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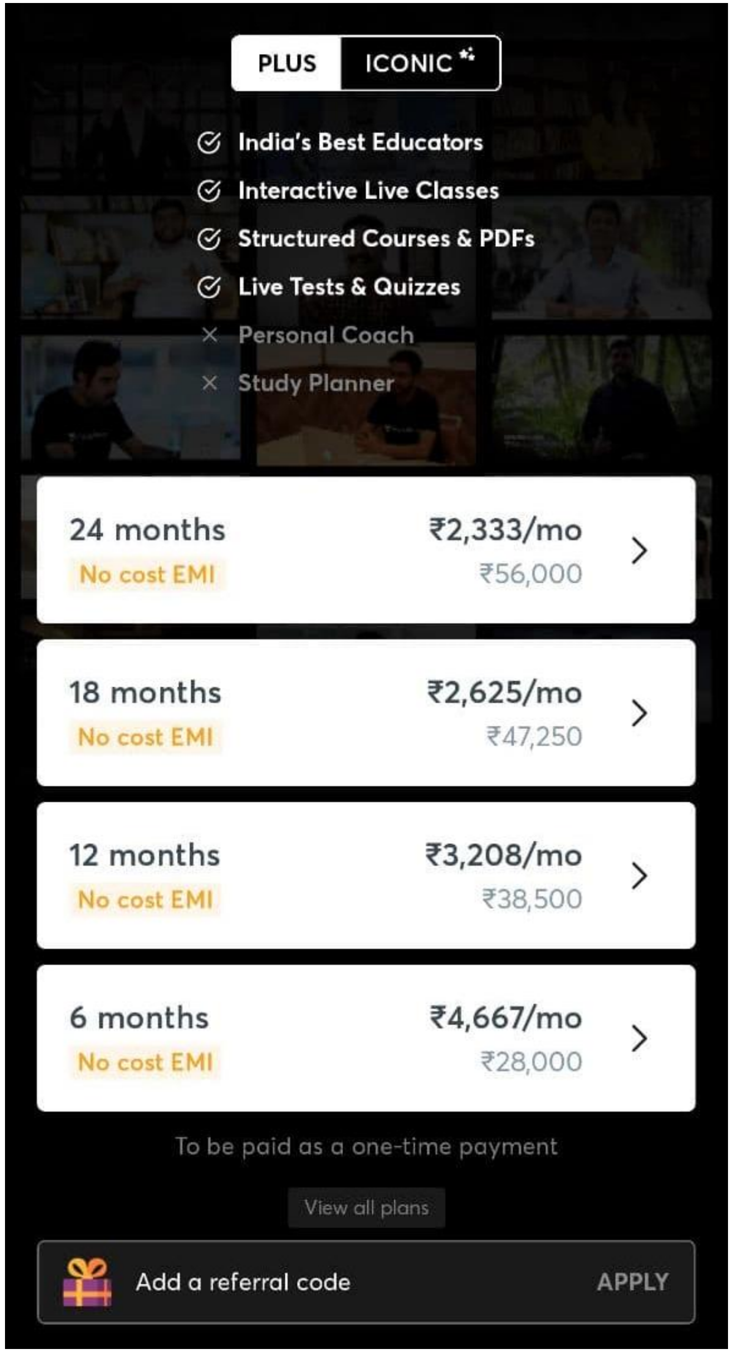

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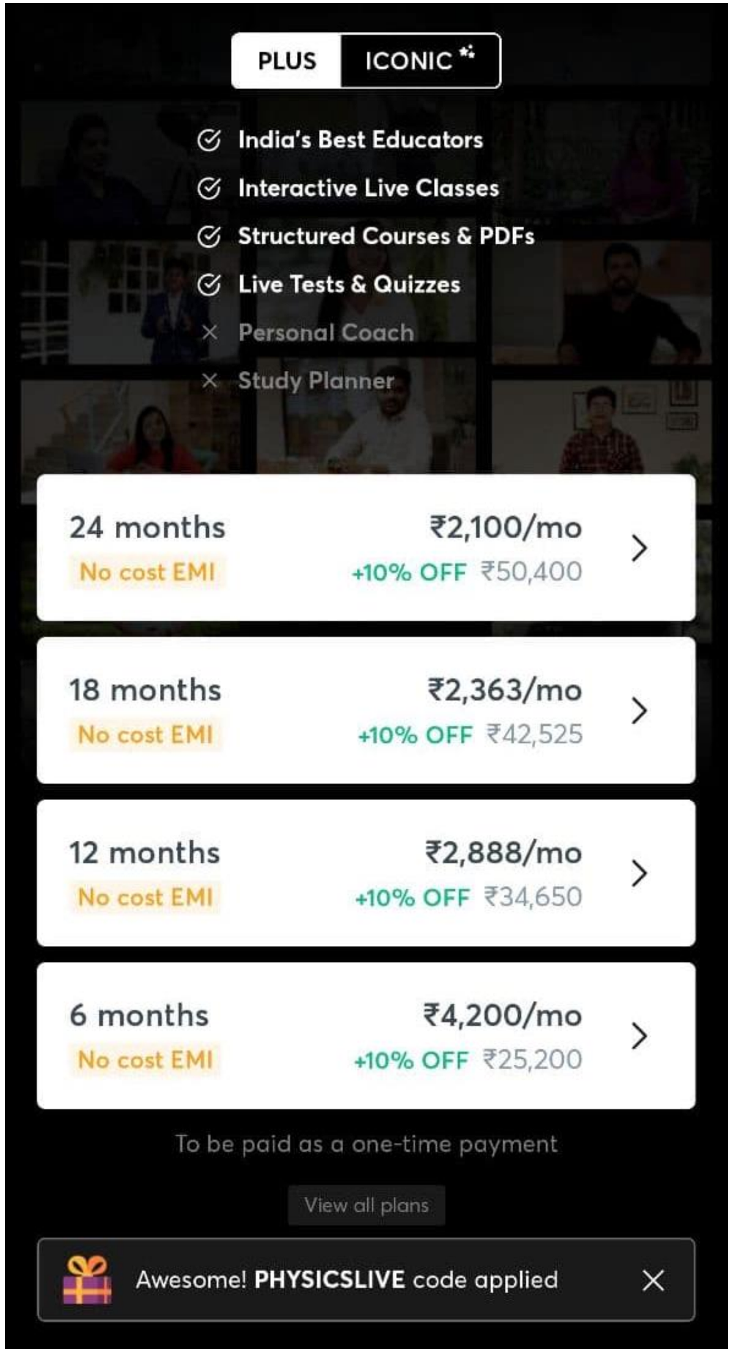

