उसे किया है। -----