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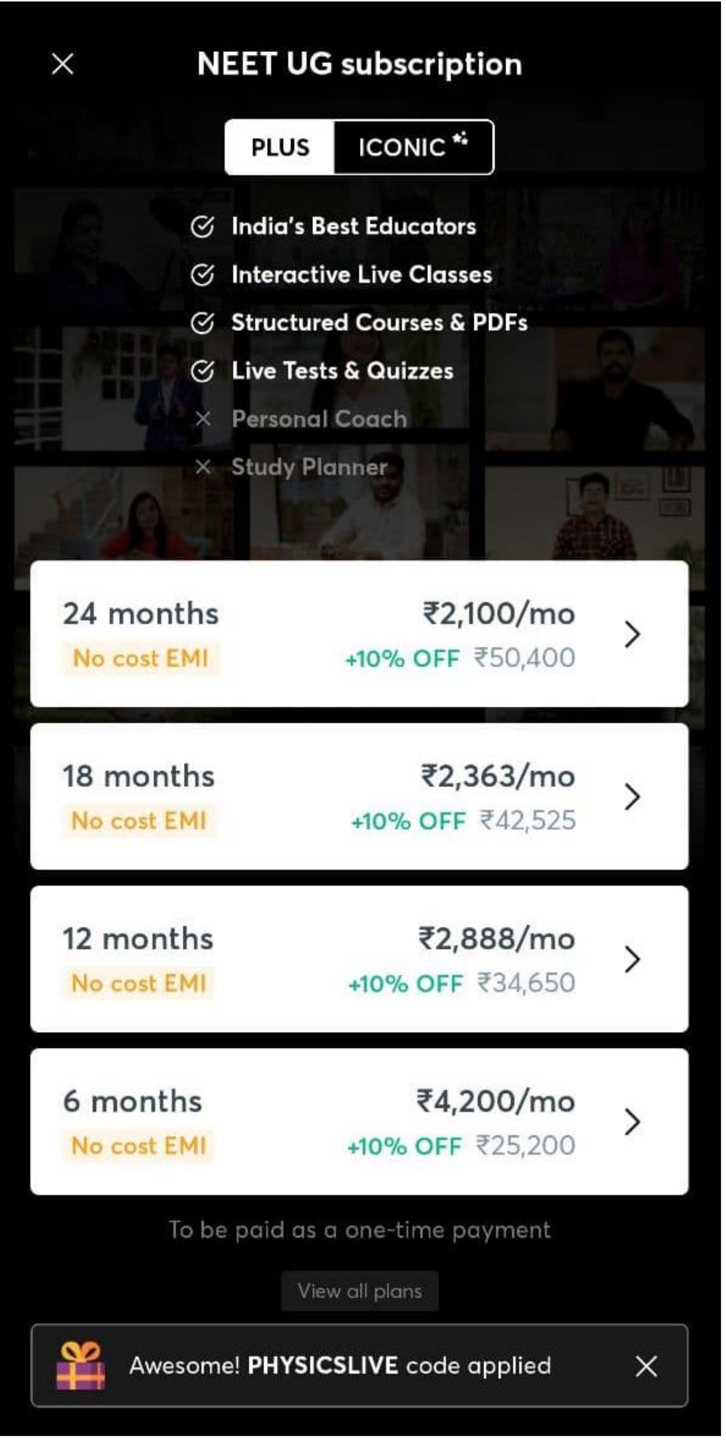


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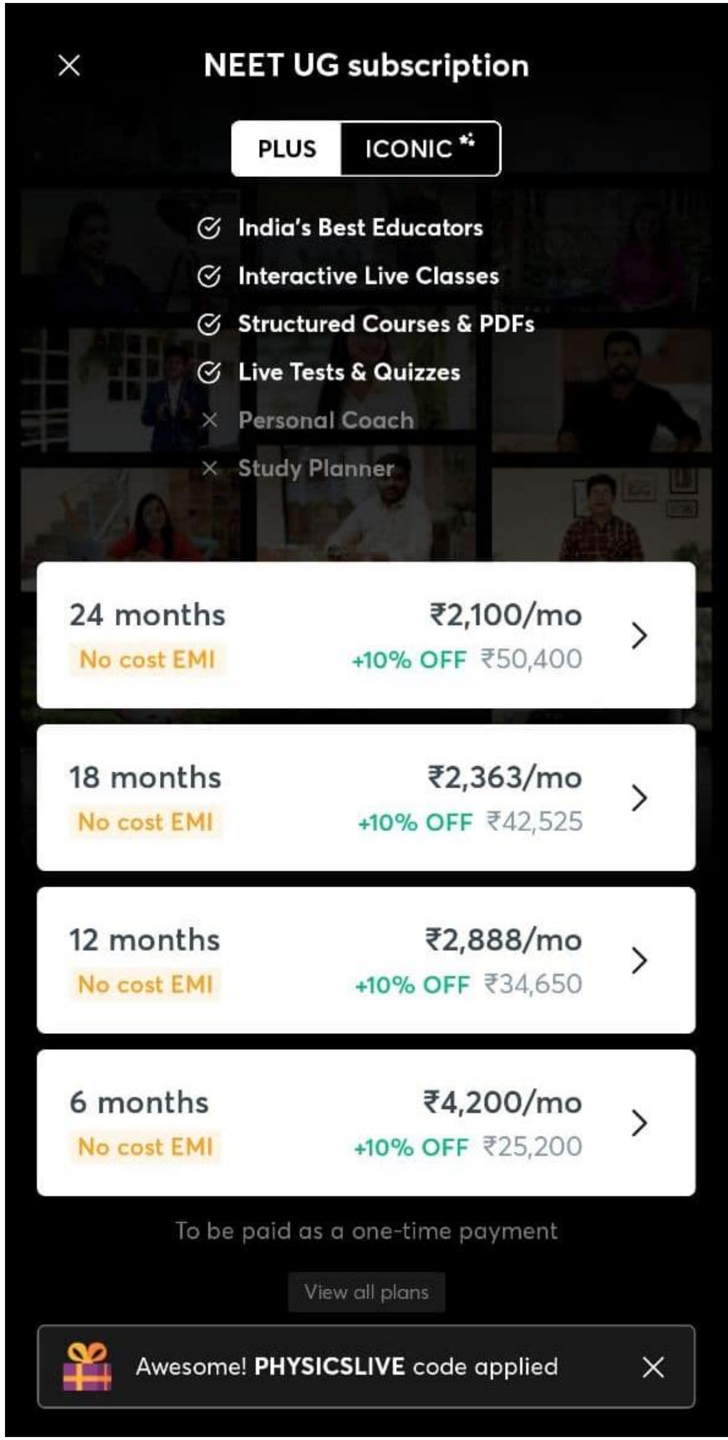

