

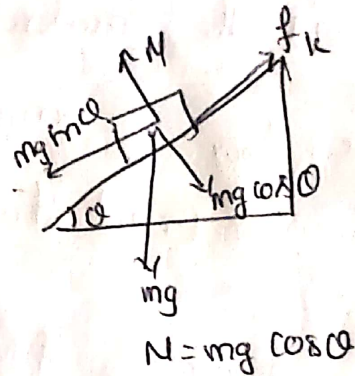
Task

①

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

Given $N = 3 F_{\text{down}} \rightarrow (1)$

$$F_{\text{down}} = mg(\sin\theta - \mu \cos\theta)$$



$$N = mg \cos\theta$$

$\therefore$ From (1) $mg \cos\theta = 3mg \left[\sin\theta - \frac{1}{3} \cos\theta \right]$

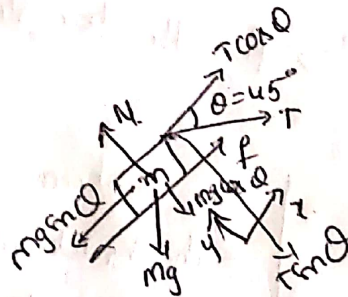
$$\Rightarrow \cos\theta = 3 \sin\theta - \frac{1}{3} \cos\theta$$

$$\Rightarrow \cos\theta + \frac{1}{3} \cos\theta = 3 \sin\theta$$

$$\Rightarrow \frac{4}{3} \cos\theta = 3 \sin\theta \Rightarrow \frac{\sin\theta}{\cos\theta} = \frac{4}{9}$$

$$\Rightarrow \tan\theta = \frac{4}{9} \Rightarrow \theta = \tan^{-1}\left(\frac{4}{9}\right)$$

②



$$mg = 150 \text{ N} ; T = 50 \text{ N}$$

in horizontal direction

$$\Sigma F_x = 0$$

$$\therefore mg \sin\theta = f + T \cos\theta \quad [f = \text{friction force}]$$

$$\Rightarrow f = \mu N = \mu$$

$$\Rightarrow mg \sin\theta - T \cos\theta = \mu N \rightarrow (1)$$

$$\Sigma F_y = 0$$

$$\Rightarrow mg \cos\theta + T \sin\theta = N \rightarrow (2)$$

From (1)

$$\frac{(1)}{(2)} = \mu = \frac{mg \sin\theta - T \cos\theta}{mg \cos\theta + T \sin\theta}$$

$$\Rightarrow \frac{150 \sin 45 - 50 \cos 45}{150 \cos 45 + 50 \sin 45} = \frac{\frac{150}{\sqrt{2}} - \frac{50}{\sqrt{2}}}{\frac{150}{\sqrt{2}} + \frac{50}{\sqrt{2}}} = \frac{100}{200} = 0.5$$

(2)

(3)

For the sand without slipping on the surface

$$\tan \theta > \mu$$

$$\tan \theta = \mu$$

$$\Rightarrow \tan \theta = \frac{h}{R}$$

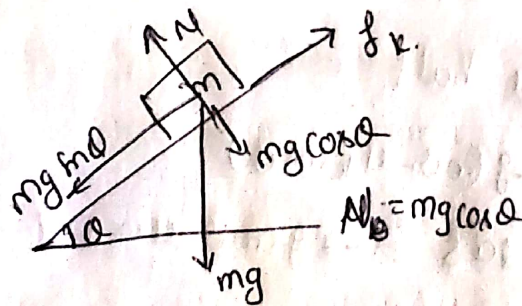
$$\therefore \frac{h}{R} = \mu \Rightarrow h = \mu R$$



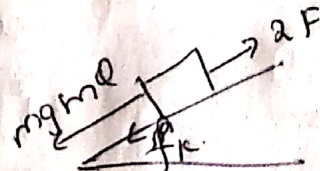
$$\text{Volume} = \frac{1}{3} \pi R^2 h$$

$$\Rightarrow \frac{1}{3} \pi R^2 (\mu R) = \frac{\mu}{3} \pi R^3$$

(4)



