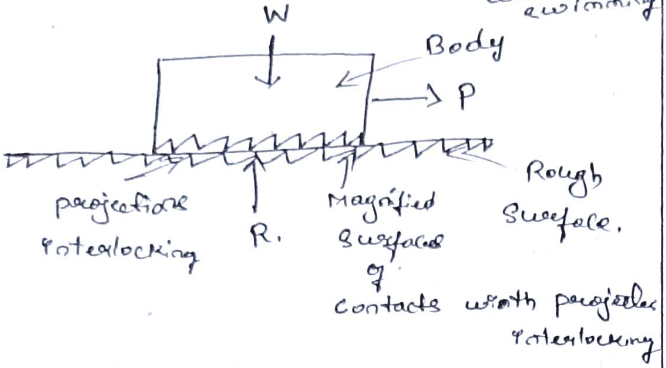
Module: 02

Friction:

eg: sliding book
Driving a car
walking
swimming



(increase)
with ↑ in the projections, more the surface is rough, then more is the resistance.

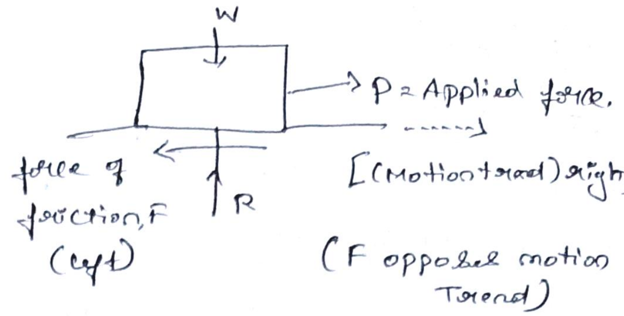
⇒ Definition of friction:

* Friction is the resistance force that opposes the relative motion or tendency of such motion of two surface in contact.

(or)

* when one body tends to move in contact over other body a resistance to its movement is set-up. This resistance to movement is called Friction (or) Force of friction (or) frictional force.

The force of friction always acts in the direction opposite to the 'motion trend' as shown in figure.



⇒ Frictional forces:

① Static Friction: The friction acting on a body which is at rest is called static friction.

② Kinetic (Dynamic friction):
The friction acting on a body which is actually in motion is called Dynamic / Kinetic friction.

③ Rolling friction:
The friction acting on a body due to rolling of one surface over another is called Rolling friction.

④ Dry friction:
when the contact surfaces are dry

⑤ fluid friction:
when the contact surfaces are Lubricated.

⇒ Limiting Frictional Force :

The maximum static friction that can act b/w two surfaces before motion starts.

$$\boxed{F_{limiting} = \mu_s N} \quad N \text{ or } R$$

where,

μ_s = co-eff of static friction,
R or N = normal reaction force.

⇒ Co-efficient of Friction (μ):

It is the ratio of the limiting friction to the normal reaction force.

$$\boxed{\mu = \frac{F}{N}} \quad \text{or} \quad \boxed{\mu = \frac{F}{R}}$$

⇒ Angle of Friction (θ):

The angle b/w the resultant of the normal force & the limiting frictional force & the normal force itself.

$$\boxed{\tan \theta = \mu}$$

⇒ Angle of Repose (ϕ):

The maximum angle of an inclined plane at which a body placed on it just begins to slide

$$\boxed{\tan \phi = \mu}$$

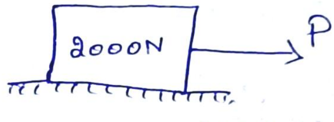
Note : Angle of repose = angle of friction

⇒ Laws of Friction :

1. Frictional force is directly proportional to the normal force.
2. Friction is independent of the contact area.
3. Static friction > kinetic friction.
4. Friction depends on the nature of the surfaces in contact.
5. Kinetic friction remains constant during motion.

⇒ problems on friction:

① A body of weight 2000N rest on a Hzl plane. if the co-efficient of friction is 0.4, find the Hzl force 'P' required to move the body.