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# JEE Main & Advanced, NSEP, INPhO, IPhO Physics DPP

## DPP- 1 Friction: Static & Kinetic Friction

## By Physicsaholics Team

Q) A body is moving down inclined plane of slope 37°. The coefficient of friction between the body and plane varies as $\mu = 0.3x$, where x is distance traveled down the plane. The body will have maximum speed at –

($\sin 37^\circ = \frac{3}{5}$ and $g = 10\ m/s^2$)

(a) $x = 1.16$ m

(b) $x = 2$ m

(c) bottom of plane

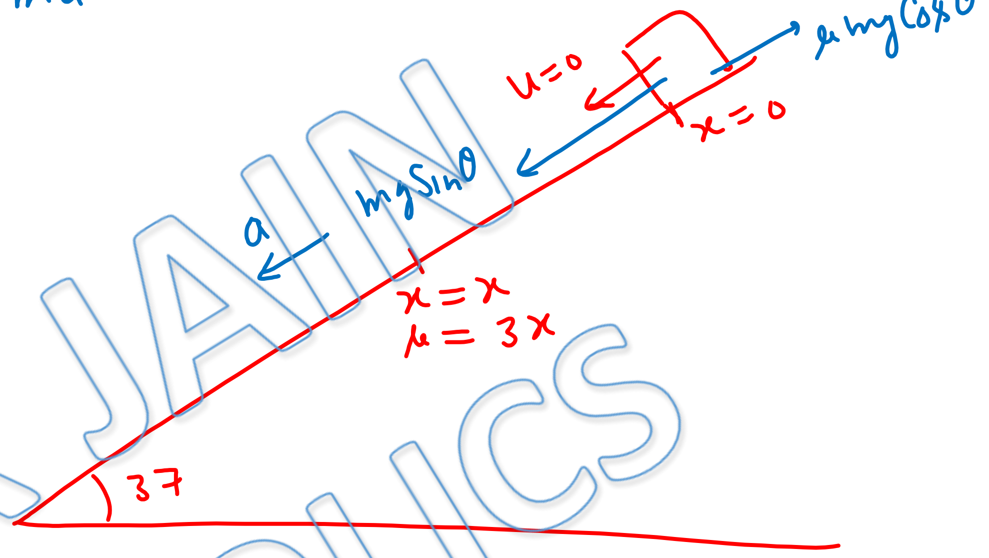
(d) $x = 2.5$ m

Ans. d

from F B D of block , $mg\sin\theta - \mu mg\cos\theta = ma$

acceleration of block at $x = x$

$$a = g(\sin\theta - \mu\cos\theta)$$




at $V = V_{max}$

$$\frac{dv}{dx} = 0$$

$\Rightarrow a = 0$

$\Rightarrow \sin\theta = \mu\cos\theta$

$\Rightarrow \mu = \tan\theta = 3/4$

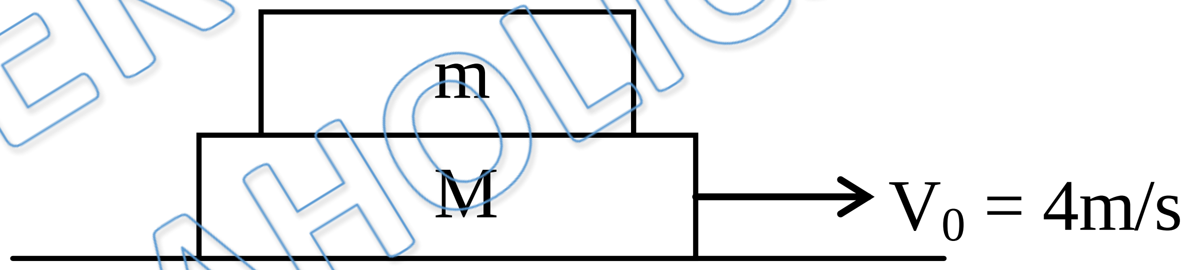
$\Rightarrow 3x = 3/4 \Rightarrow x = 1/4$

$= 5/2$

Q) A stationary body of mass m is slowly lowered ( zero initial velocity ) onto a long massive platform of mass M (M>>m) moving at a speed $V_0$ = 4 m/s as shown in fig. How far will the body slide along the platform Relative to platform ? ($\mu$ = 0.2 and g = 10 m/$s^2$)

(a) 4 m (b) 6 m

(c) 12 m (d) 8 m



Ans. a

acceleration of m wrt M

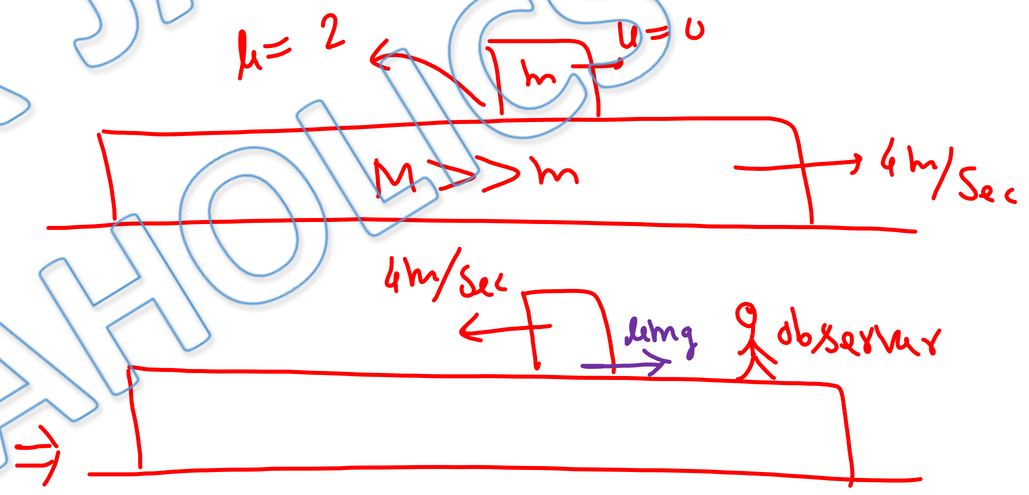
$$= \frac{\mu mg}{m} = \mu g = 2\, m/sec^2 \rightarrow$$

