# 1 PUC - CHAPTER 05
# LAWS OF MOTION

1. Three forces are acting on a particle of mass 'm' initially in equilibrium. If the first two forces ( $R_1$ and $R_2$ ) are perpendicular to each other and suddenly the third force ( $R_3$ ) is removed, then the acceleration of the particle is

(a) $\frac{R_3}{m}$ (b) $\frac{R_1+R_2}{m}$ (c) $\frac{R_1-R_2}{m}$ (d) $\frac{R_1}{m}$

**(a)**

$$a=\frac{\sqrt{R_1^2+R_2^2}}{m}=\frac{R_3}{m} \qquad \left[\therefore R_3=\sqrt{R_1^2+R_2^2}\right]$$

2. 'n' balls each of mass 'm' impinge elastically each second on a surface with velocity $u$. The average force experienced by the surface will be

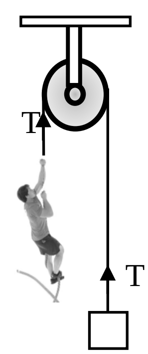
(a) $mnu$ (b) $2mnu$ (c) $4mnu$ (d) $mnu/2$

**(b)**

Change in momentum of one ball = 2 mu, time taken = 1s

$$F_{av}=\frac{\text{Total change in momentum}}{\text{Time taken}}=\frac{n(2mu)}{1}=2\,mnu$$

3. In order to raise a mass of 100 kg, a man of mass 60 kg fastens a rope to it and passes the rope over a smooth pulley. He climbs the rope with acceleration 5g/4 relative to the rope. The tension in the rope is (take $g=10\,ms^{-2}$)




(a) $\frac{4875}{8}N$ (b) $\frac{4875}{2}N$

(c) $\frac{4875}{4}N$ (d) $\frac{4875}{6}N$

**(c)**

Let T be the tension in the rope and 'a' the acceleration of rope.

The absolute acceleration of man $=\left(\frac{5g}{4}-a\right)$

Equation of motion for mass and man gives

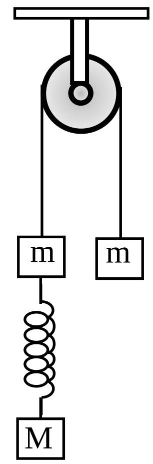
$T-100g=100a$ …. (1)

$T-60g=60\left(\frac{5g}{4}-a\right)$ …. (2)

Solving eqs (1) and (2), we get $T=\frac{4875}{4}N$.

4. The system shown in figure is released from rest. The spring gets elongated

(a) If M > m
(b) If M > 2m
(c) If M > m/2
(d) For any value of M
(Neglect the friction and masses of pulley, string and spring)




**(d)**

Let the spring does not get elongated, then net pulling force on the system is $Mg + mg - mg$ or simply $Mg$. Total mass being pulled is M + 2m.

Hence, acceleration of the system is $a = \frac{Mg}{M+2m}$

Now since $a < g$, there should be an upward force on M so that its acceleration becomes less than $g$. Which means there is some tension developed in the string, hence, for any value of M spring will get elongated.

5. A body A traveling at 5m/s collides with a body B at rest and sticks to it. If their common vel ocity after impact is 3m/s in the same direction. The ratio of masses of A and B is

(a) 3:2 (b) 2:3 (c) 5:3 (d) 3:5

**(a)**

According to the law of conservation of linear momentum,

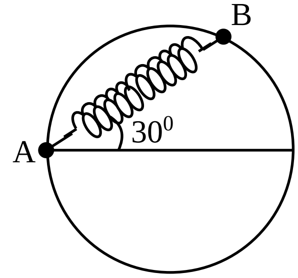
$m_A x5 + m_B x0 = (m_A + m_B)3$

$5m_A = 3m_A + 3m_B$ or $2m_A = 3m_B \Rightarrow \frac{m_A}{m_B} = \frac{3}{2}$

6. A bead of mass m is attached to one end of a spring of natural length R and spring constant $K = \frac{(\sqrt{3}+1)mg}{R}$. The other end of the spring is fixed at a point A on a smooth vertical ring of radius R as shown in figure. The normal reaction at B just after it is released to move is

(a) $\frac{mg}{2}$ (b) $\sqrt{3}\,mg$

(c) $3\sqrt{3}\,mg$ (d) $\frac{3\sqrt{3}\,mg}{2}$



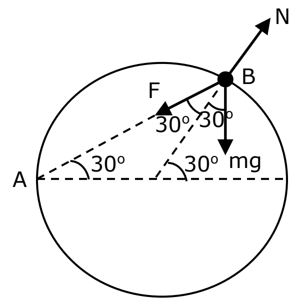
**(d)**

Extension in the spring is

$x = AB - R = 2R\cos 30^0 - R = (\sqrt{3}-1)R$

Spring force: $F = kx = \dfrac{(\sqrt{3}+1)mg}{R} \times (\sqrt{3}-1)R = 2mg$

From the figure, we have $N = (F + mg)\cos 30^0 = \dfrac{3\sqrt{3}mg}{2}$




7. A shell of mass 40kg moving at 80m/s explodes into 2 pieces. The 32kg piece comes to rest. The velocity of the other piece is

(a) 400m/s (b) 64m/s (c) 800m/s (d) Zero

**(a)**

Apply the law of conservation of linear momentum,

$mu = m_1v_1 + m_2v_2$.

$40(80) = 32(0) + 8(v_2)$ or $v_2 = 400 m/s$

8. A uniform chain of length $\ell$ is lying on the table. If coefficient of friction between chain and table top is $\mu$. What maximum length of the chain that can hang over the edge of the table without disturbing the rest of the chain on the table?

(a) $\dfrac{\mu\ell}{1+\mu}$ (b) $\dfrac{\ell}{1+\mu}$ (c) $\dfrac{\mu\ell}{1-\mu}$ (d) $\dfrac{\ell}{1-\mu}$

**(a)**

Let m be the mass of the chain and $\ell$ be its length.

Let x be the mass per unit length of the chain, ie, $x = m/\ell$.

Let y be the length of the chain that hangs over the edge at rest.

$\therefore$ mass of the chain hanging over the edge = xy.

$\Rightarrow$ force pulling the chain downward = (mass of the hanging chain)g = (xy)g.

Mass of the chain lying over the table = m – xy.

$\therefore$ The frictional force between chain and table = $\mu(m - xy)g$.

