



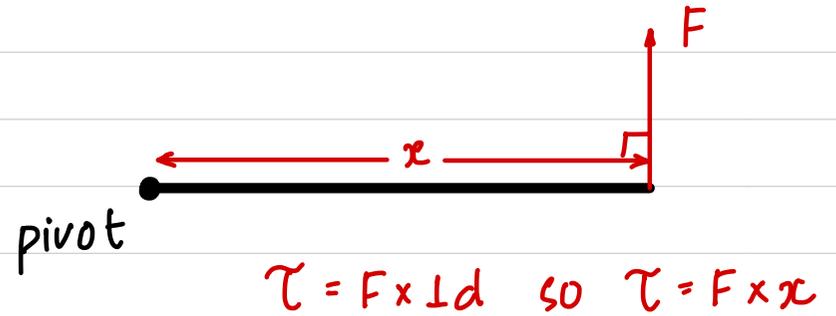
# TURNING EFFECT

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Kashan Rasid

# Moment of force / Torque

It is the product of force and perpendicular distance from the pivot to the line of action of force.



$$\tau = F \times \perp d$$

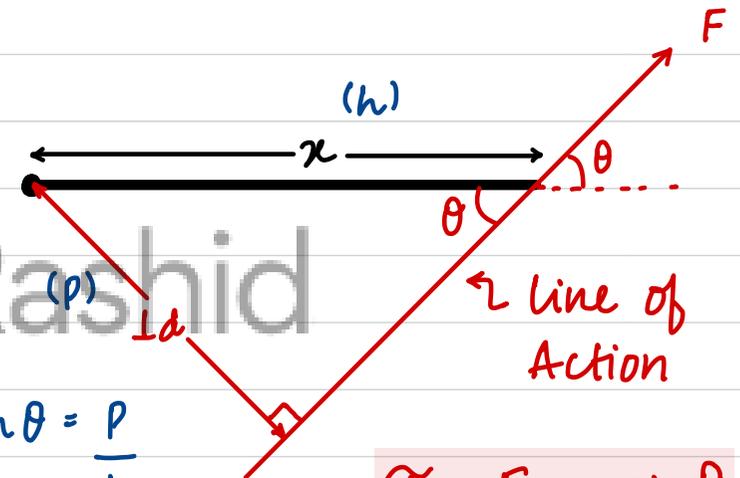
Torque

perpendicular

SI Unit: Nm

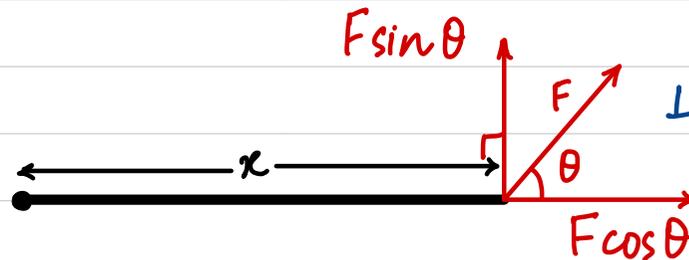
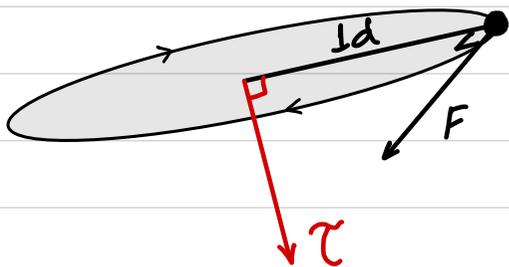
Vector Quantity

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$$\sin \theta = \frac{\perp d}{x}$$

$$\perp d = x \sin \theta$$



$$\tau = F \sin \theta \times x$$

$F \cos \theta$  doesn't produce any turning effect as it passes through pivot. NO PERPENDICULAR DISTANCE!

$$\tau = F \times L_d$$

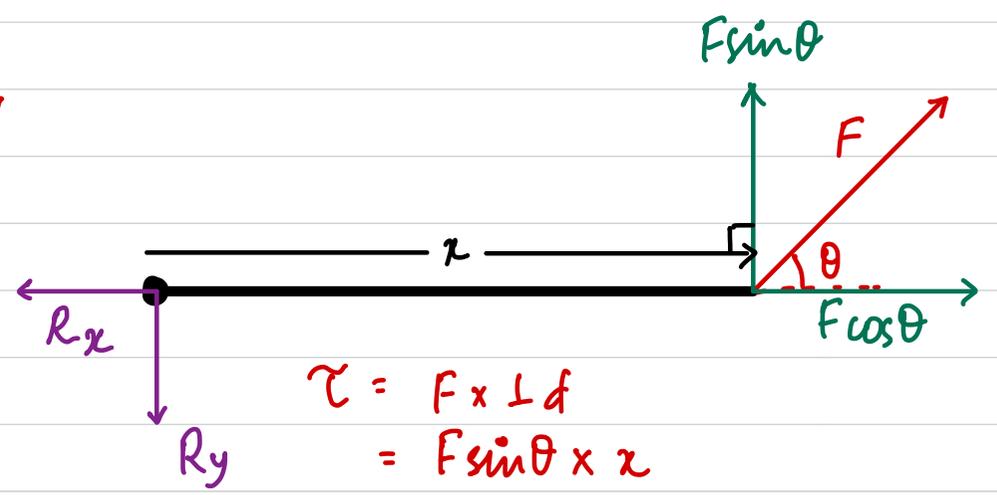
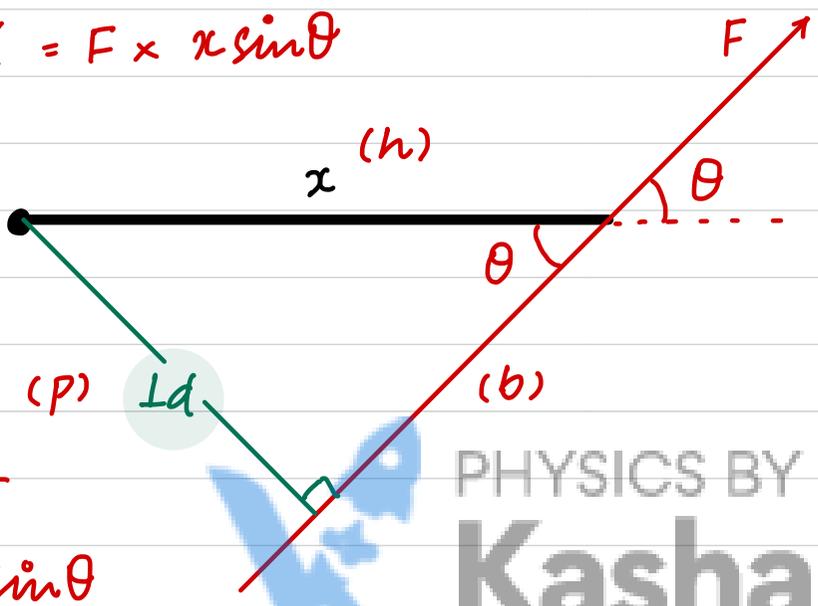
$$\tau = F \times x \sin \theta$$

