

Unit 4 Turning Effects of Force

Important Formulas

➤ Resultant Force

$$F = \sqrt{(F_x)^2 + (F_y)^2}$$

➤ Angle

$$\theta = \tan^{-1} \left(\frac{F_y}{F_x} \right)$$

➤ x-component of force

$$F_x = F \cos \theta$$

➤ y-component of force

$$F_y = F \sin \theta$$

➤ Torque

$$\tau = r \times F$$

$$\tau = rF \sin \theta$$

➤ 1st Condition of Equilibrium $\sum F = 0$

➤ 2nd Condition of Equilibrium $\sum \tau = 0$

➤ Principle of moments

clockwise moments = Anti clockwise moments

➤ Weight $w = mg$

4.1. A force of 200 N is acting on a cart at an angle of 30° with the horizontal direction. Find the x and y-components of the force.

Given Data

$$\text{Force} = F = 200 \text{ N}$$

$$\text{Angle} = \theta = 30^\circ$$

To Find

$$x - \text{component of force} = F_x = ?$$

$$y - \text{component of force} = F_y = ?$$

Solution

By using formula of F_x

$$F_x = F \cos \theta$$

$$F_x = 200 \cos 30^\circ$$

$$F_x = (200)(0.866)$$

$$F_x = 173.2 \text{ N}$$

Now by using formula of F_y

$$F_y = F \sin \theta$$

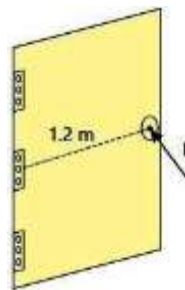
$$F_y = F \sin \theta$$

$$F_y = 200 \sin 30^\circ$$

$$F_y = (200)(0.5)$$

$$F_y = 100 \text{ N}$$

4.2. A force of 300 N is applied perpendicularly at the knob of a door to open it as shown in the given figure. If the knob is 1.2 m away from the hinge, what is the torque applied? Is it positive or negative torque?



Given Data

$$\text{Force applied} = F = 300 \text{ N}$$

$$\text{Distance from hinge} = r = 1.2 \text{ m}$$

Force is applied perpendicularly, so $\theta = 90^\circ$

To Find

$$\text{Torque} = \tau = ?$$

Solution

By using formula of torque, we have

$$\tau = rF \sin \theta$$

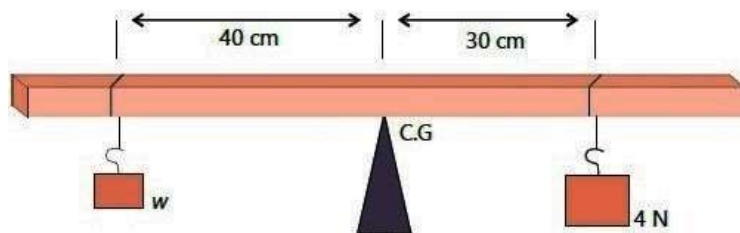
$$\tau = (1.2)(300) \sin 90^\circ$$

$$\tau = (1.2)(300)(1)$$

$$\tau = 360 \text{ Nm}$$

Since the force turns the door counterclockwise, the torque is positive.

4.3. Two weights are hanging from a metre rule at the positions as shown in the given figure. If the rule is balanced at its centre of gravity (C.G), find the unknown weight w.



Given Data

$$\text{Distance of unknown weight from C.G.} = 40 \text{ cm}$$

$$= 40 \times 10^{-2} \text{ m}$$

$$= 0.4 \text{ m}$$

$$\text{Distance of 4 N weight from C.G.} = 30 \text{ cm}$$

$$= 30 \times 10^{-2} \text{ m}$$

$$= 0.3 \text{ m}$$

$$\text{Weight on right side} = 4 \text{ N}$$

To Find

$$\text{Unknown weight} = w = ?$$

Solution

According to principle of moments,

$$\text{clockwise moments} = \text{Anti clockwise moments}$$

$$4 \times 0.3 = w \times 0.4$$

$$1.2 = 0.4w$$

$$\frac{1.2}{0.4} = w$$

$$3 = w$$

$$w = 3 \text{ N}$$

4.4. A see-saw is balanced with two children sitting near either end. Child A weighs 30 kg and sits 2 metres away from the pivot, while child B weighs 40 kg and sits 1.5 metres from the pivot. Calculate the total moment on each side and determine if the see-saw is in equilibrium.