For upward motion
applied force $2F$



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

$$f_k = \mu_k N$$

$$= \mu_k mg \cos \theta$$

$$2F = mg \sin \theta + f_k$$

$$\Rightarrow 2 [mg \sin \theta - \mu mg \cos \theta] = mg \sin \theta + \mu_k mg \cos \theta$$

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

$$\Rightarrow \sin \theta = 3\mu \cos \theta \Rightarrow \frac{\sin \theta}{\cos \theta} = 3\mu$$

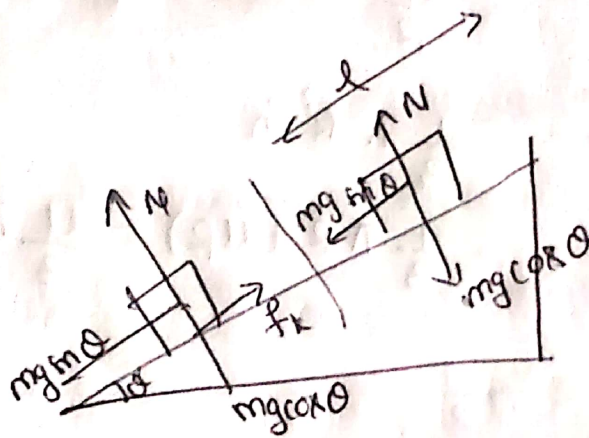
$$\Rightarrow \frac{1}{3} \tan \theta = \mu$$

5

$$V_1 = \sqrt{2gl(m\theta + \mu \cos\theta)} \quad ; \quad V_2 = \sqrt{2gl(m\theta - \mu \cos\theta)}$$

$$\frac{V_1}{V_2} = \frac{\sqrt{2gl(m\theta + \mu \cos\theta)}}{\sqrt{2gl(m\theta - \mu \cos\theta)}} = \sqrt{\frac{m\theta + \mu \cos\theta}{m\theta - \mu \cos\theta}}$$

6



For first half
 $a = g \sin\theta$

$$V^2 = 2as = 2g \sin\theta \cdot l \rightarrow (1)$$

For second half

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

$$V^2 = 2as = -2g(\sin\theta - \mu \cos\theta)l \rightarrow (2)$$

From (1) & (2)

$$2gl \sin\theta = -2gl(\sin\theta - \mu \cos\theta)$$

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

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

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

$$\Rightarrow \mu = 2 \frac{\sin\theta}{\cos\theta}$$

$$\Rightarrow \mu = 2 \tan\theta$$

⑦

$$F_{\text{up}} = 2 F_{\text{down}} \quad \theta = 60^\circ$$

$$\Rightarrow mg(\sin\theta + \mu \cos\theta) = 2 mg(\sin\theta - \mu \cos\theta)$$

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

$$\Rightarrow 3 \mu \cos\theta = \sin\theta$$

$$\Rightarrow \mu = \frac{1}{3} \tan\theta = \frac{1}{3} \tan 60^\circ = \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}}$$

⑧

when the body is just ready to slide

Angle of inclination = Angle of repose = 45°

$$\therefore \mu = \tan\theta = \tan 45^\circ = 1$$

⑨

$$m = 2 \text{ kg}$$

$$\mu = 0$$

$$\mu_s = 0.6, \theta = 30^\circ$$

frictional force

$$f_k = \mu_k mg \cos\theta$$

$$= 0.6 \times 2 \times 9.8 \times \cos 30^\circ$$

$$= 0.6 \times 19.6 \times \frac{\sqrt{3}}{2}$$

$$= 0.3 \times 19.6 \times 1.732$$

$$= 10.18 \text{ N}$$

⑩

$$t_{\text{rough}} = 1 \frac{1}{3} t_{\text{smooth}}$$

$$\Rightarrow \sqrt{\frac{2s}{g(\sin\theta - \mu \cos\theta)}} = \frac{4}{3} \sqrt{\frac{2s}{g \sin\theta}}$$

$$\Rightarrow \frac{1}{\sqrt{\sin\theta - \mu \cos\theta}} = \frac{4}{3} \sqrt{\sin\theta}$$