$$\sin \theta = \frac{p}{h}$$

(p)  $L_d$

$$\sin \theta = \frac{L_d}{x}$$

$$L_d = x \sin \theta$$



$$\tau = F \times L_d$$

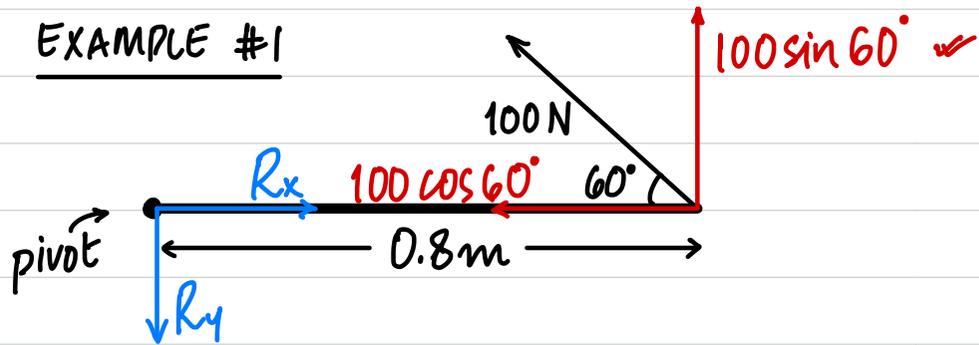
$$= F \sin \theta \times x$$

$$R_x = F \cos \theta$$

$$R_y = F \sin \theta$$

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### EXAMPLE #1



Calculate the moment produced by 100 N force.

$$\tau = F \times L_d$$

$$\tau = 100 \sin 60^\circ \times 0.8$$

$$\tau = 69.3 \text{ Nm}$$

As the rod only rotates, but not translates, the  $\sum F_x$  &  $\sum F_y$  must be zero.

$$\sum F_x = 0$$

$$R_x = 100 \cos 60^\circ$$

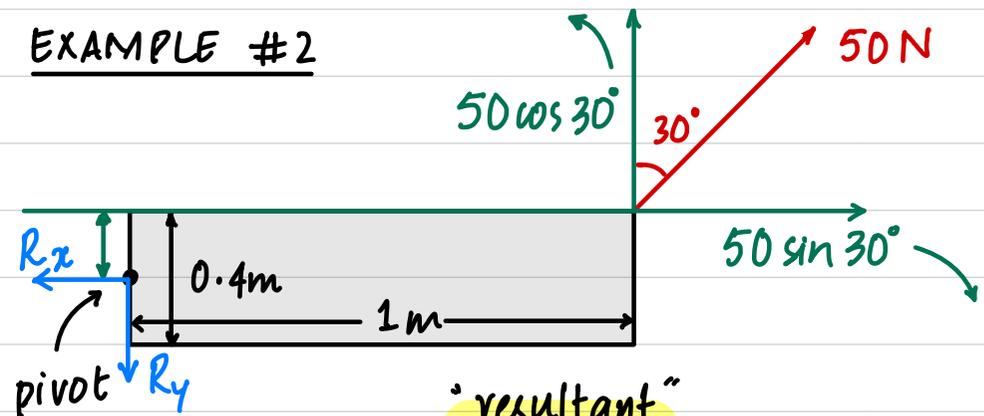
$$R_x = 50 \text{ N}$$

$$\sum F_y = 0$$

$$R_y = 100 \sin 60^\circ$$

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

### EXAMPLE #2



Calculate the "resultant" moment produced by 50 N force.

$$\tau_{\text{resultant}} = (50 \cos 30^\circ \times 1) - (50 \sin 30^\circ \times 0.2)$$

$$\tau_{\text{resultant}} = 38.3 \text{ Nm}$$

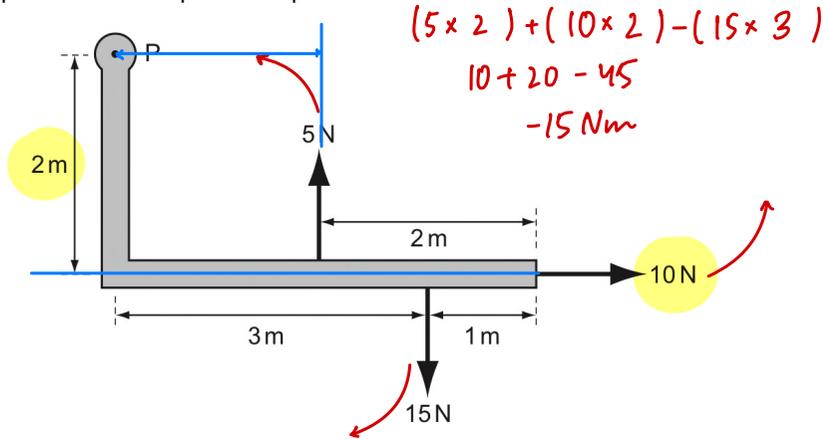
$$R_x = 50 \sin 30^\circ$$

$$R_x = 25 \text{ N}$$

$$R_y = 50 \cos 30^\circ$$

$$R_y = 43.3 \text{ N}$$

- 13 A rigid L-shaped lever arm is pivoted at point P.