Solu^n:

Note: Types of friction problems

① Simple friction.
(Sphere friction, block friction, Hzl bar friction)

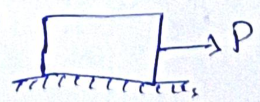
② Ladder friction

③ Wedge —"—

④ Belt friction

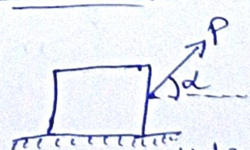
problems types in Hzl plane:

①



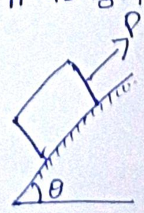
(force P is pulling ||^{le} to Hzl plane)

②



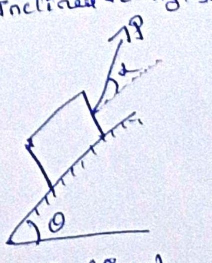
(Inclined to Hzl surface)

③



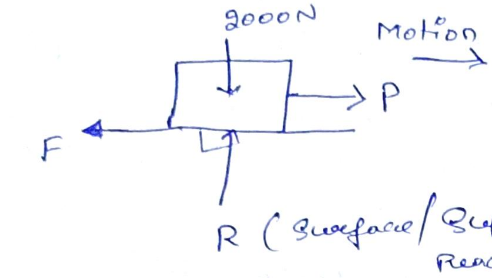
(Force P is inclined to surface parallel)

④



(Inclined surface to inclined)

⇒ FBD of block:



always frictional force is opposite to motion.

frictional force.

Normal reaction

$\boxed{F = \mu R}$ (or) $\boxed{F = \mu N}$

$\overset{+}{\uparrow} \Sigma f_y = 0$

$R - 2000 = 0$

$\boxed{R = 2000N}$

Now, frictional force,

$F = \mu R$

$= 0.4 \times 2000$

$\boxed{F = 800N}$

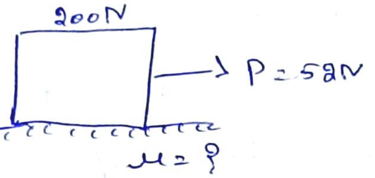
$\overset{+}{\rightarrow} \Sigma f_x = 0$

$P - F = 0$

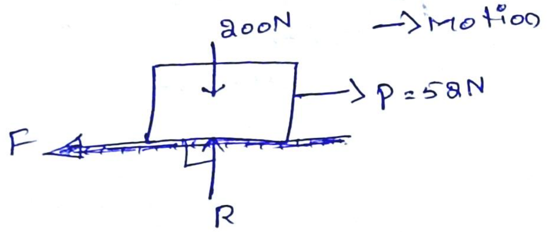
$P - 800 = 0$

$\boxed{P = 800N}$

2) A block of weight 200N is just on the point of moving Hzl by a force of 52N. What is the co-eff of friction.



Solu^n: FBD of block:



$\overset{+}{\rightarrow} \Sigma f_x = 0$

$52 - F = 0 \quad \boxed{F = 52N}$

$+\uparrow \Sigma f_y = 0.$

$R - 200 = 0 \quad \boxed{R = 200N}$

Now, frictional force,

$F = \mu R$

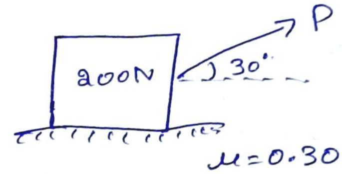
$\mu = \frac{F}{R} = \frac{52}{200}$

$\boxed{\mu = 0.26}$

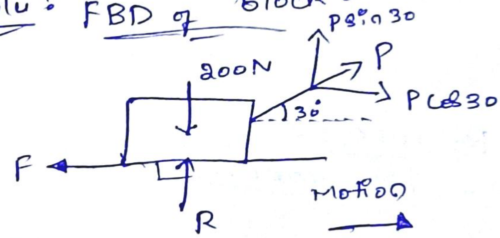
{ μ always 0 - 1

3) A block of weight 200N rest on a rough Hzl surface. Find the magnitude of the force to be applied at an angle of 30 degree to the Hzl in order to move the block on the surface.

Assume $\mu = 0.30$.



Solu^n: FBD of block:



$\overset{+}{\rightarrow} \Sigma f_x = 0$

$P \cos 30 - F = 0$

$P \cos 30 - \mu R = 0 \quad (F = \mu R)$

$\boxed{P \cos 30 - 0.3R = 0} \rightarrow (A)$

$+\uparrow \Sigma f_y = 0$

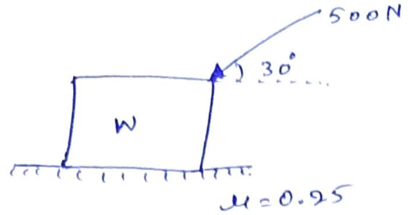
$P \sin 30 + R - 200 = 0$

$\boxed{P \sin 30 + R = 200} \rightarrow (B)$

Equating from, Eq^n (A) & (B)