relative distance covered before Comming to relative rest

$$v^2 = u^2 + 2ax$$

$$0 = 16 - 2 \times 2x$$

$$x = 4m$$



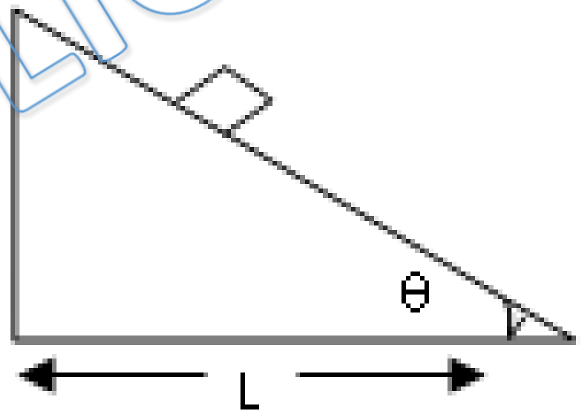
Q) A small body starts sliding down an inclined plane of inclination $\theta$, whose base length is equal to L. The coefficient of friction between the body and the surface is $\mu$. If the angle $\theta$ is varied keeping L constant, at what angle will the time of sliding be least?

(a) $tan^{-1}\left(\frac{1}{\mu}\right)$

(b) $tan^{-1}\left(\frac{-1}{\mu}\right)$

(c) $\frac{1}{2}tan^{-1}\left(\frac{1}{\mu}\right)$

(d) $\frac{1}{2}tan^{-1}\left(\frac{-1}{\mu}\right)$



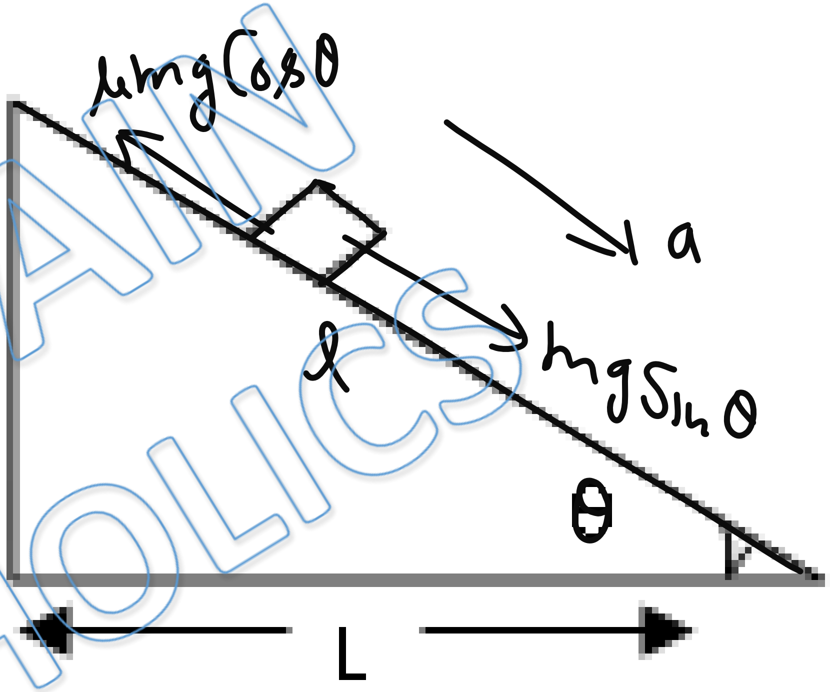
Ans. d

## Solution:

$$ma = mg\sin\theta - \mu mg\cos\theta$$

$$a = g(\sin\theta - \mu\cos\theta)$$

$$\cos\theta = \frac{L}{l} \Rightarrow l = \frac{L}{\cos\theta}$$




$$l = \frac{1}{2}at^2 \Rightarrow t^2 = \frac{2l}{a} = \frac{2L}{g(\sin\theta - \mu\cos\theta)\cos\theta}$$

$$\Rightarrow t^2 = \frac{2L}{g(\sin\theta.\cos\theta - \mu\cos^2\theta)}$$

$$t^2 = \frac{2L}{g\left(\frac{1}{2}\sin 2\theta - \mu \cos^2\theta\right)}$$

for minimum time $\left(\frac{1}{2}\sin 2\theta - \mu \cos^2\theta\right)$ should be maximum.

$$\Rightarrow \frac{d}{dt}\left[\frac{1}{2}\sin 2\theta - \mu \cos^2\theta\right] = 0$$

$$\Rightarrow \frac{1}{2}\times 2\cos 2\theta - \mu \times 2\cos\theta(-\sin\theta) = 0$$

$$\cos 2\theta = -\mu \sin 2\theta$$

$\Rightarrow$

$\Rightarrow \quad \tan 2\theta = -1/\mu$

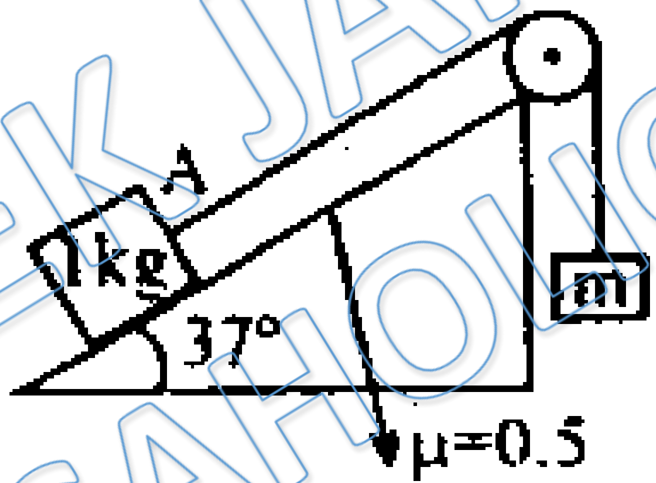
$\Rightarrow \quad 2\theta = \tan^{-1}(-1/\mu)$

$\Rightarrow \quad \theta = \frac{1}{2}\tan^{-1}(-1/\mu)$



Ans (d)

Q) In the figure, what should be mass m so that block A slide up with a constant velocity?



