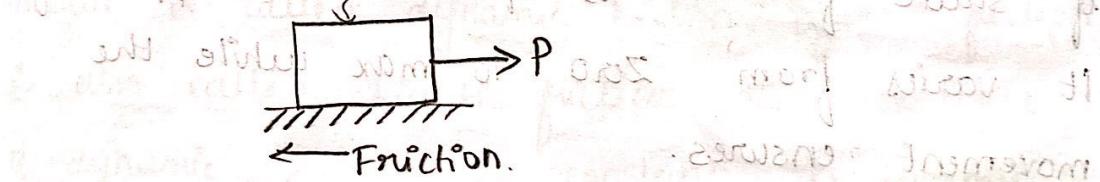


FRICITION

When a body moves or tends to move over another body, a force opposing the motion develops at the contact surfaces. This force which opposes the movement or the tendency of movement is called frictional force or friction.

When a body slides upon another body, the property due to which the motion of one relative to another is retarded is called friction.



Frictional force has a remarkable property of adjusting itself in magnitude to the force producing or tending to produce the motion so that motion is prevented.

However, there is a limit beyond which the magnitude of this force can't increase. If the applied force is more than this limit, there will be movement of one body over the other.



Types of friction:

Adora

PAGE NO.

DATE / /

Depending on the state of rest or motion, we can categorize friction into:

- i) static friction
- ii) Dynamic friction

- a) Sliding friction
- b) Rolling friction

i) static friction:

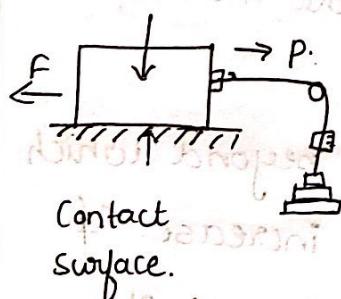
It is the friction acting on the body when the body is at the state of rest or the friction which exists before the body tends to move on the surface is called static friction. The magnitude

of static friction is equal to the applied force.

It varies from zero to max while the movement ensures.

To find the coefficient of friction

* Consider a block resting on a horizontal plane surface. Attach a string to one side of the block as shown in fig. The other end of the string is connected to spring balance.



Gradually increase the magnitude of the external force. Initially the body will not move & the effect of applied force is nullified.

This is because, there acts a force on the block which opposes the motion or movement of the block. The nature of this opposing force is called friction.

It depends on many factors. The major cause for friction is microscopic roughness of the contact surface. No surface is perfectly smooth.

i) Dynamic friction:

Friction acting on a body, when body is in motion is called dynamic friction. Dynamic friction is also called kinetic friction. The magnitude of dynamic friction is constant. The dynamic friction has two types:

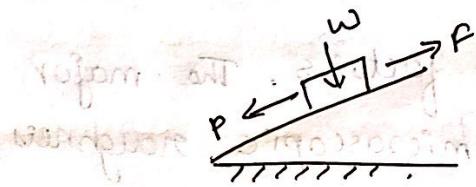
- a) Sliding friction b) Rolling friction.

a) Sliding friction:

The sliding friction acts on those bodies which slides over each other. For example, the friction b/w piston & cylinder which slides upon each other. In this case, the motion of piston in cylinder is sliding & there is a surface contact b/w piston & cylinder.

(or)

It is a resisting force which opposes the sliding motion of the body over the surface. The force acts in opposite direction to direction of motion.



b) Rolling friction :

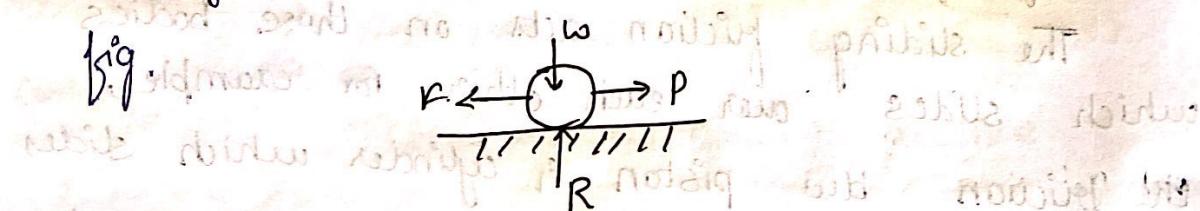
The rolling friction acts on those bodies which have point contact with each other:

For e.g.; the motion of wheel on railway track is an example of rolling motion.

The friction b/w the wheel & railway track is rolling friction.

(or)

It is the friction b/w two bodies when a body rolls over a plane as shown in fig.



Depending on the nature of contact surface, friction can be classified into:

→ Dry friction: If the surface b/w the two bodies are dry, then the friction b/w the bodies are

i) Fluid friction: The contact force between two fluid layer or between solid & fluid is termed as fluid friction.

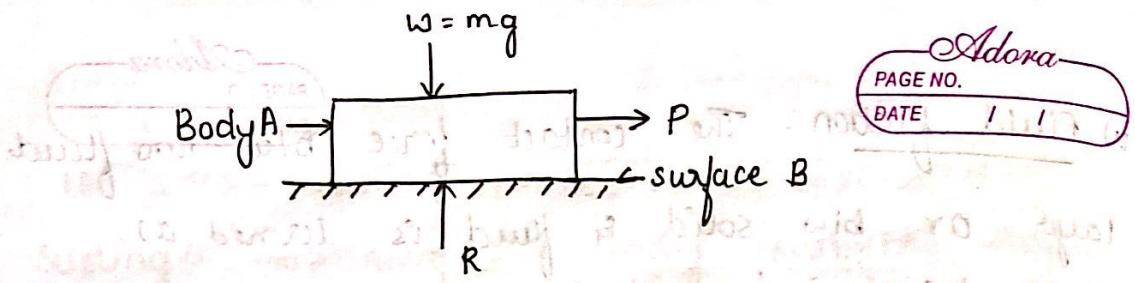
Limiting Friction:

The max friction produced at the contact surface b/w two bodies, before the movement of body is known as limiting friction.