S.O.B.S

$$\Rightarrow \frac{1}{\sin\theta - \mu \cos\theta} = \frac{16}{9 \sin\theta}$$

$$\Rightarrow 9 \sin\theta = 16 \sin\theta - 16 \mu \cos\theta$$

By putting $\theta = 45^\circ$ and

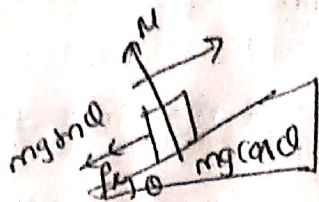
solve we get $\mu = \frac{7}{16} \tan\theta$

$$\Rightarrow \mu = \frac{7}{16}$$



(11)

Because the force of friction always opposes the motion of a body



For upward motion
 $mg \sin \theta$ & f_k are in same direction

$$\therefore F_{\text{net}} = mg \sin \theta + f_k$$

For downward motion $mg \sin \theta$ & f_k are in opposite directions

$$F_{\text{net}} = mg \sin \theta - f_k$$

$\therefore$ we clearly see require more force in rough surface

(14)

$$\mu_s = \frac{3}{4} ; \mu_k = \frac{3}{5} ; \theta = \tan^{-1}\left(\frac{3}{5}\right) \Rightarrow \sin \theta = \frac{3}{5}$$

$$mg = 10 \text{ N}$$

$$\theta = 37^\circ$$

$$\Rightarrow \cos \theta = \frac{4}{5}$$

$$f_s = \mu_s mg \cos \theta \quad f_k = \mu_k mg \cos \theta$$

$$= \frac{3}{4} \times 10 \times \frac{4}{5}$$

$$= \frac{3}{5} \times 10 \times \frac{4}{5}$$

$$= 7.5 \text{ N} \times \frac{4}{5}$$

$$= \frac{24}{5} = 4.8 \text{ N}$$

$\approx 6 \text{ N} \rightarrow$ limiting friction

$$\tan \alpha = \mu_s \Rightarrow \tan \alpha = \frac{3}{4} \Rightarrow \alpha = 37^\circ$$

$\theta = \alpha$ so the body is ready to slide down

For motion

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

$$= 10 \left[\frac{3}{5} - \frac{3}{5} \times \frac{4}{5} \right] = 10 \left[\frac{15-12}{25} \right]$$

$$= \frac{10}{25} \times 3 = 0.12 \text{ m/s}^2$$

(4)

(15)

$$\theta = 45^\circ$$

$$V \uparrow = 10 \text{ m/s}$$

$$t_{\uparrow} = \sqrt{\frac{2l}{g \sin \theta}}$$

$$a = g (\sin \theta)$$

$$= 10 \sin 45^\circ$$

$$= \frac{10}{\sqrt{2}} \text{ m/s}^2$$

$$\Rightarrow \sqrt{2gl \sin \theta} = 10$$

$$\Rightarrow \frac{10}{\sqrt{g \sin \theta}} = \sqrt{2l}$$

$$\Rightarrow \sqrt{2l} \sqrt{g \sin \theta} = 10$$

$$\Rightarrow \sqrt{2l} = \frac{10}{\sqrt{g \sin \theta}}$$

$$\Rightarrow t_{\uparrow} = \frac{10}{g \sin \theta}$$

$$\Rightarrow t_{\uparrow} = \frac{1}{\sin 45^\circ} = \sqrt{2} \text{ sec}$$

(16)

$$\theta = 45^\circ$$

$$l_d = 2$$

For rough

$$t_d = \sqrt{\frac{2l}{g (\sin \theta - \mu \cos \theta)}}$$

$$\mu = 0.5$$

For smooth

$$t_d = \sqrt{\frac{2l}{g \sin \theta}}$$

$$\Rightarrow t_d = \sqrt{\frac{2l}{g}} \times \frac{1}{\sqrt{\sin \theta - \mu \cos \theta}}$$