Three forces act on the lever arm, as shown in the diagram.

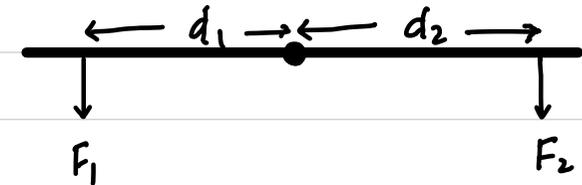
What is the magnitude of the resultant moment of these forces about point P?

- A 15 Nm    B 20 Nm    C 35 Nm    D 75 Nm

# Principle of Moments

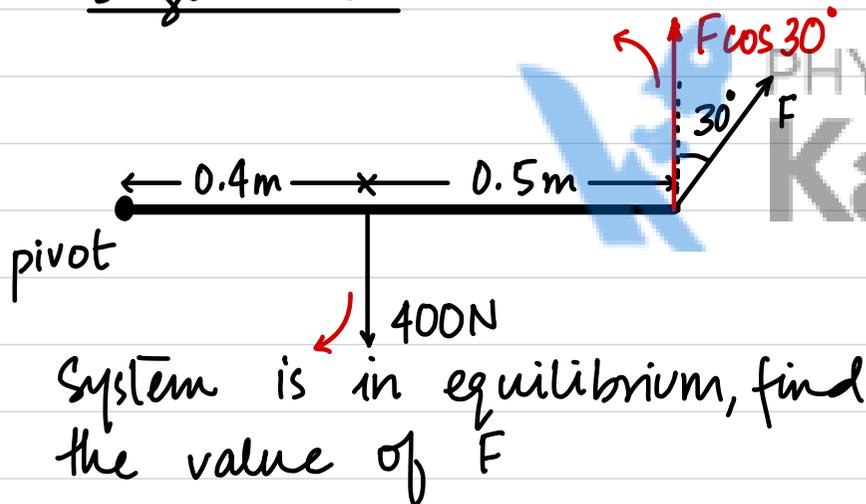
- For an object to be in equilibrium
- the sum of clockwise moments must be equal to the sum of anticlockwise moments.

$$\sum \tau_{\text{clockwise}} = \sum \tau_{\text{ant}}$$



$$F_1 \times d_1 = F_2 \times d_2$$

## Single Pivot



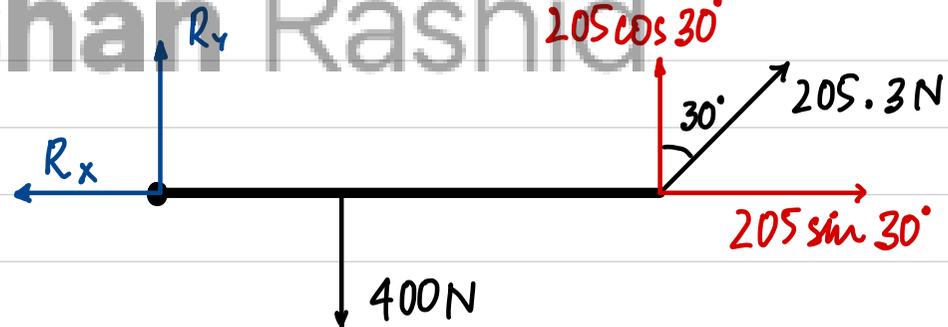
System is in equilibrium, find the value of  $F$

$$\sum \tau_c = \sum \tau_{ac}$$

$$400 \times 0.4 = F \cos 30^\circ \times 0.9$$

$$F = 205.3 \text{ N}$$

ROTATIONAL EQUILIBRIUM



$$\sum F_x = 0$$

$$R_x = 205 \sin 30^\circ$$

$$R_x = 102.5 \text{ N}$$

$$\sum F_y = 0$$

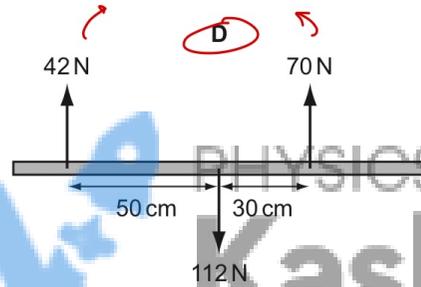
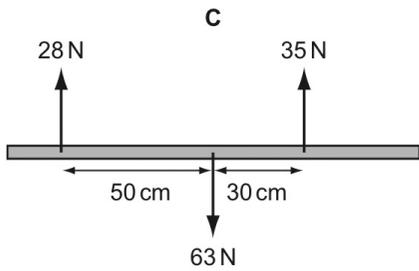
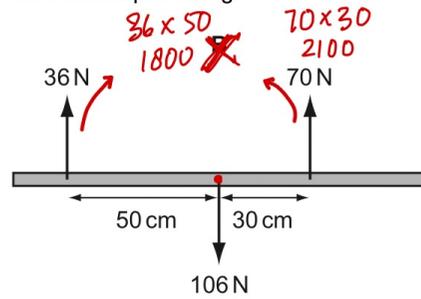
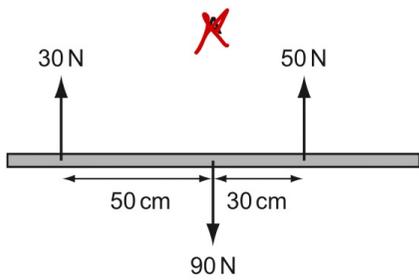
$$R_y + 205 \cos 30^\circ = 400$$