For equilibrium, these two forces must be equal, ie, $(xy)g = \mu(m - xy)g$

or $\dfrac{my}{\ell} = \mu\left(m - \dfrac{my}{\ell}\right)$ on solving, $y = \dfrac{\mu\ell}{\mu + 1}$.

9. A particle of mass 2 kg moves with an initial velocity of $\vec{v} = 4\hat{i} + 4\hat{j}\, ms^{-1}$. A constant force of $\vec{F} = 20\hat{j}\, N$ is applied on the particle. Initially, the particle was at (0, 0). The x-coordinate of the particle when its y-coordinate again becomes zero is given by

(a) 1.2 m (b) 4.8 m (c) 6.0 m (d) 3.2 m

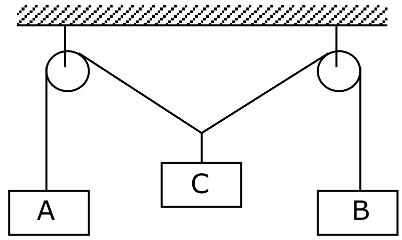
**(d)**

$\vec{a} = \dfrac{\vec{F}}{m} = -10\hat{j}(ms^{-1})^2$

Displacement in y-direction $y = ut + \dfrac{1}{2}at^2 \Rightarrow 0 = 4 \times t \times -\dfrac{1}{2} \times 10 \times t^2$

$t = \dfrac{4}{5}s \Rightarrow x = 4t = 4 \times \dfrac{4}{5} = 3.2\,m$.

10. Three blocks A, B and C are suspended as shown in figure. Mass of each of blocks A and B is m. If the system is in equilibrium and mass of C is M, then




(a) $M > 2m$ (b) $M = 2m$

(c) $M < 2m$ (d) none of these

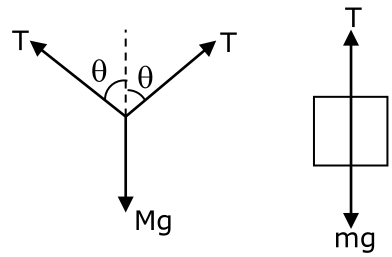
**(c)**

From fig. $2T\cos\theta = Mg$ , $T = mg$

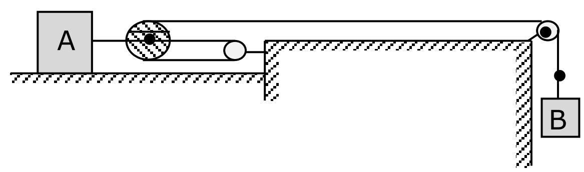
$\cos\theta = \dfrac{Mg}{2mg} = \dfrac{M}{2m}$

$\Rightarrow \cos\theta < 1$

$\dfrac{M}{2m} < 1 \Rightarrow M < 2m$ .




11. A block A has a velocity of $0.6\,ms^{-1}$ to the right. Determine the velocity of block B.




(a) $1.2\,ms^{-1}$ (b) $2.4\,ms^{-1}$

(c) $1.8\,ms^{-1}$ (d) $3.6\,ms^{-1}$

**(c)**

Tx (Hanged part) = $2Tx'$ (Sliding part)

$\therefore\ x = 3x' \Rightarrow x = 3\times 0.6 = 1.8\,ms^{-1}$

12. A car is moving along a straight horizontal road with the speed of v. If the coefficient of friction between the tyres and the road is μ, the shortest distance in which the car can be stopped is

(a) $\dfrac{v^2}{2\mu g}$ (b) $\dfrac{v^2}{\mu g}$ (c) $\left(\dfrac{v}{\mu g}\right)^2$ (d) $\dfrac{v^2}{\mu}$

**(a)**

Kinetic frictional force brings the car to rest.

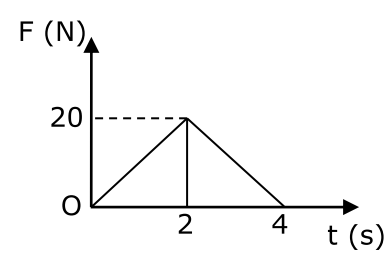
Kinetic frictional force $F = \mu N$ , Where N is the normal reaction = mg, weight of the car.

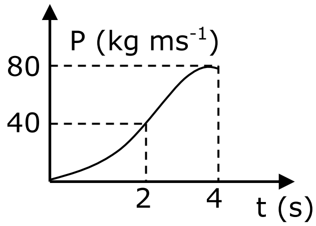
$\therefore\ F = \mu mg$ .

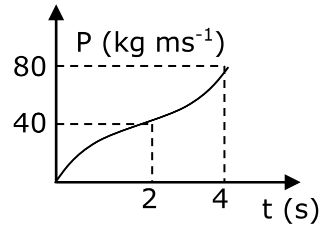
$a = \dfrac{F}{m} = \mu g$

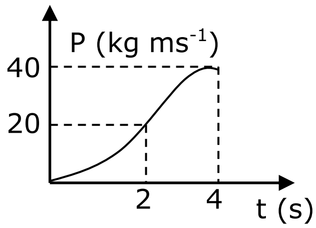
Distance covered $s = \dfrac{v^2}{2a} = \dfrac{v^2}{2\mu g}$

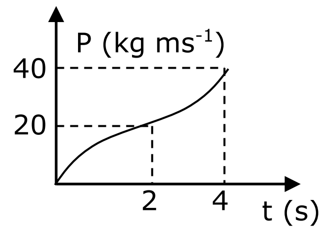
13. Figure shows the variation of force acting on a body with time. Assuming the body to start from rest, the variation of its momentum with time is best represented by which plot?