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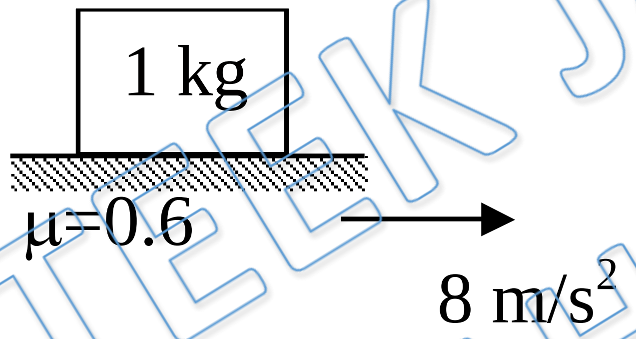
JEE Main & Advanced, NSEP, INPhO, IPhO
Physics DPP

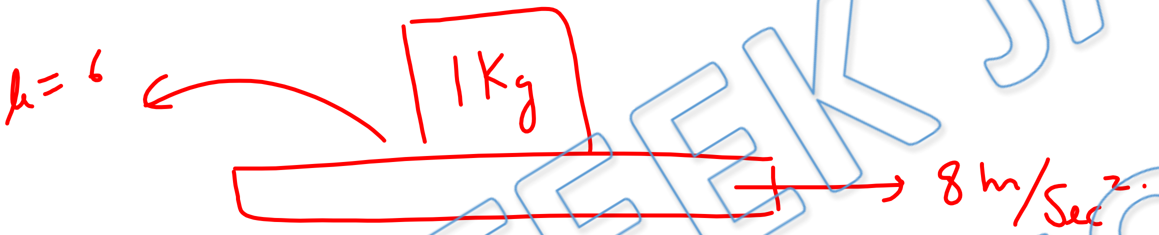
DPP- 2: Friction- Limiting Friction, Angle of repose, Angle of Friction, Block over Block Problems

By Physicsaholics Team

(Q) If the surface is moving at 8 m/s^2. What is the acceleration of block in m/s^2 ?



Ans. 6



maximum possible friction on block $= \mu mg = .6 \times 1 g = 6N$

" " acceleration of block $= 6\, m/sec^2$

⇒ block will slide on surface

⇒ Kinetic friction will act in forward direction

⇒ block will move with acceleration $6\, m/sec^2$

ANS(6)

(Q) A body is placed on a rough inclined plane of inclination θ. As the angle θ is increased from $0°$ to $90°$ the contact force between the block and the plane

(a) remains constant

(b) first remains constant then decreases

(c) first decreases then increases

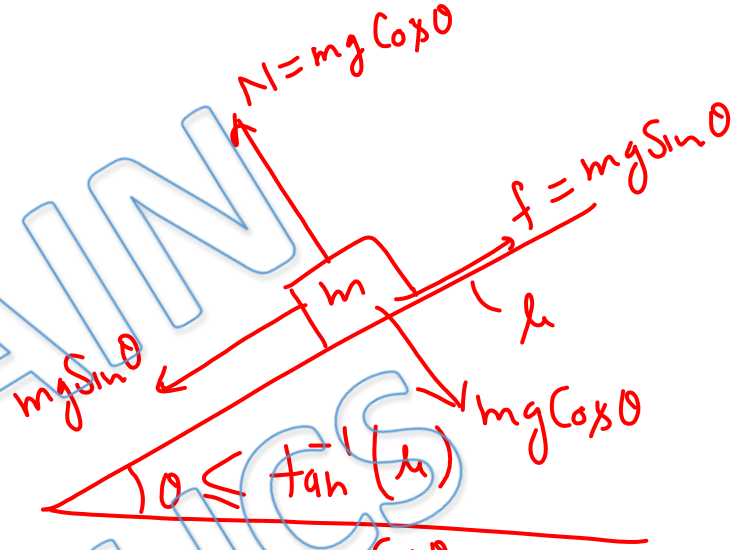
(d) first increases then decreases.

Ans. b

for $\theta \leq \tan^{-1}(\mu)$

$$F_c = \sqrt{N^2+f^2} = mg\sqrt{\sin^2\theta + \cos^2\theta} = mg$$

$$= \text{Constant}$$

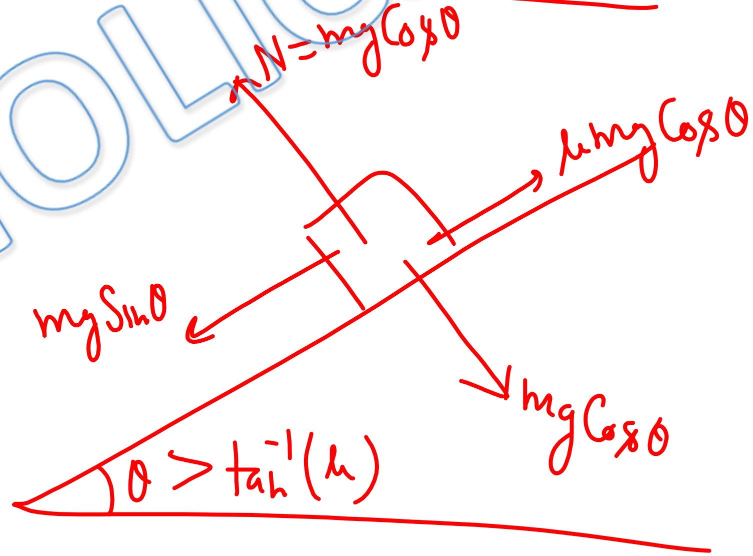


for $\theta > \tan^{-1}(\mu)$

$$F_c = \sqrt{N^2+\mu^2N^2} = N\sqrt{1+\mu^2}$$

$$= mg\sqrt{1+\mu^2}\,\cos\theta$$

= decreases on increasing θ.



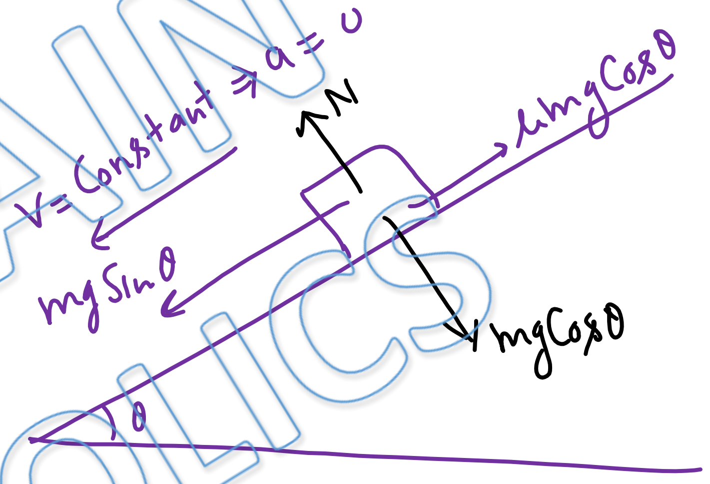
Ans(b)

(Q) A block of mass m slides down an inclined plane of inclination θ with uniform speed. The coefficient of friction between the block and the plane is μ . The contact force between the block and the plane is:

(a) mg
(b) mg sin θ $\sqrt{1+\mu^2}$
(c) mg sin θ
(d) $\sqrt{(mg\ sin\ \theta)^2 + (\mu mg\ cos\ \theta)^2}$

Ans. a

$a = 0 \Rightarrow mg\sin\theta = \mu mg\cos\theta$



$$\text{Contact force} = \sqrt{N^2 + f_r^2}$$

$$= \sqrt{(mg\cos\theta)^2 + (\mu mg\cos\theta)^2}$$

$$= \sqrt{(mg\cos\theta)^2 + (mg\sin\theta)^2}$$

$$= mg$$

$N = mg\cos\theta$

Ans (a)

Q) A block is placed over a plank. The coefficient of friction between the block and the plank is $\mu = 0.2$. Initially both are at rest, suddenly the plank starts moving with acceleration $a_0 = 4\ m/s^2$. The displacement of the block in 1s is : $(g = 10\ m/s^2)$

(a) 1 m relative to ground

(b) 1 m relative to plank

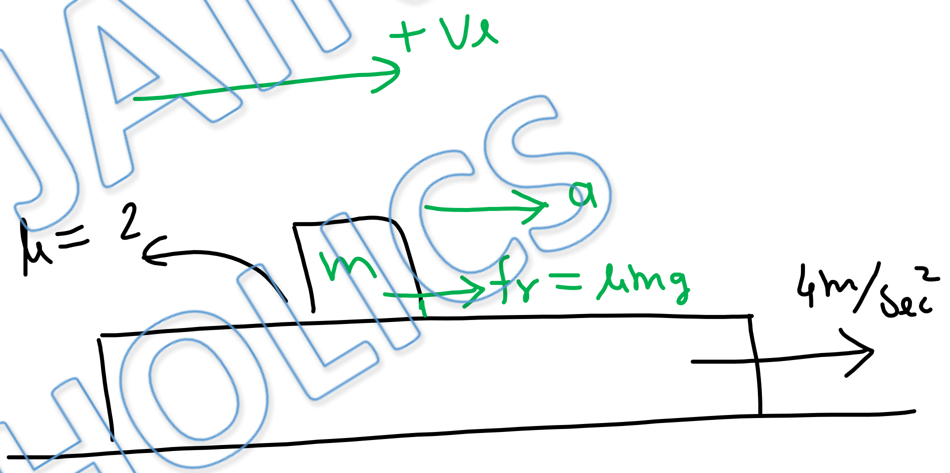
(c) zero relative to plank

(d) 2 m relative to ground

Ans. a,b

acceleration of block

$$= \frac{\mu m g}{m} = \mu g = 2\,m/sec^2$$



Displacement of block

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

$$= 0 + \frac{1}{2} \times 2 \times 1^2$$

$$= 1m$$

Displacement of plank in 1 sec

$$= 0 + \frac{1}{2} \times 4 \times 1^2 = 2m$$

Displacement of block w.r.t. plank

$$= D_{b,g} - D_{p,g}$$

$$= 1 - 2 = -1m = 1m \text{ left side}$$

Ans (a, b)

(Q) A block of mass m = 2 kg is resting on a rough inclined plane of inclination 30° . The coefficient of friction between the block and the plane is $\mu = 0.5$. What minimum force F should be applied perpendicular to the plane on the block, so that block does not slip on the plane: ($g = 10\ m/s^2$)

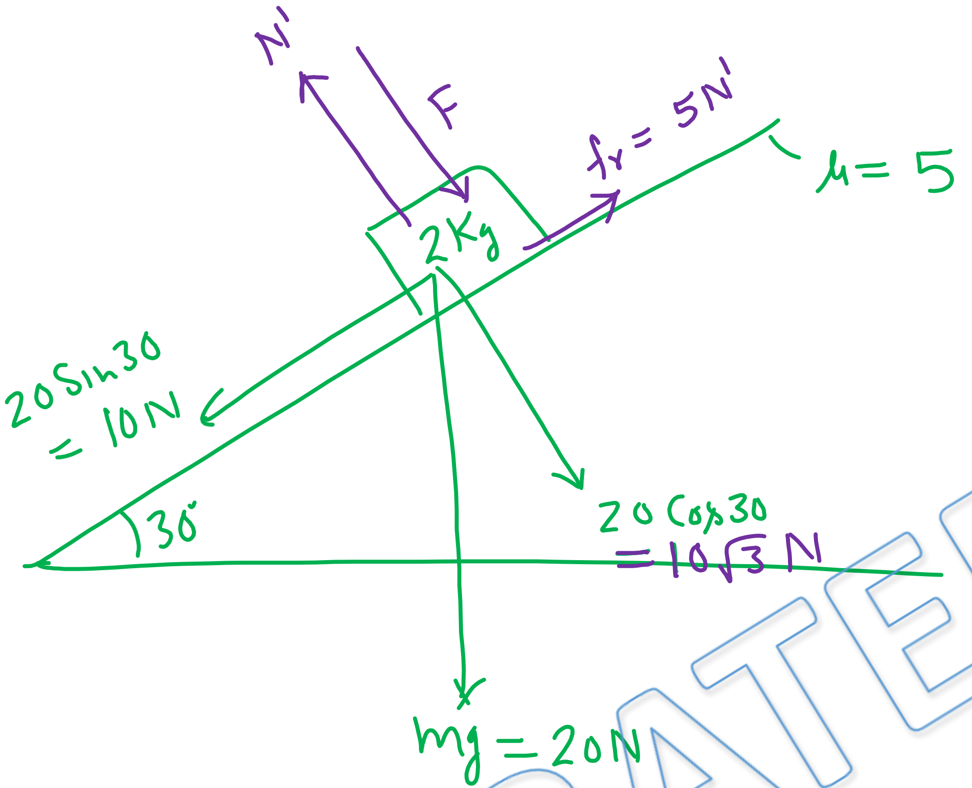
(a) zero

(b) 6.24 N

(c) 2.68 N

(d) 4.34 N

Ans. c



$$.5N' = 10$$

$$N' = \frac{10}{.5} = 20$$

$$N' = F + 10\sqrt{3}$$

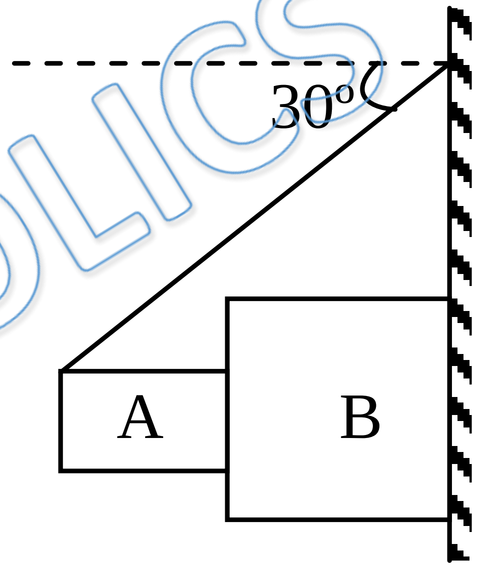
$$20 = F + 10\sqrt{3}$$

$$\Rightarrow F = 20 - 10\sqrt{3}$$

$$\simeq 2.68N$$

Ans(c)

