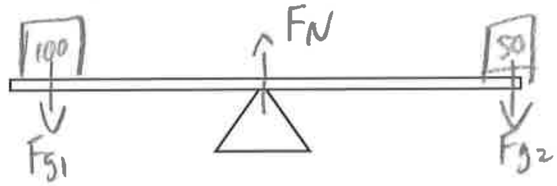
Physics 12 – Equilibrium – Torque Part 1

A body in translational equilibrium will have no acceleration in the x or y directions. However it still could be accelerating.

Consider a teeter-totter, with a 100 kg student on one end and a 50 kg student on the other.

What are the net translational forces in:



The x-direction? $\Sigma F_x = 0$
The y-direction? $\Sigma F_y = 0$

Although the net translational forces are zero, the system has a net torque - so it is not in equilibrium.

An object in equilibrium must have both translational and rotational equilibrium.

The second condition of equilibrium is that in order to have no rotation, there must be no net torque.

Torque is defined as: force × distance to pivot

$\tau = F \cdot d$

Unit of torque: N·m

Torque is a vector quantity, which must work in either the clockwise (c) or counterclockwise (cc) directions.

If an object is in rotational equilibrium then:

$\Sigma \tau = 0 \qquad \tau_c = \tau_{cc}$

Ex: A torque of 24.0 Nm is needed to tighten a nut. If a person can apply a force of 120 N, what is the minimum length of wrench that is required?

$\tau = F \cdot d$

$\therefore d = \frac{\tau}{F} = \frac{24.0\ \text{Nm}}{120\ \text{N}} = \boxed{0.20\ \text{m}}$

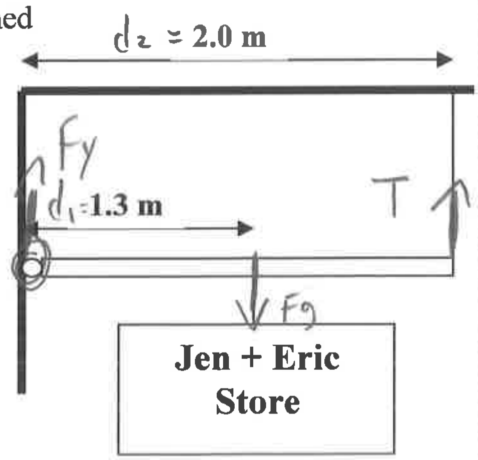
A few more terms we need to learn before we go on…

Centre of Gravity: The position where the average weight of the object acts

Uniform Beam: a beam of uniform shape and density

Pivot Point: point on an object that acts as the point of rotation (it can be anywhere)

Ex: A 350 N store sign hangs from a pole of negligible mass. The pole is attached to a wall by a hinge and supported by a vertical rope. What is the tension in the rope?



$F_g = 350\ \text{N}$
$d_1 = 1.3\ \text{m}$
$d_2 = 2.0\ \text{m}$
$T = ?$

$\Sigma \tau = 0$

$\tau_c = \tau_{cc}$

$F_g \cdot d_1 = T \cdot d_2$

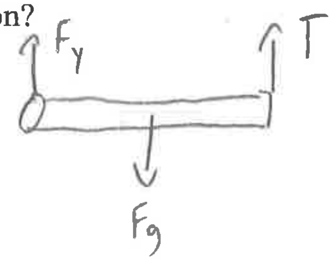
$\therefore T = \frac{F_g \cdot d_1}{d_2}$

$T = \frac{(350\text{N})(1.3\text{m})}{2.0\text{m}}$

$= 227.5$

$\boxed{= 230\ \text{N}}$

Extension:
What are the vertical and horizontal components of the supporting force provided by the hinge in the last question?



$\Sigma F_y = 0$

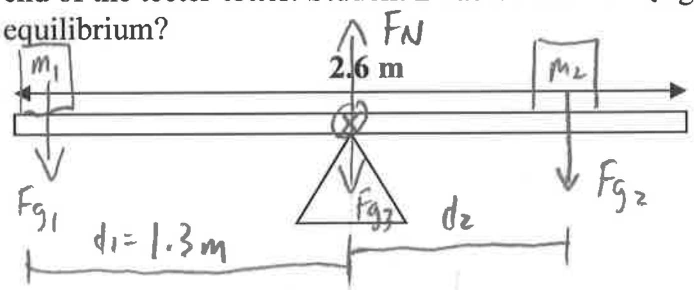
$F_g = T + F_y$

$\therefore F_y = F_g - T$

$= 350N - 227.5N$

$= 122.5 = \boxed{120N}$

Ex:
Two students sit on opposite sides of an 800 N teeter-totter. Student 1 has a mass of 65 kg and sits at the very end of the teeter-totter. Student 2 has a mass of 90 kg. How far from the pivot should he sit in order to achieve equilibrium?



$m_1 = 65kg$

$m_2 = 90 kg$

$d_1 = 1.3 m$

$F_{g3} = 800 N$

$\Sigma \tau = 0$

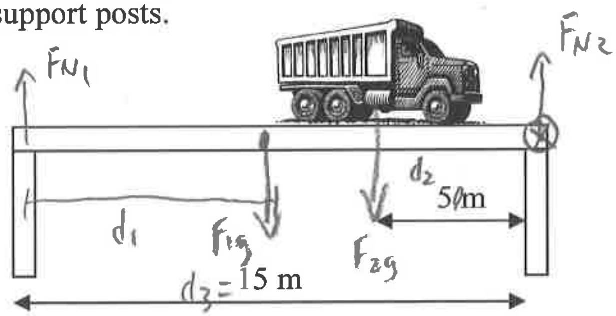
$\tau_c = \tau_{cc}$

$F_{g1} \cdot d_1 = F_{g2} \cdot d_2$

$\therefore d_2 = \frac{F_{g1} \cdot d_1}{F_{g2}} = \frac{m_1 g d_1}{m_2 g}$

$d_2 = \frac{65kg \cdot 1.3m}{90kg} = \boxed{0.94 m}$

Ex:
A 3500 kg truck is parked on a bridge as shown. If the bridge deck itself has a mass of 6500 kg find the supporting force provided by each of the two support posts.



$m_1 = 6500 kg$

$m_2 = 3500 kg$

$d_1 = 7.5m$

$d_2 = 5.0m$

$d_3 = 15m$

$\Sigma \tau = 0$

$\tau_c = \tau_{cc}$

$F_{N1} \cdot d_1 = F_{1g} \cdot d_1 + F_{2g} d_2$

$F_{N1} = \frac{m_1 g d_1 + m_2 g d_2}{d_3} = \frac{g(m_1 d_1 + m_2 d_2)}{d_3}$

$F_{N1} = \frac{(9.80 m/s^2)(6500kg \cdot 7.5m + 3500kg \cdot 5.0m)}{15m}$

$= 43283.\overline{3} = 43000N$

$\Sigma F_y = 0$

$F_{N1} + F_{N2} = F_{g1} + F_{g2}$

$\therefore F_{N2} = F_{g1} + F_{g2} - F_{N1}$

$F_{N2} = 6500kg \cdot 9.80 m/s^2 + 3500kg \cdot 9.8 m/s^2 - 43283.\overline{3} N$

$= 54716\overline{6}$

$\boxed{= 55\,000 N}$