(a) 


(b) 


(c) 


(d) 


**(c)**

From 0 to 2s, at any time t, F = 10 t $\Rightarrow a = F/m = 10t/m$

$\Rightarrow \int_0^v dv = \int_0^t \frac{10t}{m} dt \Rightarrow v = \frac{5t^2}{m}$

Momentum, $P = mv = 5t^2$

At t =2s, $P = 5(2)^2 = 20\,kg\,ms^{-1}$, v = 20/m

From 2 to 4s, $F = 40 - 10t$

$\int_{20/m}^{v} dv = \int_2^t \frac{40-10t}{m} dt \Rightarrow v = \frac{1}{m}[40t - 40 - 5t^2]$

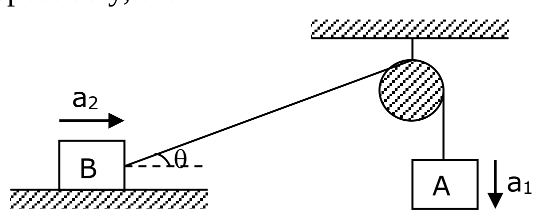
$P = mv = 40t - 40 - 5t^2$

At t = 4s, P = 40×4 – 40 – 5 × 16 = 40 kgm/s

14. Figure shows two blocks, each of mass m. The system is released from rest. If the acceleration of blocks A and B at any instant (not initially) are $a_1$ and $a_2$ respectively, then

(a) $a_1 = a_2 \cos\theta$ (b) $a_2 = a_1 \cos\theta$

(c) $a_1 = a_2$ (d) none of these




**(d)**

Let at any time, their velocities be $v_1$ and $v_2$ respectively. Then $v_1 = v_2 \cos\theta$.

Differentiating $a_1 = a_2 \cos\theta - v_2 \sin\theta \frac{d\theta}{dt}$

Hence, none of them is correct.

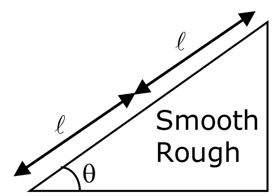
15. A box of mass 8 kg is placed on a rough inclined plane of inclination $\theta$. Its downward motion can be prevented by applying an upward pull F and it can be made to slide upwards by applying a force 2F. The coefficient of friction between the box and the inclined plane is

(a) $\frac{\tan\theta}{3}$ (b) $3\tan\theta$ (c) $\frac{\tan\theta}{2}$ (d) $2\tan\theta$

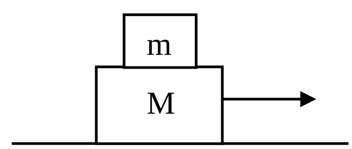
**(a)**
During downward motion:
$F + f_s = mg\sin\theta$
$F = mg\sin\theta - \mu mg\cos\theta$
During upward motion:
$2F = mg\sin\theta + \mu mg\cos\theta$
Solving above two equations, we get $m = \dfrac{\tan\theta}{3}$.

16. The upper half of an inclined plane with inclination $\phi$ is perfectly smooth while the lower half is rough. A body starting from rest at the top will again come to rest at the bottom if the coefficient of friction for the lower half is given by
(a) $2\tan\phi$ (b) $\tan\phi$ (c) $2\sin\phi$ (d) $2\cos\phi$

**(a)**
For first half acceleration = $g\sin\phi$
Therefore, velocity after traveling half distance.
$v^2 = 2(g\sin\phi)\ell$ …. (1)
For second half, acceleration = $g(\sin\phi - \mu_k\cos\phi)$
So, $0^2 = v^2 + 2g(\sin\phi - \mu_k\cos\phi)\ell$ …. (2)
Solving (1) and (2), we get $\mu_k = 2\tan\phi$.




17. A block of mass $m$ is placed on another block of mass M, which itself is lying on a horizontal surface. The coefficient of friction between two blocks is $\mu_1$ and that between the block of mass M and horizontal surface is $\mu_2$. What maximum horizontal force can be applied to the lower block so that the two blocks move without separation?
(a) $(M+m)(\mu_2 - \mu_1)g$
(b) $(M-m)(\mu_2 - \mu_1)g$
(c) $(M-m)(\mu_2 + \mu_1)g$
(d) $(M+m)(\mu_2 + \mu_1)g$




**(d)**
Here the force applied should be such that friction force acting on the upper block of $m$ should not be more than the limiting friction $(= \mu_1 mg)$. Let the system moves with acceleration $a$.
Then, for whole system
$F - \mu_2(M+m)g = (M+m)a$ ….. (1)
For block of mass $m$: $f_1 = ma$ or $\mu_1 mg = ma$ or $a = \mu_1 g$ ….. (2)
From eqs. (1) and (2), we get $F = (M+m)g(\mu_1 + \mu_2)$.

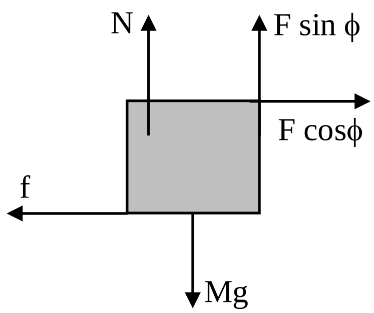
18. A wooden block of mass M resting on a rough horizontal floor is pulled with a force F at an angle $\phi$ with the horizontal. If $\mu$ is the coefficient of kinetic friction between the block and the surface, then the acceleration of the block is
(a) $\dfrac{F}{M}(\cos\phi - \mu\sin\phi) - \mu g$ (b) $\dfrac{\mu F}{M}\cos\phi$

(c) $\frac{F}{M}(\cos\phi + \mu\sin\phi) - \mu g$ (d) $\frac{F}{M}\sin\phi$

**(c)**

$N = Mg - F\sin\phi$

From figure,




$$a = \frac{F\cos\phi - f}{M} = \frac{F\cos\phi - \mu N}{M} = \frac{F\cos\phi - \mu(Mg - F\sin\phi)}{M}.$$

19. A given object takes $n$ times to slide down $45^{\circ}$ rough inclined plane it takes to slide down a perfectly smooth $45^{\circ}$ incline. The coefficient of kinetic friction between the object and the incline is

(a) $\sqrt{\frac{1}{1-n^2}}$ (b) $\sqrt{1-\frac{1}{n^2}}$ (c) $1-\frac{1}{n^2}$ (d) $\sqrt{\frac{1}{2-n^2}}$

**(c)**

From $s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}at^2, t = \sqrt{\frac{2s}{a}}$

For smooth plane $a = g\sin\theta$

For rough plane $a' = g(\sin\theta - \mu\cos\theta)$

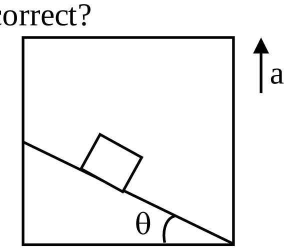
$\therefore\ t' = nt = \sqrt{\frac{2s}{g(\sin\theta - \mu\cos\theta)}} = n\sqrt{\frac{2s}{g\sin\theta}}$

$\therefore\ n^2 g(\sin\theta - \mu\cos\theta) = g\sin\theta$

When $\theta = 45^0$, $\sin\theta = \cos\theta = \frac{1}{\sqrt{2}}$

Solving, we get $\mu = \left(1 - \frac{1}{n^2}\right)$.