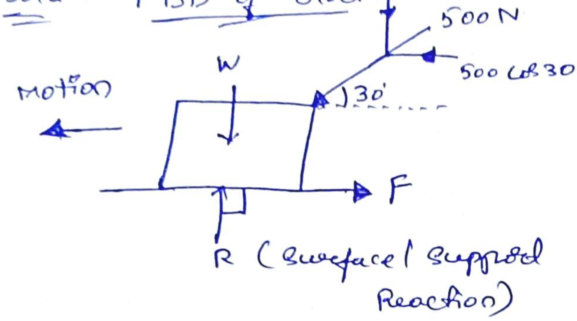
$$\boxed{\begin{array}{c} P = 59.053N \\ \hline R = 170.473N \end{array}}$$

(4)



Find the value of weight 'W' if the body is in limiting equilibrium condition.

Solu^n: FBD of block



$\overset{+}{\rightarrow} \Sigma fx = 0$

$F - 500 \cos 30 = 0$

$\boxed{F = 433.012 N}$

∴ frictional force,

$F = \mu R$

$R = \frac{F}{\mu} = \frac{433.012}{0.25}$

$\boxed{R = 1732.048 N}$

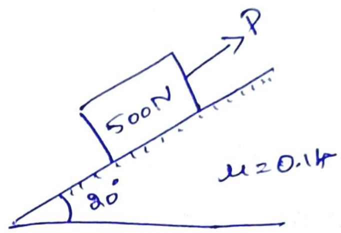
$\overset{+}{\uparrow} \Sigma fy = 0$

$1732.048 - W - 500 \sin 30 = 0$

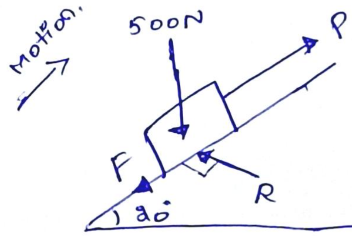
$1732.048 - W - 250 = 0$

$\therefore \boxed{W = 1482.048 N}$

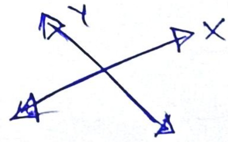
(5) A block of weight 500N is resting on the inclined plane making an angle of 20 degree to the H.zl. Calculate the value of force 'P' applied parallel to the plane to just move the block up the plane if the co-eff of friction is 0.14.



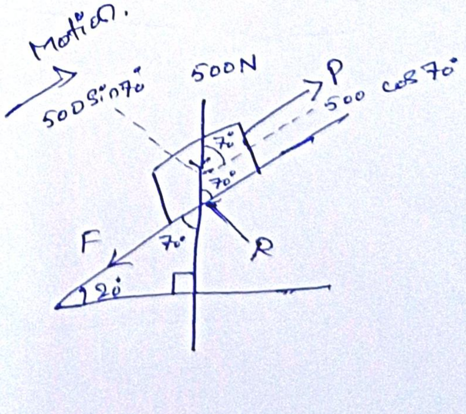
Solu^n: FBD of block:



Note:



Difficult for 3 Inclined force.