$$R_y = 222 \text{ N}$$

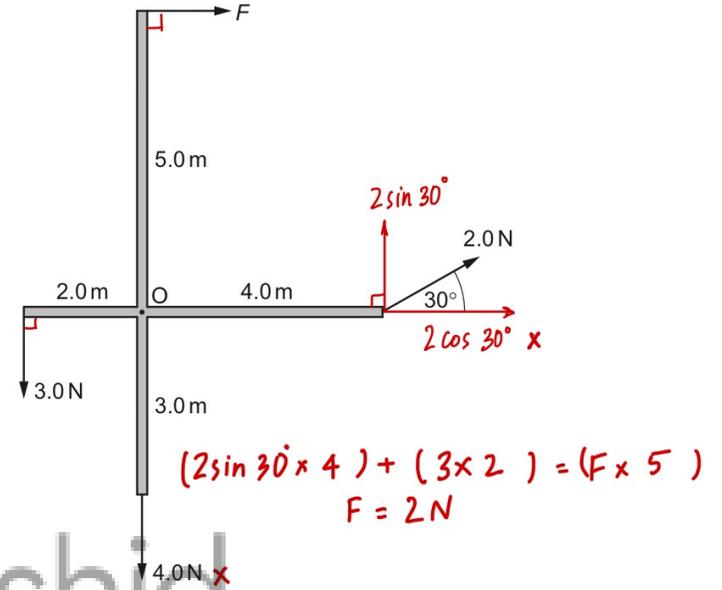
TRANSLATIONAL EQUILIBRIUM

- 16 Four beams of the same length each have three forces acting on them.

Which beam has both zero resultant force and zero resultant torque acting?



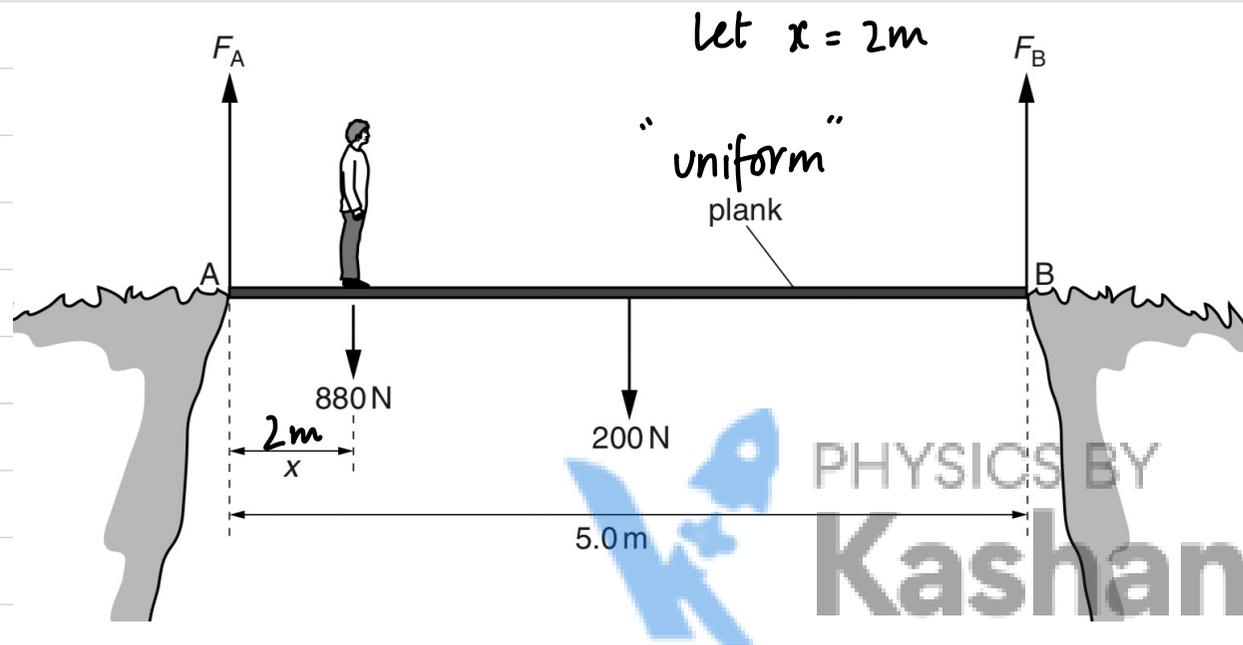
- 15 A cross-shaped structure, freely pivoted at O, has arms of lengths 5.0m, 4.0m, 3.0m and 2.0m. It is acted on by forces of 2.0N, 3.0N, 4.0N and an unknown force  $F$ . The structure is in rotational equilibrium.



What is the magnitude of force  $F$ ?

- A 0.40 N    B 2.0 N    C 2.6 N    D 4.4 N

## Double Pivot



If the plank is in Equilibrium, find the values of  $F_A$  &  $F_B$ .