20. A block of mass $m$ is at rest with respect to a rough incline kept in elevator moving up with acceleration $a$. Which of following statements is correct?




(a) The contact force between block and incline is parallel to the incline.

(b) The contact force between block and incline is of the magnitude $m(g+a)$.

(c) The contact force between block and incline is perpendicular to the incline.

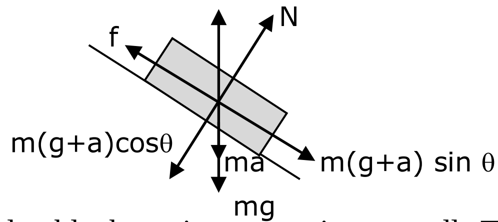
(d) The contact force is of the magnitude $mg\cos\theta$

**(b)**

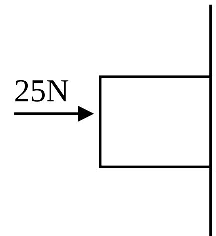
$F_C = \sqrt{f^2 + N^2} = m(g+a)$

$f = m(g+a)\sin\theta$, $N = m(g+a)\cos\theta$

Net contact force, $F_C = \sqrt{f^2 + N^2} = m(g+a)$




21. A horizontal force of 25 N necessary to just hold a block stationary against a wall. The coefficient of friction between the block and the wall is 0.4. The weight of the block is




(a) 2.5 N (b) 20 N

(c) 10 N (d) 5 N

**(c)**

Given horizontal force F = 25 N and coefficient of friction between block and wall $(\mu) = 0.4$.

We know that at equilibrium horizontal force provides the normal reaction to the block against the wall. Therefore, normal reaction to the block (R) = F = 25 N.

We also know that weight of the block, (W) = Frictional force = $\mu R = 0.4 \times 25 = 10\,N$.

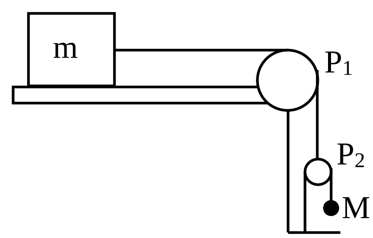
22. A circular road of radius 1000m has banking angle 45°. The maximum safe speed (in $ms^{-1}$) of a car having a mass 2000 kg will be (Coefficient of friction between tyre and road = 0.5) (g = 10 m/s$^2$)

(a) 173 (b) 124 (c) 99 (d) 86

**(a)**

$$v_{\max} = \sqrt{\frac{Rg(\tan\theta + \mu)}{1-\mu\tan\theta}} = \sqrt{\frac{1000 \times 10(1+0.5)}{1-0.5}} = \sqrt{30,000} = 173 m/s$$

23. In the pulley arrangement shown in figure, the pulley $P_2$ is movable. Assuming the coefficient of friction between $m$ and surface to be $\mu$, the minimum value of M for which $m$ is at rest is




(a) $M = \frac{\mu m}{2}$ (b) $m = \frac{\mu M}{2}$

(c) $M = \frac{m}{2\mu}$ (d) $m = \frac{M}{2\mu}$

**(a)**

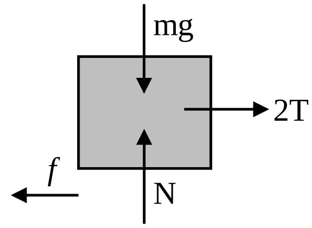
Frictional force $f = 2T$ ….. (1)

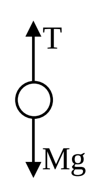
and $T = Mg$ …. (2)

If $m$ is at rest, then friction will be static

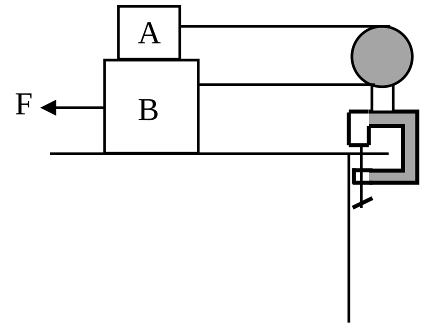
$$f \le \mu N$$

$2Mg \le \mu mg \Rightarrow M = \frac{\mu m}{2}$.



24. Block A, as shown in figure weighs, 2.0 N and block B weighs 6.0 N. The coefficient of kinetic friction between all surfaces is 0.25. Find the magnitude of the horizontal force necessary to drag block B to the left at constant speed if A and B are connected by a light, flexible cord passing around a fixed, frictionless pulley.




(a) 2 N (b) 3 N

(c) 5 N (d) 6 N

**(b)**

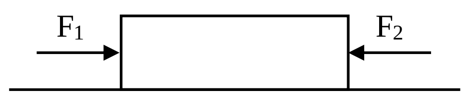
The frictional force on block A is $\mu_k w_A = (0.25)(2N) = 0.5N$ .

This is the magnitude of the frictional force that block A exerts on block B, as well as the tension in the string. The force F must then have a magnitude equal to

$F = \mu_k(w_B + w_A) + \mu_k w_A + T = \mu_k(w_B + 3w_A) = (0.25)(6N + 3(2N)) = 3N$ .

Note that the normal force exerted on block B by the table is the sum of the weights of the blocks.

25. Figure shows a wooden block at rest in equilibrium on a rough horizontal plane being acted upon by force $F_1 = 10N$, $F_2 = 2N$ as shown. If $F_1$ is removed, the resultant force acting on the block will be

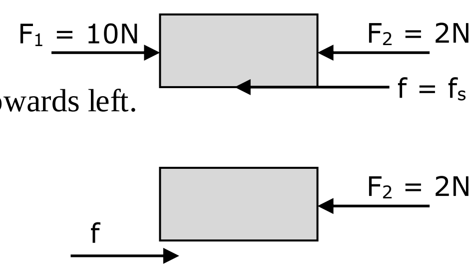



(a) 2 N towards left
(b) 2N towards right
(c) 0 N
(d) cannot be determined.

**(c)**

The driving force on the block

$F_1 - F_2 = 10 - 2 = 8N$



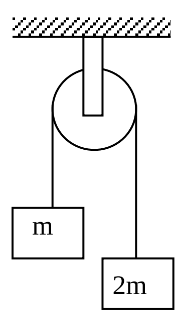

As the block is at rest the friction will be static and towards left.

