RAMAIAH
Institute of Technology

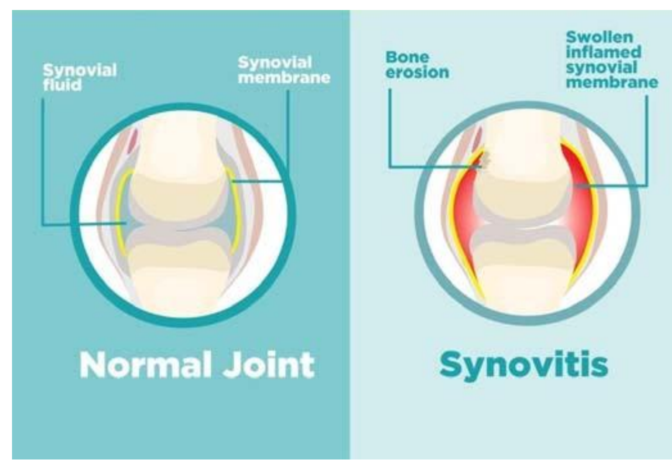
BASICIS OF CIVIL ENGINEERING & MECHANICS

Course code:CV14/CV24
Credits:3:0:0

Topic Covered
Friction

FRICTION

HERO Or VILLAIN



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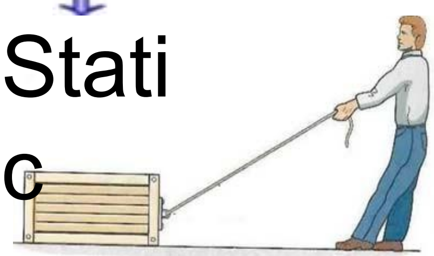

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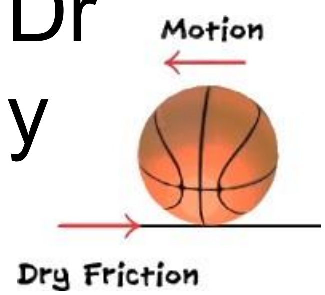

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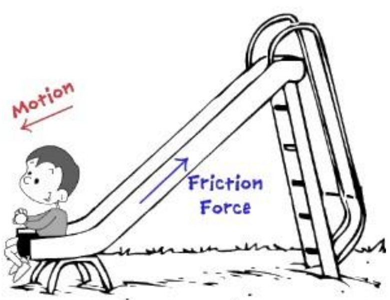
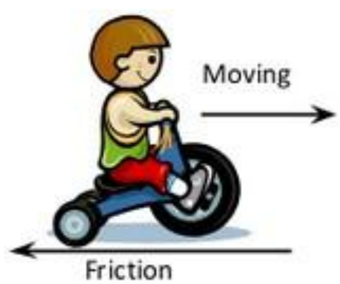


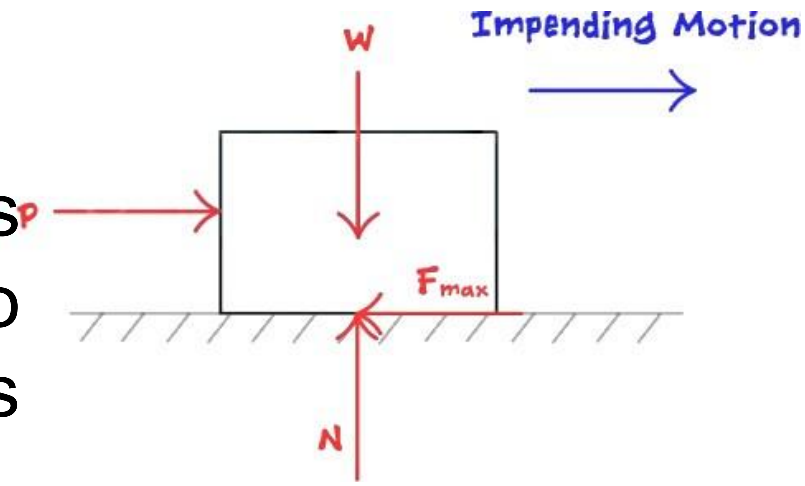
Rollin




Snow


FRICTION

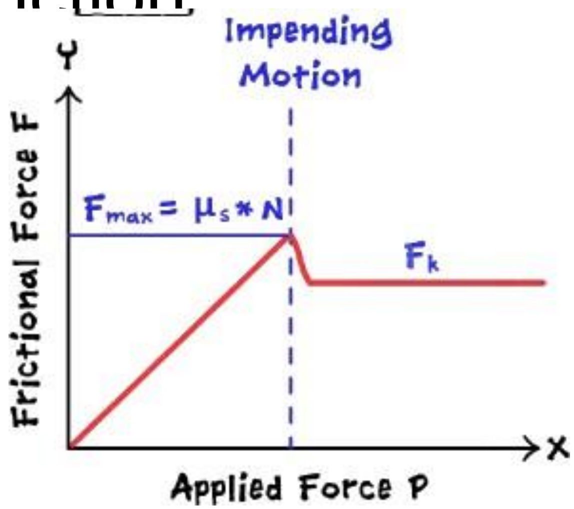
Law of Static Friction

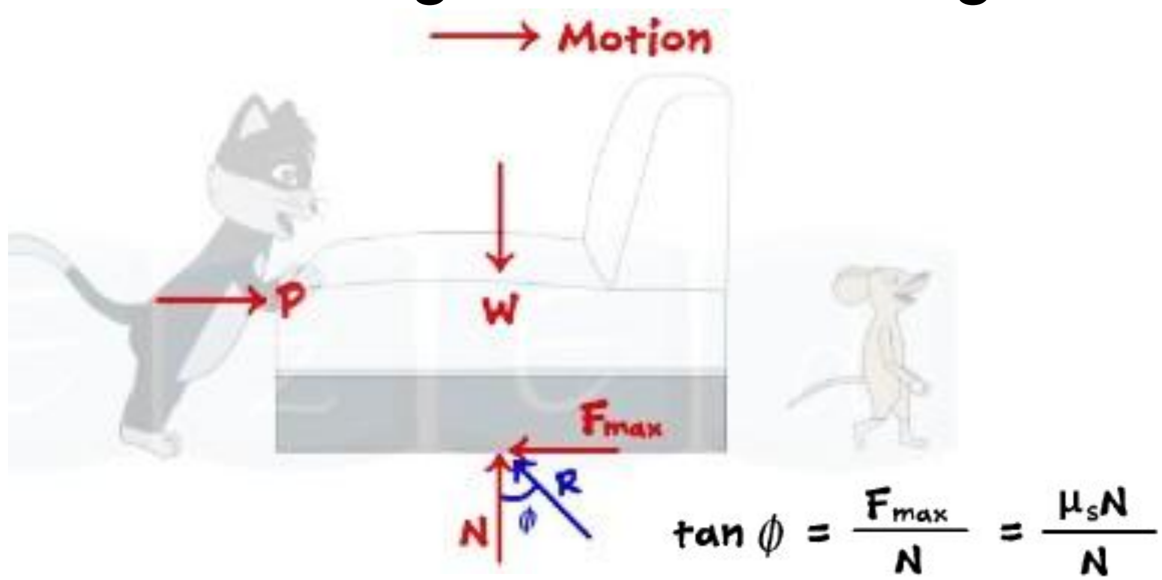


- The force of friction always acts in a direction, opposite to that in which the body tends to move.
- The magnitude of the force of friction is exactly equal to the applied force which just moves the body
- The magnitude of the limiting friction bears a constant ratio to the normal reaction between the two surfaces in contact
- The force of friction is independent of the area of contact between the two surfaces.