$$\sum F_y = 0$$

$$F_A + F_B = 880 + 200$$

$$F_A + F_B = 1080$$

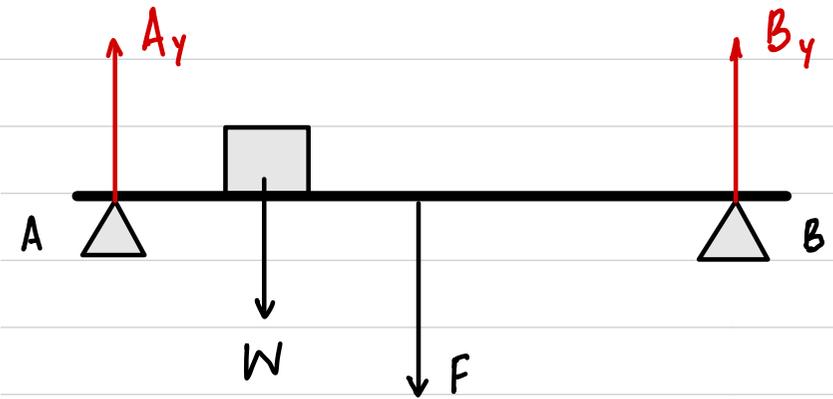
Taking A as pivot

$$(880 \times 2) + (200 \times 2.5) = F_B \times 5$$

$$F_B = 452\text{N}$$

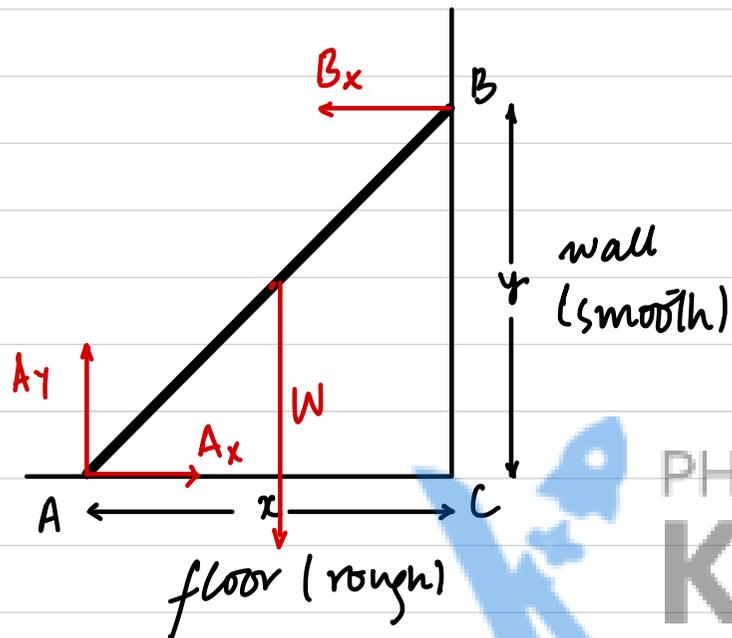
$$F_A + F_B = 1080$$

$$F_A + 452 = 1080 \text{ so } F_A = 628\text{N}$$



- Consider one of the two ends as a pivot and other as a force
- The point which is taken as a pivot has its force eliminated from the moment equation as perpendicular distance becomes zero.
- uniform: density is same so weight (COG) acts in the middle of body.