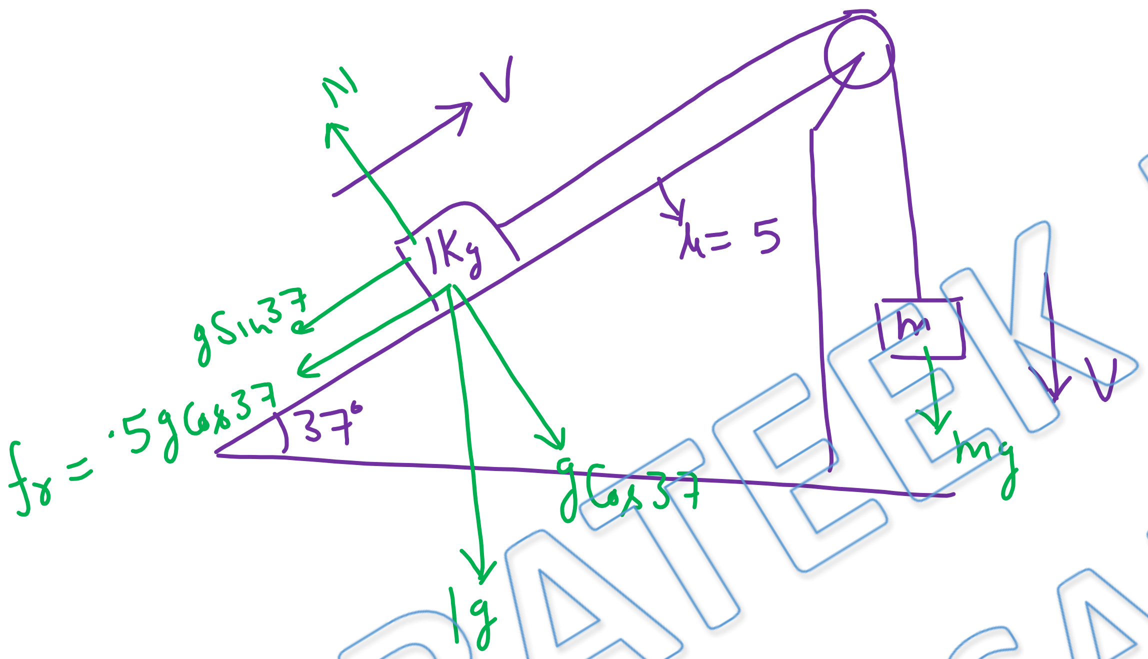

(a) 2 Kg

(b) 1 Kg

(c) 4 Kg

(d) 2.5 Kg

Ans. b




Since $a = 0$

$\Rightarrow$ supporting forces = opposing forces

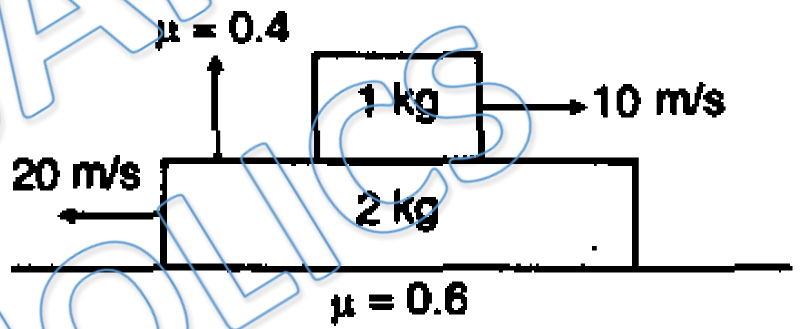
$\Rightarrow m\cancel{g} = \cdot 5\cancel{g}\cos 37 + \cancel{g}\sin 37$

$\Rightarrow m = \cdot 5 \times \frac{4}{5} + \frac{3}{5}$

$= 1\ \text{Kg}$

Ans (b)

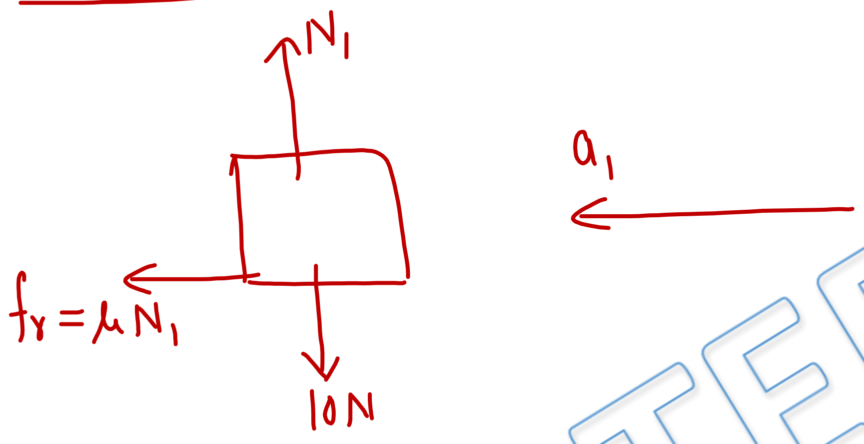
Q) In the diagram shown in figure. Match the following table

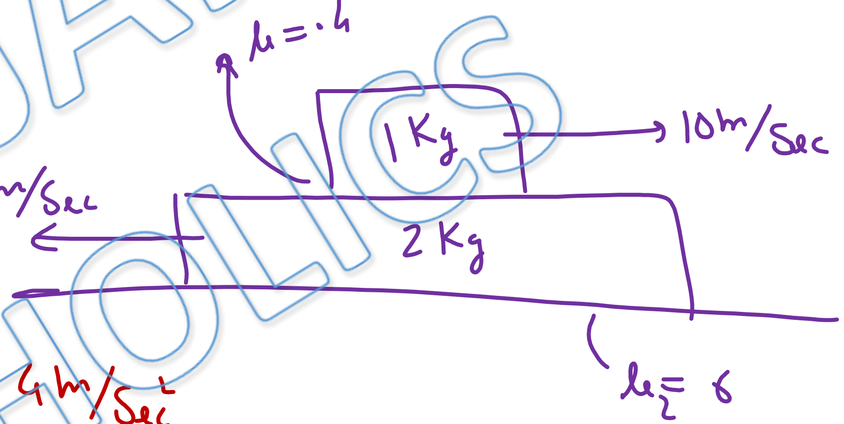



| Table-1 | | Table-2 | |
|---|---|---|---|
| (A) | Absolute acceleration of 1 kg block | (P) | 11 $m/s^2$ |
| (B) | Absolute acceleration of 2 kg block | (Q) | 6 $m/s^2$ |
| (C) | Relative acceleration between the two | (R) | 17 $m/s^2$ |
| | | (S) | None |

Ans. A(S), B(P), C(S)