Consider a block resting on a rough surface. Let w be the wt of block. Let the block be subjected to an applied force P . When this applied force is sufficiently small, the block will remain in equilibrium. Suppose if force F continues to oppose ' P ' with longer magnitude but attains a max value ' F_m ' beyond which the block starts sliding/moving. This max resistance offered by the body is called limiting friction.

Normal reaction:

Let us consider a body A of wt ' w ' rest over another surface B & a force P acting on the body to slide the body on the surface B as shown in fig.



Body A presses the surface B downward equal to the weight of body A. & in reaction, surface B lift the body in upward direction of same magnitude but in opposite direction. For the body to be in equilibrium, this upward reaction is termed as normal reaction. It is denoted by R or N.

It is to be noted that, weight 'w' is not always \perp^{to} to the surface of contact & hence normal reaction, R is not equal to wt 'w' of body.

In such case, the normal reaction, ^{is equal} to the component of weight perpendicular to surface.

Co-efficient of friction (μ)

It is defined as ratio of limiting force of friction (F) to the normal reaction (R) b/w the two bodies. It is denoted by the symbol μ .

$$\mu = \frac{\text{Limiting force of friction}}{\text{Normal reaction}} = \frac{F}{R}$$

$$\text{or } F = \mu R$$

Coefficient of friction is of 2 types:

(i) Coefficient of static friction (μ_s)

It is the ratio of max static friction force (F_m) to the normal reaction R .

$$\therefore \mu_s = \frac{F_m}{R}$$

(ii) coefficient of kinematic friction (μ_k)

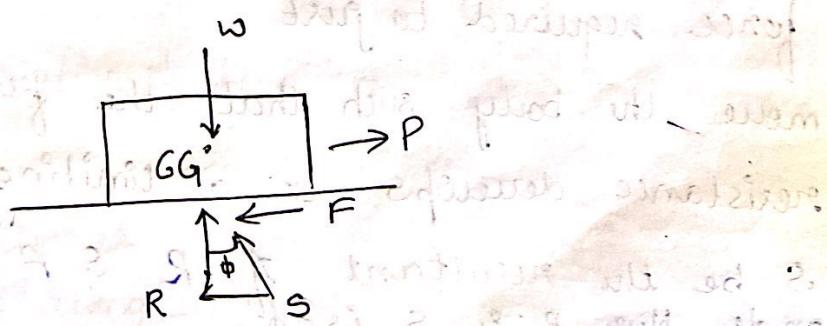
It is the ratio of Kinematic friction force (F_k) to the normal reaction R .

$$\mu_k = \frac{F_k}{R}$$

μ_k is app 25% less than μ_s .

Angle of friction

Angle of friction is defined as the angle made by the resultant of the normal reaction (R) and the limiting force of friction (P) with the normal reaction (R). It is denoted by ϕ . The following fig shows a solid body resting on a rough plane.



Let s be the resultant of the normal reaction (R) & limiting force of friction (P)

(a) Then the angle of friction, $\phi = \text{angle b/w } s \text{ & } R$

From fig. we have $\tan \phi = \frac{F}{R} = \frac{\mu R}{R}$

$$(F = \mu R)$$

$\mu = \text{coefficient of friction}$

** Thus, the tangent of the angle of friction is equal to the coefficient of friction.

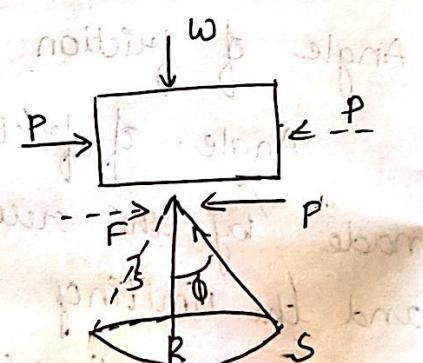
Cone of friction:

This is an imaginary inverted cone with semi- \angle equal to the angle of friction.

Consider a body of weight w resting on a H^e surface as shown in fig. Let P be the

force required to just move the body such that the frictional resistance develops to a limiting value. Let

s be the resultant of R & P . & the angle b/w R & s is ϕ .



If the direction of force P is changed, the direction of F is also changes & in turn, S is also changes. If P is rotated through 360° , S is also rotated through 360° & hence it generates an imaginary cone called cone of friction.

The conical path is traced by the resultant when the force, P is applied in all the directions covering angle of 360° .

Angle of repose (θ).

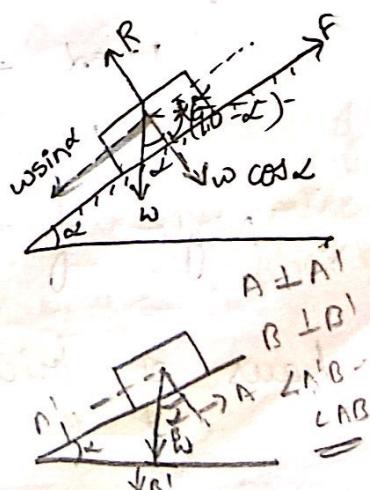
The angle of repose is defined as the maximum inclination of a plane at which a body remains in equilibrium over the inclined plane by the assistance of friction only.

Consider a body of weight w , resting on a rough inclined plane as shown in fig.

Let R be the normal reaction acting at right angle to the inclined plane.

α be the inclination of the plane with the H.C.

F be the frictional force acting downwards along the plane



Let the angle of inclination α be gradually increased, till the body just starts sliding down the plane. This angle of inclination of the plane with the H^e when the object starts sliding down the plane without applying any additional force is called angle of repose:

Resolving the forces along the plane, we get

$$w \sin \alpha = F \quad (1)$$

Resolving the forces normal to the plane, we get

$$w \cos \alpha = R \quad (2)$$

Dividing eqn (1) & (2)

$$\frac{w \sin \alpha}{w \cos \alpha} = \frac{F}{R} \quad \text{or} \quad \tan \alpha = \frac{F}{R} \quad (3)$$

$$\text{But } \tan \phi = \frac{F}{R} \quad (4)$$

ϕ = angle of friction.

from eqn (3) & (4)

$$\tan \alpha = \tan \phi$$

$$\therefore \alpha = \phi$$

Angle of repose = angle of friction.