Basic Terms in Friction

- **Limiting Friction** The maximum static friction after which the body will start moving is called limiting friction.

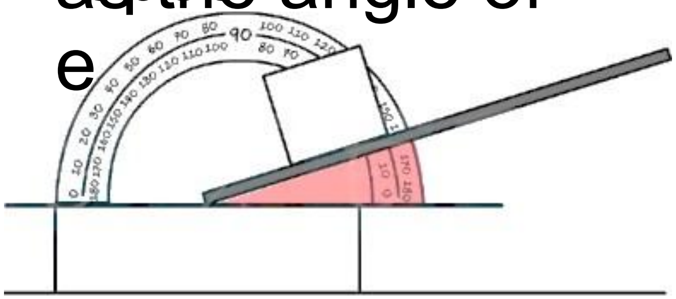




- **Angle of Friction** The angle of friction for two contacting surfaces is the angle between the resultant R (of friction force F and the normal reaction N) and the normal reaction N.

Basic Terms in Friction

- **Angle of Repose** The maximum angle made by the inclined plane with the horizontal, when the body placed on that plane is just at the point of sliding down the plane without any external force is known as the angle of repose



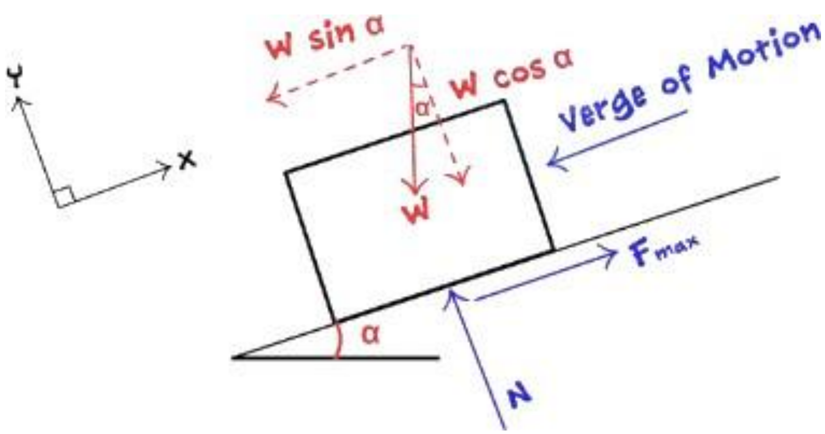
Apply COE

$$\mu_s N - W \sin\alpha = 0 \;....(i)$$

$$N = W\cos\alpha ....(ii)$$

$$\mu_s (W\cos\alpha) - W\sin\alpha = 0$$

$$\tan\alpha = \mu_s \qquad \alpha = \tan^{-1}\mu_s$$