(Q) Two blocks A and B of mass 10 kg and 20 kg respectively are placed as shown in figure. Coefficient of friction between all the surfaces is 0.2. Then– ($g = 10\ m/s^2$)



(a) tension in the string is 306 N

(b) tension in the string is 132 N

(c) acceleration of block B is 2.6 m/s^2

(d) acceleration of block B is 4.7 m/s^2

Ans.a,d

A will remain stationary since length of string is constant

from FBD of A $\rightarrow$

$$N_{AB} = \frac{T\sqrt{3}}{2} \quad \text{- - - (1)}$$

$$\frac{T}{2} = 100 + .2 N_{AB} = 100 + .2\frac{T\sqrt{3}}{2}$$

$$\Rightarrow T(5 - .173) = 100$$

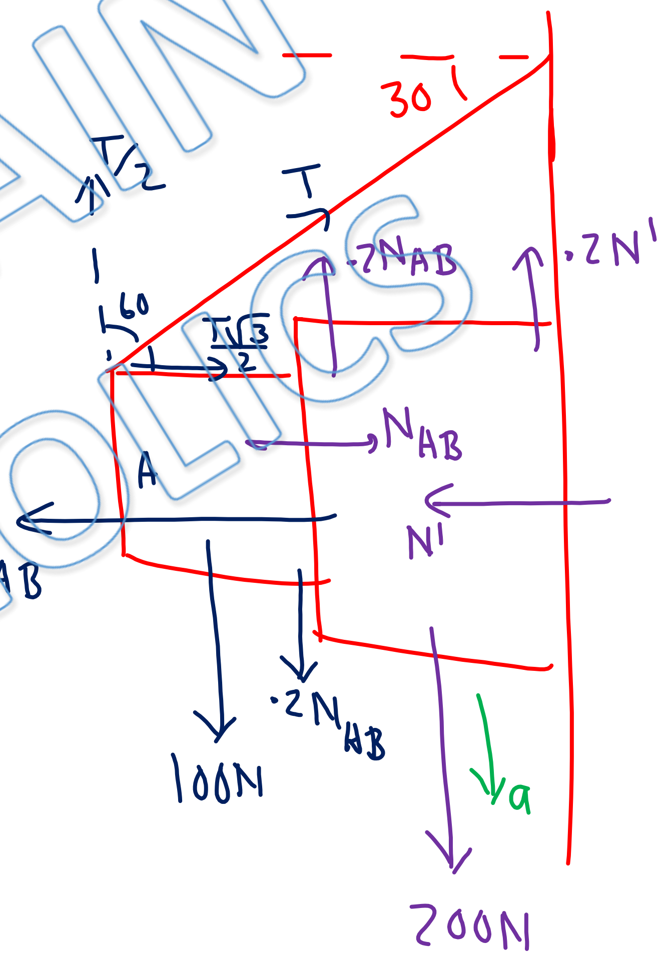
$$\Rightarrow T = 306\,N$$

for B $\rightarrow$ $200 - 2N_{AB} - .2N' = 20a$ (6

$$\Rightarrow 20a = 200 - .4 \times \frac{T\sqrt{3}}{2} = 200 - 106$$

$$\Rightarrow 20a = 94$$

$$a = 4.7\, m/sec^2$$



(Q) A weight W can be just supported on a rough inclined plane by a force P either acting along the plane or horizontally. The limiting angle of friction is ϕ and is θ the angle which incline makes with the horizontal. Then –

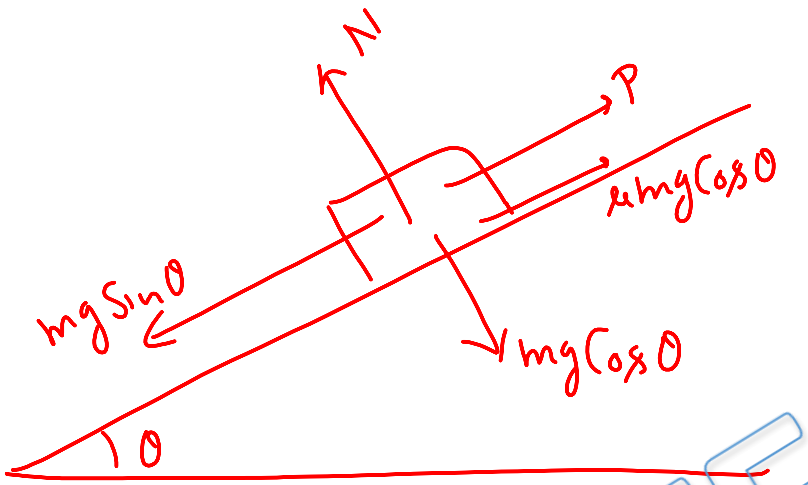
(A) the incline makes an angle with the horizontal twice the limiting angle of friction i.e. $\theta = 2\phi$

(B) the incline makes an angle with the horizontal equal to the limiting angle of friction i.e. $\theta = \phi$

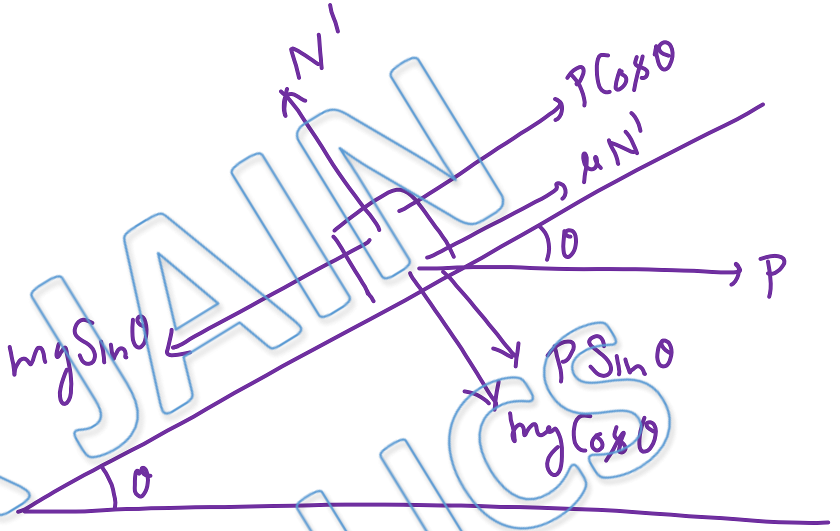
(C) the ratio of the force to the weight is $\frac{P}{W} = \cot\phi$