Laws of static friction or coulomb's law of friction.

- Frictional force is a self adjusting force & acts tangentially over the surface of contact.
- Frictional force always acts in the opposite direction of the body intended to move.
- Frictional force is independent of the shape & size of surface of contact.
- Frictional force depends on the nature of the surface contact.
- The ratio of limiting friction (F) to the normal reaction (R) is constant & is termed as coefficient of friction (μ)

Laws of dynamic or kinetic friction:

- Frictional force always acts in a direction opposite to that in which the body is moving.
- The ratio of kinetic friction to the normal reaction is a constant & termed as coefficient of kinetic friction (μ_k)
- Dynamic friction is always less than the static friction ($\mu_k < \mu_s$)
- The force of friction remains constant for moderate (less) speed but decreases with increase in speed.

1. A horse exerts a pull of 3KN just to move a carriage having a mass of 800 kg. Determine the co-efficient of friction b/w wheel & ground.

Take $g = 10 \text{ m/sec}^2$.

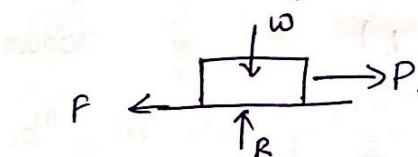
$$P = 3 \text{ KN}$$

$$\text{mass, } m = 800 \text{ kg}$$

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

To find, μ

$$w = mg = 800 \times 10 = 8000 \text{ N or } 8 \text{ kN.}$$



wt of the carriage is equal to normal reaction because the body is H.R to the plane as shown.

$$w = R = 8 \text{ kN}$$

$$P = F$$

$$\mu = \frac{F}{P} = \frac{3}{8} = 0.375$$

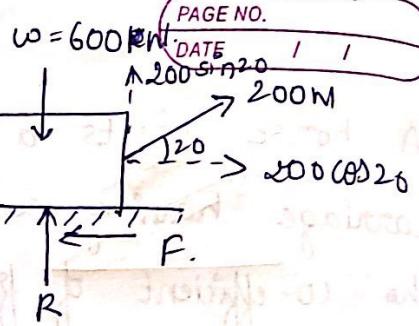
co-efficient of friction, $\mu = \underline{\underline{0.375}}$

2. A block shown in fig is just moved by force of 200N. The wt of the block is 600N. Determine the coefficient of static friction b/w the block & floor.

$$W = 600 \text{ N}$$

$$P = 200 \text{ N}$$

$$\mu = ?$$



The body is in equilibrium under the action of all the forces as shown in fig.

$$\Sigma H = 0$$

$$200 \cos 20^\circ - F = 0$$

$$F = 187.94 \text{ N} (\leftarrow)$$

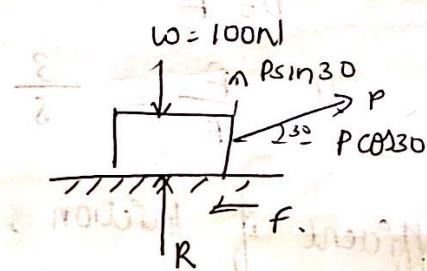
$$\Sigma V = 0 \Rightarrow R + 200 \sin 20^\circ - 600 = 0$$

$$R = -531.59 \text{ N} (\downarrow)$$

$$\mu = \frac{F}{R} = \frac{187.94}{531.59} = 0.353$$

co-efficient of friction, $\mu = 0.353$

3. Find the max value of the force P required to start the body as shown in fig. Take coefficient of friction as, 0.2



$$\text{Soln: } \mu = 0.2$$

$$\therefore \mu W = 100 \text{ N}$$

$$\Sigma H = 0 \Rightarrow 100 - P \cos 30^\circ - F = 0 \Rightarrow F = P \cos 30^\circ$$

$$\Sigma V = 0 \Rightarrow 100 - P \sin 30^\circ + R = 0 \Rightarrow F = 100 - P \sin 30^\circ$$

-(2)

$$\mu = \frac{F}{P}$$

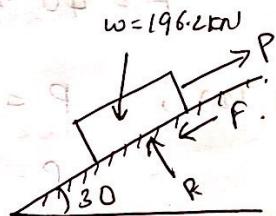
$$0.2 = \frac{P \cos 30}{100 - P \sin 30}$$

$$P \cos 30 = 20 - 0.1P$$

$$P = \frac{20}{0.966} = 20.7 \text{ N.}$$

4. A block of mass 20kg placed on a inclined plane as shown in fig is subjected to a force p. i.e parallel to the plane. Take the inclination of plane w.r.t H.C is 30° . The coefficient of friction is 0.24. Determine the value of P for impending motion of the table.

Soln: In this problem, the body may move above the plane or the body may move down the plane.

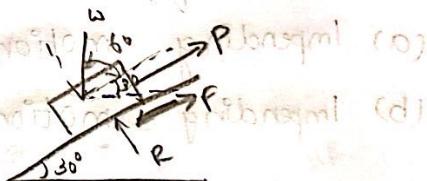


Care (i): Let the body move down the plane.

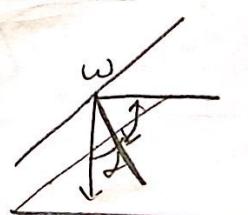
$$P + f - W \cos 30 = 0$$

$$W = 20 \times 9.81 = 196.2 \text{ N}$$

~~$$P + f = 98.1 \quad (i)$$~~



Resolve the forces ~~per~~ to the plane



$$-W \sin 30 + R = 0$$

$$R = 169.9 \text{ N.}$$

$$\mu = \frac{f}{R} \Rightarrow 0.24 = \frac{f}{169.91} \Rightarrow f = 40.78 \text{ N}$$

$$\text{from (i), } P = 98.1 - 40.78 = 57.32 \text{ N}$$

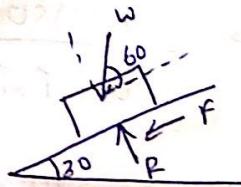
case ii) Let the body move up the plane.