$f = f_s = 8N$

If $F_1$ is removed, only $F_2 = 2N$ acts on the body.

Since $F_2 < f$, net force on the body is zero.

26. Two masses m and 2m are joined to each other by means string passing over a frictionless pulley as shown in figure. When the mass 2m is released, the mass m will ascend with an acceleration of




(a) $\frac{g}{3}$

(b) $\frac{g}{2}$

(c) g

(d) 2 g

**(a)**

For m: T – mg = ma

For 2m: 2mg – T = 2ma

Acceleration of the mass m is a= $\left(\frac{2m-m}{2m+m}\right)g = \frac{g}{3}$

27. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force F is applied at the free end of the rope, the net force exerted on the block will be

a) $\frac{FM}{(M+m)}$ b) $\frac{Fm}{(M+m)}$ c) $\frac{FM}{(M-m)}$ d) F

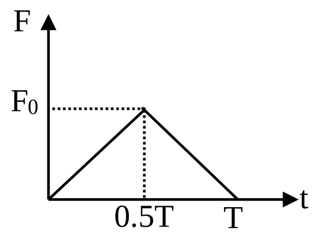
**(a)**

The total mass of the block-rope system = M + m.

Therefore, the acceleration of the block-rope system a= $\frac{F}{M+m}$.

Thus, the net force acting on the block = acceleration x mass of block = $\frac{FM}{M+m}$.

28. A ball of mass 'm' moving with a velocity 'u' rebounds from a wall. The collision is assumed to be elastic and the force of intersection between the ball and wall varies as shown in figure. Then the value of $F_0$ is




(a) $\frac{mu}{T}$ (b) $\frac{2mu}{T}$ (c) $\frac{4mu}{T}$ (d) $\frac{mu}{2T}$

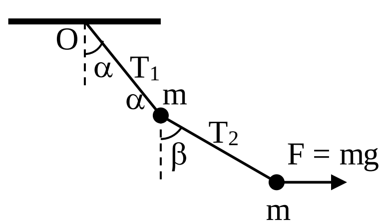
**(c)**

Area under the force-time graph is impulse, and impulse is change in momentum.

Area of graph = change in momentum.

$\Rightarrow \frac{1}{2}TF_0 = 2mu \Rightarrow F_0 = \frac{4mu}{T}$

29. Two particles A and B, each of mass $m$, are kept stationary by applying a horizontal force F = mg on particle B as shown in figure. If $T_1$ and $T_2$ are tension in the strings, then




(a) $2\tan\beta = \tan\alpha$ (b) $2T_1 = 5T_2$

(c) $T_1\sqrt{2} = T_2\sqrt{5}$ (d) none of these

**(c)**

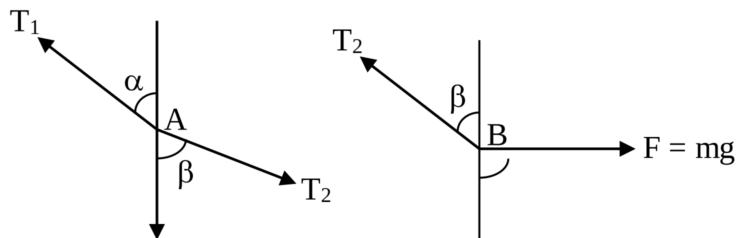
From figure, $T_2\cos\beta = mg$, $T_2\sin\beta = mg$

$\tan\beta = 1; \sin\beta = \frac{1}{\sqrt{2}}; \cos\beta = \frac{1}{\sqrt{2}}$

$T_2 = mg\sqrt{2}$

$T_1\sin\alpha = T_2\sin\beta = mg$

$T_1\cos\alpha = mg + T_2\sin\beta = 2mg$



$$\Rightarrow \frac{\sin\alpha}{\cos\alpha} = \frac{mg}{2mg}$$

$$\tan\alpha = \frac{1}{2} \Rightarrow \cos\alpha = \frac{2}{\sqrt{5}}; \sin\alpha = \frac{1}{\sqrt{5}}$$

$$T_1 \frac{2}{\sqrt{5}} = 2mg \Rightarrow T_1 = mg\sqrt{5}$$

$$\frac{T_1}{T_2} = \frac{\sqrt{5}}{\sqrt{2}} \Rightarrow \sqrt{2}T_1 = \sqrt{5}T_2$$

30. A block is placed on the top of a smooth inclined plane of inclination θ kept on the floor of a lift. When the lift is descending with a retardation a, the block is released. The acceleration of the block relative to the incline is
(a) g sin θ (b) a sin θ (c) (g – a) sin θ (d) (g + a) sin θ

**(d)**
When the lift is descending with a retardation (negative acceleration) a, the effective value of g is
$g_{eff}$ = g + a.
The component of this acceleration along the inclined plane is $g_{eff}$ sin θ = (g + a) sin θ.

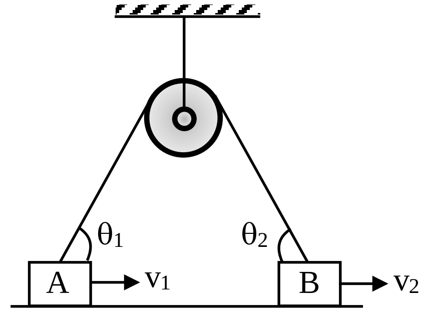
31. A balloon of mass M is descending at a constant acceleration $\alpha$. When a mass m is released from the balloon, it starts rising with the same acceleration $\alpha$. Assuming that its volumes does not change, what is the value of m?
(a) $\frac{\alpha}{\alpha+g}M$ (b) $\frac{2\alpha}{\alpha+g}M$ (c) $\frac{\alpha+g}{\alpha}M$ (d) $\frac{\alpha+g}{2\alpha}M$

**(b)**
Suppose F = upthrust due to buoyancy
Then while descending, we find $Mg - F = M\alpha$ ….. (1)
When ascending, we have $F - (M-m)g = (M-m)\alpha$ ….. (2)
Solving eqs. (1) and (2), we get $m = \left[\frac{2\alpha}{\alpha+g}\right]M$.

32. A person is sitting facing the engine in a moving train. He tosses a coin. The coin falls behind him. This shows that the train is
(a) moving forward with a finite acceleration
(b) moving forward with a finite retardation
(c) moving backward with a uniform speed
(d) moving forward with a uniform speed.