(D) the ratio of the force to the weight is $\frac{P}{W} = \tan\phi$

Ans. a,d



$$P = mg(\sin\theta - \mu\cos\theta) \quad \text{--- (I)}$$



$$N' = P\sin\theta + mg\cos\theta$$

$$mg\sin\theta = \mu N' + P\cos\theta$$

$$mg\sin\theta = \mu P\sin\theta + \mu mg\cos\theta + P\cos\theta$$

$$P = \frac{mg(\sin\theta - \mu\cos\theta)}{\cos\theta + \mu\sin\theta} \quad \text{--- (II)}$$

from (I) & (II)

$$\cos\theta + \mu\sin\theta = 1$$

$$\Rightarrow \cos\theta + \tan\phi\sin\theta = 1$$

$$\Rightarrow \cos\theta\cos\phi + \sin\theta\cdot\sin\phi = \cos\phi$$

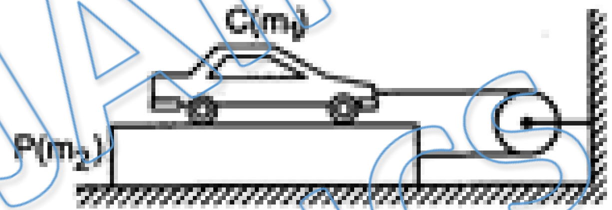
$$\Rightarrow \cos(\theta - \phi) = \cos\phi$$

$$\Rightarrow \theta - \phi = \phi \Rightarrow \theta = 2\phi$$

$$\Rightarrow \frac{P}{W} = \frac{P}{mg} = \sin 2\phi - \tan\phi\cos 2\phi$$

$$= \frac{\sin 2\phi\cos\phi - \cos 2\phi\sin\phi}{\cos\phi} = \frac{\sin\phi}{\cos\phi} = \tan\phi$$

(Q) A car C of mass m_1 rests on a plank P of mass m_2. The plank rests on a smooth floor. The string and pulley are ideal. The car starts and moves towards the pulley with acceleration.



(a) If $m_1 > m_2$, the string will remain under tension.

(c) If $m_1 < m_2$, the string will become slack.

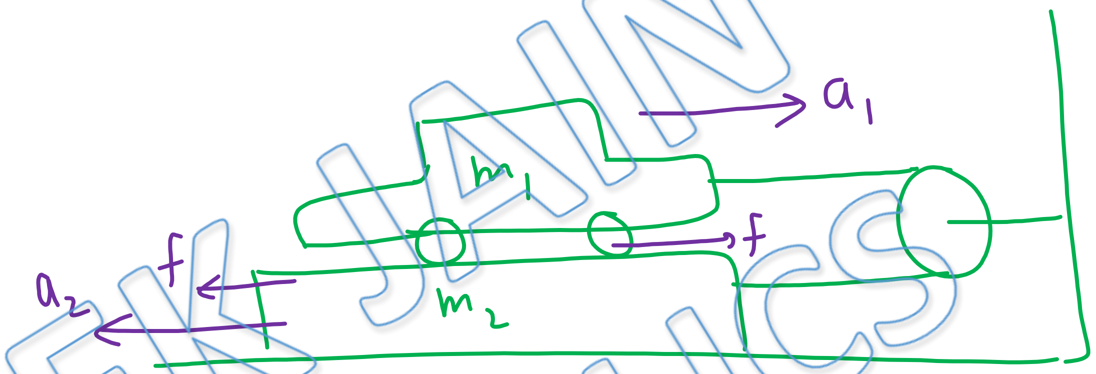
(c) If $m_1 = m_2$, the string will have no tension, and C and P will have accelerations of equal magnitude.

(d) C and P will have accelerations of equal magnitude if $m_1 > m_2$.

Ans. a,b,c,d

If string is absent

$a_1 = \frac{f}{m_1}$, $a_2 = \frac{f}{m_2}$



$f \rightarrow$ friction b/w m_1 & m_2

If $m_1 = m_2$

$\Rightarrow$ $a_1 = a_2 \Rightarrow T = 0$ if string is present

If $m_1 > m_2$

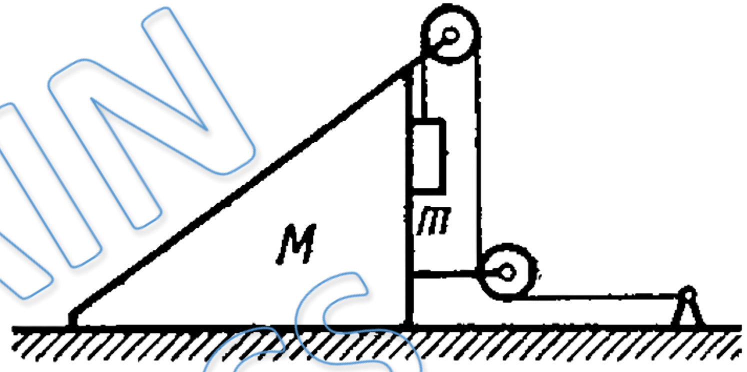
$\Rightarrow$ $a_1 < a_2 \Rightarrow T > 0$ If string is present & both move with same magnitude of acceleration

If $m_1 < m_2$

$\Rightarrow$ $a_1 > a_2 \Rightarrow$ string will slack

ANS (a, b, c, d)

Q) In the figure shown, friction exists between wedge and block and also between wedge and floor. The system is in equilibrium in the shown position. Which of the following is incorrect



(a) minimum coefficient of friction required to hold the system in equilibrium is $\frac{m}{M+m}$.

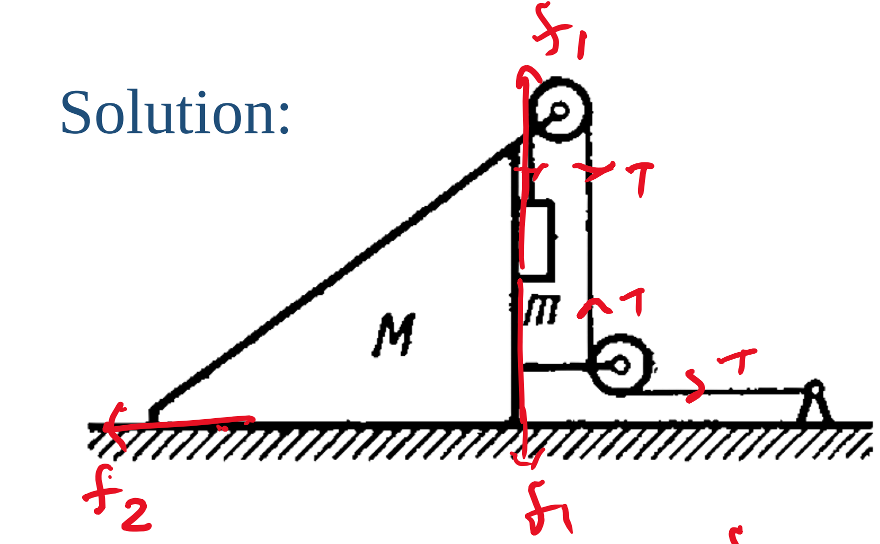
(b) frictional force between wedge and block is 0.