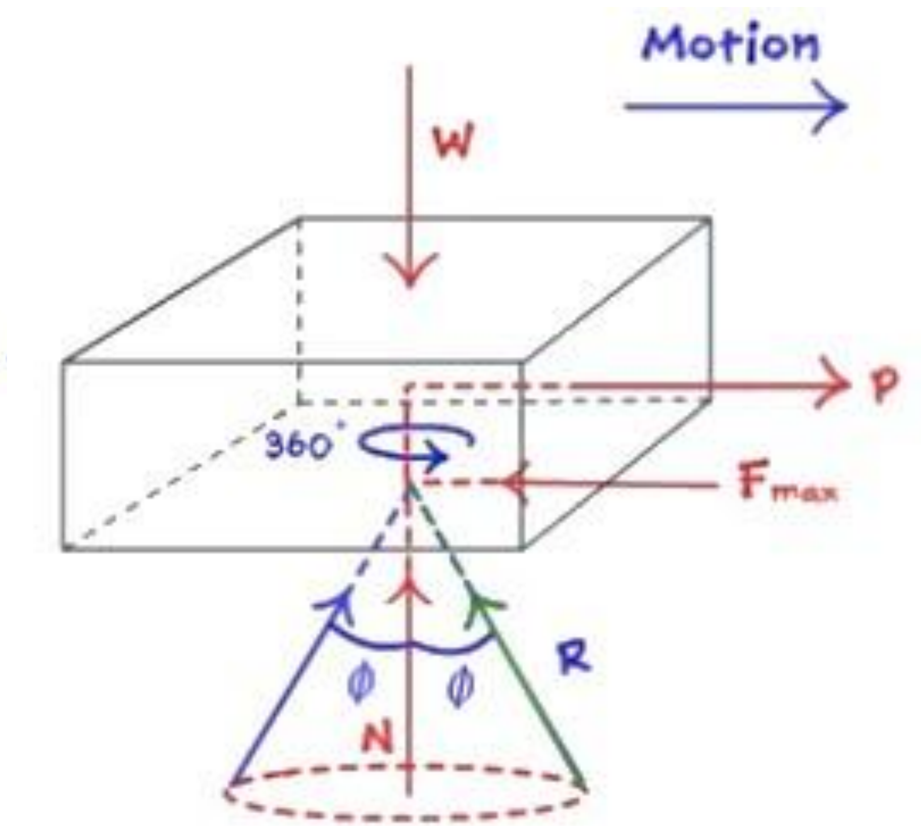
We know that,

$$\phi = \tan^{-1}\mu_s$$

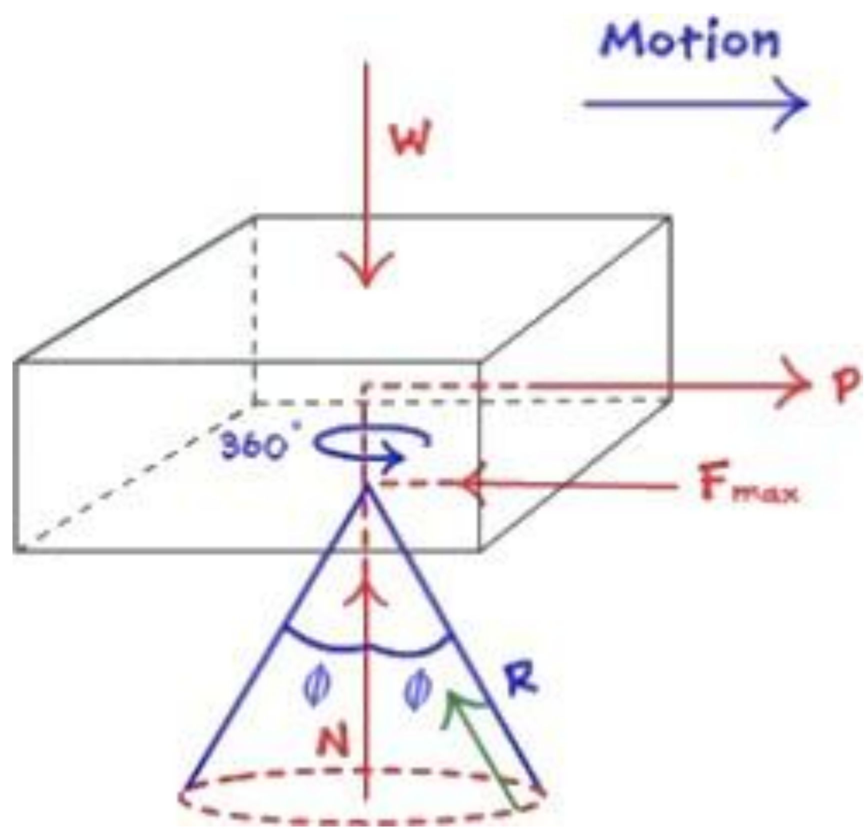
$$\alpha = \phi$$

Basic Terms in Friction

- Cone of Friction

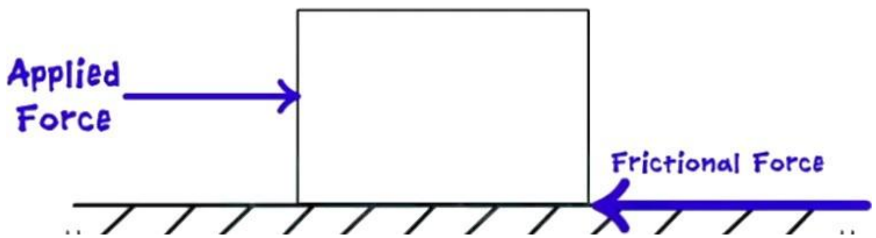


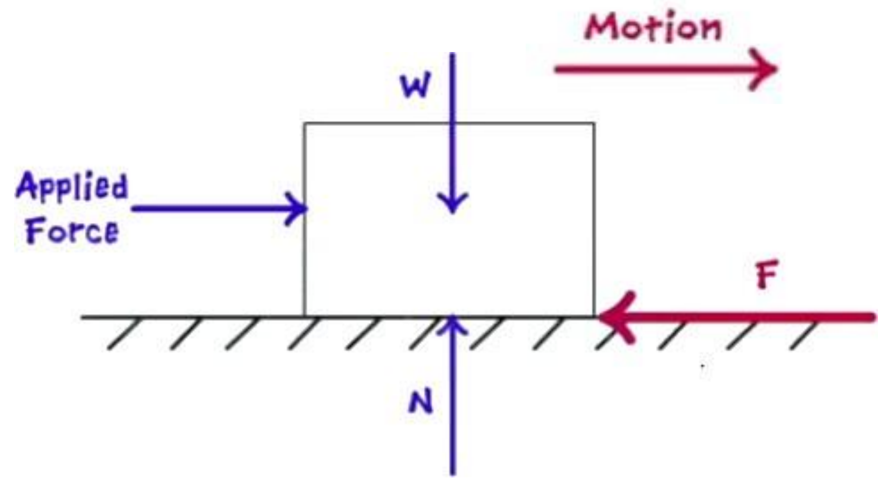
Static body under verge of motion

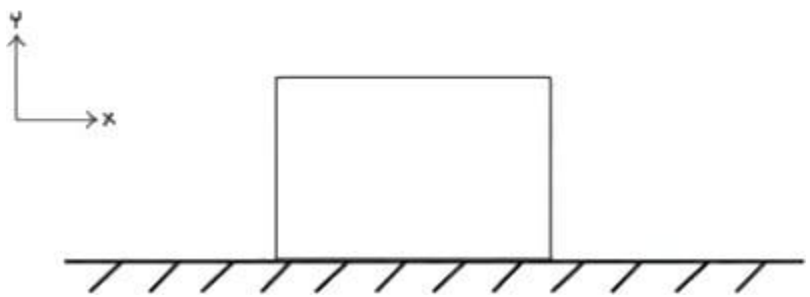


Static body under Equilibrium

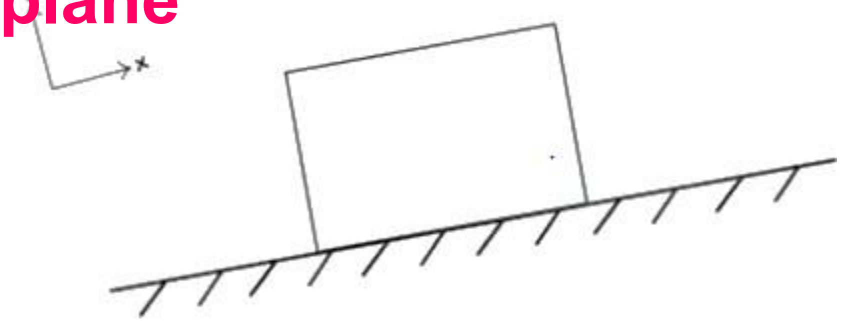
Block Friction







- Block Friction on Horizontal plane



- Block Friction on Inclined plane

Apply COE to the system

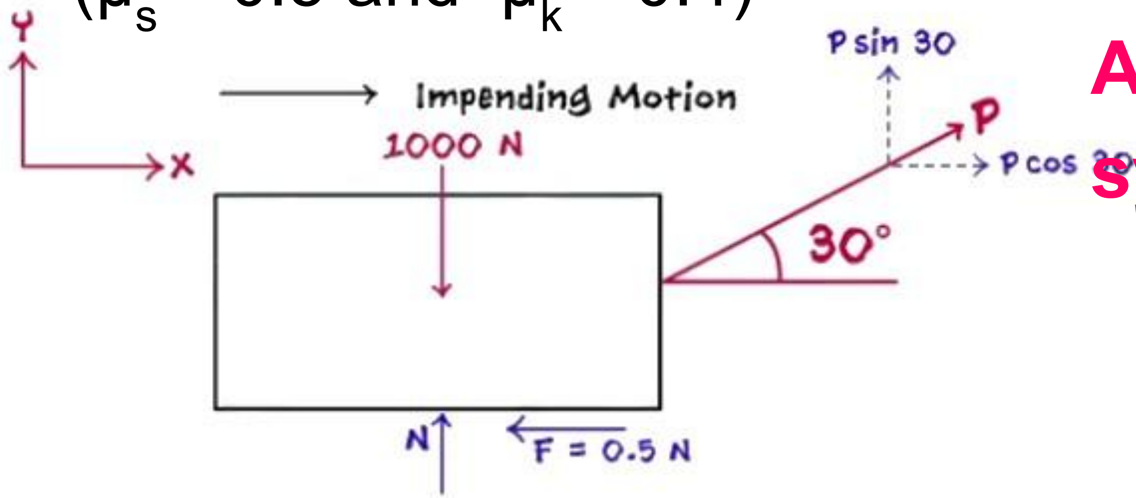
$\sum F_X = 0$ ⇨ +ve

$\sum F_Y = 0$ ⇧ +ve

Find Unknowns

Block Friction on Horizontal Plane

1. A block of weight 1000N is kept on a rough horizontal surface
. A force P is applied on the block to induce the motion. Find the magnitude of force ‘P’ for motion to just impend. ($\mu_s = 0.5$ and $\mu_k = 0.4$)