## Ladder (uniform body)



$A_x$ : friction force

Taking Moment about A

$$\left( W \times \frac{x}{2} \right) = (B_x \times y)$$

Taking Moment about B

$$\left( W \times \frac{x}{2} \right) + (A_x \times y) = (A_y \times x)$$

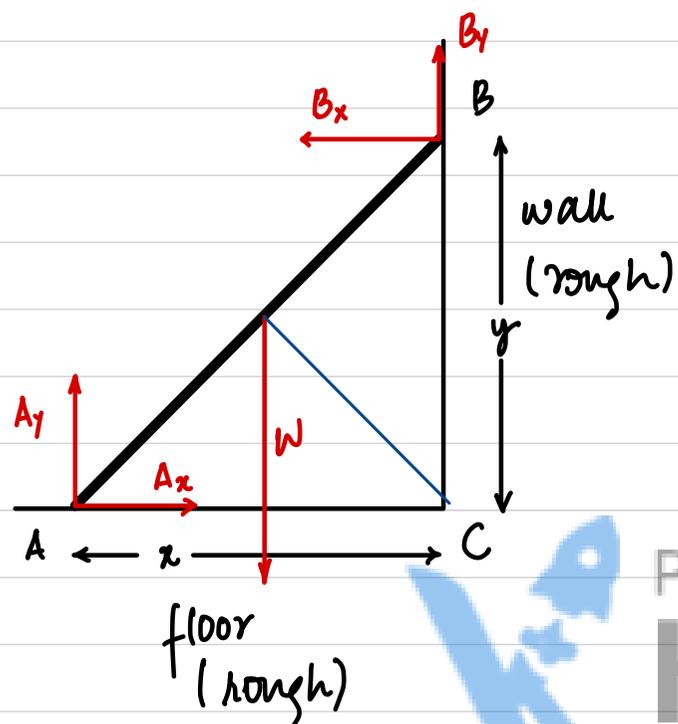
Taking Moment about C

$$\left( W \times \frac{x}{2} \right) + (B_x \times y) = (A_y \times x)$$

$$\sum F_x = 0 \quad A_x = B_x$$

$$\sum F_y = 0 \quad A_y = W$$

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Taking Moment about A

$$(W \times \frac{x}{2}) = (B_x \times y) + (B_y \times x)$$

Taking Moment about B

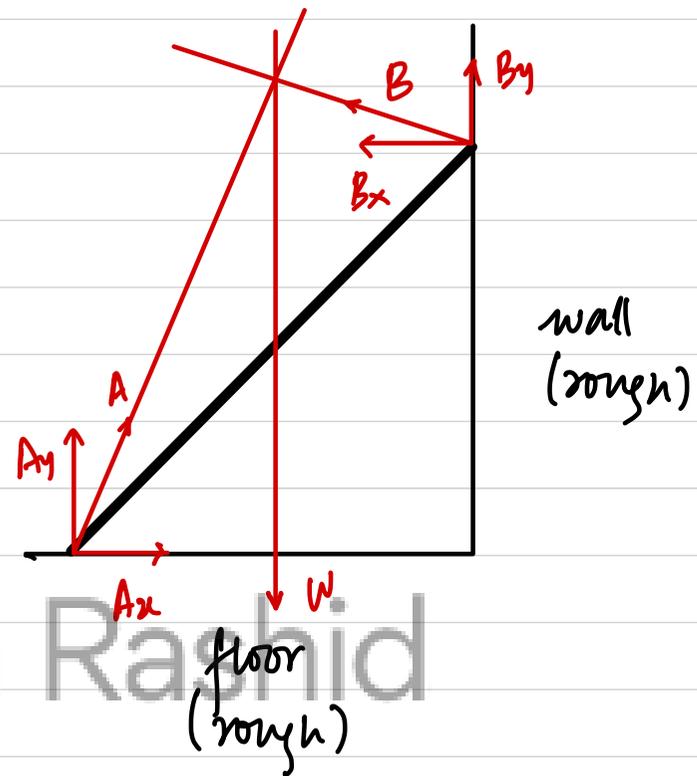
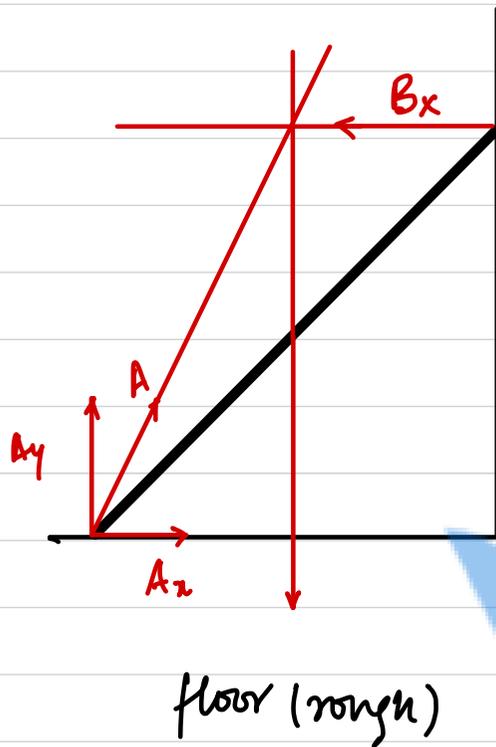
$$(W \times \frac{x}{2}) + (A_x \times y) = (A_y \times x)$$

Taking Moment about C

$$(W \times \frac{x}{2}) + (B_x \times y) = (A_y \times x)$$

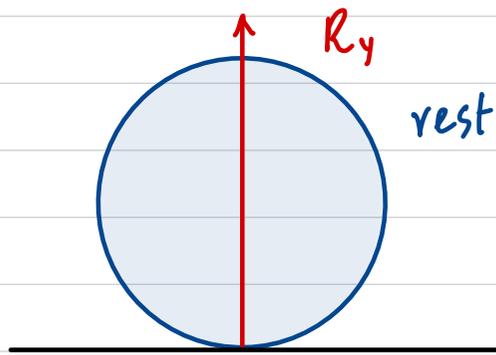
$$\sum F_x = 0 \quad A_x = B_x$$

$$\sum F_y = 0 \quad A_y + B_y = W$$

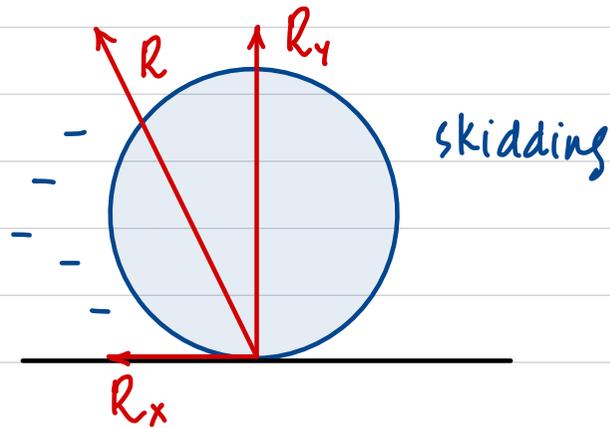


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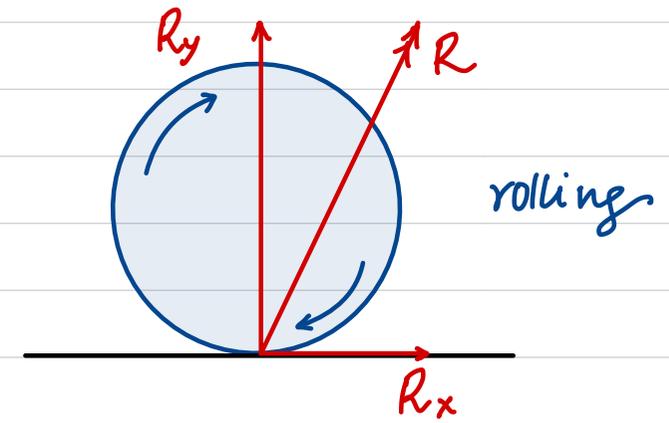
- If the system is in rotational equilibrium, all the forces acting on the body must pass through a common point.



$R_y$ : Normal contact force



$R_x$ : friction force  
 $R$ : resultant contact force



Friction acts in the forward direction as it is in direction opposite to motion.