Adora
PAGE NO.
DATE: / /

$$\Sigma \text{along plane} = 0$$

$$P - F - w \cos 60^\circ = 0$$

$$P - F = 98.1 \quad \text{--- (2)}$$



$$\Sigma \text{fre plane} = 0$$

$$R - w \sin 60^\circ = 0$$

$$R - w \sin 60^\circ = 0$$

$$R = 169.91 \text{ N}$$

$$\mu = \frac{F}{R} \Rightarrow F = 0.24 \times 169.91$$

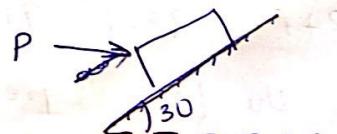
$$F = 40.78 \text{ N}$$

$$\text{from (2), } P = 98.1 + 40.78$$

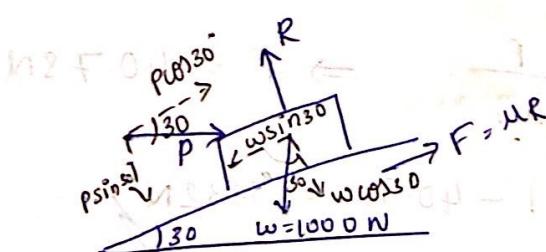
$$P = 138.88 \text{ N}$$

5. A small block of wt 1000N is placed on a 30° inclination with coefficient of friction = 0.25. as shown in fig. Find the force P required for.

- (a) Impending motion down the plane.
- (b) Impending motion up the plane.



Soln.



case i): Impending motion down the plane Resolving forces along the plane,

$$w \sin 30 = P \cos 30 + \mu R$$

$$w = 1000 \text{ N}$$

$$\mu = 0.25$$

$$0.866P + 0.25R = 500 \quad (1)$$

Resolving forces \perp to the plane,

$$w \cos 30 + P \sin 30 = R$$

$$0.5P - R = -866.025 \quad (2)$$

Multiply eqn (2) by 0.25 & add (1) & (2)

$$0.866P + 0.25R = 500$$

$$0.125P - 0.25R = -216.506$$

$$0.991P = 283.494$$

$$P = \underline{\underline{286.07 \text{ N}}}$$

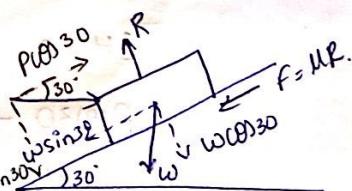
Case ii) Impending motion up the plane.

Resolving forces along the plane,

$$w \sin 30 + F = P \cos 30$$

$$500 + 0.25R = 0.866P$$

$$0.866P - 0.25R = 500 \quad (3)$$



Resolving forces \perp to plane,

$$w \cos 30 + P \sin 30 = R$$

$$866.025 + 0.5P = R$$

$$0.5P - R = -866.025 \quad (4)$$

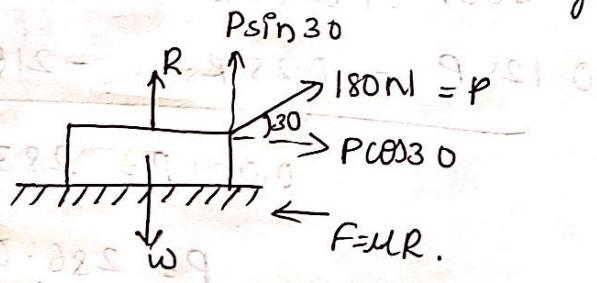
$$0.866P - 0.25R = 500$$

(E) (F)

$$-0.741P = -716.506$$

$$P = 966.94 \text{ N}$$

6. A body resting on a rough H^{le} plane required a pull of 180N inclined at 30° to the plane just to move it. It was found that push of 220N inclined at 30° to the plane just to move the body. Determine the wt of the body.



case i)

$$\Sigma V = 0$$

$$P \sin 30 + R = w$$

$$90 + R = w \quad \text{--- (1)}$$

$$\Sigma H = 0$$

$$P \cos 30 = \mu R$$

$$\mu R = 155.88$$

$$\mu = \frac{155.88}{w - 90} \quad \text{--- (2)}$$

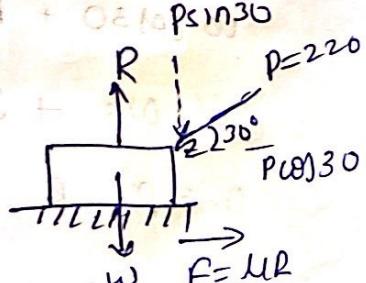
case ii)

$$\Sigma V = 0$$

$$w + P \sin 30 = R$$

$$110 - R = -w$$

$$- (3)$$



$$\Sigma H = 0$$

$$P \cos 30^\circ = \mu R$$

$$\mu R = 190.52$$

$$\mu = \frac{190.5}{\omega + 110} \rightarrow (4)$$

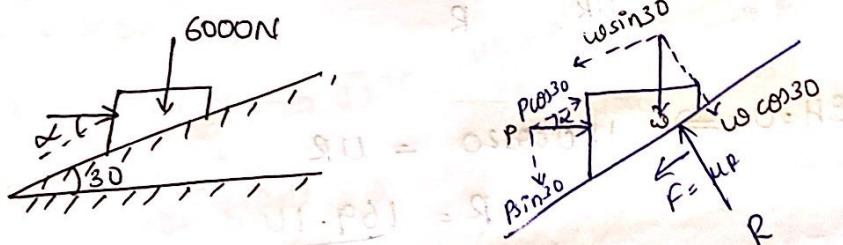
from eqn (2) & (4)