$\xrightarrow{+} \Sigma f_x = 0$

$-F + 40\cos 25^\circ = 0$

$\boxed{F = 36.252\ N}$

frictional force,

$F = \mu R$

$R = \dfrac{F}{\mu} = \dfrac{36.252}{0.3}$

$\boxed{R = 120.84N}$

$\uparrow^{+} \Sigma f_y = 0$

$R + 40\sin 25 - W = 0$

$120.84 + 40\sin 25 - W = 0$

$\boxed{W = 137.744N}$

$\uparrow^{+} \Sigma f_y = 0$

$R - 500\sin 70 = 0$

$\boxed{R = 469.846\ N}$

frictional force,

$F = \mu R$

$F = 0.14 \times 469.846$

$\boxed{F = 65.778\ N}$

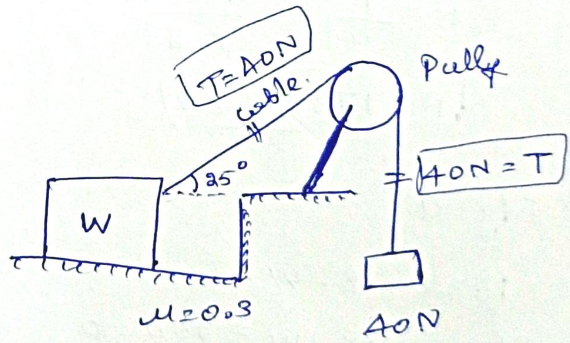
$\xrightarrow{+} \Sigma f_x = 0$

$P - F - 500\cos 70 = 0$

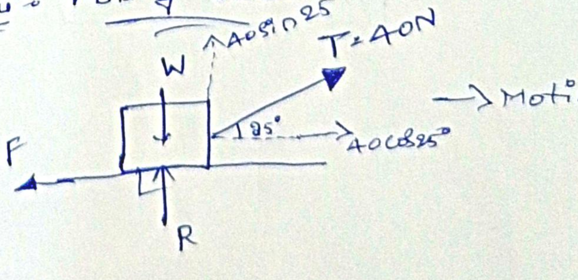
$P - 65.778 - 500\cos 70 = 0$

$\boxed{P = 236.788N}$

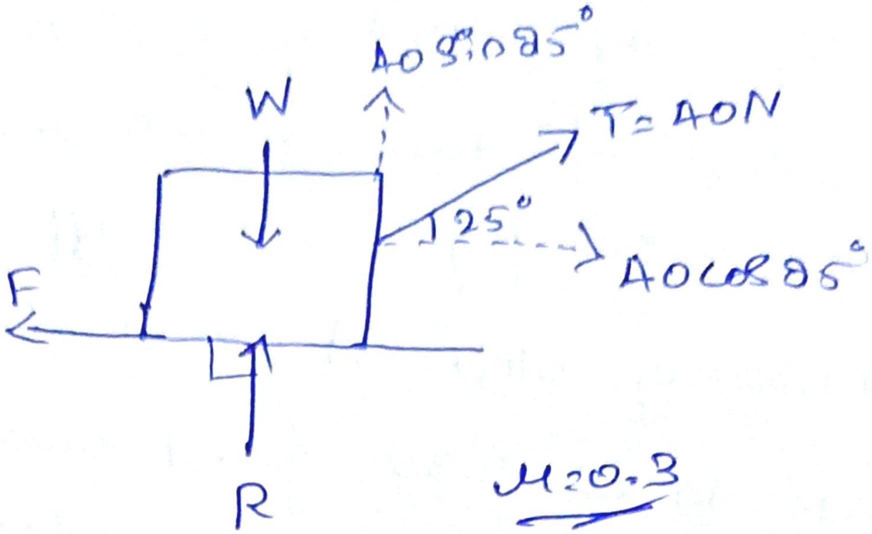
(6) Figure shows an arrangement for just moving the block of weight 'W' horizontally. An effort of 40N just move the block. if the co-eff of static friction is 0.30. Determine the weight of the block.



Solu^n: FBD of block :-



⇒ FBD of block:



$\mu = 0.3$

⇒ $\Sigma f_x = 0$

$40\cos 25 - F = 0$

$\boxed{F = 36.252\,N}$

frictional force,

$F = \mu . R$

$\therefore R = \frac{F}{\mu} = \frac{36.252}{0.3}$

$\boxed{R = 120.84\,N}$

$\uparrow^{+} \Sigma f_y = 0.$

$R + 40\sin 25 - W = 0$

$\boxed{W = 137.744\,N}$

(7)

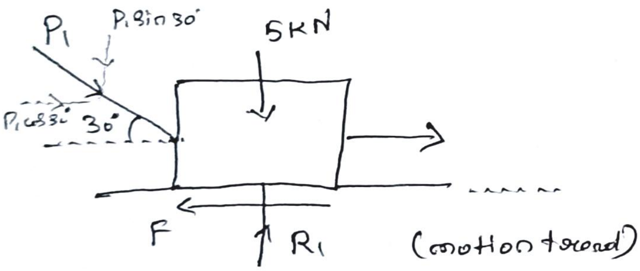
A-I : A block of weight 5 KN rests on a rough Hzl surface & the co-eff of friction b/w them is 0.4. Show that the magnitude of force required to pull is less than the magnitude of push, if the angle made by both the forces (pull & push) is 30°.

$\Rightarrow W = 5 KN, \quad \mu = 0.4.$

$F = \mu . R = 0.4 R$

(i) when the block is pushed by force P_1 @ an angle $\theta = 30°$.