**(a)**
As long as the coin is in the hand of the person, it shares the acceleration of the train; it has the inertia of motion. When he tosses the coin, it falls behind him opposite to the direction of accelerated motion but now it no longer shares the acceleration of the train.

33. In figure, blocks A and B moves with velocities $v_1$ and $v_2$ along horizontal direction. Find the ratio of $v_1 / v_2$.



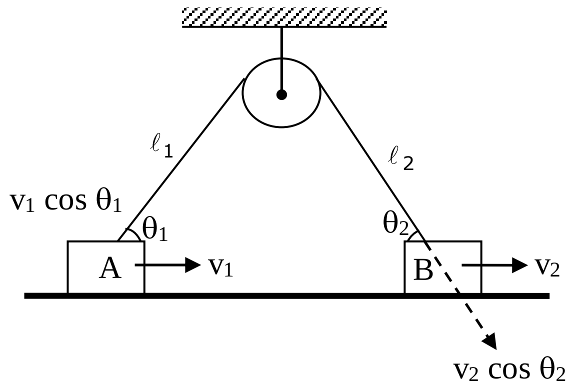

(a) $\frac{\sin\theta_1}{\sin\theta_2}$ (b) $\frac{\sin\theta_2}{\sin\theta_1}$

(c) $\frac{\cos\theta_2}{\cos\theta_1}$ (d) $\frac{\cos\theta_1}{\cos\theta_2}$

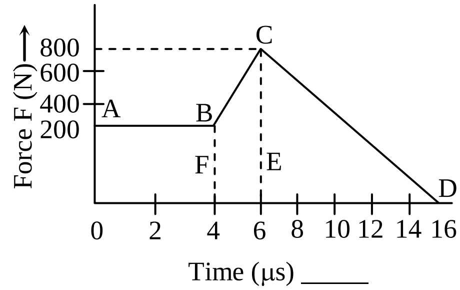
**(c)**

From figure, $\ell_1 + \ell_2 = C$ or $\frac{d\ell_1}{dt} + \frac{d\ell_2}{dt} = 0$

$-v_1 \cos\theta_1 + v_2 \cos\theta_2 = 0$ or $\frac{v_1}{v_2} = \frac{\cos\theta_2}{\cos\theta_1}$




34. The magnitude of the force (in Newtons) acting on a body varies with time t (in microseconds) as shown in fig. AB, BC, and CD are straight line segments. The magnitude of the total impulse of the force on the body from t = 4 μs to t = 16 μs is ..........N-s.




(a) $5 \times 10^{-4}$ N.s (b) $5 \times 10^{-3}$ N.s (c) $5 \times 10^{-5}$ N.s (d) $5 \times 10^{-2}$ N.s

**(b)**

Impulse = F . t = Area under F-t curve from 4 μs to 16 μs = Area under BCDFB

= Area of trapezium BCEF + area of ΔCDE

$= \frac{1}{2}(200+800)(2\times10^{-6}) + \frac{1}{2}\times10\times10^{-6}\times800$

$= 10 \times 10^{-4} + 40 \times 10^{-4}$ N–s $= 50 \times 10^{-4}$

$= 5.0 \times 10^{-3}$ N-s

35. An aeroplane of mass M requires a speed v for take off. The length of the runway is s and the coefficient of friction between the tyres and the ground is μ. Assuming that the plane accelerates uniformly during the take-off, the minimum force required by the engine of the plane for take-off is given by

(a) $M\left(\frac{v^2}{2s} + \mu g\right)$ (b) $M\left(\frac{v^2}{2s} - \mu g\right)$ (c) $M\left(\frac{2v^2}{s} + 2\mu g\right)$ (d) $M\left(\frac{2v^2}{s} - 2\mu g\right)$

**(a)**

The required force is to (i) accelerate the plane from rest to a speed v over a distance s and (ii) to overcome the force of friction (= $\mu R = \mu Mg$).
The acceleration a required to impart a speed v in a distance s is given by $v^2 - u^2 = 2as$.
Since, u = 0, we have $v^2 = 2as$ or $a = v^2/2s$.

The force needed to produce this acceleration is $F_1$ = mass x acceleration = $\frac{Mv^2}{2s}$

The force needed to overcome the force of friction is $F_2 = \mu Mg$

$\therefore$ Total force needed = $F_1 + F_2 = M\left(\frac{v^2}{2s} + \mu g\right)$

36. A car, moving at a speed of 54 km/h, is to go round a curved road of radius 30 m. If the curved road is not banked, what must be the coefficient of friction between the tyres and the road for the car to negotiate the curve? Take $g = 10\ m/s^2$.
(a) zero (b) 0.25 (c) 0.50 (d) 0.75

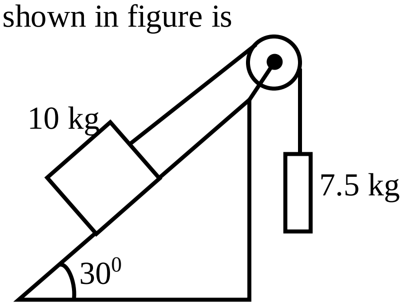
**(d)**

The maximum centripetal force that the friction can provide is $F = \mu mg = \frac{mv^2}{R}$

Or $\mu = \frac{v^2}{Rg} = \frac{15 \times 15}{30 \times 10} = 0.75$ ($\because$ 54 km/h = 15 m/s)

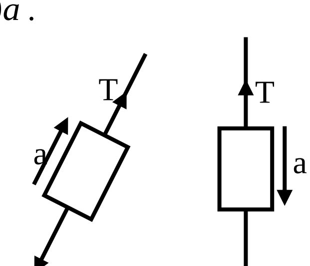
37. A rocket sanding vertically on a launch pad has to start moving up with practically zero velocity. If the initial mass of the rocket is $5\times10^5 kg$, then the rate of burning of the fuel should be [Take $g = 10\,ms^{-2}$ and velocity of exhaust gases = $10\,km\,s^{-1}$]
(a) $10\,kg\,s^{-1}$ (b) $50\,kg\,s^{-1}$ (c) $500\,kg\,s^{-1}$ (d) $5000\,kg\,s^{-1}$
**(c)**
$v_r \frac{dm}{dt} = m_0 g$ or $\frac{dm}{dt} = \frac{m_0 g}{v_r}$ or $\frac{dm}{dt} = \frac{5\times10^5\times10}{10\times10^3} kg\,s^{-1} = 500\,kg\,s^{-1}$.