$$\frac{155.88}{\omega - 90} = \frac{190.5}{\omega + 110}$$

~~W = 987.46 N.~~

7. A block 6000N is resting on a 30° inclined surface as shown in fig. Determine the magnitude of a horizontal force P required to cause impending motion of the block up the plane ($\mu = 0.3$)

$$w = 6000N$$



$$\Sigma H = 0 \text{ (Along plane)}$$

$$P \cos 30^\circ = w \sin 30^\circ + F$$

$$0.866 P = 3000 + 0.3 R \rightarrow (1)$$

$$\Rightarrow 0.866 P - 0.3 R = 3000$$

$$\Sigma V = 0 \text{ (Tangential to plane)}$$

$$P \sin 30^\circ + w \cos 30^\circ = R$$

$$0.5 P + 5196.15 = R \rightarrow (2)$$

$$0.5 P - R = -5196.15$$

subtract both eqn.

$$0.866P - 0.3P = 3000$$

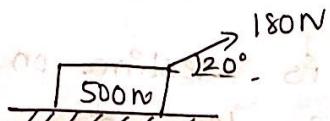
$$0.15P - 0.3R = -1558.845$$

(-) (+) (+)

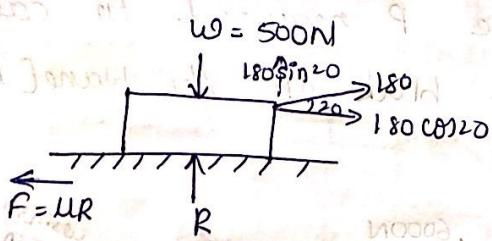
$$0.716P = 4558.84$$

$$P = \underline{\underline{6367.2 \text{ N}}}$$

8. A block of 500N on a ~~12°~~ plane is just moved by a pull of 180N as shown in fig. Determine the coefficient of friction b/w floor & block.



Soln:



$$\Sigma H = 0 \Rightarrow 180\cos20 = \mu R$$

$$R = \underline{\underline{169.14}}$$

$$\Sigma V = 0 \Rightarrow 180\sin20 + R = 500$$

$$R = 438.44 \text{ N}$$

$$\mu = \frac{169.14}{438.44}$$

$$\mu = 0.388$$

9. Determine range of values that a cut 'w' may have so that the block 'A' of 1000N as shown in fig will neither start up nor slip down the plane. Take $\mu = 0.3$ & assume smooth pulley.

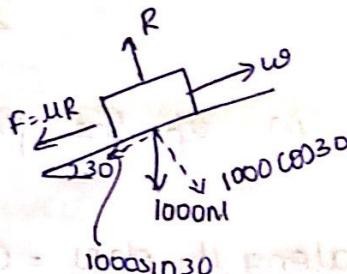
Adora
PAGE NO.
DATE / /

case i). Block starting up.

ΣF along the plane = 0

$$w = \mu R + 1000 \sin 30$$

$$w = 0.3R + 500 \quad \text{--- (1)}$$



ΣF ~~perp~~ to the Plane = 0

$$R = 1000 \cos 30$$

$$R = 866.025 \quad \text{--- (2)}$$

$$\text{sub } R \text{ in (1)}$$

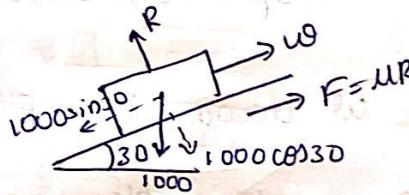
$$w = 759.81 \text{ N.}$$

case ii) Block slipping down.

ΣF forces along plane = 0

$$w + \mu R = 1000 \sin 30$$

$$w + 0.3R = 500 \quad \text{--- (3)}$$



ΣF ~~perp~~ to the plane = 0

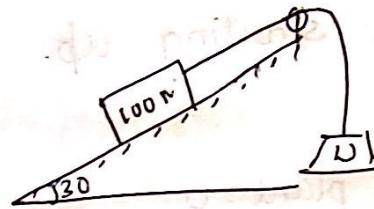
$$1000 \cos 30 = R$$

$$R = 866.025$$

$$w = 240.2 \text{ N.}$$

Range of weights = 759.81 to 240.2 N.

10. Find the range of values of w for which the body of 100N block neither move up nor down the plane. Take angle of friction for all contact surfaces as $\tan^{-1}(0.2)$ for the block shown in fig.



Soln: (i) w up the plane.

Σ forces along the plane = 0

$$w = 100 \sin 30 + \mu R_1$$

$$w = 50 + 0.2 R_1 \quad \text{--- (1)}$$

$$\phi = \tan^{-1}(0.2)$$

Σ forces \perp to plane = 0

$$100 \cos 30 = R_1$$

$$\tan(\phi) = \mu$$

$$\mu = 0.2$$

$$R_1 = 86.6 \text{ N}$$

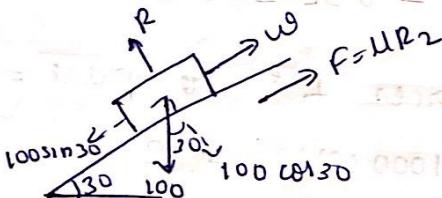
$$w_{\text{up}} = 67.32 \text{ N.}$$

(ii) w down the plane:

Σ forces along Plane = 0

$$w + \mu R_2 = 100 \sin 30$$

$$w = 50 - 0.2 R_2 \quad \text{--- (2)}$$



Σ forces \perp to plane = 0

$$100 \cos 30 = R_2$$

$$R_2 = 86.6 \text{ N}$$

$$w = 32.67 \text{ N}$$

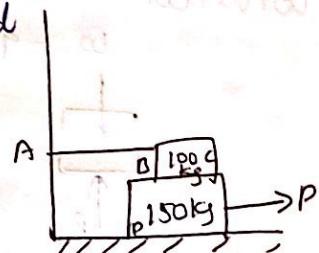
Range of values of $w = 32.67 \text{ N}$ to 67.32 N.

start the block D moving. Take $\mu = 0.3$ for all contact surface.