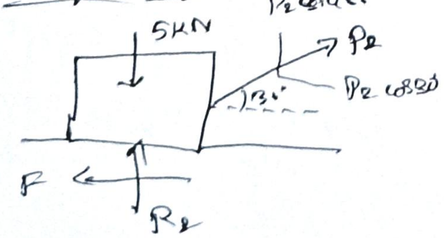
FBD of body for push :



$\therefore \boxed{P_1 = 3.12 KN}$

(ii) when the block is pulled by a force P_2 at an angle $\theta = 30°$

FBD of body for pull :



$\boxed{P_2 = 1.876 KN}$

from ① & ②, it is seen that $P_1 > P_2$, The magnitude of push P_1 is greater than pull P_2,

A-II : A 500N block is resting on a rough Hzl surface. the co-eff of friction is 0.30. Determine the force 'P' required to cause motion to impend. if applied the block.

i) Horizontally

ii) Downward at 30° to the Horizontal.

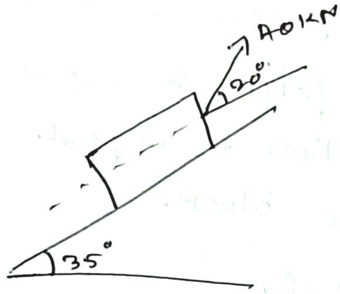
A-III : A block weighing 400N is in contact with an inclined plane. will the block move under its own weight. Determine the mini force

a) parallel.

b) perpendicular to the plane, to prevent the motion down the plane.

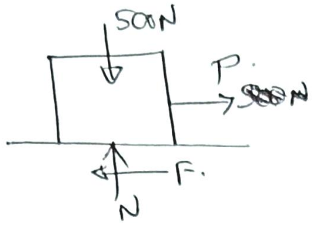
what force 'P' will be required to just cause the motion up the plane. Take $\mu = 0.25$.

A – IV : A body of weight 200 kN is acted upon a force of 40 kN as shown in fig. If the co-eff of friction b/w the inclined plane & the body is 0.3, Check whether the body moves up the plane or remain stationary



* A 500 N block is resting on a rough horizontal surface the coeff. of friction is 0.30. Determine the force P req cause motion to impend if applied the block
i) Horizontally   ii) Downward at 30° to the horizontal

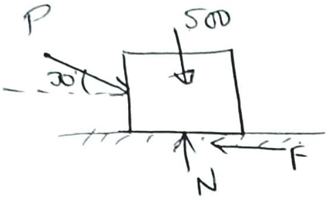
Soln: i)



$\Sigma f_y = 0$.
$N = 500\,N$
$F = 0.3 \times 500 = 150\,N$

$\Sigma f_x = 0$
$P = F = 150\,N$

ii)



$\Sigma f_y = 0$.
$N = 500 + P\sin 30°$
$F = \mu N = 150 + 0.15P$.

$\Sigma f_x = 0$
$P\cos 30 = F$
$P = 209.50\,N$

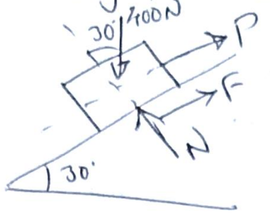
*. A block weighing 400N is in contact with an inclined plane. Will the block move under its own weight. Determine the minimum force a) Parallel b) perpendicular to the plane. to prevent the motion down the plane. What force P will be required to just cause the motion up the plane. Take $\mu = 0.25$.

Soln: //

From the equilibrium,
$\Sigma V = 0 \Rightarrow N - W\cos 30° = 0$
$N = 0.866W$
$\Sigma H = 0 \Rightarrow \mu N - W\sin 30 = 0$
$\mu N = W\sin 30°$

Body will move down only if the value of $\mu N < W\sin 30°$
$\therefore \mu N = 0.25 \times 0.866W = 0.2165W$.
& $W\sin 30° = 0.5W$.
Since $0.216W < 0.5W$ the body will move down.

...en force acting parallel to plane



$\Sigma V = 0 \Rightarrow N - 400 \cos 30 = 0$

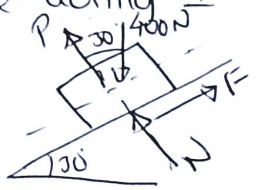
$N = 346.14\ N$

$\Sigma H = 0 \Rightarrow P + \mu N - 400 \sin 30 = 0$

$P = 400 \sin 30 - \mu N$

$\boxed{P = 113.40\ N}$

b) When force acting $\perp^{er}$ to plane



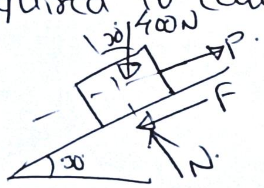
$\Sigma H = 0 \Rightarrow 0.25 N - 400 \sin 30 = 0$