$$\Rightarrow 2 = \sqrt{\frac{2l}{g}} \times \frac{1}{\sqrt{\sin \theta}}$$

$$\Rightarrow t_d = 2 \sqrt{\sin \theta} \times \frac{1}{\sqrt{\sin \theta - \mu \cos \theta}}$$

$$\Rightarrow 2 \sqrt{\sin \theta} = \sqrt{\frac{2l}{g}}$$

$$= 2 \sqrt{\sin 45^\circ} \times \frac{1}{\sqrt{\sin 45^\circ - 0.5 \cos 45^\circ}}$$

$$= 2 \sqrt{\frac{1}{\sqrt{2}}} \times \frac{1}{\sqrt{\frac{1}{\sqrt{2}} - \frac{0.5}{\sqrt{2}}}}$$

$$= 2 \frac{1}{\sqrt{2}} \times \frac{1}{\frac{1-0.5}{\sqrt{2}}} = 2 \times \frac{1}{\sqrt{0.5}}$$

$$= 2\sqrt{2} \text{ sec}$$

$$= 2 \times 1.414$$

$$= 2.828 \text{ sec}$$

(17)

$$m = 0.5 \text{ kg}$$

$$\theta = 30^\circ ; \mu = 0.2$$

For the body to move with uniform velocity : acceleration = 0

$$\therefore mg \sin \theta - \mu N + F = ma$$

$$\Rightarrow 0.5 \times 10 \times \sin 30 - \mu mg \cos 30 + F = 0$$

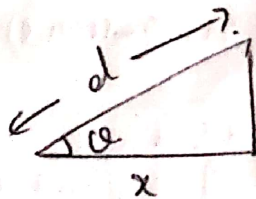
$$\Rightarrow 5 \times \frac{1}{2} - 0.2 \times 0.5 \times 10 \times \frac{\sqrt{3}}{2} + F = 0$$

$$\Rightarrow 2.5 - 0.1 \times 5 \times 1.732 + F = 0$$

$$\Rightarrow F = -1.633 \text{ N}$$

Force is 1.6 N (upward) parallel to inclined plane

(18)



$$\cos \theta = \frac{x}{d} \Rightarrow d = \frac{x}{\cos \theta}$$

d is distance travelled by the body in t s

$$\therefore \text{From } S = ut + \frac{1}{2} at^2 \quad a = g \sin \theta ; u = 0$$

$$\Rightarrow d = 0 \times t + \frac{1}{2} g \sin \theta t^2$$

$$\Rightarrow d = \frac{g \sin \theta}{2} t^2 \Rightarrow t = \sqrt{\frac{2d}{g \sin \theta}}$$

For min time

$$\therefore \frac{dt}{d\theta} = 0 \Rightarrow \frac{d}{d\theta} \left[\sqrt{\frac{2d}{g \sin \theta}} \right] = 0$$

$$\Rightarrow \sqrt{\frac{2d}{g}} \frac{d}{d\theta} \frac{1}{\sqrt{\sin \theta}} = 0$$

$$\Rightarrow \sqrt{\frac{2d}{g}} \left[-\frac{1}{2} (\sin \theta)^{-\frac{3}{2}} \cos \theta \right] = 0 \Rightarrow \theta = 45^\circ$$

$$\therefore a = g \sin \theta$$

$$= g \sin 45^\circ$$

$$= \frac{g}{\sqrt{2}}$$

$$\Rightarrow \cos \theta (\sin \theta)^{-\frac{3}{2}} = 0$$

$$\Rightarrow \frac{\cos \theta}{\sin \theta} \times \sin \theta^{-\frac{3}{2}} = 0$$

$$\Rightarrow \cot \theta \times \frac{1}{\sqrt{\sin \theta}} = 0 \Rightarrow \cot \theta = 0$$

(20)

