Rotational Equilibrium

An object in translational equilibrium is not accelerating in the x or y directions, but it still could be rotating. An object in rotational equilibrium is not rotating.

If an object is not rotating and not moving through space, we say it is in static equilibrium.

For an object to be in rotational equilibrium the total torque on it must be zero.

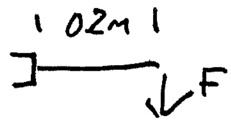
Torque = τ = Fd

F ← Force; d ← distance from pivot point

Torque is a rotational vector it works either: clockwise ↻ counter clockwise ↺

Consider tightening a bolt with a wrench, if the bolt needs 24 Nm of torque to tighten it:

How much force must be applied if using a 0.20 m long wrench?



$\tau = Fd$

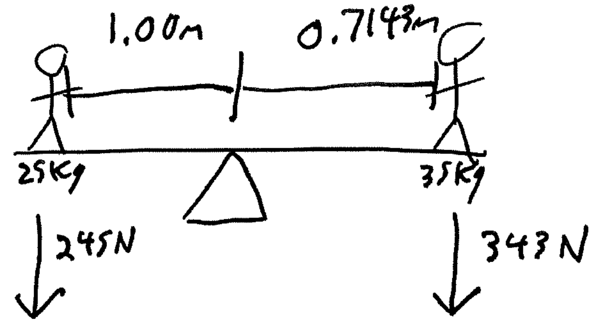
$\frac{\tau}{d} = F \qquad \frac{24\,Nm}{0.2\,m} = 120\,N$

How much force must be applied if using a 1.00 m long wrench?

$F = \frac{\tau}{d} = \frac{24}{1} = 24\,N$

Two kids sit on a see saw, if it is in rotational equilibrium the torques on each kid must cancel out.

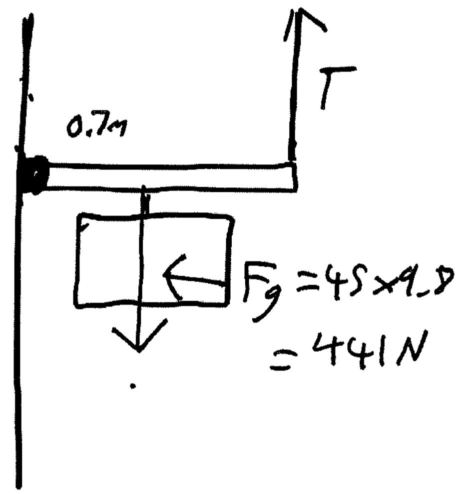
One kid is 1.00 m from the centre and has mass of 25.0 kg, the other kid is 35.0 kg and is 0.7143 m from the centre. Is the see-saw in rotational equilibrium?



τ_c	τ_{cc}
Fd	Fd
$343\,N \times 0.7143\,m$	$245\,N \times 1.00\,m$
$= 245\,Nm$	$= 245\,Nm$

In rotational equilibrium $\tau_c = \tau_{cc}$

EXAMPLE: A 45 kg sign is attached to the middle of a 1.4 m long board of negligible mass which is connected to a wall with a hinge. The board is supported also by a rope. What is the tension in the rope? What are the forces acting on the hinge?



τ_c	τ_{cc}
$0.7 \times 441 = 308.7$	$T \times 1.4$

$$\frac{308.7}{1.4} = T$$

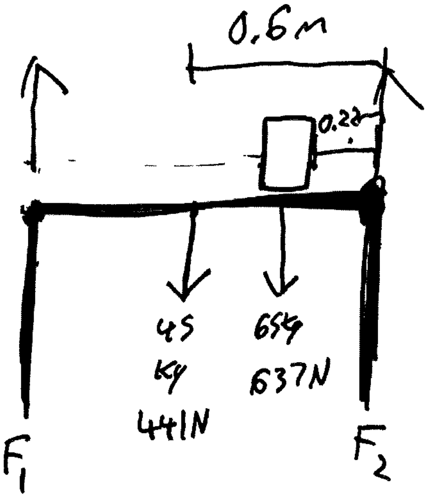
$$T = 220.5\ N$$

Total up force = Total down forces

$$F_{hinge} + 220.5N = 441N$$

$$F_{hinge} = 220.5N \text{ upwards}$$

EXAMPLE: A stone table top of length 1.2 metres has a mass of 45 kg, a 65 kg pile of bricks is placed 0.22 metres from the right side of the table. What are the support forces provided by each side of the table?



$$\tau_c = \tau_{cc}$$

$$F_1 \times 1.2m = 441 \times 0.6m + 637 \times 0.22m$$

$$F_1 \times 1.2m = 404.74Nm$$

$$F_1 = \frac{404.74Nm}{1.2m} = 337.28\ N$$

$$F_{up} = F_{down}$$

$$337.28 + F_2 = 441N + 637N$$

$$337.28 + F_2 = 1078\ N$$

$$-337.28 \qquad -337.28$$

$$F_2 = 740.72\ N$$