FBD

Apply COE to the system

$\sum F_X = 0$ **+ ve**

$P - \cos 30 - 0.5N = 0$

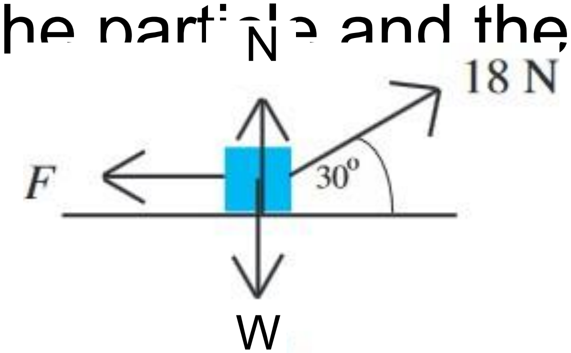
N = 1.732P

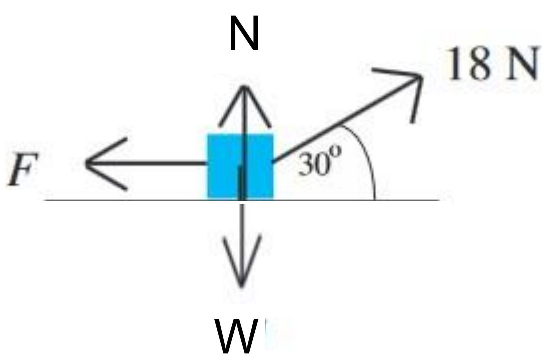
$N - 1000 + P \sin 30$

$\sum F_Y = 0$ **+ ve**

P = 448.02 N

2. A force of 18 N acts on a particle, of mass 7.5 kg, at an angle of 30◦above the horizontal. The particle is on a rough horizontal plane. Given that the particle is on the point of slipping, what is the coefficient of friction, between the particle and the plane?





FBD

Apply COE to the system

$\Rightarrow$ $\sum F_X = 0$ **+ve**

$F = 18 \cos 30 = \mu_s * N$

$\Uparrow$ $\sum F_Y = 0$ **+ve**

$N = 7.5*9.81 + 18 \sin 30 = 0$ $N = 7.5*9.81 - 18 \sin 30$

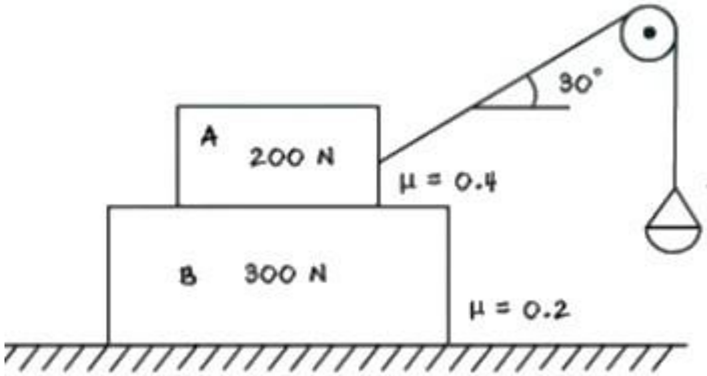
$18 \cos 30 = \mu_s(7.5*9.81 - 18 \sin 30)$

$\mu s = 0.24$

$ma = 18 \cos 30 − 0.24(7.5*9.81 − 18 \sin 30)$

$a = 0.012\ m/s^2$

3. Block A is on block B which is resting on the ground. Block A is attached to a string which is connected to a pan carrying some weight, P. Find the minimum value of weight in the pan so that motion can start. (Ground & ... ck A &



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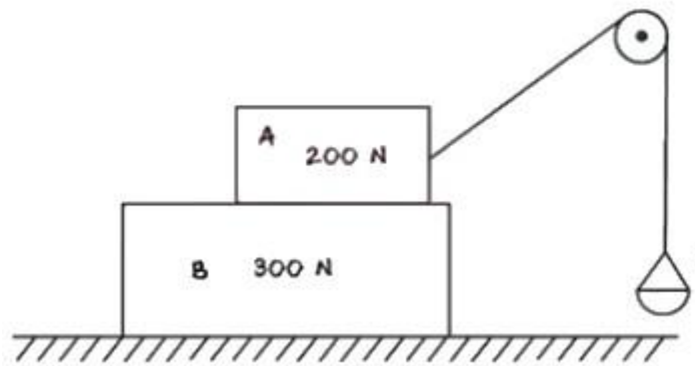

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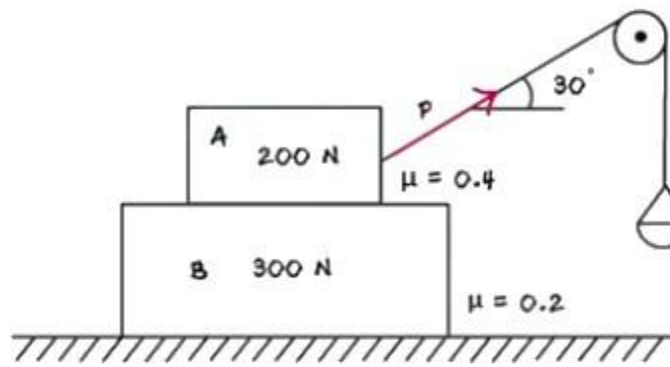
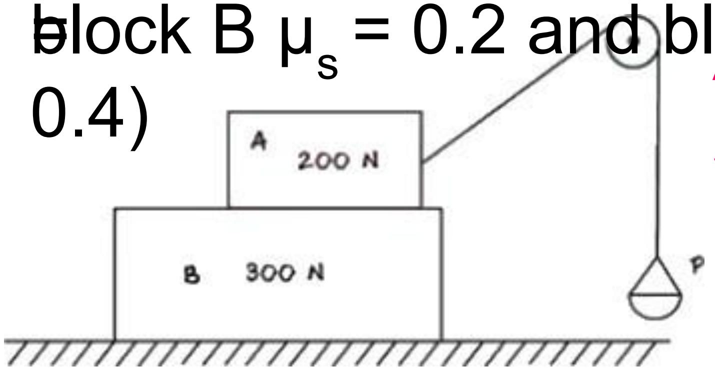
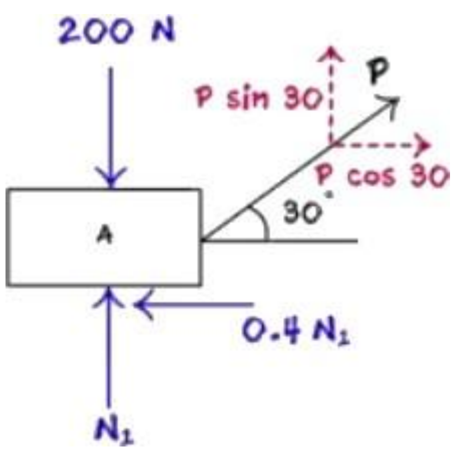


3. Block A is on block B which is resting on the ground. Block A is attached to a string which is connected to a pan carrying some weight, P. Find the minimum value of weight in the pan so that motion can start. (Ground & block B $\mu_s = 0.2$ and block A & B $\mu_s = 0.4$)