For a body sliding down $a = g \sin \theta$

(a) $\theta = 30^\circ$ $\therefore a = g \sin 30 = \frac{g}{2}$

(b) $\theta = 45^\circ$ $a = g \sin 45 = \frac{g}{\sqrt{2}} = \frac{g}{1.414}$

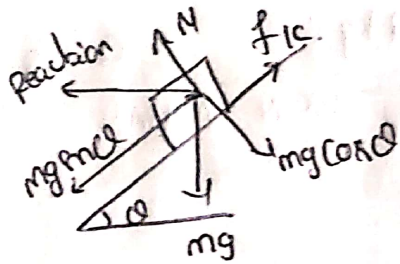
(c) $\theta = 60^\circ$ $a = g \sin 60 = g \times \frac{\sqrt{3}}{2} = \frac{1.732}{2} g$

(d) $\theta = 90^\circ$ $a = g \sin 90 = g$

L Tasse

(UQ)

(1)



As block is stationary on inclined plane force = $mg \sin \theta$ and Normal reaction on block $= mg \cos \theta$

$\therefore$ Net Reaction on the block by plane

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

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

(2)

The velocity obtained will be same since heights are same

$$v = \sqrt{2gh}$$

But acceleration for vertical fall is g , and for the sliding wooden block it will be $g \sin 30^\circ = 0.5g$

$$\therefore \underline{v_1 = v_2} \quad t = \sqrt{\frac{2h}{g \sin \theta}} \quad t \propto \frac{1}{\sqrt{g \sin \theta}} \quad \therefore \frac{t_1}{t_2} = \frac{g}{0.5g}$$

$$\Rightarrow \underline{t_1 = 2t_2}$$

④

From

$$u^2 - u^2 = 2as \quad ; \quad a = g(\sin\theta + \mu \cos\theta)$$

$$10 - u^2 = -2g(\sin\theta + \mu \cos\theta)l \quad ; \quad \mu = \tan\theta$$

$$\Rightarrow u^2 = 2gl(\sin\theta + \tan\theta \cos\theta)$$

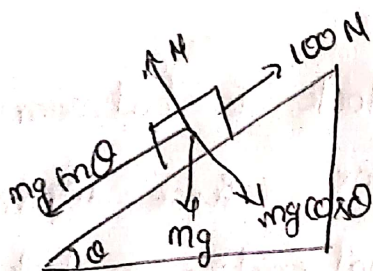
$$\Rightarrow u^2 = 2gl\left[\sin\theta + \frac{\sin\theta}{\cos\theta} \cos\theta\right]$$

$$\Rightarrow u^2 = 4gl \sin\theta$$

From this equation it is clear that the body stays at rest and not will slide down

SAG'N

①



$$m = 2 \text{ kg}$$

$$a = 2 \text{ m/s}^2$$

$$F_{\text{parallel}} = 100 \text{ N} = mg \sin\theta$$

Given, velocity is moving with uniform velocity
so block is in equilibrium $\Rightarrow mg \sin\theta = 100 \text{ N}$

let Force F is applied to the block parallel to the inclined plane to move the block with $a = 2 \text{ m/s}^2$

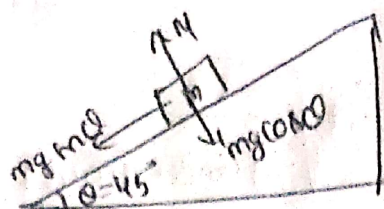
$$\Rightarrow F - mg \sin\theta = ma$$

$$\Rightarrow F = mg \sin\theta + ma$$

$$= 100 + 2 \times 2$$

$$= 104 \text{ N}$$

②



we consider the case with no friction.

In this case

$$a_s = g \sin \theta = g \sin 45^\circ = \frac{g}{\sqrt{2}}$$

From $v = \sqrt{2 a_s l}$ Here l is length of inclination

$$v = \sqrt{2 \frac{g}{\sqrt{2}} l} \quad ; \text{ we are given that } v_{\text{rough}} = \frac{1}{2} v_{\text{smooth}}$$

$$v_{\text{rough}} = \frac{1}{2} \sqrt{2 a_{\text{smooth}} l}$$

$$\Rightarrow \sqrt{2 a_{\text{rough}} l} = \frac{1}{2} \sqrt{2 a_{\text{smooth}} l} \quad \text{s.o.b.s}$$

$$\Rightarrow 2 a_{\text{rough}} = \left(\frac{1}{4}\right) a_{\text{smooth}}$$

$$\Rightarrow a_{\text{rough}} = \frac{1}{4} a_{\text{smooth}} \quad ; \quad f = \mu N = \mu mg \cos \theta$$

$$f = \mu mg \cos 45^\circ = \frac{\mu mg}{\sqrt{2}}$$

Now consider the case of the rough inclined plane.