Given Data

Mass of child A = $m_A = 30 \text{ kg}$
 Distance of child A from pivot = $r_A = 2 \text{ m}$
 Mass of child B = $m_B = 40 \text{ kg}$
 Distance of child B from pivot = $r_B = 1.5 \text{ m}$
 Acceleration due to gravity = $g = 10 \text{ ms}^{-2}$

To Find

Total moment on each side = ?
 Determine if the see – saw is in equilibrium = ?

Solution

By using formula of the moment (torque)

Child A's Moment (Clockwise)

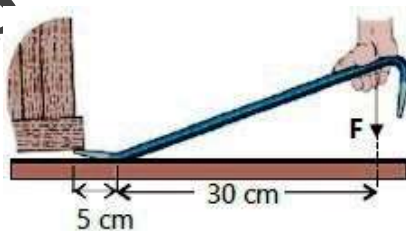
$$\begin{aligned}\tau_A &= r_A \times F \\ \tau_A &= r_A \times w \\ \tau_A &= r_A mg \quad \because w = mg \\ \tau_A &= (2)(30)(10) \\ \tau_A &= 600 \text{ Nm}\end{aligned}$$

Child B's Moment (Anticlockwise)

$$\begin{aligned}\tau_B &= r_B \times F \\ \tau_B &= r_B \times w \\ \tau_B &= r_B mg \quad \because w = mg \\ \tau_B &= (1.5)(40)(10) \\ \tau_B &= 600 \text{ Nm}\end{aligned}$$

Since both moments are equal and opposite, the see-saw is in equilibrium. i.e. $\tau_A = \tau_B = 600 \text{ Nm}$

4.5. A crowbar is used to lift a box as shown in the given figure. If the downward force of 250 N is applied at the end of the bar, how much weight does the other end bear? The crowbar itself has negligible weight.



Given Data

Downward force = $F_1 = 250 \text{ N}$
 Distance from pivot to downward force = $r_1 = 30 \text{ cm}$
 $r_1 = 30 \times 10^{-2} \text{ m}$
 $r_1 = 0.3 \text{ m}$
 Distance of load from pivot = $r_2 = 5 \text{ cm}$
 $r_2 = 5 \times 10^{-2} \text{ m}$

$$r_2 = 0.05 \text{ m}$$

To Find

Weight bear at other end = $F_2 = ?$

Solution

According to principle of moments,

clockwise moments = Anti clockwise moments

$$\begin{aligned}r_1 \cdot F_1 &= r_2 \cdot F_2 \\ (0.3)(250) &= (0.05)(F_2) \\ \frac{(0.3)(250)}{0.05} &= F_2 \\ 15000 &= F_2 \\ F_2 &= 15000 \text{ N}\end{aligned}$$

4.6. A 30 cm long spanner is used to open the nut of a car.



If the torque required for it is 150 N m, how much force F should be applied on the spanner as shown in the given figure.

Given Data

Length of spanner = $r = 30 \text{ cm}$
 $r = 30 \times 10^{-2} \text{ m}$
 $r = 0.3 \text{ m}$
 Torque = $\tau = 150 \text{ Nm}$

To Find

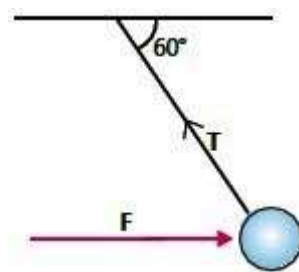
Force = $F = ?$

Solution

By using formula of torque, we have

$$\begin{aligned}\tau &= rF \\ (150) &= (0.3)(F) \\ \frac{150}{0.3} &= F \\ 500 &= F \\ F &= 500 \text{ N}\end{aligned}$$

4.7. A 5 N ball hanging from a rope is pulled to the right by a horizontal force F. The rope makes an angle of 60° with the ceiling, as shown in the given figure. Determine the magnitude of force F and tension T in the string.