Apply COE to the system



$\Sigma F_x = 0 \ldots \rightarrow +ve$

$P \cos 30 - 0.4 N_1 = 0$

$N_1 = \dfrac{P \cos 30}{0.4}$ $\quad N_1 = 2.165\ P$

$\Sigma F_y = 0 \ldots \uparrow +ve$

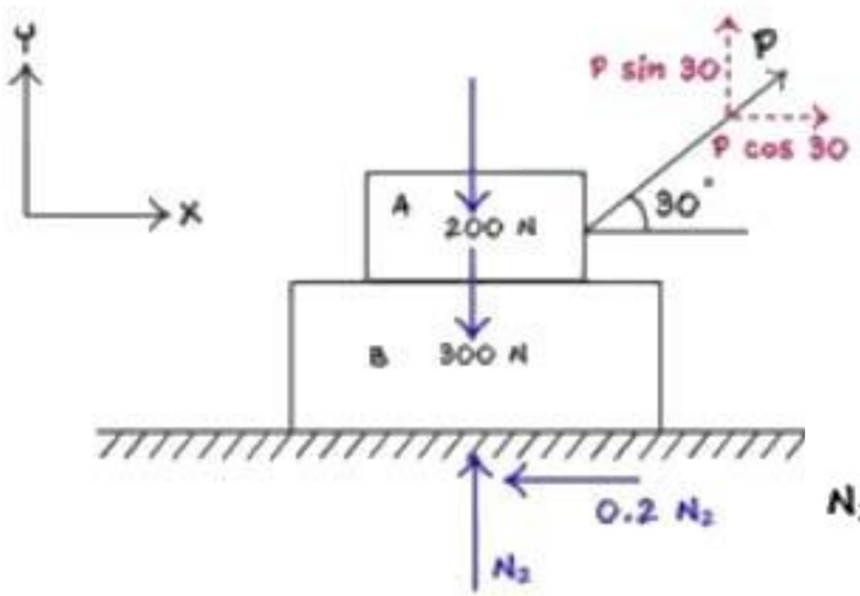
$N_1 - 200 + P \sin 30 = 0$

$2.165\ P - 200 + P \sin 30 = 0$

$P = 75.05\ N$

3. Block A is on block B which is resting on the ground. Block A is attached to a string which is connected to a pan carrying some weight, P. Find the minimum value of weight in the pan so that motion can start. (Ground & block B μ_s = 0.2 and block A & B μ_s 0.4)

Apply COE to the system



$\Sigma F_x = 0 \ldots\ldots \rightarrow +ve$

$P \cos 30 - 0.2 N_2 = 0$

$$N_2 = \frac{P \cos 30}{0.2}$$

$N_2 = 4.33\ P$

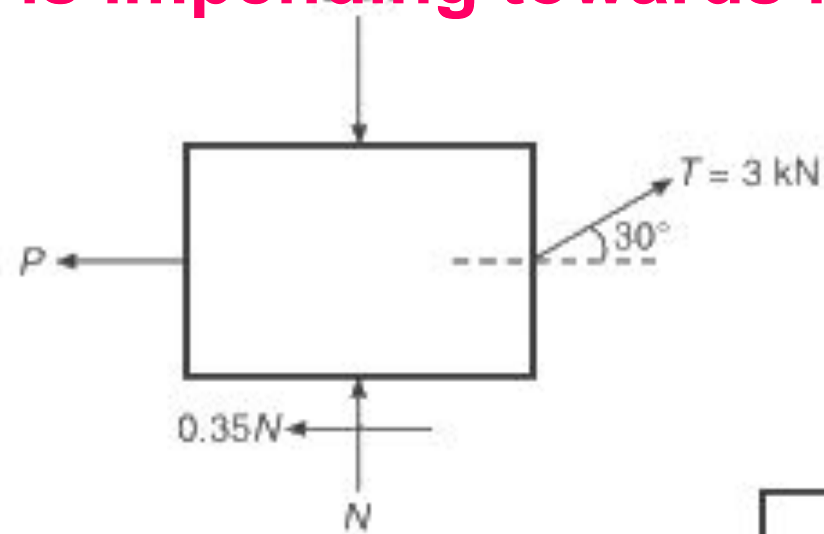
$\Sigma F_y = 0 \ldots\ldots \uparrow +ve$

$N_2 - 200 - 300 + P \sin 30 = 0$

$4.33\ P - 500 + P \sin 30 = 0$

$P = 103.52\ N$

4. A block weighing 6 kN is attached to a string, which passes over a frictionless pulley and supports a weight of 3kN. Determine the value of force P when the (i) motion is impending towards right. (ii) motion is impending towards left. μ = 0.35 **Case 1: When motion is impending towards right**



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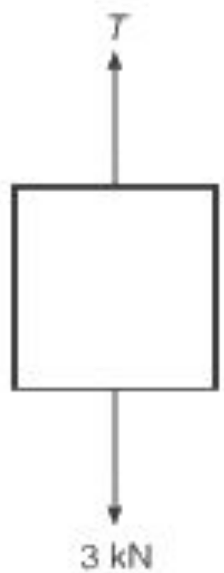


Apply COE to the system

$\sum F_Y = 0$ ↑ **+ve**

$3 \sin 30° – 6 + N = 0$

N = 4.5 kN

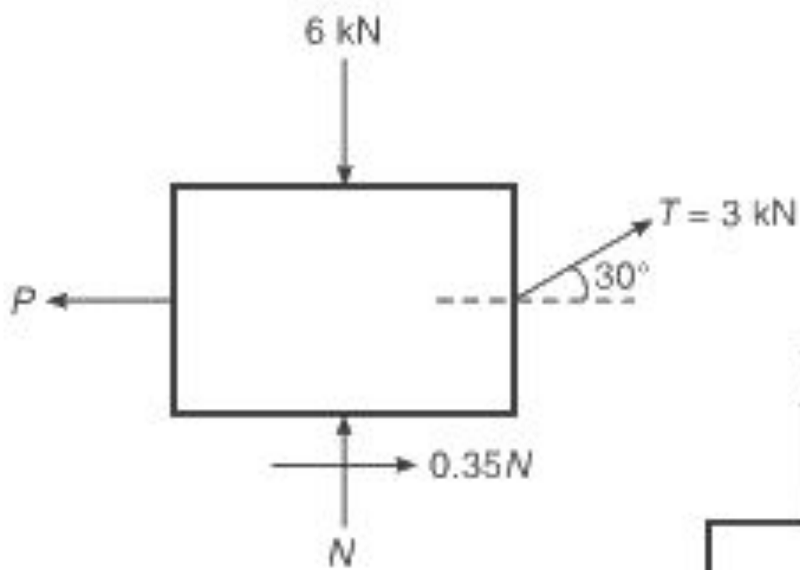
$\sum F_X = 0$ → **+ve**

$–P + 3 \cos 30° – 0.35 N = 0$

P = 1.023 kN

4. A block weighing 6 kN is attached to a string, which passes over a frictionless pulley and supports a weight of 3kN. Determine the value of force P when the (i) motion is impending towards right. (ii) motion is impending towards left. μ = 0.35 **Case 1: When motion**