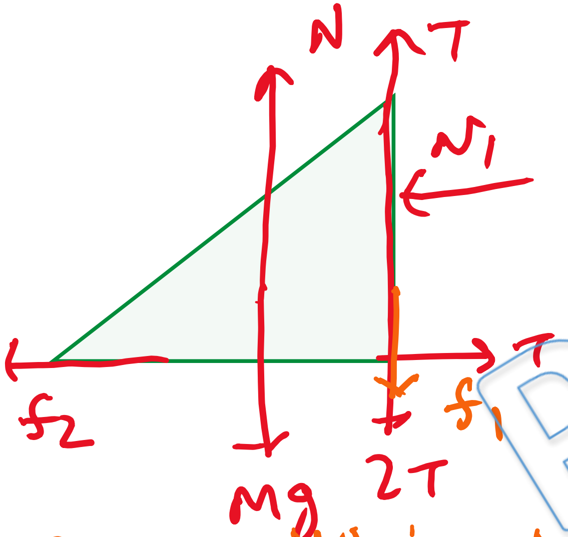
(c) frictional force between wedge and surface is mg.

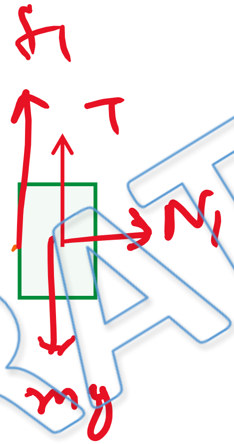
(d) none of these

Ans. d

Solution:







For equilibrium :

on mass m

$\boxed{N_1 = 0}$ —(1) & then; $\boxed{f_1 = 0}$ —(2)

and $\boxed{T = mg}$ —(3)

on wedge :

$N + T = Mg + 2T + \cancel{f_1}^{\,0}$

$N = Mg + T = Mg + mg$

$\boxed{N = (M+m)g}$ —(3)

& $f_2 + N_1 = T$

$\because N_1 = 0$

$f_2 = T$

$\boxed{f_2 = mg}$ —(4)

friction coefficient between wedge & floor

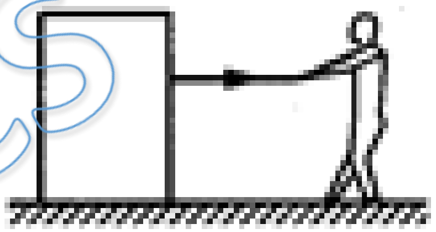
$f_2 = \mu N$

$mg = \mu (M+m)g$

$\boxed{\mu = \dfrac{m}{M+m}}$ —(5)

Ans

(Q) A man pulls a block heavier than himself with a light rope. The coefficient of friction is the same between the man and the ground, and between the block and the ground.



(a) The block will not move unless the man also moves.

(b) The man can move even when the block is stationary.

(c) If both move, the acceleration of the man is greater than the acceleration of the block.

(d) None of the above assertions is correct.

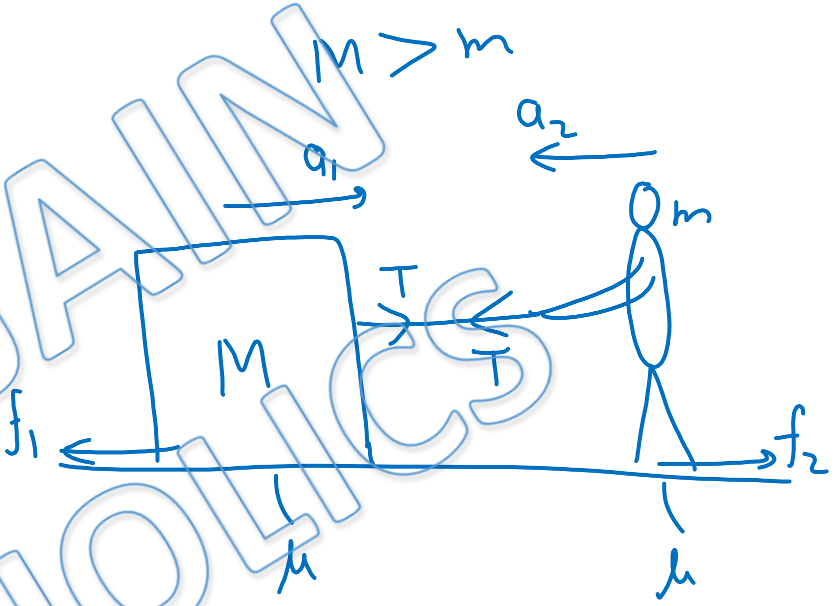
Ans. a,b,c

To move block

$T > \mu M g$

Since $M > m$, $T > \mu m g$

$\Rightarrow$ man will also move



If both move

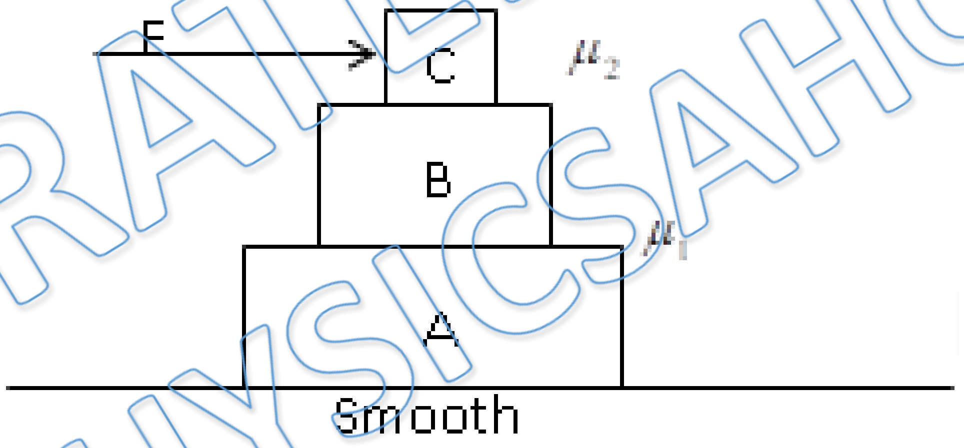
$$a_1 = \frac{T - \mu M g}{M} = \frac{T}{M} - \mu g$$

$$a_2 = \frac{T - \mu m g}{m} = \frac{T}{m} - \mu g$$

Since $M > m$, $a_2 > a_1$ $\Rightarrow$ man will move with greater acceleration

Linked Comprehension

Three blocks A, B and C each having mass 1kg are kept one above the other as shown in the figure on a smooth horizontal surface. Coefficient of friction between A and B is μ_1=0.3 and that between B and C is μ_2=0.8 . A horizontal force F acts on block C. (Take g = 10 ms^{-2})



(Q) For what maximum value of force F, can all the three blocks move together?

