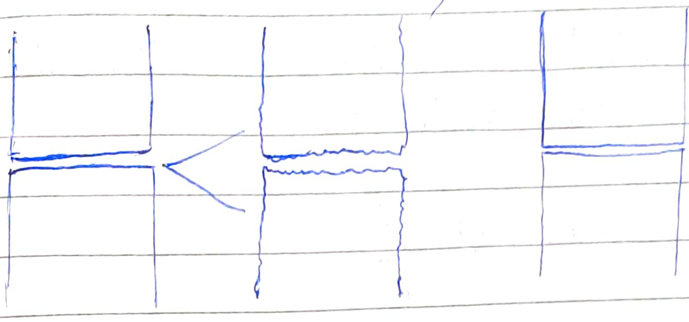
# ☆ Friction



MACROSCOPIC LEVEL
Appears smooth, Friction developed

MICROSCOPIC LEVEL
Criss-cross, crest & trough

MICROSCOPIC LEVEL
Smooth, Ideal, Impractical

→ Aqua-planing

## Friction

It is the force developed or the property by virtue of which a resistance is developed b/w the contact surfaces, when one body moves or tends to move over the other body.

* Friction developed b/w perfectly smooth (ideal) is 0 or tending to zero.

## Limiting friction

→ The self adjusting opposing force developed b/w two bodies when they slide against each other has a limiting value & if this applied force exceeds this value, body begins to move.

→ This limiting value of force is called limiting friction.

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## Coefficient of friction

It is the constant ratio which the limiting friction (F) bears to the normal reaction (N)

$$\text{Coefficient of friction } (\mu) = \frac{F}{N}$$

## Types of friction:

(i) Static friction:
Friction developed b/w two bodies when they are at rest.

(ii) Dynamic friction:
Friction developed b/w two bodies in motion.

(a) Sliding friction:
It is the resisting force which opposes the sliding motion of one body over another. Ex: Car

(b) Rolling friction:
It is resisting force which opposes the rolling motion of one body over another. Ex: Ball

(c) Dry friction:
If the contact surfaces are dry, then it is called dry friction. Ex: Walking,

(d) Fluid friction: b/w two bodies
If contact surfaces is filled w fluid, two fluid layers, it is called fluid friction.
Ex: Swimming

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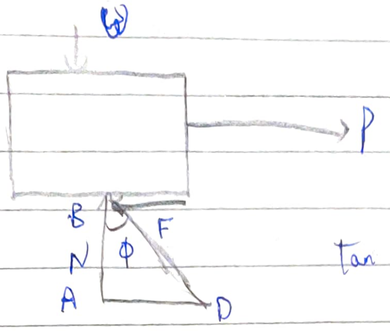
# Angle of friction

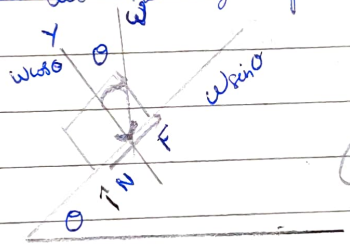
The angle of friction for two contact surface, is the angle b/w $\vec{R}$ result & normal reaction N. It is denoted by $\phi$




$\tan\phi = \frac{AD}{AB} = \frac{F}{N} = \mu$

## Sleep/Angle of repose

→ The maximum angle ~~until which~~ of inclination w.r.t. horizontal until which an object does not undergo friction reaction takes place, is called the angle of repose/sleep.




Consider a body of weight W which is placed on an inclined plane as shown
The body is just at the point of sliding down, when angle of inclination : θ (Angle of repose)

The various forces acting on the body are;
self weight
normal weight
Directional

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Applying the conditions of equilibrium:

$\Sigma F_x = 0,$

$$+F - W\sin\theta = 0 \Rightarrow W\sin\theta = F$$

$\Sigma F_y = 0,$

$$+N - W\cos\theta = 0 \Rightarrow W\cos\theta = N$$

We kt

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

$$= \frac{W\sin\theta}{W\cos\theta} = \tan\theta = \mu$$

From definition of coeff. of friction,

$$\mu = \tan\phi$$

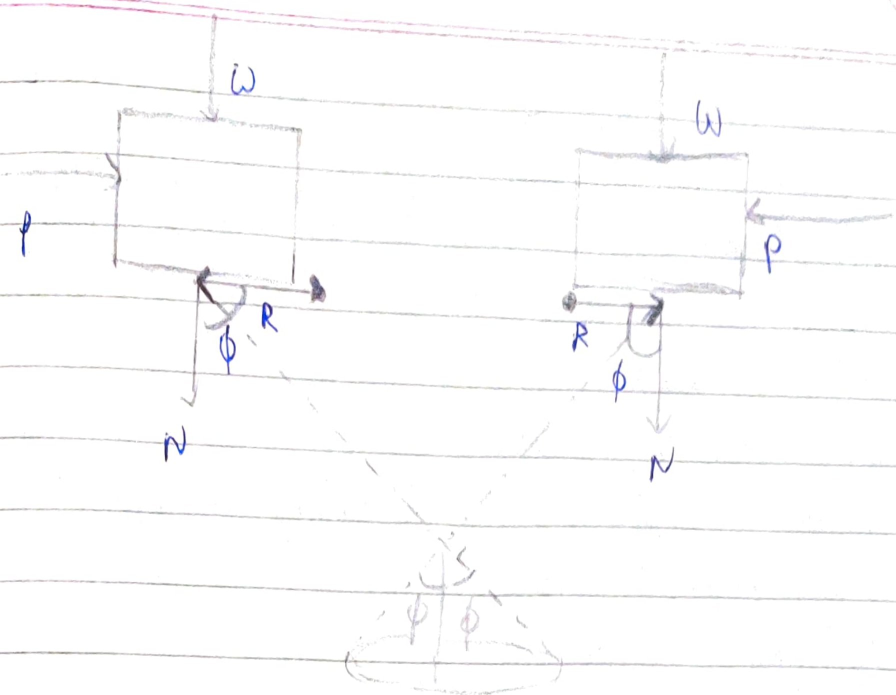
$$\Rightarrow \tan\theta = \tan\phi$$

(Angle of repose) (Angle of friction)

~~Laws of friction~~

Cone of friction

The combination of resultant $\vec{R}$ of frictional forces obtained by applying forces in opposite direction form a rightangular cone of angle $2\phi$ known as cone of friction.




## Laws of friction

### Static friction

1. The force of friction always acts in a direction opposite in which the body tends to move.

2. The magnitude of frictional force is exactly equal to applied force which just moves the body.

3. The magnitude of the limiting friction bears a constant ratio to the normal reaction b/w the two surfaces in contact.

4. The force of friction is independent of the area of contact b/w the two surfaces.

5. The force of friction depends upon the roughness of surfaces in contact.

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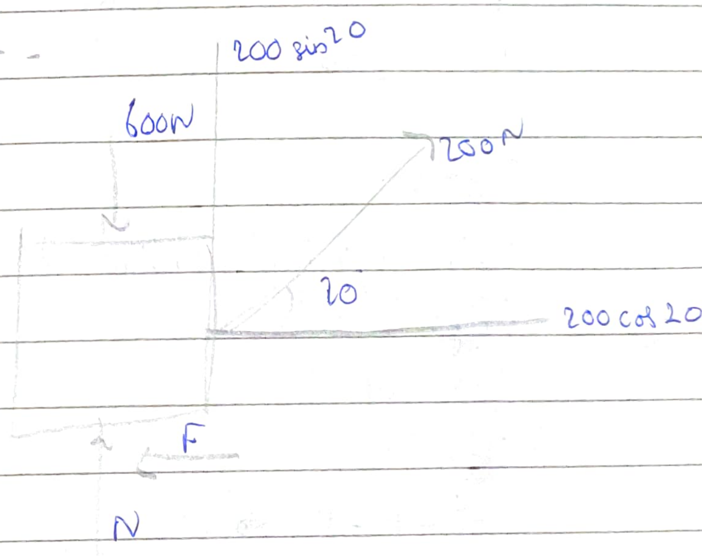
# Problems based on Block Friction

Step 1: Draw FBD considering self weight, normal, External & Frictional forces

Step 2: Coeff. of friction $\mu = F/N$

Step 3: Use principle of equilib to solve for $\Sigma F_x = 0$, $\Sigma F_y = 0$.

Q: A block of self weight 600N is just moved by a force of 200N. Determine coeff. of static friction b/w block & floor.