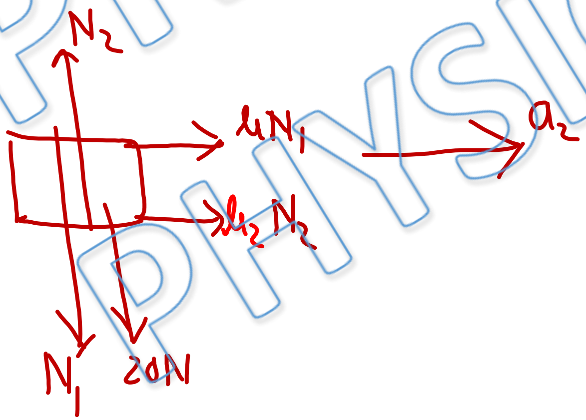
## FBD of 1Kg block




$N_1 = 10N$ , $\mu N_1 = 1 \times a_1 \Rightarrow 4 \times 10 = a_1 \Rightarrow a_1 = 4\ m/Sec^2$

## FBD of 2Kg block




$N_2 = N_1 + 20 \Rightarrow N_2 = 30N$

$\mu N_1 + \mu_2 N_2 = 2a \Rightarrow 2a = .4 \times 10 + .6 \times 30$

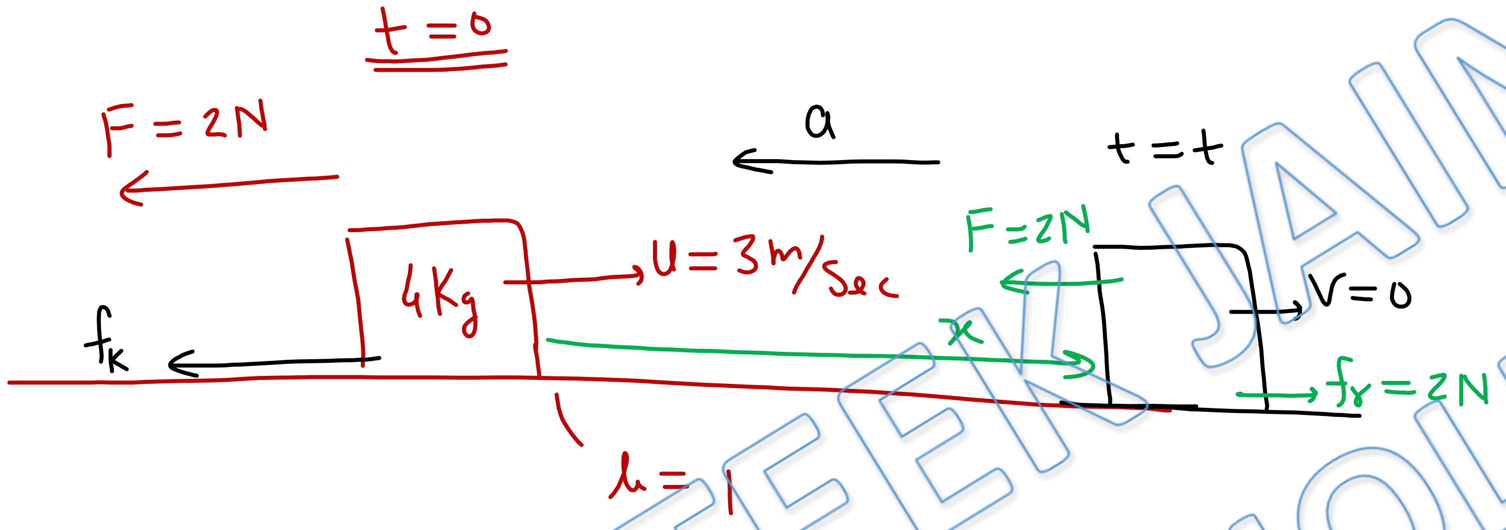
$\Rightarrow a = 11\ m/Sec^2$

Relative acceleration $= 11 + 4 = 15\ m/Sec^2$

Q) A block of mass 4 kg is kept over a rough horizontal surface. The coefficient of friction between the block and the surface is 0.1. At $t = 0$, velocity 3 m/s $\hat{\imath}$ is imparted to the block and simultaneously force 2N($-\hat{\imath}$) starts acting on it. Its displacement before coming to rest is

(a) $8\hat{\imath}$
(b) $-8\hat{\imath}$
(c) $3\hat{\imath}$
(d) $-3\hat{\imath}$

Ans. c




$$f_K = \mu N = .1 \times 40 = 4\,N$$

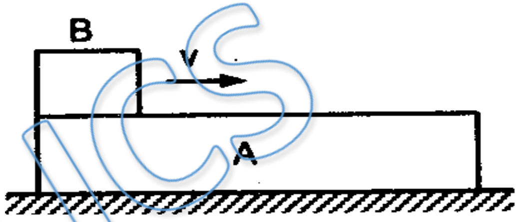
$$a = \frac{4+2}{4} = 3/2\ m/sec^2$$

block will retard & stop after some time

$$V^2 = u^2 + 2ax \Rightarrow 0 = 9 - 2 \times 3/2\, x \Rightarrow x = 3m$$

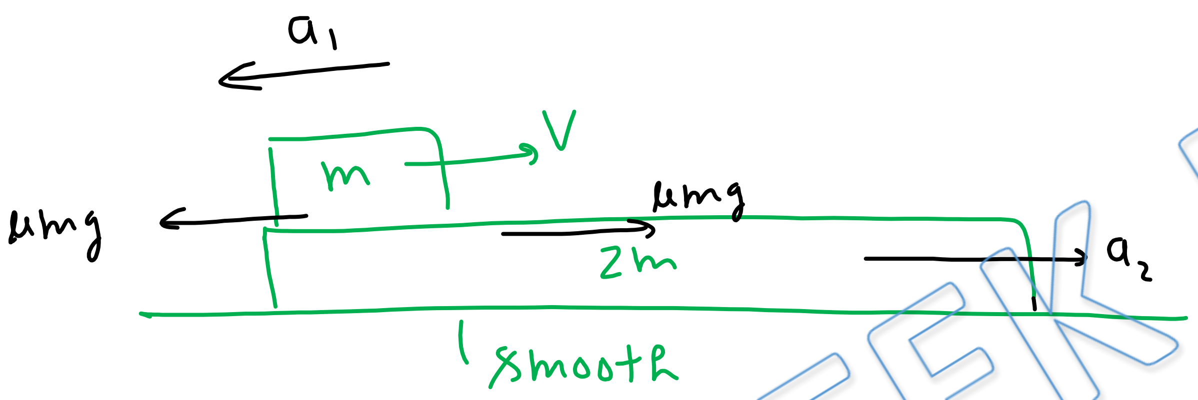
Ans (c)

Q) A long block A is at rest on a smooth horizontal surface. A small block B, whose mass is half of A, is placed on A at one end and projected along A with some velocity u. The coefficient of friction between the blocks is μ.