38. The acceleration of the system shown in figure is



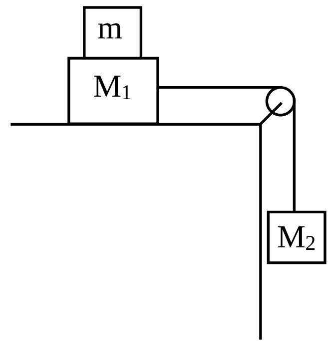

(a) $\frac{3.5}{17.5}g$ (b) $\frac{7.5}{17.5}g$ (c) $\frac{14.5}{17.5}g$ (d) $\frac{g}{7}$.
**(d)**
From free body diagrams, $T - 10g\sin30^0 = 10a$ or $T - 5g = 10a$.

Again, $7.5g - T = 7.5a$,



Adding, $2.5g = 17.5a$ or $a = \dfrac{25g}{175} = \dfrac{g}{7}$.

39. Two blocks of mass $M_1$ and $M_2$ are connected with a string passing over a pulley as shown in figure. The block $M_1$ lies on a horizontal surface. The coefficient of friction between the block $M_1$ and the horizontal surface is $\mu$. The system accelerates, what additional mass $m$ should be placed on the block $M_1$ so that the system does not accelerate?



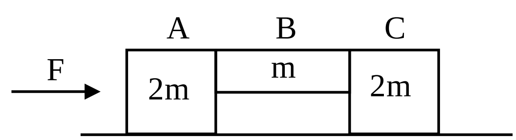

(a) $\dfrac{M_2 - M_1}{\mu}$ (b) $\dfrac{M_2}{\mu} - M_1$

(c) $M_2 - \dfrac{M_1}{\mu}$ (d) $(M_2 - M_1)\mu$

**(b)**
For the equilibrium of block of mass $M_1$:
Frictional force, f = tension in the string T, where, $T = f = \mu(m + M_1)g$ …… (1)
For the equilibrium of block of mass $M_2$: $T = M_2 g$ …… (2)
From eqs. (1) and (2), we get $\mu(m + M_1)g = M_2 g$

$$m = \frac{M_2}{\mu} - M_1$$

40. A system is pushed by a force F as shown in figure. All surfaces are smooth except between B and C. Friction coefficient between B and C is $\mu$. Minimum value of F to prevent block B from downward slipping is



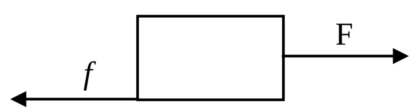

(a) $\left(\dfrac{3}{2\mu}\right)mg$ (b) $\left(\dfrac{5}{2\mu}\right)mg$

(c) $\left(\dfrac{5}{2}\right)\mu mg$ (d) $\left(\dfrac{3}{2}\right)\mu mg$

**(b)**

Horizontal acceleration of the system is $a = \dfrac{F}{2m + m + 2m} = \dfrac{F}{5m}$

Let N be the normal reaction between B and C.

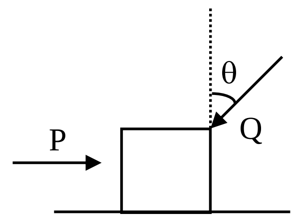



Free body diagram of C gives $N = 2ma = \dfrac{2}{5}F$

Now B will not slide downwards if $\mu N \geq m_B g$

or $\mu\left(\dfrac{2}{5}F\right) \geq mg$ or $F \geq \dfrac{5}{2\mu}mg$ or $F_{\min} = \dfrac{5}{2\mu}mg$ .

41. A block of mass $m$, lying on a horizontal plane, is acted upon by a horizontal force P and another force Q, inclined at an angle $\theta$ to the vertical. The block will remain in equilibrium if the coefficient of friction between it and the surface is (assume P > Q).




(a) $\dfrac{(P\sin\theta - Q)}{(mg - \cos\theta)}$ (b) $\dfrac{(P - Q\sin\theta)}{(mg + Q\cos\theta)}$

(c) $\dfrac{(P\cos\theta + Q)}{(mg - Q\cos\theta)}$ (d) $\dfrac{(P + Q\sin\theta)}{(mg + Q\cos\theta)}$

**(b)**

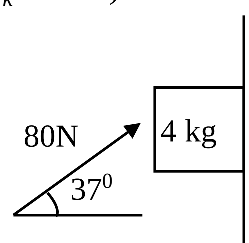
When Q is resolved, components Qcosθ is downward; Qsinθ horizontal to the left

Frictional force f = $\mu R$ = $\mu(mg + Q\cos\theta)$ and horizontal push = $P - Q\sin\theta$

For equilibrium, we have $\mu(mg + Q\cos\theta) = P - Q\sin\theta$

$\Rightarrow \mu = \dfrac{P - Q\sin\theta}{mg + Q\cos\theta}$.

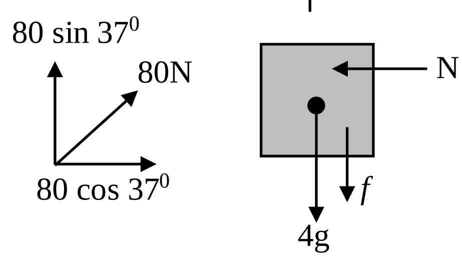
42. A block of mass 4kg is pressed against the wall by a force of 80 N as shown in figure. Determine the value of frictional force and block's acceleration (take $\mu_s = 0.2$, $\mu_k = 0.15$)




(a) 8 N, $0\,ms^{-2}$ (b) 32 N, $6\,ms^{-2}$

(c) 8 N, $6\,ms^{-2}$ (d) 32 N, $2\,ms^{-2}$

**(a)**




The FBD of the block is shown in the figure.

$N = 80\cos 37^0 = 64\,N$ $\quad \cos 37^o = \dfrac{4}{5}; \sin 37^o = \dfrac{3}{5}$

So, $f = \mu_s N = 0.2 \times 64 = 32\,N$

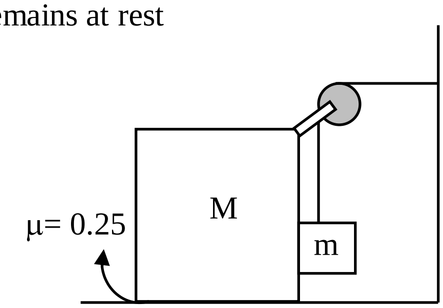
As $4g < 80\sin 37^0$, frictional force will act downwards.