$\Sigma F_x = 0$

$-F + 200 \cos 20 = 0$

$F = 187.93$

$\Sigma F_y = 0$

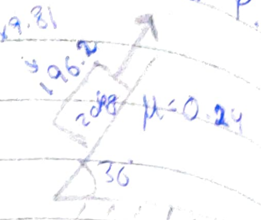
$-600 + N + 200 \sin 20$

$N = 600 - 200 \sin 20$

$= 531 N$

$\mu = \frac{F}{N} = 0.35$

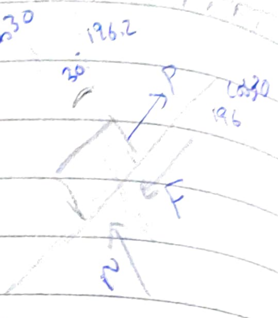
Q: A block of mass 20kg placed on an incline plane of 30° is subjected to a force P, that is ∥ to plane, coeff of friction b/w inclined plane & body is 0.24. Determine P for impending motion of the block.




Case 1:

The value of P ~~...~~

for impending motion up the plane.




$\Sigma F_y = 0$

$+N - 20\times 9.81 \cos 30 = 0$

$N = 169.0\ N$

$\Sigma F_x = 0$ $\quad F = \mu N = 40.56$

$+P - F - 20\times 9.81 \sin 30 = 0$

$P = 138.66$

Case-2

Value of P for impending motion down the plane

$\Sigma F_y = 0$

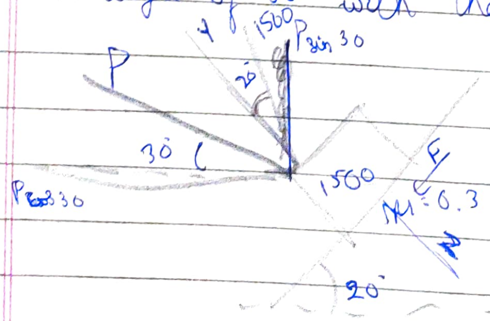
$N = 169\ N$

$\Sigma F_x = 0$

$-P + F - 196 \cos 30$

$P = 57$

Q: A block weighing 1500 N rests on an inclined plane of 20° to the horizontal. If μ=0.3, find the force P required to push the block when line of action of force makes an angle of 30° with the plane.



$\Sigma F_y = 0$

$F + N - 1500\cos 20 - P\sin 30 = 0$

$N - 1409.53 - 0.37N = 0$

$0.63N - 1409.53 = 0$ $\quad N = \dfrac{1409.53}{0.63} = 2236.98\,N$

$\Sigma F_x = 0$

$-F + P\cos 30 - N\sin 20 = 0$

$-0.3N + P\cos 30 - \overset{1500}{N}\sin 20 = 0$

$-0.3N + 0.86P \cancel{-0.34N} \cancel{0.2343} - 510$

$P = \dfrac{0.64N}{0.86}\ 0.79N$

$-0.3N + 0.86P - 510 = 0 \Rightarrow P = \dfrac{510 + 0.3N}{0.86}$

$\Sigma F_y = 0$

$N - 1500\cos 20 - P\sin 30 = 0$

$N - 1409.53 - P = 0$

$\cancel{N - 1409.53 - 296.68N = 0}$

$\cancel{N = 1706.28\,N}$

$N - 296.68N = 1409.53$

$-295.68N = 1409.53$

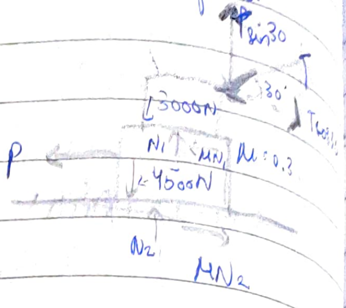
$N = 4.76$

$N - 1409 - \left(\dfrac{510 + 0.3N}{0.86}\right)\sin 30$

$N = 2064$

$P = \dfrac{510 + 0.3(2064)}{0.86} = 13\ldots N$

Q:- A block of 4500N rests on horizontal surface, supports another block of 3000N as shown. Find horizontal force P required to just move the block to left. Take coeff of friction $\mu = 0.3$ for all contact surfaces.