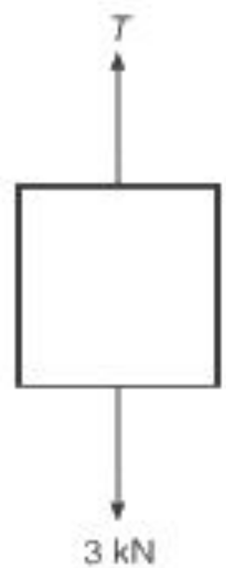
eft



Apply COE to the system

$\sum F_Y = 0$ **+ve** 3 sin 30° – 6 + N = 0 **N = 4.5 kN**

FBD



$\sum F_X = 0$ **+ve**

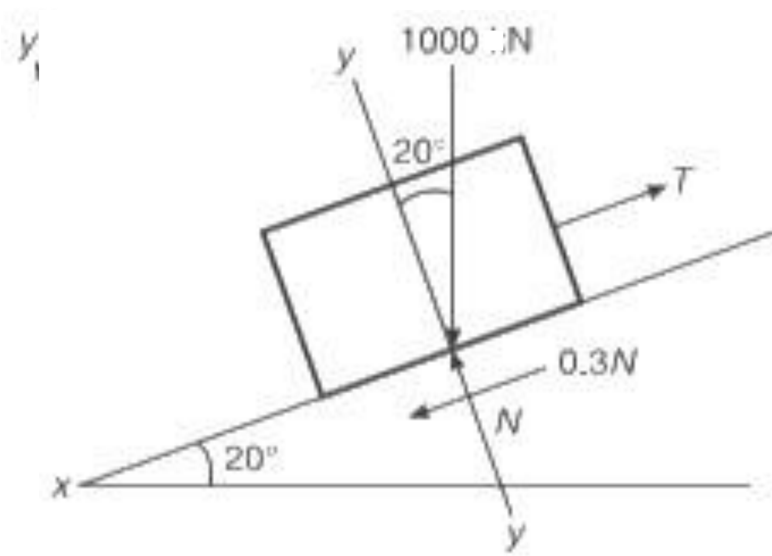
– P + 3 cos 30° + 0.35 N = 0

P = 4.173 kN

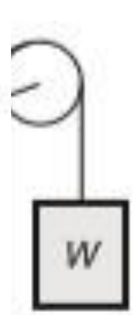
Block Friction on Inclined Plane

1. Calculate the value of W required for (i) To cause the body to move in the upward direction. (ii) To cause the body to move in the downward direction. Take μ = 0.3.

Case 1: When motion is impending towards upward



FBD



Apply COE to the system

$\sum F_Y = 0$ **+ve** ↑

$-1000 \cos 20° + N = 0$

N = 939.693 N

$\sum F_X = 0$ **+ve** →

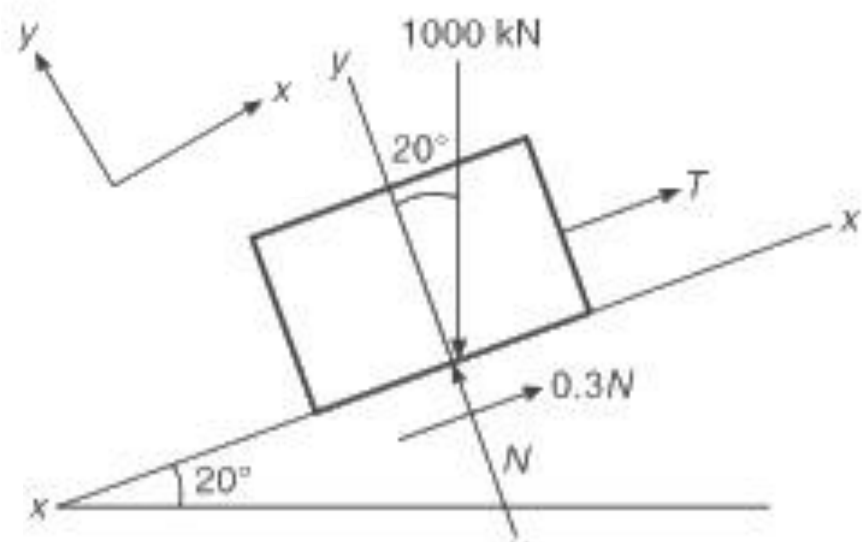
$T - 0.3 * 939.693 - 1000 \sin 20° = 0$

T = 623.911 kN

Block Friction on Inclined Plane

1. Calculate the value of W required for (i) To cause the body to move in the upward direction. (ii) To cause the body to move in the downward direction. Take μ = 0.3.

Case 1: When motion is impending towards downward



FBD

Apply COE to the system

$\sum F_Y = 0$ ⇧ **+ve**

$-1000 \cos 20° + N = 0$

N = 939.693 N

$\sum F_X = 0$ ⇨ **+ve**

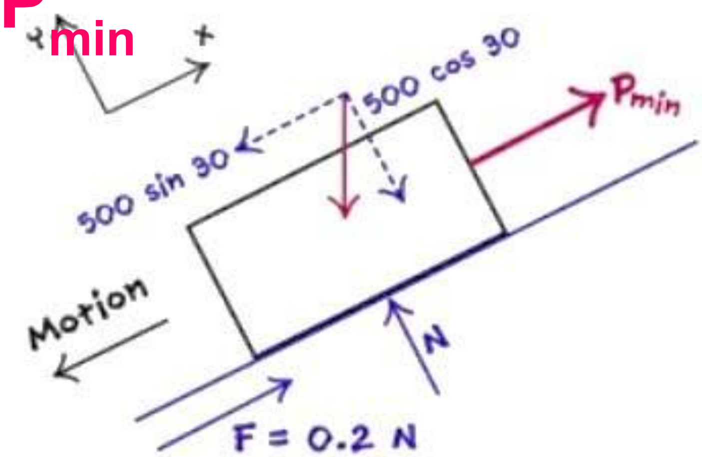
$T + 0.3N - 1000 \sin 20° = 0$

T = 60.112 kN

Block Friction on Inclined Plane

1. A block of weight 500N is placed on a inclined plane. A force P is applied parallel to inclined plane on the block to keep it in equilibrium. Determine the range of values of force 'P' for which the block will be in equilibrium. (μ = 0.2)

Case 1: P_{min}



FBD

Apply COE to the system

$\sum F_Y = 0$ ⇧ **+ve**

$N - 500\cos 30 = 0$

$N = 433$ N

$\sum F_X = 0$ ⇨ **+ve**

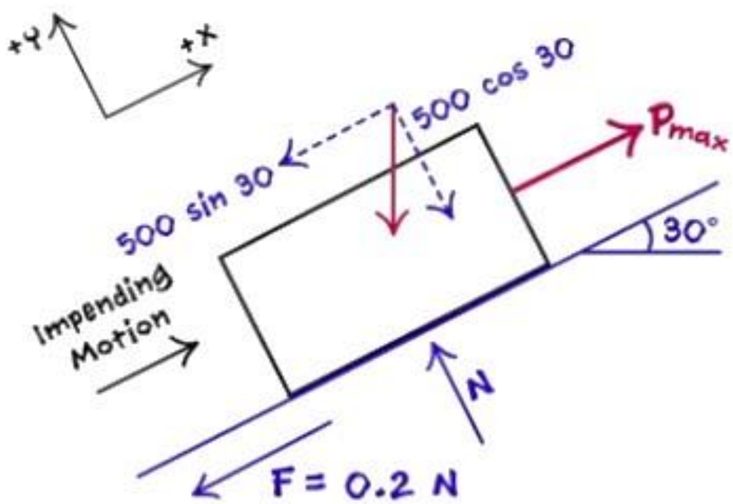
$P_{min} - 500\sin 30 + 0.2N = 0$

$P_{min} = 163.4$ N

Block Friction on Inclined Plane

2. A block of weight 500N is placed on a inclined plane. A force P is applied parallel to inclined plane on the block to keep it in equilibrium. Determine the range of values of force 'P' for which the block will be in equilibrium. ($\mu = 0.2$)

Case 2:



FBD

Apply COE to the system

$\sum F_Y = 0$ ↑+ve

$N - 500\cos 30 = 0$

$N = 433$ N

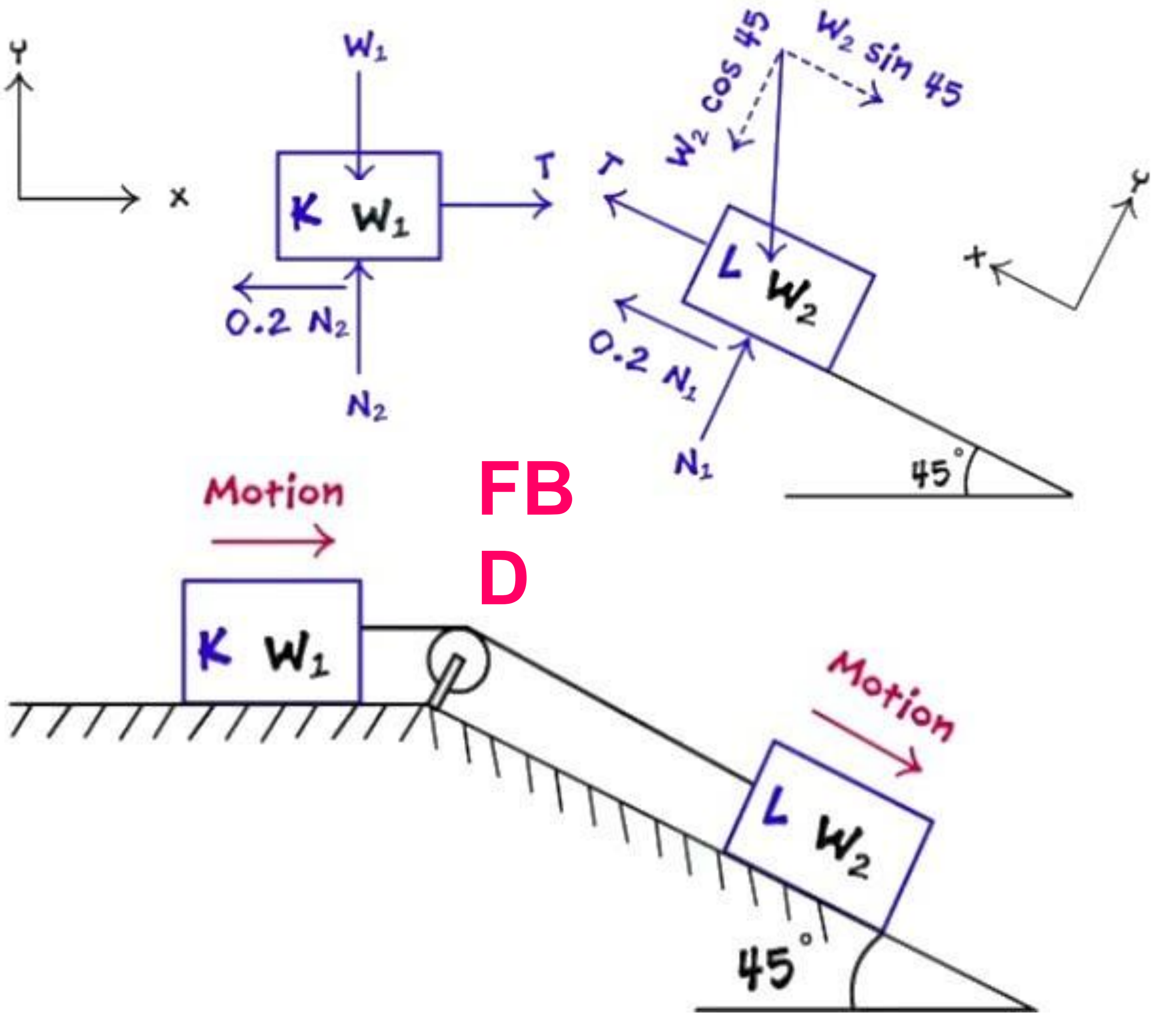
$\sum F_X = 0$ ⇨+ve

$P_{max} - 500\sin 30 - 0.2N = 0$

$P_{min} = 336.6$ N

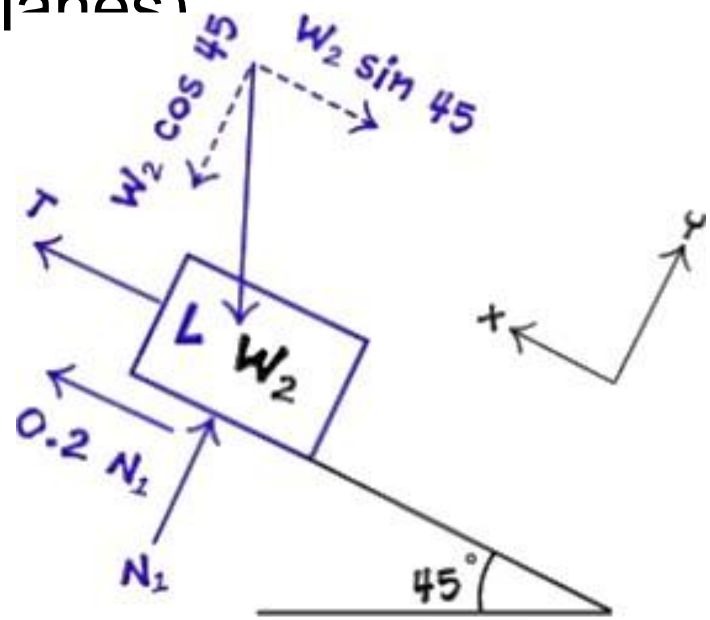
163.4 N ≤ P ≤ 336.6 N

3. A string passes through a small pulley connecting 2 blocks (K and L) weighing W_1 and W_2. One block is on horizontal plane and other on inclined plane. Calculate the min ratio of W_1/W_2 to maintain equilibrium. (μ = 0.2 for both the planes)



FBD

3. A string passes through a small pulley connecting 2 blocks weighing W_1 and W_2. One block is on horizontal plane and other on inclined plane. Calculate the min ratio of W_1/W_2 to maintain equilibrium. (μ = 0.2 for both the planes)



FBD

Apply COE Inclined plane (L) ⇧

$\sum F_Y = 0$ **+ ve**

$N_1 - W_2 \cos 45 = 0$

$N_1 = 0.707\, W_2$

⇨

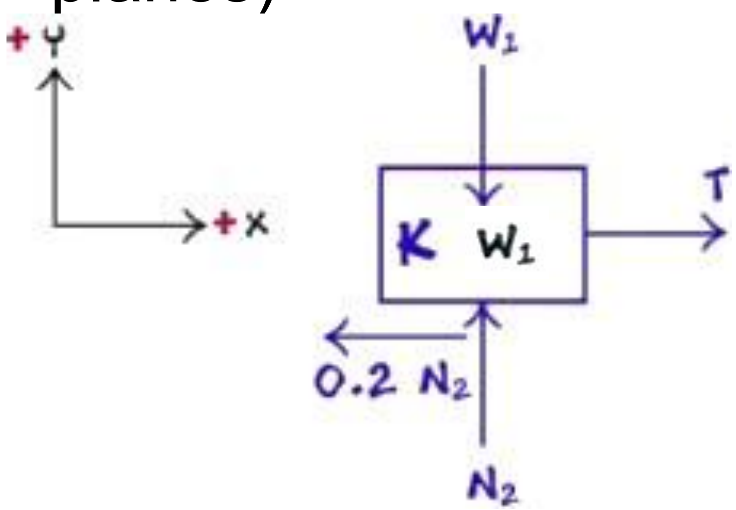
$\sum F_X = 0$ **+ ve**

$- T - 0.2\, N_1 + W_2 \cos 45 = 0$

T = 0.566 W2

3. A string passes through a small pulley connecting 2 blocks weighing W_1 and W_2. One block is on horizontal plane and other on inclined plane. Calculate the min ratio of W_1/W_2 to maintain equilibrium. (μ = 0.2 for both the planes)