(a) The blocks will reach a final common velocity u/3
(b) Friction on A is towards right.
(c) Before the blocks reach a common velocity, the acceleration of A relative to B is $\frac{2}{3}\mu g$.
(d) Before the blocks reach a common velocity the acceleration of A relative to B is $\frac{3}{2}\mu g$.

Ans. a, b, d




$$a_1 = \frac{\mu mg}{m} = \mu g$$

$$a_2 = \frac{\mu mg}{2m} = \frac{\mu g}{2}$$

relative acceleration

$$= \mu g + \frac{\mu g}{2} = \frac{3}{2}\mu g$$

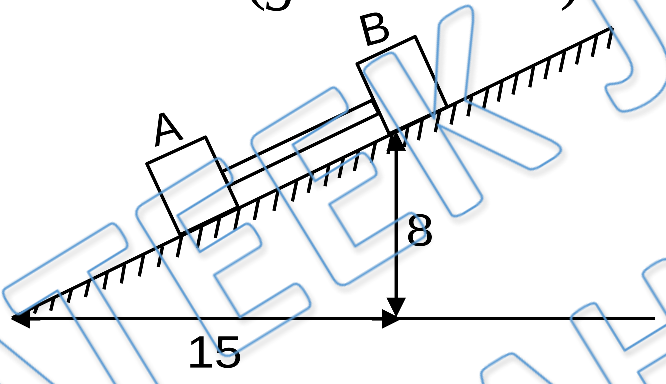
Let final common velocity is $V'$ & blocks achieve it at $t = t$

$$V' = V - \mu g t = \frac{\mu g}{2} t \Rightarrow \frac{3}{2}\mu g t = V \Rightarrow t = \frac{2V}{3\mu g}$$

$$\Rightarrow V' = \frac{\mu g t}{2} = \frac{\mu g}{2} \times \frac{2V}{3\mu g} = V/3$$

ANS (a, b, d)

Q) Blocks $A$ and $B$ in the figure are connected by a bar of negligible weight and they are sliding down due to their weight. If mass of $A$ and $B$ are 170 kg each and $\mu_A$ = 0.2 and $\mu_B$ = 0.4, where $\mu_A$ and $\mu_B$ are the coefficients of friction between blocks and plane, calculate the force in the bar. ($g$ = 10 m/s$^2$).




(a) 150 N (b) 75 N (c) 200 N (d) 250 N

Ans. a

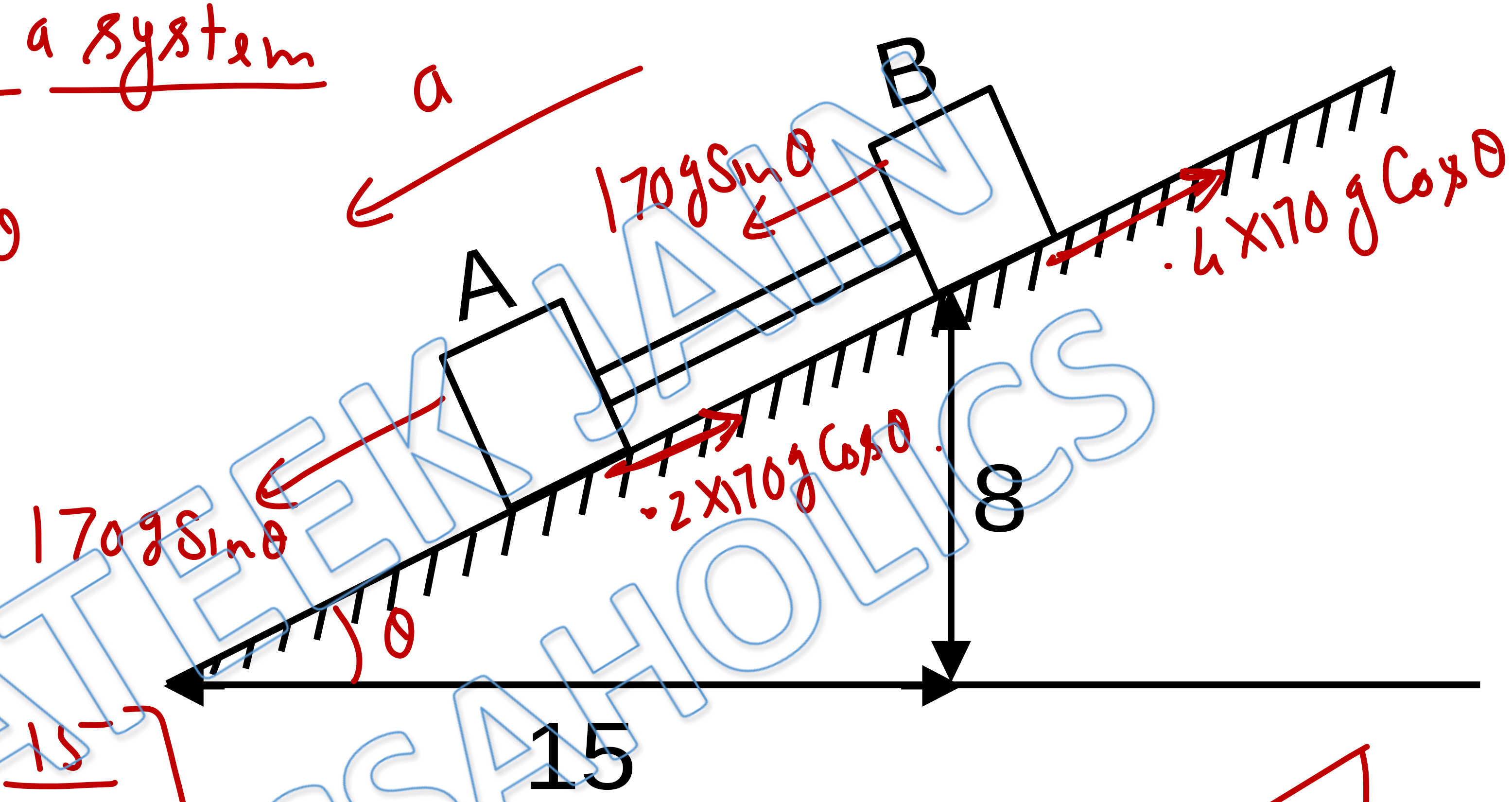
Solution: taking $(A+B)$ as a system

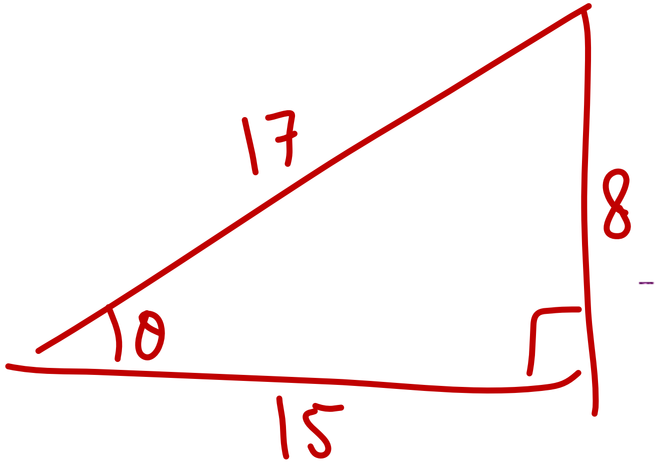
$$\Rightarrow 340 g\sin\theta - .6\times 170 g\cos\theta = 340\,a$$