(a) Block C is restrained by cable AB

(b) The cable AB is removed.

solⁿ: when one body is placed over another body equal & opp reaction & equal & opp frictional force will be developed at contact surface.



(a) The block is restrained by cable AB

consider FBD of C

$$\Sigma V = 0 \Rightarrow R_1 + 100g = 100 \times 9.81$$

$$R_1 - w_1 = 0$$

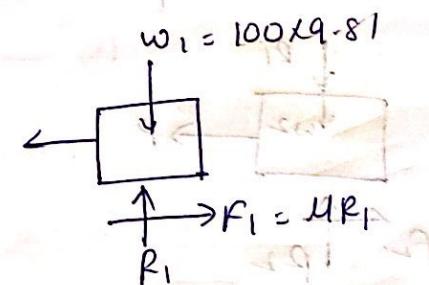
$$R_1 = 981 \text{ N.}$$

$$\Sigma H = 0$$

$$-T + R_1 = 0$$

$$-T + \mu R_1 = 0$$

$$T = 0.3 \times 981 \Rightarrow T = 294.3 \text{ N.}$$



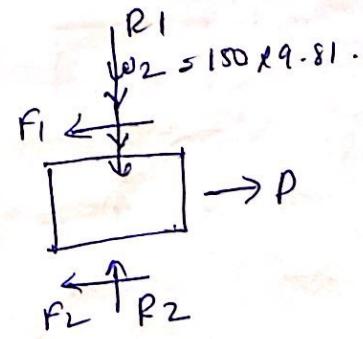
consider FBD of D

$$\Sigma V = 0$$

$$R_1 + w_2 = R_2$$

$$R_2 = 981 + (150 \times 9.81)$$

$$R_2 = 2452.5 \text{ N}$$



$$\Sigma H = 0$$

$$P = P_1 + P_2$$

$$P = \mu R_1 + \mu R_L$$

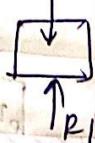
$$P = 0.3 \times 981 + 0.3 \times 2452.5$$

$$P = 1030.05 N$$

(b) when cable AB is removed

consider PBD of C.

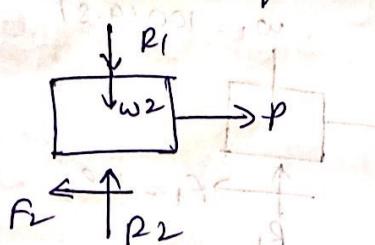
$$w_1 = 981$$



$$\Sigma V = 0$$

$$R_1 = w_1 \therefore R_1 = 981 N$$

consider PBD of D



$$\Sigma V = 0$$

$$R_1 + w_2 = R_2$$

$$R_2 = 981 + (150 \times 9.81)$$

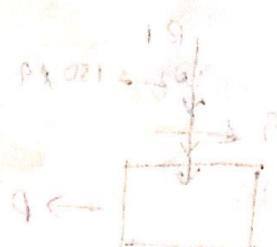
$$R_L = 2452.5 N$$

$$\Sigma H = 0$$

$$P = P_2$$

$$P = 0.3 \times 2452.5$$

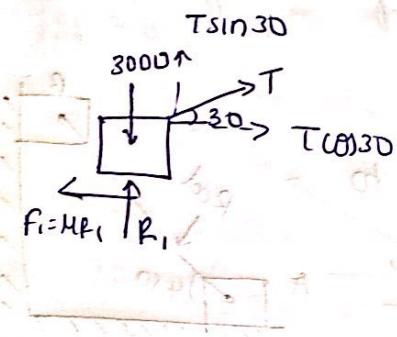
$$P = 735.75 N$$



Adora
PAGE NO. / /
DATE / /

A block of 4500N resting on a H^e surface supports another block of 3000N as shown in fig. find the H^e force P required to just move the block to the left. Take $\mu = 0.3$

FBD of A.



$$\sum H = 0$$

$$T \cos 30 = F_1$$

$$T \cos 30 = \mu R_1$$

$$T \cos 30 - 0.3 R_1 = 0 \quad \text{--- (1)}$$

$$\sum V = 0$$

$$T \sin 30 + R_1 - 3000 = 0$$

$$T \sin 30 + R_1 = 3000 \quad \text{--- (2)}$$

Solving (1) & (2)

$$R_1 = 2557.086 \text{ N}$$

$$T = 885.827$$

FBD of B

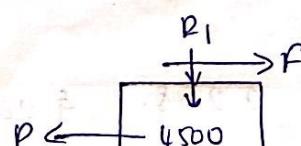
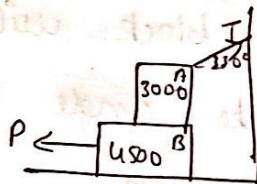
$$\sum H = 0$$

$$P = \mu R_2 + \mu R_1$$

$$P = 0.3 R_2 + 0.3 R_1 \quad \text{--- (1)}$$

$$\sum V = 0$$

$$R_1 + 4500 = R_2 \Rightarrow R_2 = 7057.086 \text{ N}$$



13. Two blocks A & B held in position by a rod as shown in figure. The weight of the block B is 1000N. Find the weight of the block A such that the block will not slide away from the wall. Take angle of friction for all the contact surfaces as 15° .