$N_1 = 0.707\ W_2$ **$T = 0.566\ W_2$**



FBD

Apply COE Horizontal plane (K)

$\sum F_Y = 0 \Uparrow$ **+ve**

$N_2 - W_1 = 0$

$N_2 = W_1$

$\sum F_X = 0 \Rightarrow$ **+ve**

$T - 0.2\ N_2 = 0$

$0.556\ W_2 - 0.2\ W_1 = 0$

$W_1 / W_2 = 2.83$

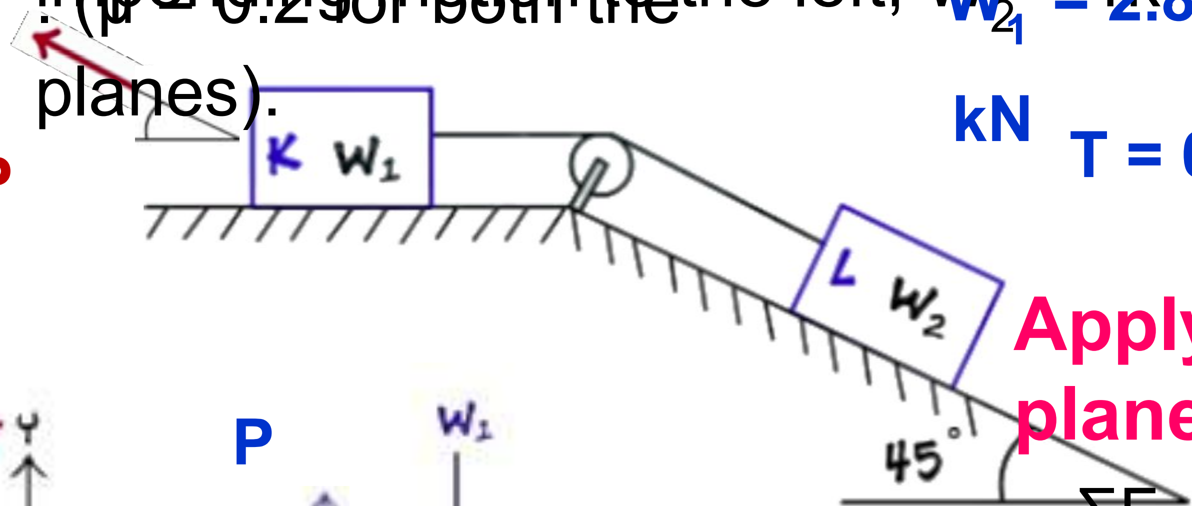
4. A string passes through a small pulley connecting 2 blocks weighing W_1 and W_2. One block is on horizontal plane and other on inclined plane. Find the least value of P required to cause the system of blocks to have impending motion to the left, W_1 = 1kN. (μ = 0.2 for both the planes).

W_2 = 2.83 kN

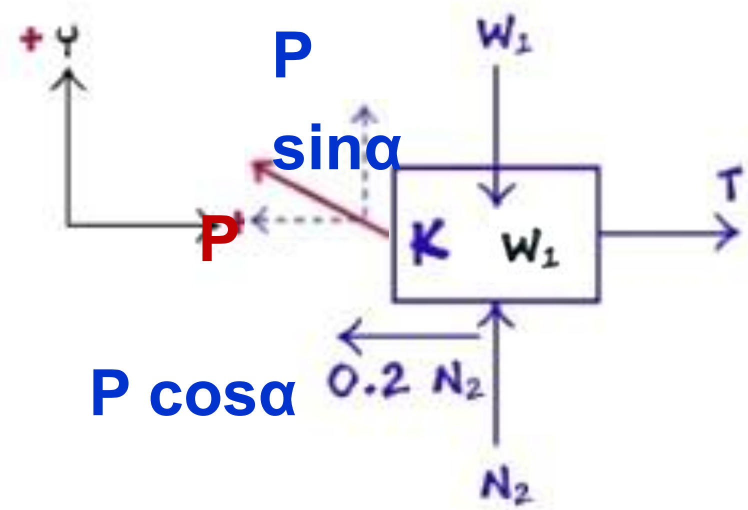
N_1 = 0.707 kN

T = 0.566 kN

P



Apply COE Horizontal plane



P sinα

P

P cosα

FBD

$\sum F_Y = 0$ **+ ve**

$N_2 + P \sin\alpha - W_1 = 0$

$\Rightarrow$ **$N_2 = 2.83 - P \sin\alpha$**

$\sum F_X = 0$ **+ ve**

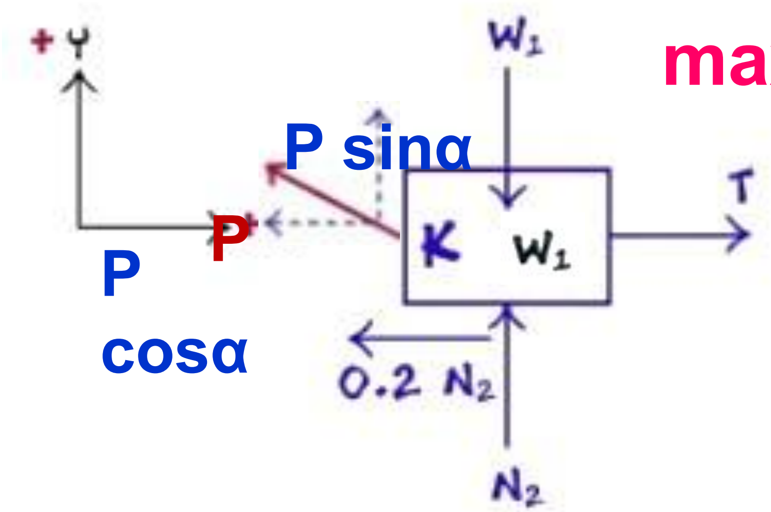
$0.566 - 0.2N_2 + P \cos\alpha = 0$

$P = 1/(\cos\alpha + 0.2 \sin\alpha)$

2. A string passes through a small pulley connecting 2 blocks weighing W_1 and W_2. One block is on horizontal plane and other on inclined plane. Find the least value of P required to cause the system of blocks to have impending motion to the left. W_2 = 1kN

: (μ = 0.2 for both the planes).

P is min, when the denominator is max



FBD

$$\frac{d}{d\alpha}(\cos\alpha + 0.2\sin\alpha) = 0$$

$-\sin\alpha + 0.2\cos\alpha = 0$

$\tan\alpha = 0.2$ **α = 11.31**

$P_{min} = 1/(\cos\alpha + 0.2\sin\alpha)$

P_{min} = 0.98 kN