66

Friction force is component of contact force"

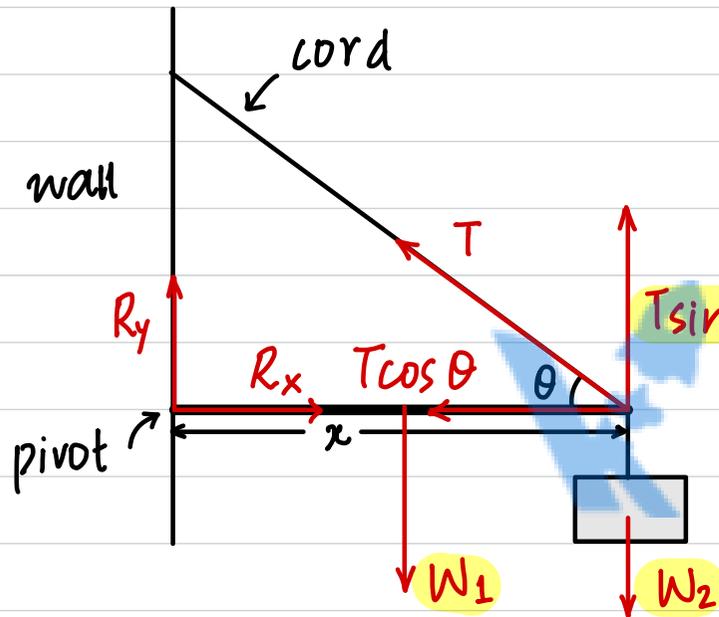
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# Flagpole (Cantilever Beam)

(Uniform Flagpole)

- Taking moment about the pivot



$$(W_1 \times \frac{x}{2}) + (W_2 \times x) = (T \sin \theta \times x)$$

$$\sum F_x = 0$$

$$R_x = T \cos \theta$$

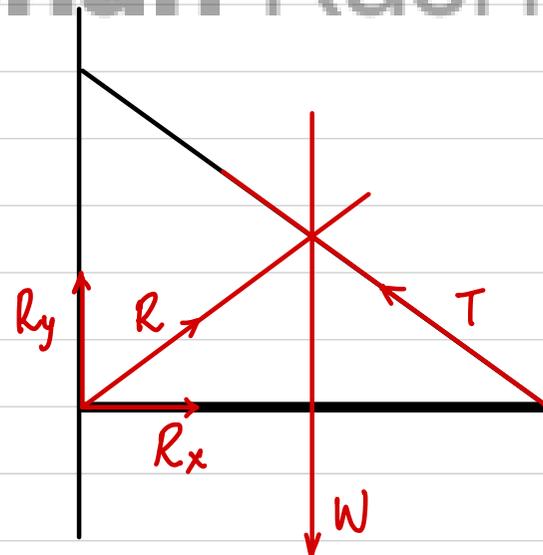
$$\sum F_y = 0$$

$$R_y + T \sin \theta = W_1 + W_2$$

The system is in equilibrium

$$\sum F = 0$$

$$\sum \tau = 0$$

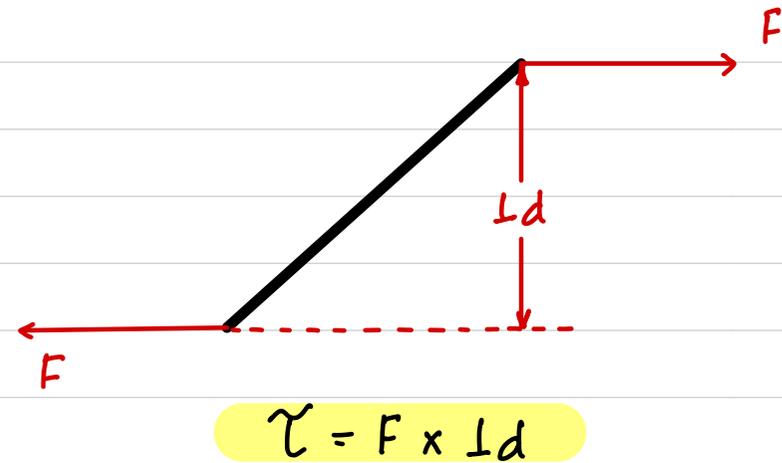


Tension, Weight and Contact force from pivot on rod intersect at a common point.

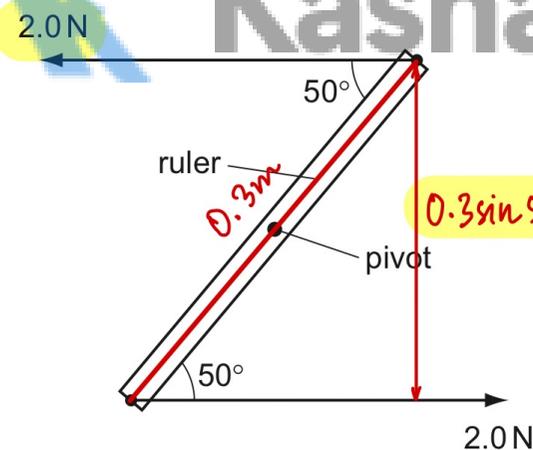
## Torque of a Couple

Two forces of equal magnitude but opposite direction

- It is the product of one of the two forces and the perpendicular distance between them.



- 14 A ruler of length 0.30 m is pivoted at its centre. Equal and opposite forces of magnitude 2.0 N are applied to the ends of the ruler, creating a couple as shown.



$$\begin{aligned}\tau &= F \times Ld \\ \tau &= 2 \times 0.3 \sin 50^\circ \\ &= 0.459 \text{ Nm}\end{aligned}$$

What is the magnitude of the torque of the couple on the ruler when it is in the position shown?

- A 0.23 N m    B 0.39 N m    **C 0.46 N m**    D 0.60 N m

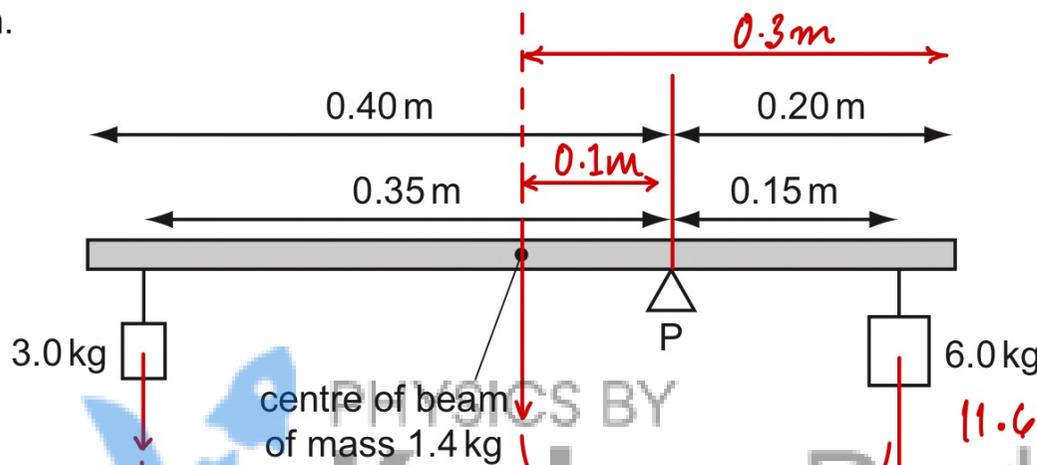
Additional Materials:

- 14 A uniform beam of mass 1.4 kg is pivoted at P as shown. The beam has a length of 0.60 m and P is 0.20 m from one end. Loads of 3.0 kg and 6.0 kg are suspended 0.35 m and 0.15 m from the pivot as shown.

$$(3 \times 9.8) \times (0.35)$$

$$+ (1.4 \times 9.8) \times (0.1)$$

$$11.662 \text{ Nm}$$



$$(6 \times 9.8) \times 0.15$$

$$8.82 \text{ Nm}$$

$$11.662 = 8.82 + x$$

$$11.662 - 8.82 = x$$

$$x = 2.842 \text{ Nm}$$

What torque must be applied to the beam in order to maintain it in equilibrium?

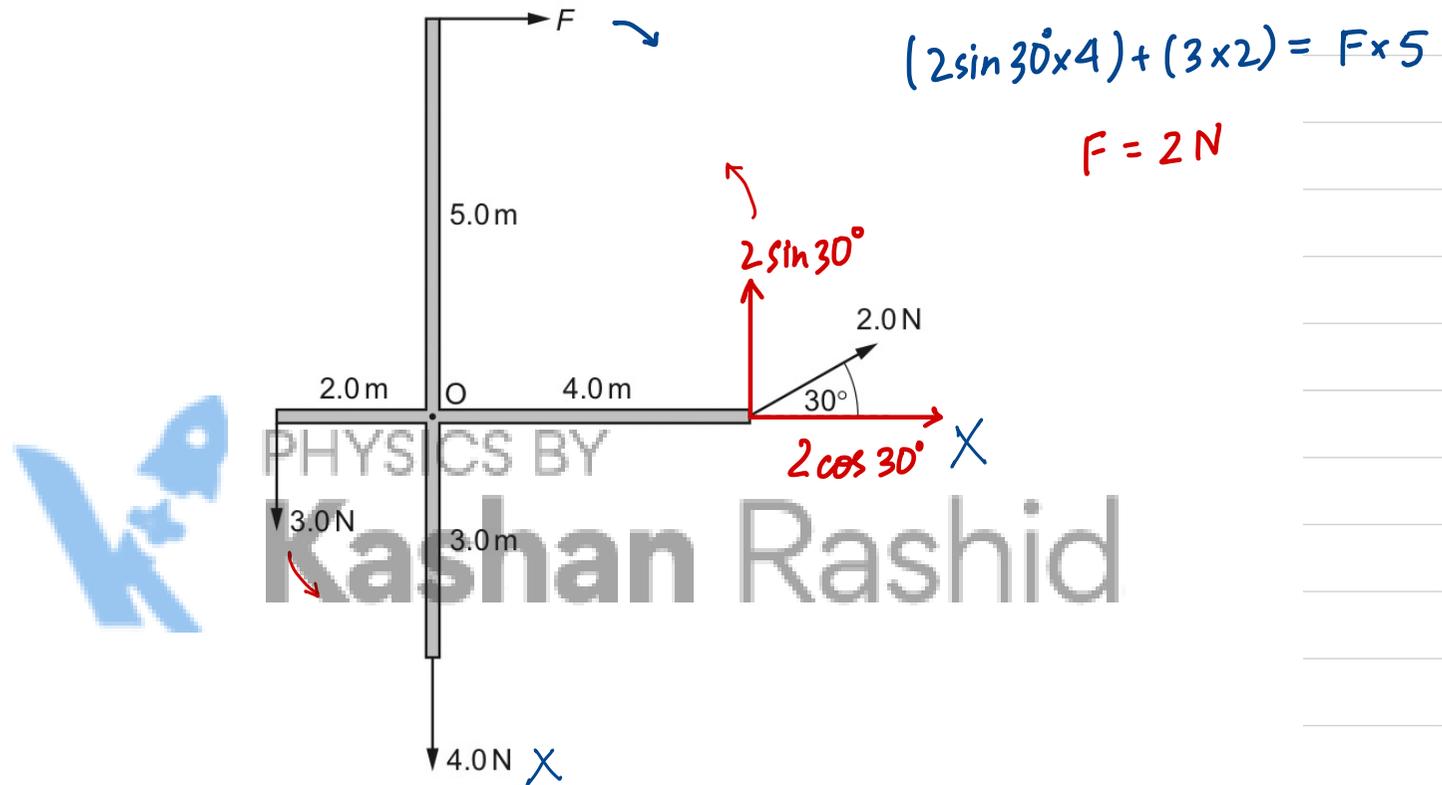
A 0.010 Nm

B 0.10 Nm

C 0.29 Nm

D 2.8 Nm

- 15 A cross-shaped structure, freely pivoted at O, has arms of lengths 5.0m, 4.0m, 3.0m and 2.0m. It is acted on by forces of 2.0N, 3.0N, 4.0N and an unknown force  $F$ . The structure is in rotational equilibrium.



What is the magnitude of force  $F$ ?

- A 0.40N      B 2.0N      C 2.6N      D 4.4N