Sol: Here, Block B tends to move downwards while, Block A tends to move leftwards. Since the blocks have been connected by the rod AB, it is subjected to compressive force.

$$\phi = 15^\circ \therefore \mu = \tan \phi \Rightarrow \mu = 0.268$$

Consider PBD of block B

$$\begin{aligned}
 & \text{W}_B = 1000 \text{ N} \\
 & \text{For equilibrium: } \sum F_x = 0 \Rightarrow R_1 = \mu R_2 \\
 & \sum F_y = 0 \Rightarrow W_B + P \sin 45^\circ - R_2 = 0 \\
 & \sum M_A = 0 \Rightarrow P \cos 45^\circ \cdot R_2 = R_1 \cdot P \sin 45^\circ \\
 & \text{EV} = 0 \Rightarrow 1000 = P \sin 45^\circ + \mu R_2 \\
 & 1000 = P \sin 45^\circ + 0.268 P \cos 45^\circ \\
 & 1000 = P(0.707 + 0.268 \cdot 0.707) \\
 & 1000 = P(0.707 + 0.189) \\
 & 1000 = P \cdot 0.896 \\
 & P = 1115.48 \text{ N}
 \end{aligned}$$

$\times ①$ by 0.268 & add ① & ②

$$0.707P + 0.268R_1 = 1000$$

$$0.189P - 0.268R_1 = 0$$

$$P = 1115.48 \text{ N} \Rightarrow R_1 = 788.64 \text{ N}$$

$$1000 \text{ N} \cdot \cos 45^\circ = 707 \text{ N}$$

FBD of block A.

$$P \sin 45^\circ = 788.76$$

$$w_2 = ?$$

$$P = 1115.48$$

$$788.76 = P \cos 45^\circ$$

$$f_2 = M R_2$$

$$R_2$$

$$\Sigma H = 0$$

$$M R_2 = 788.76$$

$$R_2 = 2943.13 N$$

$$\Sigma V = 0$$

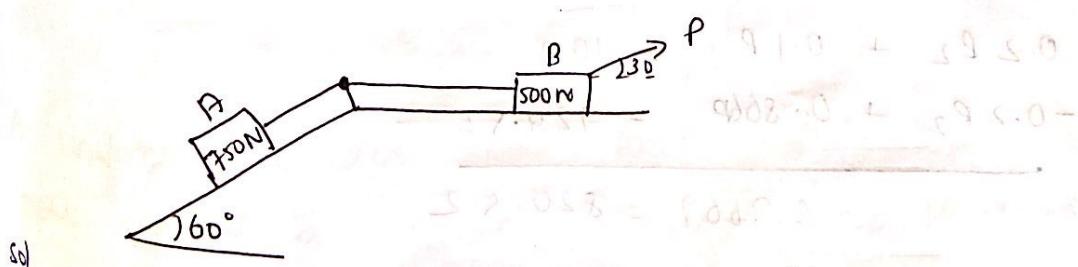
$$w_2 + 788.76 = R_2$$

$$w_2 = 2943.13 - 788.76$$

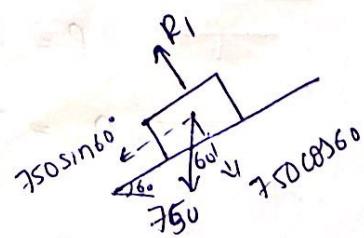
$$w_2 = 2154.37 N$$

The min wt required to prevent the block A is $w_A = 2154.37 N$.

What is the value of P shown in fig to cause the motion to impend? Assume the pulley is smooth & coefficient of friction b/w the other contact surface is 0.2



Consider FBD of block A.



$$\Sigma V = 0$$

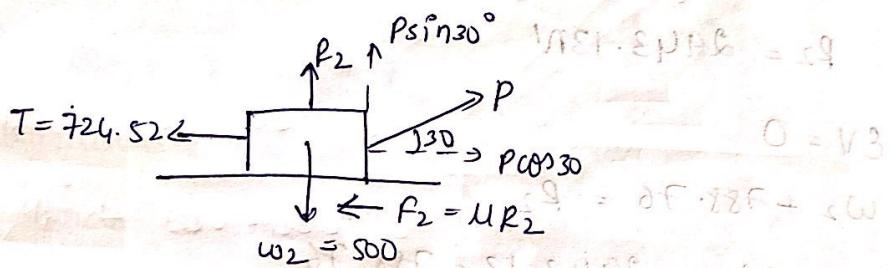
$$R_L = 750 \cos 60^\circ \Rightarrow R_L = 375 \text{ N}$$

$$\Sigma H = 0$$

$$750 \sin 60^\circ + \mu R_L = T$$

$$649.52 + 0.2 \times 375 = T \Rightarrow T = 724.52$$

Consider PBD of Block B



$$\Sigma U = 0$$

$$R_2 + P \sin 30^\circ = 500$$

$$\Sigma H = 0$$

$$P \cos 30^\circ = 724.52 + \mu R_2$$

$$-0.2 R_2 + P \cos 30^\circ = 724.52 \quad (2)$$

Now (1) by 0.2 & add both

$$0.2 R_2 + 0.1 P = 100$$

$$-0.2 R_2 + 0.866 P = 724.52$$

$$0.966 P = 824.52$$

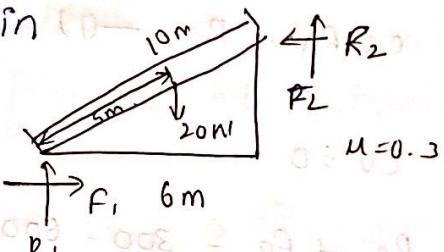
$$P = 853.54 \text{ N}$$

$$\Rightarrow R_2 = 73.23 \text{ N}$$

A uniform ladder of length 10m is placed against a vertical wall with its lower end 6m from the wall. The coefficient of friction of contact surface is 0.3. What is the frictional force acting on the ladder at the points of contact.