Net applied force is in upward direction F = $80\sin 37^0 - 40 = 48 - 40 = 8N$

As $F_{\text{applied}}$ in vertical direction is less than f, block will not move in vertical direction and value of static friction force is $f = 8\,N$.

43. Two blocks ($m$ and $M$) are arranged as in figure. There is friction between ground and M and other surfaces are frictionless. The coefficient of friction between ground and M is $\mu = 0.25$. The maximum ratio of $m$ and $M$ ($m/M$) so that the system remains at rest

(a) $\dfrac{1}{3}$ (b) $\dfrac{1}{4}$



(c) 3 (d) none of these

**(a)**

As block is at rest

$T = mg$ ….. (1)

$f = T$ ….. (2)

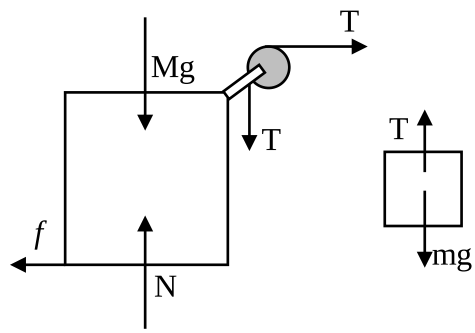
and $f \le \mu N$

Here, $N = Mg + T = (M+m)g$

$T \le \mu(M+m)g$ , $mg \le \mu(M+m)g$

$\frac{m}{M} \le \frac{\mu}{(1-\mu)}$

$\frac{m}{M} \le \frac{0.25}{(1-0.25)} \Rightarrow \frac{m}{M} \le \frac{1}{3}$.




44. A truck moving at $\frac{250}{9} ms^{-1}$ carries steel girder which rests on its wooden floor. The minimum time in which the truck can come to a stop without the girder moving forward is: Given: $\mu_s = 0.5$.

(a) 3s (b) 4s (c) 5s (d) 5.7 s

**(d)**

$u = \frac{250}{9} ms^{-1}, v = 0$

$a = -\mu g = -0.5 \times 9.8 ms^{-2} = -4.9 ms^{-2}$ , $t = ?$

Using $t = \frac{v-u}{a}$, $t = \frac{250}{9} \times \frac{1}{4.9} s = 5.7 s$ .

45. A force vector applied on a mass is represented as $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$ and accelerates $1 ms^{-2}$. The mass of the body is (in kg)

(a) $2\sqrt{10}$ (b) $10\sqrt{2}$ (c) 10 Kg (d) 20 Kg

**(b)**

$\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$ , a = $1 ms^{-2}$, m = ?.

Magnitude of the force $F = \sqrt{6^2 + (-8)^2 + 10^2} = 10\sqrt{2}$ N.

Mass of the body $m = \frac{F}{a} = \frac{10\sqrt{2}}{1} = 10\sqrt{2}$ kg.

46. Which one of the following four statements is false?

(a) A body can have zero velocity and still be accelerated

(b) A body can have a constant speed and still have a varying velocity

(c) The direction of the velocity of a body can change when its acceleration is constant

(d) A body can have a constant velocity and still have a varying speed

**(d)**

a) A body can have zero velocity and still be accelerated ✔ (Eg: when body reaches highest point then velocity = o but acceleration a = g)
b) A body can have a constant speed and still have a varying velocity ✔ (Eg: Uniform circular motion)
c) The direction of the velocity of a body can change when its acceleration is constant ✔ (Eg: Uniform circular motion)
d) A body can have a constant velocity and still have a varying speed ✕

47. Two boys weighing 40 kg and 50 kg stand facing each other on roller skates. The first boy is pushing away the second boy with a force of 10 N. the acceleration of the first and second boys are respectively (in $ms^{-2}$)
(a) 0.25 and 0.25 (b) 0.2 and 0.2 (c) 0.25 and 0.2 (d) 0.2 and 0.25

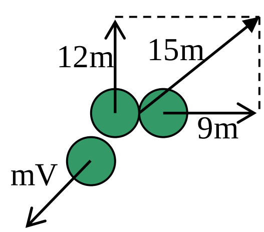
**(c)**
Both the boys are experiencing the same force i.e, 10N (action and reaction)
$\therefore$ Acceleration of the first boy $a_1 = \frac{F}{m} = \frac{10}{40} = 0.25 m/s^2$
Acceleration of the second boy $a_2 = \frac{10}{50} = 0.2 m/s^2$.

48. A man weighing 70 kg is standing on a weighing scale in a lift at rest. If the lift moves upwards with an acceleration g, the reading on the scale is
(a) zero (b) 70 kg (c) 686 kg (d) 140 kg

**(d)**
Acceleration of the lift a = g, m = 70kg
Apparent weight of the person when lift accelerates upward $W^1 = m(g+a) = 70(g+g) = 140 g$.
Reading of the scale in terms of kg-wt = $\frac{140\ g}{g} = 140\,kg.wt.$
$\therefore$ Weighing scale indicates 140kg.

49. A shell explodes into 3 pieces of equal masses. Two fragments fly off at right angles to each other with a speed of 9 and 12m/s respectively. The speed of the third fragments is
(a) 9m/s (b) 12m/s (c) 15m/s (d) 18m/s

**(c)**
Momentum of the first piece = 9m. ($\because$ momentum = mv).
Momentum of the second piece = 12m.
Resultant momentum $= \sqrt{(9m)^2 + (12m)^2} = 15m.$
To conserve the linear momentum, third piece must move in the opposite direction to the resultant momentum of the first two pieces.
$\therefore$ mv = 15m $\Rightarrow$ Velocity of the third piece v = 15m/s.




50. Two billiard balls each of mass 50g moving in opposite directions each with a speed of 6m/s collide and rebound with the same speed. The impulse imparted to each ball due to the other is
(a) 0.3Ns (b) 0.6Ns (c) 0.9Ns (d) Zero

**(b)**
m = 50g = 0.05kg, u = 6m/s and v = - 6m/s

($\because$ after collision, billiard ball moves in the opposite direction).
Impulse = change in momentum of the body = m (v – u) = 0.05 (-6 – 6) = -0.6Ns. (Neglect –ve sign)