$$\Rightarrow a = g\sin\theta - .3g\cos\theta$$

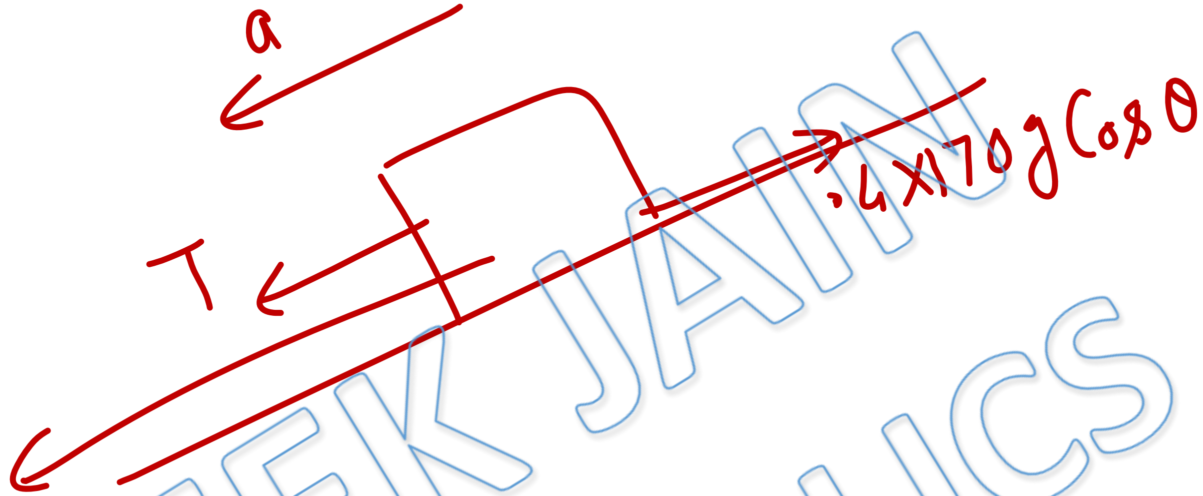
$$= g\left[\frac{8}{17} - .3\times\frac{15}{17}\right]$$

$$= \frac{3.5g}{17} = \frac{35}{17}\ m/sec^2$$



## F.B.D of B →

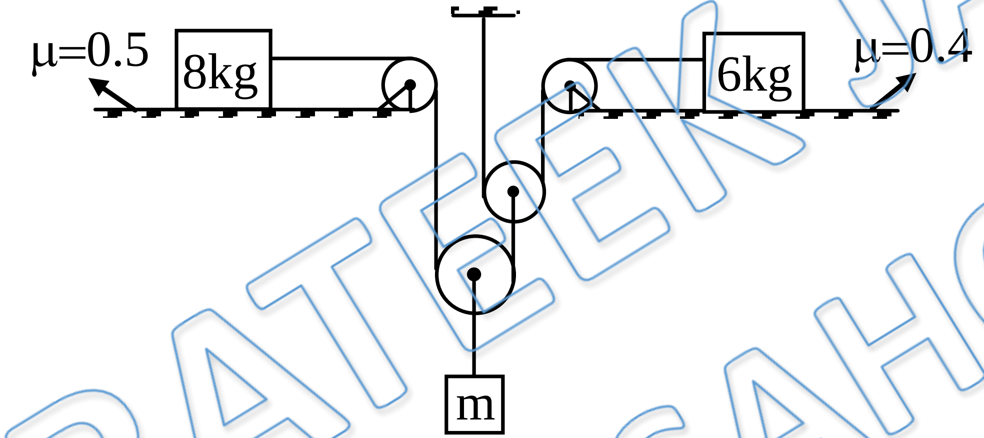



$$T + \frac{\cancelto{100}{1700} \times 8}{\cancel{17}} - \frac{\cancelto{40}{680} \times 15}{\cancel{17}} = \frac{\cancelto{10}{170} \times 35}{\cancel{17}}$$

$$T = 350 + 600 - 800 = 150\,N$$

Ans (a)

Q) 8kg and 6kg blocks are moving towards each other. Find m if it is moving down with acceleration 1 m/$Sec^2$ ?