Soln: Since the ladder is in equilibrium.

$$\sum F_L = 0, \sum F_y = 0, \sum M = 0$$



$$\sum F_L = 0$$

$$\Rightarrow R_1 = R_2$$

$$UR_1 = R_2 \quad \text{or} \quad 0.3 R_1 = R_2 \quad (1)$$

$$\sum F_y = 0$$

$$R_1 + f_L = 20$$

$$R_1 + 0.3 R_2 = 20$$

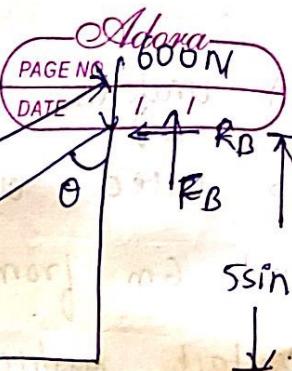
$$R_1 + 0.3(0.3 R_1) = 20$$

$$R_1 = 18.35 \text{ N} \Rightarrow f_L = 5.505 \text{ N}$$

$$R_2 = 0.3 \times 18.35$$

$$R_2 = 5.505 \text{ N} \Rightarrow f_L = 1.652 \text{ N}$$

A uniform ladder 5m long weighs 300N is at rest against a smooth vertical wall at one end & a rough floor at the other end. The coefficient of friction b/w ladder & floor is 0.4. What should be the inclination of the ladder with the vertical so that man wt 600N can reach at the top of ladder?



$$\Sigma H = 0$$

$$F_A = R_B$$

$$\Sigma M_A F_A = R_B$$

$$0.4 R_A = R_B \quad (1)$$

$$\Sigma V = 0$$

$$R_A + F_B - 300 - 600 = 0$$

$$R_A + \mu_B R_B - 300 - 600 = 0$$

Because μ_B is 0 for smooth surface.

$$R_A = 900 \text{ N}$$

$$R_B = 300 \text{ N}$$

$$\Sigma M_A = 0$$

$$300 \times 2.5 \cos \alpha + 600 \times 5 \cos \alpha - R_B 5 \sin \alpha - R_B \times 5 \cos \alpha = 0$$

$$750 \cos \alpha + 3000 \cos \alpha = 1800 \sin \alpha$$

$$\alpha = 64.36^\circ$$

$$\theta = 180 - 90 - \alpha = 25.64^\circ$$

In 30° wood wedge problem we studied medium A has one in 30° incline (600N) is discuss that
30°, but fully up the incline after Appling
300N in rock is subject with noising to problem

A ladder of 5m long & 250N weight is resting on ground & leans against a vertical wall. The coefficient of friction b/w the ladder & floor is 0.3 & b/w wall is 0.2. When a man weighing 900N has climbed the ladder & experience that ladder just begins to slide, when he is at distance 2m along ladder from its top. Determine angle made by ladder.

at equilibrium @ A : $\sum F_x = 0$

$$\sum F_y = 0$$

$$\sum M = 0$$

$$\sum F_{Lx} = 0$$

$$F_1 - R_2 = 0$$

$$\mu R_1 - R_2 = 0$$

$$0.3 R_1 = R_2 \quad \text{(1)}$$

$$\sum F_y = 0$$

$$R_1 + F_2 = 250 + 900$$

$$R_1 + \mu R_2 = 1150$$

$$1.06 R_1 = 1150$$

$$R_1 = 1084.904 \text{ N} \Rightarrow F_1 = 325.4 \text{ N}$$

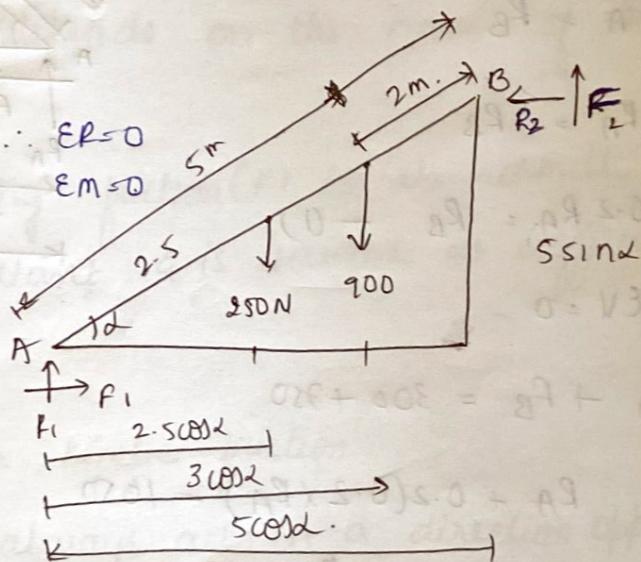
$$R_2 = 325.4 \text{ N} \Rightarrow F_2 = 65.094 \text{ N.}$$

Moment @ A = 0

$$250 \times (2.5 \cos \alpha) + 900(3 \cos \alpha) - F_2(5 \cos \alpha) - F_2(5 \sin \alpha) = 0$$

$$\cos \alpha (2999.53) = 1627.35 \sin \alpha$$

$$\tan \alpha = \frac{\sin \alpha}{\cos \alpha} \Rightarrow \alpha = 61.52^\circ$$



Adora
PAGE NO.
DATE

A 6m long ladder weighing 300N rests against vertical wall at an angle of 60° with the H^e. floor. A man wt 750N climbs the ladder. At what ht along the ladder from the floor does he experience slipping? Take $\mu = 0.2$ for all contact surfaces is rough. ~~and is not smooth~~

$$\Sigma H = 0$$

$$P_A = P_B$$

$$\Sigma P_A = P_B$$

$$0.2 P_A = R_B - 0$$

$$\Sigma V = 0$$

$$P_A + F_B = 300 + 750$$

$$P_A + 0.2(0.2 \times P_A) = 1050$$

$$P_A = 1009.62 \text{ N} \Rightarrow P_A = 201.9 \text{ N}$$

$$R_B = 201.92 \text{ N} \Rightarrow R_B = 40.38 \text{ N}$$

$$\Sigma M_A = 0$$

$$300 \times 3 \cos 60^\circ + 750 \times 2 \cos 60^\circ - R_B \times 6 \sin 60^\circ -$$

$$R_B \times 6 \times \cos 60^\circ = 0$$

$$450 + 750 \times 2 \cos 60^\circ - 1049.21 - 121.14 = 0$$

$$x = 1.92 \text{ m}$$