(a) 8N

(b) 18N

(c) 12N

(d) 6N

Ans. c

maximum possible acceleration of A

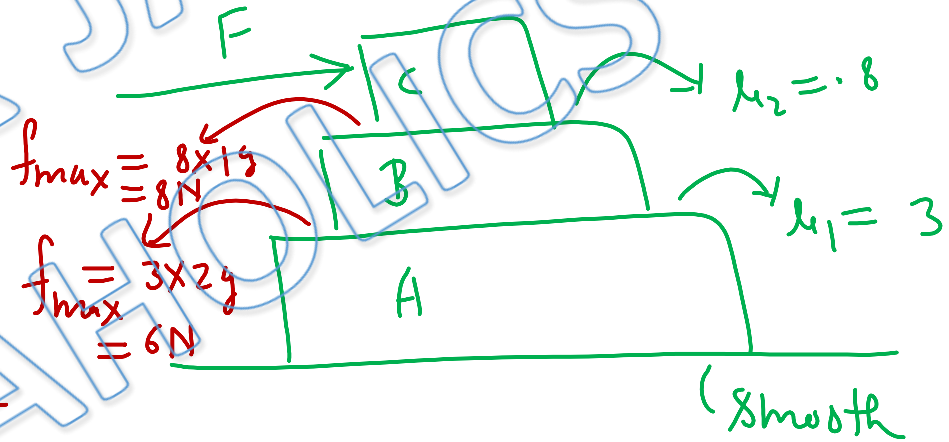
$= \frac{6}{1} = 6 m/sec^2$

maximum possible acceleration of A & B togather $= \frac{8}{2} = 4 m/sec^2$

$\Rightarrow$ A & B will always move togather

maximum possible acceleration of $(A+B+C)$ without sliding b/w them $= 4 m/sec^2$

$\Rightarrow$ $F = 3 \times 4 = 12 N$



ANS (C)

(Q) If F = 3N, the value of frictional force acting between blocks B and C is

(a) 2N

(b) 1N

(c) 0.5N

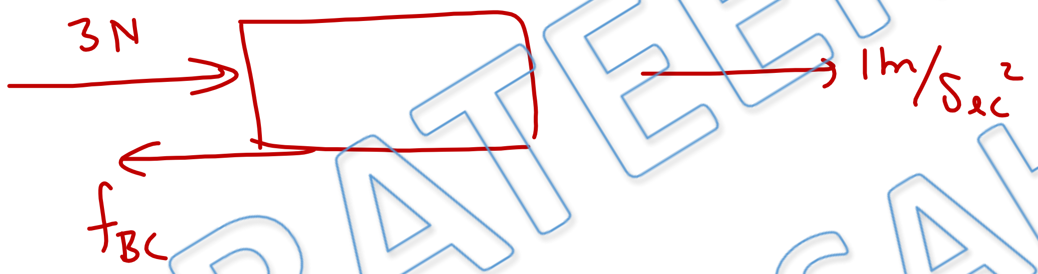
(d) Zero

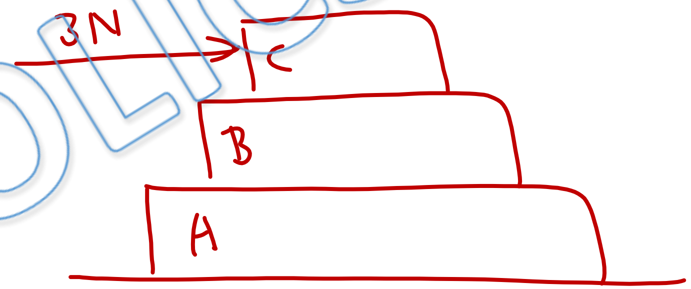
Ans. a

Since $F < 12N$

$\Rightarrow$ all three blocks will move together with $a = \frac{3}{3} = 1\,m/sec^2$

FBD of C





$$3 - f_{BC} = 1 \times 1$$

$$f_{BC} = 2N$$

Ans(a)

(Q) If F = 15N, the value of frictional force acting between blocks A and B is

(a) 2N (b) 4N (c) 8N (d) 7N

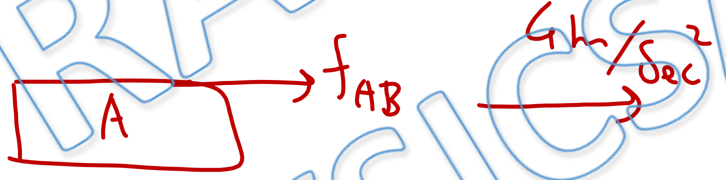
Ans. b

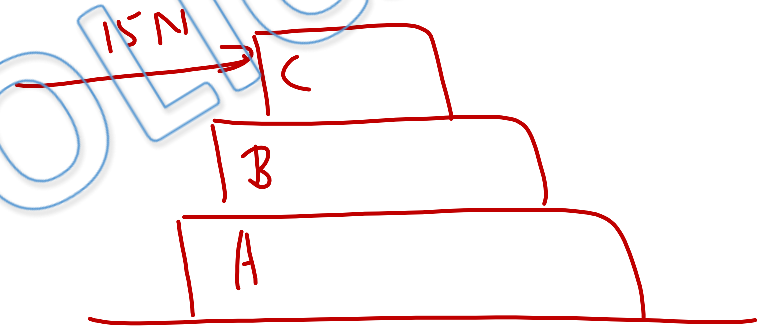
Since $F > 12N$, There will be sliding b/w B & C but A & B will move together

acceleration of $(A+B)$

$$= \frac{8}{2} = 4\,m/sec^2$$

FBD of A





$$f_{AB} = 1 \times 4 = 4\,N$$

Ans(b)

Passage

A small block of mass m is kept on a long plank of same mass. Ground is smooth and coefficient of friction between block and plank is 0.5. At $t = 0$ initial velocity of 20 m/s is given to the system. At $t = 1sec$ plank is suddenly hinged such that it comes to the rest and at $t = 3sec$ again the hinge is removed.

(Q) Velocity of the block in time interval t=0 to t=1sec will

A) remains constant

B) decreases

C) increases

D) none of these

Ans. a

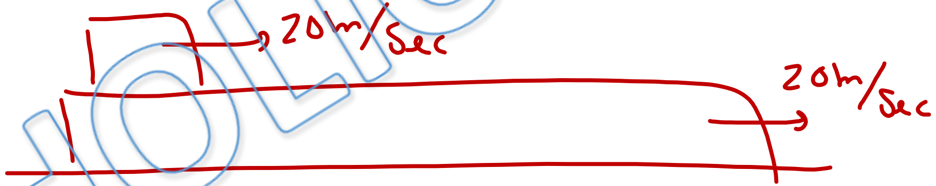
from $t=0$ to $t=1$

both move with same velocity

$\Rightarrow$ friction $=0$

$\Rightarrow$ both move with Constant velocity

20 m/sec.