Net force is given by $mg \sin \theta - f = m a_{\text{rough}}$

$$\Rightarrow mg \sin 45^\circ - f = m a_{\text{rough}}$$

$$\Rightarrow \frac{mg}{\sqrt{2}} - f = m \times \frac{a_{\text{smooth}}}{4}$$

$$\Rightarrow \frac{mg}{\sqrt{2}} - \frac{\mu mg}{\sqrt{2}} = \frac{m}{4} \frac{g}{\sqrt{2}}$$

$$\Rightarrow \frac{1}{\sqrt{2}} - \frac{\mu}{\sqrt{2}} = \frac{1}{4\sqrt{2}}$$

$$\Rightarrow 1 - \mu = \frac{1}{4}$$

$$\Rightarrow \mu = 1 - \frac{1}{4}$$

$$\Rightarrow \mu = \frac{3}{4}$$

③

$$\theta = 45^\circ$$

$$t_d = 2t_a$$

$$\Rightarrow \sqrt{\frac{2l}{g(\sin\theta - \mu \cos\theta)}} = 2 \sqrt{\frac{2l}{g(\sin\theta + \mu \cos\theta)}}$$

squaring on both sides we get

$$\Rightarrow \left(\sqrt{\frac{2l}{g(\sin\theta - \mu \cos\theta)}} \right)^2 = 2^2 \left(\sqrt{\frac{2l}{g(\sin\theta + \mu \cos\theta)}} \right)^2$$

$$\Rightarrow \frac{2l}{g(\sin\theta - \mu \cos\theta)} = 4 \frac{2l}{g(\sin\theta + \mu \cos\theta)}$$

$$\Rightarrow \sin\theta + \mu \cos\theta = 4(\sin\theta - \mu \cos\theta)$$

$$\Rightarrow \sin\theta + \mu \cos\theta = 4\sin\theta - 4\mu \cos\theta$$

$$\Rightarrow 5\mu \cos\theta = 3\sin\theta$$

$$\Rightarrow \mu = \frac{3}{5} \frac{\sin\theta}{\cos\theta} = 0.6 \tan\theta = 0.6 \times \tan 45^\circ$$

$$\Rightarrow \mu = 0.6$$

④

$$l = 5m ; \theta = 30^\circ$$

$$t = \sqrt{\frac{2l}{g \sin\theta}}$$

$$= \sqrt{\frac{2 \times 5}{10 \sin 30^\circ}}$$

$$= \sqrt{\frac{10}{10 \times \frac{1}{2}}}$$

$$= \sqrt{2} \text{ sec}$$

⑤

$$\theta = 30^\circ \quad u = 10 \text{ m/s} \quad v = 0$$

$$\text{From } v^2 - u^2 = 2as$$

$$\Rightarrow 0 - 10^2 = 2(-g \sin\theta) s$$

$$\Rightarrow -100 = -2 \times 10 \times \sin 30^\circ s$$

$$\Rightarrow 100 = 2 \times 10 \times \frac{1}{2} \times s$$

$$\Rightarrow s = 10m$$

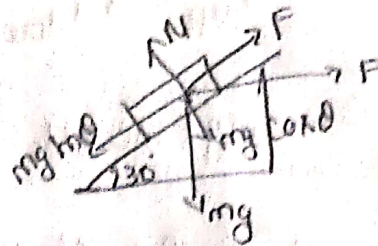
6

$$m = 30 \text{ kg}$$

$$v = 5 \text{ m/s}$$

$$\theta = 30^\circ$$

$$f_k = 150 \text{ N}$$



Given a 30 kg box has to move up an inclined slope of 30° to the horizontal at a uniform velocity of 5 m/s. If the frictional force retarding the motion is 150 N.