For block of 3000N

$\Sigma F_y = 0$

$+N_1 - 3000 - T\sin 30° = 0$

$\Rightarrow N_1 + 0.5T = 30$

$\Sigma F_x = 0$

$-0.3N_1 + T\cos 30 = 0$

$0.3N_1 = 0.86T$

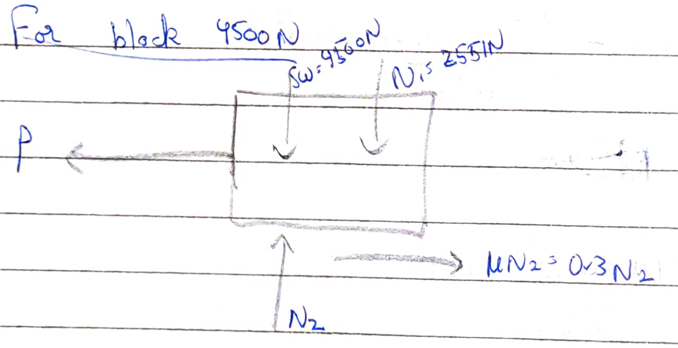
$N_1 = \frac{0.86T}{0.3} = 2.86T$

$\Rightarrow 2.86T + 0.5T = 3000$

$\Rightarrow T = 892.85\,N$

$\Rightarrow N_1 = 2.86 \times 892 = 2551\,N$

For block 4500N




$\Sigma F_y = 0$

$-4500 - 2551 + N_2 = 0$

$\Rightarrow N_2 = 7051\,N$

$\Sigma F_x = 0$

$-P + \mu N_2$

$-P + 0.3 \times 7051 + 765.3$

$P = 2880.6$

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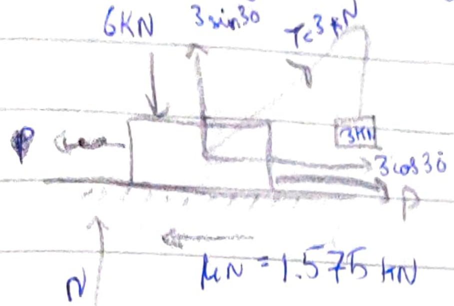
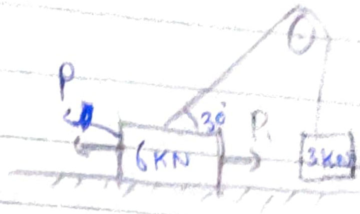
Q:- A block weighing 6KN is attached to a string which passes over a frictionless pulley & supports a weight 3KN, when coeff. of friction b/w block & the floor is 0.35 ($\mu$), determine the force P required for the following cases:

(i) Motion is impending towards right

(ii) Motion is impending towards left

Ans:- (i)




$\Sigma F_y = 0$

$N - 6 + 3\sin 30$

$N = 6 - 4.5 \Rightarrow N = 4.5$ KN

$\mu N = 1.575$ KN

$\Sigma F_x = 0$

$-1.575 - P + 3\cos 30$

$P = 3\cos 30 - 1.575 = 2.598 - 1.575$

$P = 1.023$ KN

(ii) $P = 4.17$ KN

$\Sigma F_y = 0$

$N + 3\sin 30 - 6$

$\Rightarrow N = 6 - 3\sin 30$

$N = 6 - 1.5 \Rightarrow 4.5$

$\Sigma F_x = 0$

$(0.35 \times 4.5) + 2.598 - P$

$P = 4.173$ N

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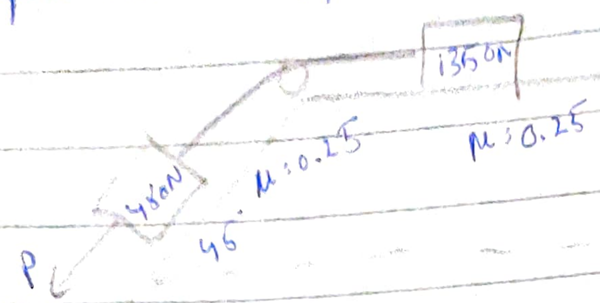
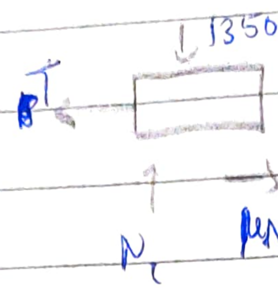
Q:- determine force P acting // to the plane as shown in the figure, to impend the motion, $\mu = 0.25$