$N = 800\ N$

$\Sigma V = 0 \Rightarrow N + P = W \cos 30°$

$\boxed{P = -453.6\ N} \rightarrow$ downward.

c) The force required to cause motion up the plane



$\Sigma V = 0 \Rightarrow N = 346.14\ N$

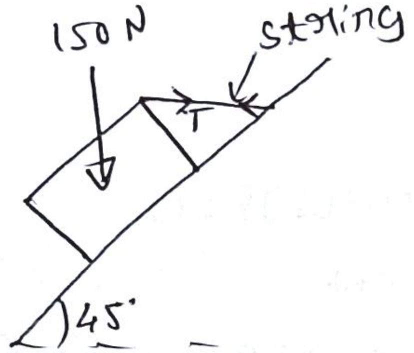
$\Sigma H = 0 \Rightarrow P - \mu N - 400 \sin 30 = 0$

$\boxed{P = 286.53\ N}$

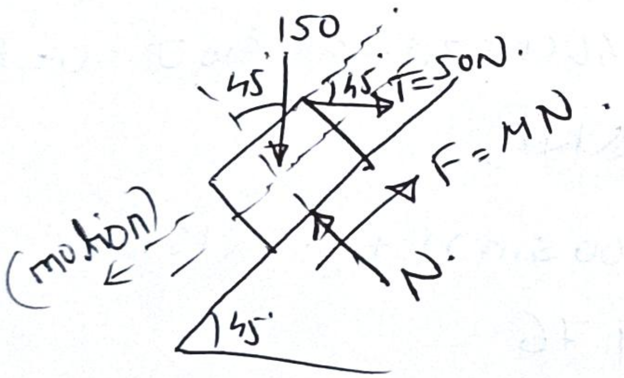
* A block is resting on a rough inclined plane. The block is tied up by horizontal string has a tension of 50N. Find.

i) friction force on the block & the normal reaction in the inclined plane.

ii) the coefficient of friction b/w contact forces



Soln:



$\Sigma V = 0.$

$N - 150\cos 45 - 50\sin 45 = 0$

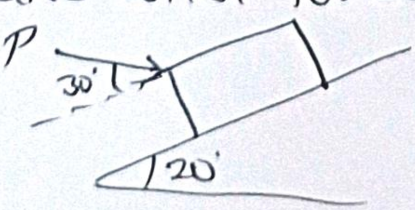
$N = 141.42N.$

$\Sigma H = 0$

$\mu \times 141.42 + 50\cos 45 - 150\sin 45 = 0$

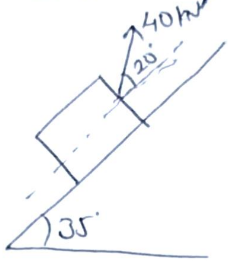
$\boxed{\mu = 0.50}$.

* A block weighing 1500 N rests on a plane inclined at 20° to the hzl. If $\mu = 0.3$, Find the force required to push the block up the plane when force makes an angle of 30° with plane

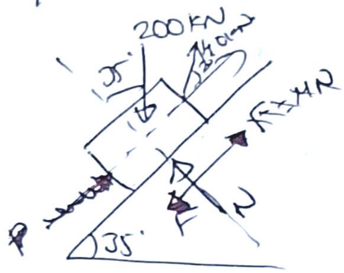


Soln: P = 1307 N.

* A body of weight 200 kN is acted upon a force of 40 kN as shown in fig. If the coefficient of friction b/w the inclined plane & the body is 0.3, check whether the body moves up the plane or remain stationary



Soln: Assuming that the motion is ~~downwards~~ upwards, ~~let R be the force required to prevent motion~~.



$\Sigma F_y = 0 \Rightarrow \quad +N + 40\sin 20 - 200\cos 35 = 0$

$N = 150.15\ kN$

$F = \mu N = 0.3 \times 150.15 = 45.05\ kN$

$\Sigma F_x = 0 \Rightarrow \quad \cancel{+R} \mp 0.3 \times 150.15 + 40\cos 20 - 200\sin 35 = 0$

$\boxed{\cancel{R = 32.08\ kN}}$

$40\cos 20 = 200\sin 35 + 0.3 \times 150.15$

$37.6 = 159.76$

∴ The applied force component up the plane is much less than the sum of resisting forces (weight component + Friction). So body remains stationary or moves downward.