To find the horizontal force required to move up

From fig Force of friction = 150 N.

$$\text{Net horizontal force } F - f = mg \sin \theta$$

$$\Rightarrow F = mg \sin \theta + f$$

$$\Rightarrow F = 30 \times 10 \times \sin 30^\circ + 150$$

$$= 30 \times 10 \times \frac{1}{2} + 150 = 300 + 150 = 450 \text{ N}$$

$\therefore$ To pull the body up the plane

Horizontal force is $F \cos \theta = 450$

$$F \cos 60^\circ = 450$$

$$\Rightarrow F \cos 60^\circ = 450$$

$$\Rightarrow F \cdot \frac{1}{2} = 450$$

$$\Rightarrow F = 900 \text{ N}$$

$$\Rightarrow F \cos 60^\circ = 300$$

$$\Rightarrow F \cdot \frac{1}{2} = 300 \Rightarrow F = 600 \text{ N}$$

7

$$m = 1 \text{ metric ton} = 10^3 \text{ kg}$$

$$\sin \theta = \frac{1}{2} \therefore v = 96 \text{ kmph} = 10 \text{ m/s}$$

$$\mu = \frac{1}{\sqrt{3}} \therefore \cos \theta = \sqrt{1 - \sin^2 \theta} = \sqrt{1 - \frac{1}{4}} = \frac{\sqrt{3}}{2}$$

As is known force required

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

$$= mg [\sin \theta + \mu \cos \theta]$$

$$\Rightarrow F = 10^3 \times 9.8 \left[\frac{1}{2} + \frac{1}{\sqrt{3}} \cdot \frac{\sqrt{3}}{2} \right]$$

$$\Rightarrow F = 98 \times 10^2 \text{ N}$$

$$\text{Power} = F \times v$$

$$= 98 \times 10^2 \times 10$$

$$= 98 \times 10^3 \text{ W}$$

$$= 98 \text{ kW}$$

(8)

$$F_{up} = 3 F_{down} \quad ; \quad \mu = \frac{1}{2\sqrt{3}}$$

$$\Rightarrow mg [\sin \theta + \mu_k \cos \theta] = 3 mg [\sin \theta - \mu_k \cos \theta]$$

$$\Rightarrow \sin \theta + \mu_k \cos \theta = 3 \sin \theta - 3 \mu_k \cos \theta$$

$$\Rightarrow 4 \mu_k \cos \theta = 2 \sin \theta$$

$$\Rightarrow 2 \times \frac{1}{2\sqrt{3}} = 2 \frac{\sin \theta}{\cos \theta} \quad \Rightarrow \tan \theta = \frac{1}{\sqrt{3}}$$

$$\Rightarrow \theta = 30^\circ$$

(9)

$$m = 10 \text{ kg} \quad ; \quad \theta = 30^\circ \quad ; \quad \mu = 0.5$$

Force required to pull the body up

$$F = mg [\sin \theta + \mu \cos \theta]$$

$$= 10 \times 9.8 [\sin 30^\circ + 0.5 \cos 30^\circ]$$

$$\Rightarrow 98 \left[\frac{1}{2} + \frac{0.5 \times \sqrt{3}}{2} \right]$$

$$= 49 [1 + 0.5 \times 1.732]$$

$$\Rightarrow 49 \times 1.866 = 91.4 \text{ N}$$

(10)

$$m = 0.5 \text{ kg} \quad ; \quad \theta = 30^\circ \quad ; \quad \mu = 0.2$$

Force required to slide down $F = mg [\sin \theta - \mu \cos \theta]$

$$F = 0.5 \times 9.8 [\sin 30^\circ - 0.2 \cos 30^\circ]$$

$$= 4.9 \left[\frac{1}{2} - 0.2 \times \frac{\sqrt{3}}{2} \right]$$

$$= 4.9 [0.5 - 0.1732]$$

$$= 4.9 \times 0.3268$$

$$= 1.6 \text{ N}$$



(11)

$$t_{\text{down}} = \sqrt{\frac{2l}{g(m\theta + \mu \cos\theta)}} \quad ; \quad t_{\text{up}} = \sqrt{\frac{2l}{g(m\theta - \mu \cos\theta)}}$$