Given Data

Weight of ball = $w = 5 \text{ N}$
 Angle with ceiling = $\theta = 60^\circ$

To Find

Horizontal force = $F = ?$
 Tension in string = $T = ?$

Solution

The tension T in the rope has two components *i. e*

$$T_x = T \cos \theta$$
$$T_y = T \sin \theta$$

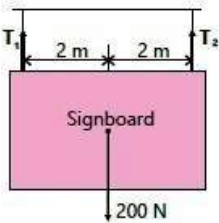
The upward force T_y equals the ball's weight w because it is in balance.

$$T_y = w$$
$$T \sin \theta = w$$
$$T \sin 60^\circ = 5$$
$$T = \frac{5}{\sin 60^\circ}$$
$$T = \frac{5}{0.866}$$
$$T = 5.8 \text{ N}$$

The horizontal force F is equal to the tension's horizontal part T_x

$$F = T_x$$
$$F = T \cos \theta$$
$$F = (5.8) \cos 60^\circ$$
$$F = (5.8)(0.5)$$
$$F = 2.9 \text{ N}$$

4.8. A signboard is suspended by means of two steel wires as shown in the given figure. If the weight of the board is 200 N, what is the tension in the strings?



Given Data

$$\text{Weight of the board} = w = 200 \text{ N}$$

To Find

$$\text{Tension in first string} = T_1 = ?$$
$$\text{Tension in second string} = T_2 = ?$$

Solution

Since wires are symmetrically placed so tension in each string will be equal *i.e* $T = T_1 = T_2$

As signboard is in equilibrium. So

$$T = w$$
$$T_1 + T_2 = w$$
$$T + T = 200$$
$$2T = 200$$
$$T = \frac{200}{2}$$
$$T = 100 \text{ N}$$
$$T_1 = 100 \text{ N}$$
$$T_2 = 100 \text{ N}$$

4.9. One girl of 30 kg mass sits 1.6 m from the axis of a see-saw. Another girl of mass 40 kg wants to sit on the other side, so that the see-saw may remain in

equilibrium. How far away from the axis, the other girl may sit?

Given Data

$$\text{Mass of first girl} = m_1 = 30 \text{ kg}$$
$$\text{Distance of first girl from axis} = r_1 = 1.6 \text{ m}$$
$$\text{Mass of second girl} = m_2 = 40 \text{ kg}$$

To Find

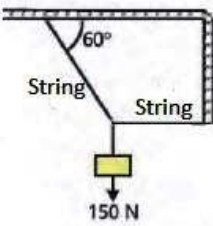
$$\text{Distance of second girl from axis} = r_2 = ?$$

Solution

According to principle of moments,

$$\text{clockwise moments} = \text{Anti clockwise moments}$$
$$r_1 \cdot F_1 = r_2 \cdot F_2$$
$$r_1 \cdot m_1 g = r_2 \cdot m_2 g$$
$$(1.6)(30)(10) = (r_2)(40)(10)$$
$$\frac{(1.6)(30)(10)}{(40)(10)} = r_2$$
$$r_2 = 1.2 \text{ m}$$

4.10. Find the tension in each string of the as shown in the given figure, if the block weighs 150 N.



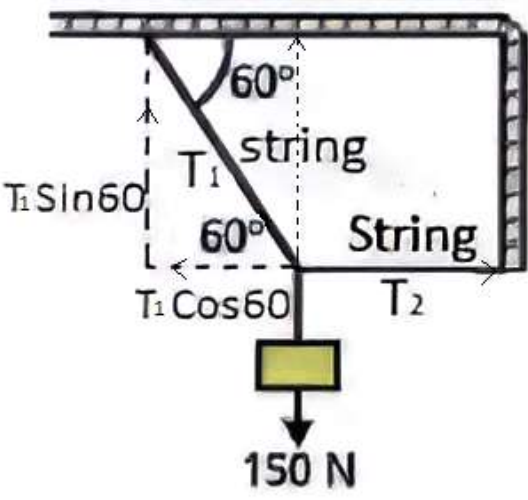
Given Data

$$\text{Weight of block} = w = 150 \text{ N}$$

To Find

$$\text{Tension in first string} = T_1 = ?$$
$$\text{Tension in second string} = T_2 = ?$$

Solution



As block is in equilibrium. So, the vertical component of T_1 balances the weight w

$$T_1 \sin \theta = w$$
$$T_1 \sin 60^\circ = 150$$
$$T_1 = \frac{150}{\sin 60^\circ}$$
$$T_1 = \frac{150}{0.866}$$

$$T_1 = 173.21 \text{ N}$$

Now, the horizontal component of T_1 is balanced by T_2

$$T_1 \cos \theta = T_2$$

$$T_1 \cos 60^\circ = T_2$$

$$(173.21) \cos 60^\circ = T_2$$

$$(173.21)(0.5) = T_2$$

$$86.6 = T_2$$

$$T_2 = 86.6 \text{ N}$$

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