Ans (a)

(Q) Displacement of the block in time interval t=0 to t=3sec

(a) 20 m (b) 30 m (c) 50 m (d) 60 m

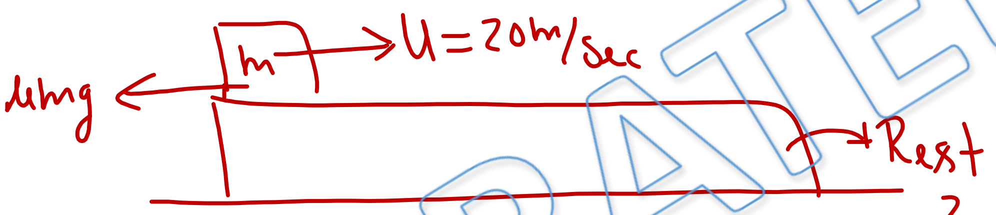
Ans. c

from $t=0$ to $t=1$

velocity of block is Constant

$\Rightarrow \quad \Delta x_1 = 20 \times 1 = 20\,m$

from $t=1$ to $t=3$



acceleration of block

$a = \frac{\mu m g}{m} = 5\,m/sec^2$

$\Delta x_2 = 20 \times 2 - \frac{1}{\cancel{2}} \times 5 \times \cancel{4}^{\,2} = 30\,m$

$\Delta x = \Delta x_1 + \Delta x_2 = 50\,m$

Ans(c)

(Q) Velocity of the plank after a long time is

(a)2 m/s

(b) 5 m/s

(c) 10 m/s

(d) 12 m/s

Ans. b

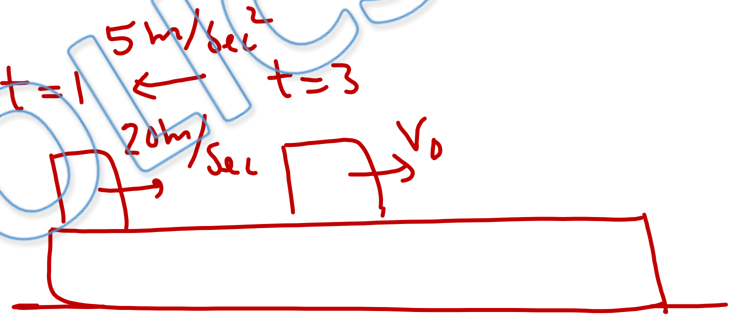
Velocity of block at t=3

$$V_0 = 20 - 5 \times 2 = 10\, m/sec$$

for t>3 (until they move with same velocity)

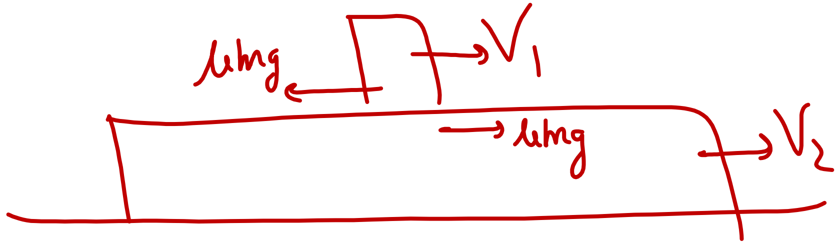
acceleration of block $= \frac{\mu m g}{m} = 5\, m/sec^2$

" " plank $= \frac{\mu m g}{m} = 5\, m/sec^2$



Let their final common velocity is V & they take t_0 sec more after t=3 to achieve it

for t>3 sec



$$V = 10 - 5t_0 = 0 + 5t_0$$

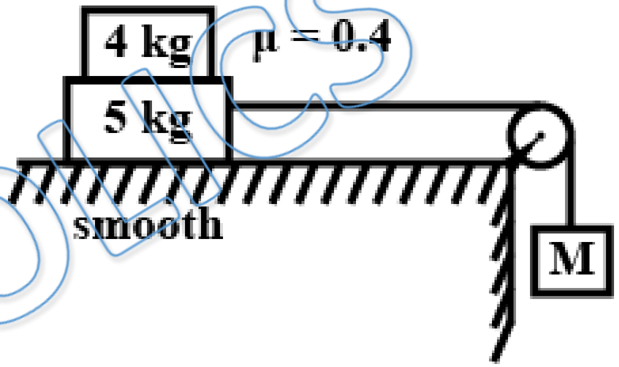
$$\Rightarrow 10t_0 = 10$$

$$t_0 = 1$$

$$\Rightarrow V = 5\, m/sec$$

ANS(b)

Q) What should be the maximum value of M so that the 4 kg block does not slip over the 5 kg block : (Take g=10m/s^2)



(a) 12 kg

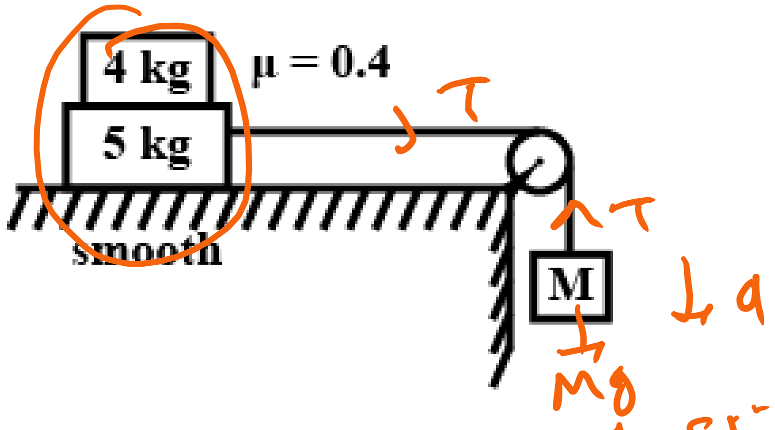
(b) 8 kg

(c) 10 kg

(d) 6 kg

Ans. d

Solution:



If 4 kg does not slip

then $(a)_{5kg} = (a)_{4kg} = a$

$T = 9a$ — ①

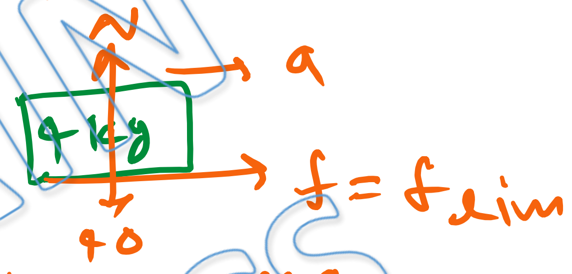
$Mg - T = Ma$ — ②

① + ② ⇒ $Mg = 9a + Ma$ — ③

$M = \frac{9a}{g-a} = \frac{9}{\left(\frac{g}{a} - 1\right)}$ — ④

For max value of M

$a \rightarrow$ max



$f_{lim} = ma$

$0.4 \times 40 = 4a$

$\boxed{a = 4\, m/s^2}$

Put 'a' in eqn ④

max: $M = \frac{9}{\left(\frac{10}{4} - 1\right)} = \frac{36}{6}$

$\boxed{M = 6\text{ kg}}$ Ans.

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