(a) 98 Kg (b) 49 Kg (c) 12 Kg (d) 60 Kg

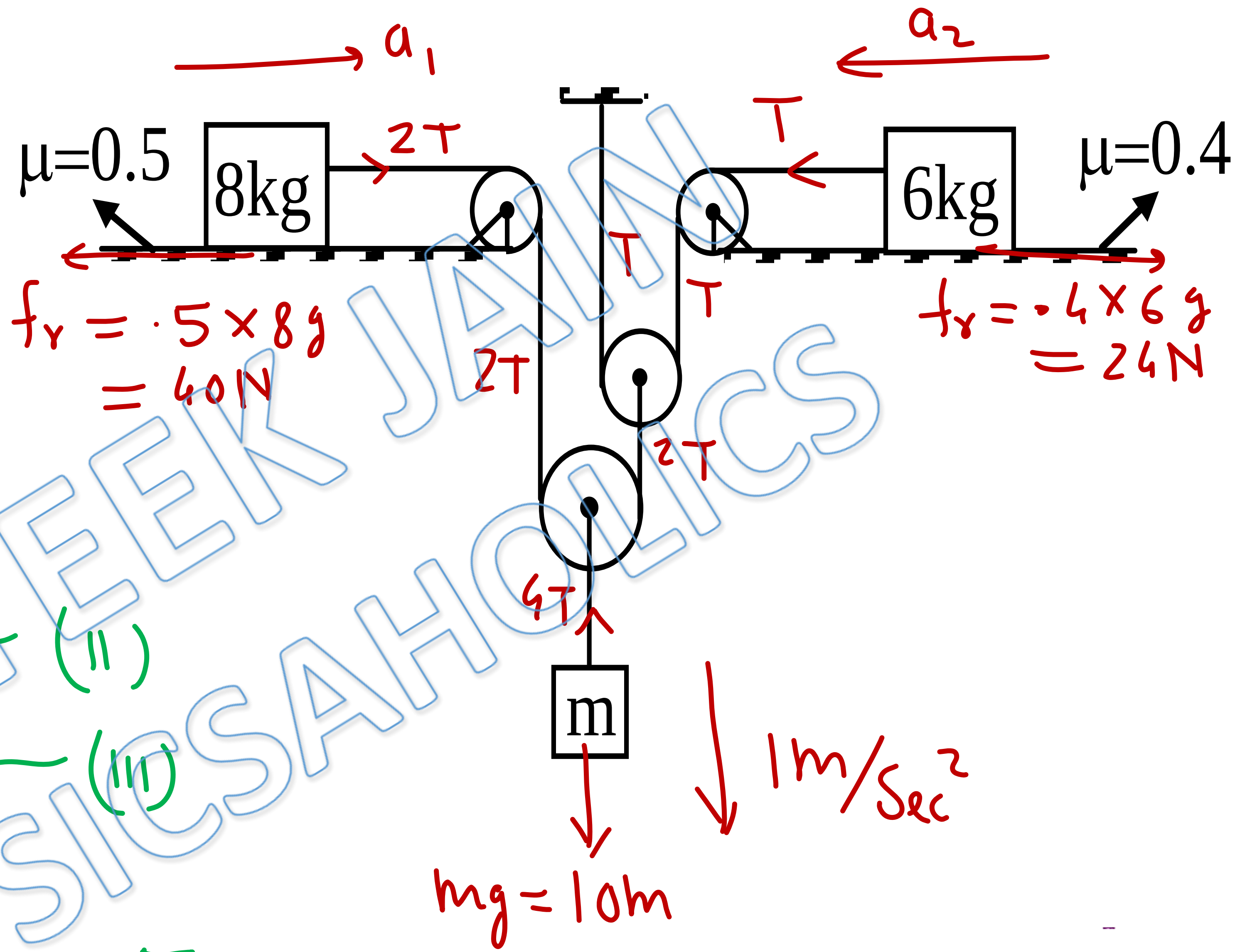
Ans. c

Solution:

by Using power method

$$2Ta_1 + Ta_2 - 4T\times 1 = 0$$

$$\Rightarrow \quad 2a_1 + a_2 = 4 \quad \text{---}(1)$$




$$T - 24 = 6a_2 \quad \text{---}(II)$$

$$2T - 40 = 8a_1 \quad \text{---}(III)$$

$$\Rightarrow \quad a_2 = \frac{T}{6} - 4$$

$$2a_1 = \frac{T}{2} - 10 \quad \Rightarrow \frac{T}{6} - 4 + \frac{T}{2} - 10 = 4$$

$$T\left(\frac{1+3}{6}\right) = 18 \Rightarrow T = \frac{6\times 18}{4} = 27\,N$$

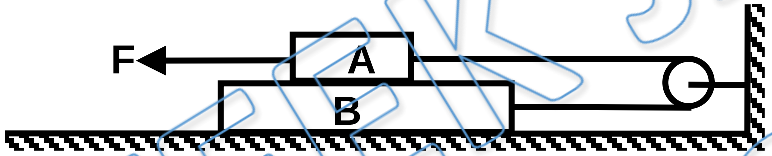
from F.B.D of m

$$10m - 4T = m\times 1$$

$$\Rightarrow \quad 9m = 4\times 27$$

$$m = 12\,Kg$$

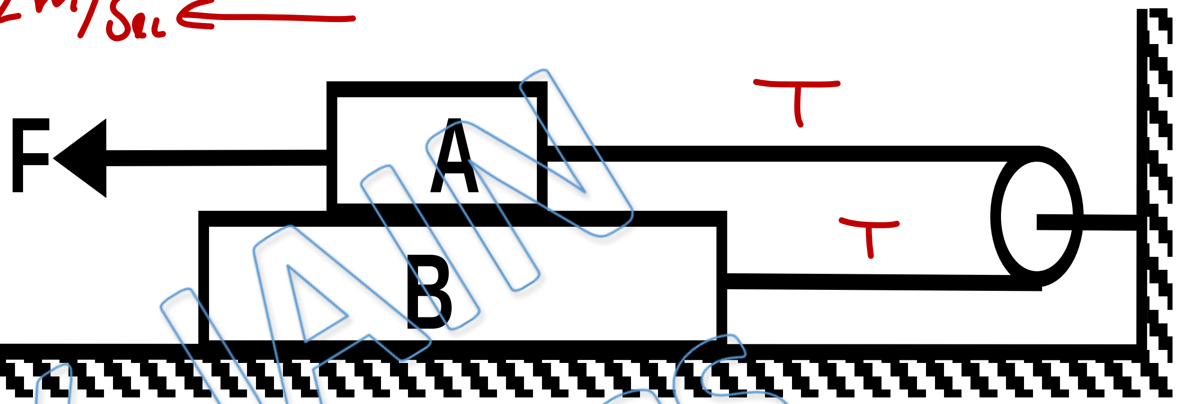
Q) In given figure mass of A is 10 kg and that of B is 20 kg. friction coefficient at all surfaces is 0.5. Find F if acceleration of A is 2 m/$Sec^2$ ?




(a) 150 N (b) 210 N (c) 260 N (d) 310 N

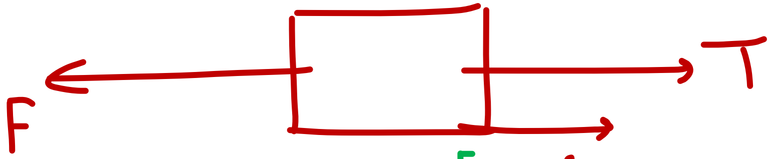
Ans. d

$2\,m/sec^2 \leftarrow$




## F.B.D of A

$2\,m/sec^2 \leftarrow$




$f_1 = \mu m g = .5 \times 10 g = 50\,N$

$F - T - 50 = 10 \times 2 \Rightarrow F - T = 70 \quad ---(1)$

## F.B.D. of B →


$f_2 = \mu (m_A + m_B) g$

$= .5 \times 30 g$

$= 150 N$

$2\,m/sec^2$

$\Rightarrow T - 200 = 20 \times 2 = 40 \quad ---(11)$

$F - 200 = 110$

$F = 310 N$

Ans(d)

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