For block 1350N




$\mu N_1 = 0.25 N \Rightarrow 337.5$

$\Sigma F_y = 0$

$N_1 - 1350N = 0$

$N_1 = 1350$

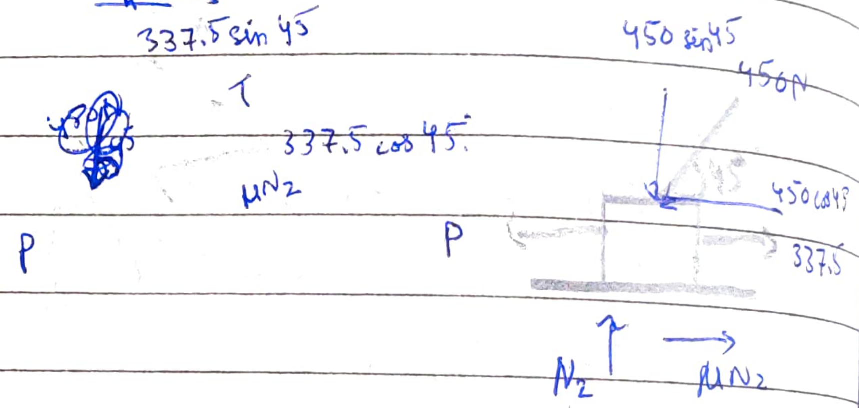
$\Sigma F_x = 0$

$+T - 337.5 = 0$

$T = 337.5$

For block 450N

$P = 98.85$




$\Sigma F_y = 0$

$N_2 - 450 \cos 45$

$N_2 = 318.19N$

$\Rightarrow \mu N_2 = 79.54N$

$\Sigma F_x = 0$

$-P - 450 \sin 45 + 337.5 + 79.54N$

$-P - 318.19 + 337.5 + 79.54$

$P = 98.85N$

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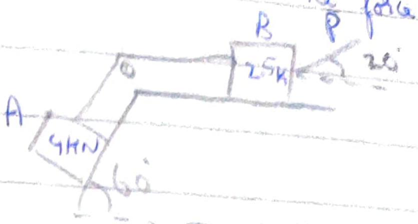
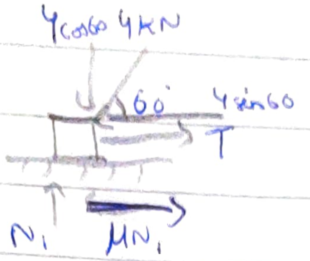
Q: Two blocks A & B weighing 4KN & 2.5KN rspt. are attached with a string, passing over a frictionless pulley as shown. Determine the force P for impending the motion. ($\mu = 0.2$)




$T = 3.884$, $P = 4.329$

Ans: For block 4KN,

$\Sigma F_x = 0$




~~$-0.2N - 4\sin 60 = 0$~~

~~$+0.2N = 3.764$~~

~~$N = 18.82$~~

$\Sigma F_y = 0$

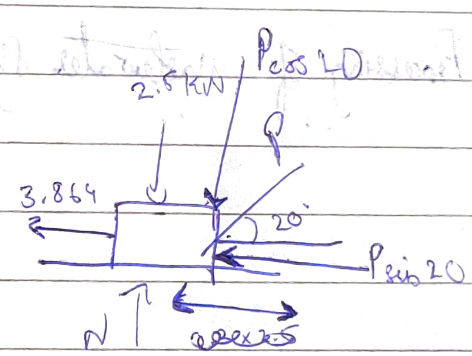
$N = 2$

$\Sigma F_x = 0$

$0.4 + T - 4\sin 60$

$T = 3.864$ KN

For block of 2.5 KN




$\Sigma F_y = 0$ $\quad N = 3.439P$

$N = 2.5 - 0.239P$

$\Sigma F_x = 0$

~~$-3.864 + P - 1.25$~~

$\Sigma F_x = 0$

$(0.2 \times 3.439P) - 3.864 - 3.42P$ $\quad -0.68P - 3.86 + 3.42P$

$0.68P - 3.86 - 3.42$

$-2.74P = 3.86$

$P = 1.408$