(15)

$$\mu = 0.5$$

$$N = 2 F_{\text{down}}$$

$$\Rightarrow 2 \cos\theta = 2 m\theta$$

$$\Rightarrow mg \cos\theta = 2 mg (m\theta - \mu \cos\theta)$$

$$\Rightarrow \cos\theta = m\theta$$

$$\Rightarrow \cos\theta = 2m\theta - 2\mu \cos\theta$$

$$\Rightarrow \theta = 45^\circ$$

$$\Rightarrow \cos\theta = 2m\theta - 2(0.5)\cos\theta$$

$$\Rightarrow \cos\theta = 2m\theta - \cos\theta$$

(16)

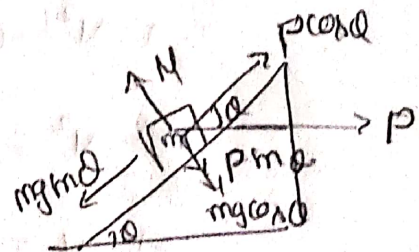
The force required to a body up an inclined plane is

$$F = mg \sin\theta + \text{frictional force}$$

$$= 30 \times 10 \times \sin 30 + 150$$

$$= 30 \times 10 \times \frac{1}{2} + 150$$

$$= 300 \text{ N}$$



$$\text{friction} = 150 \text{ N}$$

$$m = 30 \text{ kg}$$

$$\theta = 30^\circ$$

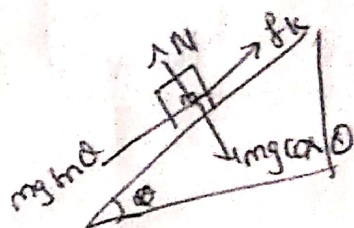
If $P \Rightarrow$ horizontal force

$$F = P \cos\theta$$

$$\Rightarrow 300 = P \cos 30$$

$$\Rightarrow 300 = P \frac{\sqrt{3}}{2} \Rightarrow P = \frac{2}{\sqrt{3}} \times 300 = 346 \text{ N}$$

(13)



when body is moving down
frictional force acts in upward
direction $f_k = \mu_k N$

$$\therefore \text{Net force} = mg \sin \theta - f_k \quad [N = mg \cos \theta]$$

$$\Rightarrow ma = mg \sin \theta - \mu_k mg \cos \theta$$

$$\Rightarrow f_k = \mu_k mg \cos \theta$$

$$\Rightarrow ma = mg [\sin \theta - \mu_k \cos \theta]$$

$$\Rightarrow a = g [\sin \theta - \mu_k \cos \theta]$$

$$\begin{aligned} \text{work done by friction } W &= f_r \times s \\ &= \mu_k mg \cos \theta \cdot l \end{aligned}$$

$$\text{From } v^2 - u^2 = 2as \quad s = l$$

$$\Rightarrow v^2 - 0^2 = 2g (\sin \theta - \mu_k \cos \theta) \cdot l$$

$$\Rightarrow v^2 = 2gl (\sin \theta - \mu_k \cos \theta)$$

$$\Rightarrow v = \sqrt{2gl (\sin \theta - \mu_k \cos \theta)}$$

(14)

if angle of inclination = angle of repose

$$\mu = \tan \theta$$

$$\Rightarrow a = 2g \sin \theta \quad [-ve \text{ shows retardation}]$$

$$a = -g [\sin \theta + \mu \cos \theta]$$

$$\text{Time of ascent} = \sqrt{\frac{2l}{a}} = \sqrt{\frac{2l}{2g \sin \theta}}$$

$$a = -g [\sin \theta + \tan \theta \cos \theta]$$

$$= \sqrt{\frac{1}{g \sin \theta}}$$

$$a = -g [\sin \theta + \frac{\sin \theta}{\cos \theta} \cos \theta]$$

C, a are correct