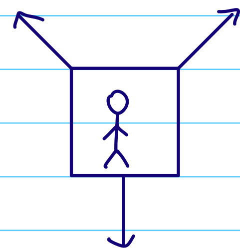
OCT 18

# Equilibrium

## 1) Translational equilibrium

- ALL FORCES act through one point and there is no net force. $F_{net} = 0$

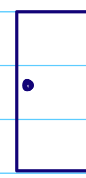
$$x = T_1x = T_2x$$
$$y = F_g = T_1y + T_2y$$



## 2) Rotational Equilibrium

- Forces DO NOT act through one point
- The points in the body are not moving about an axis

Think about door opening / closing
where do you apply force?



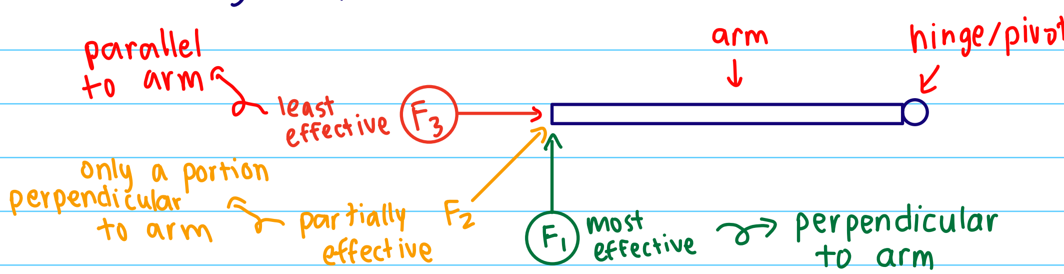
Moment of force about an axis, describes how easy it is to rotate

Torque ($\tau$)

There is rotational equilibrium when

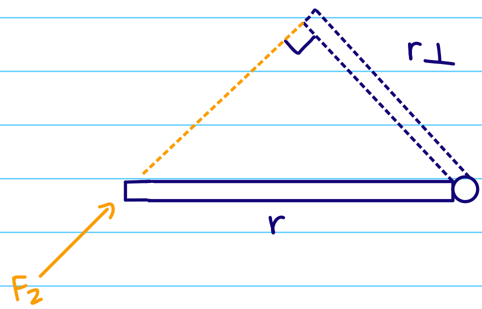
$$\underset{\text{clockwise}}{\tau_{cw}} = \underset{\text{counter clockwise}}{\tau_{ccw}}$$

Calculating torque:



$\tau = F_{\perp} r$ distance to pivot

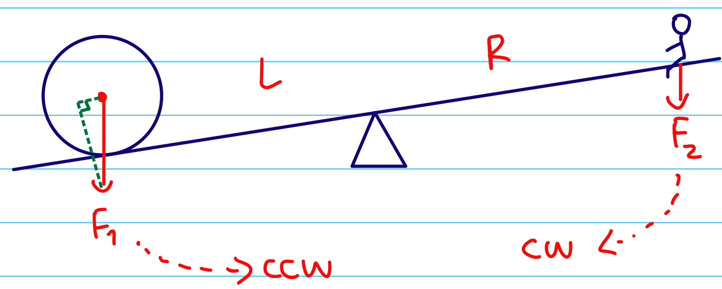
$\boxed{\tau = F \sin\theta \, r}$




$\tau = F r_{\perp}$

$\boxed{\tau = F r \sin\theta}$

Ex ① See saw




If this is in equilibrium (no one touches ground) what is the comparison of forces & torques?

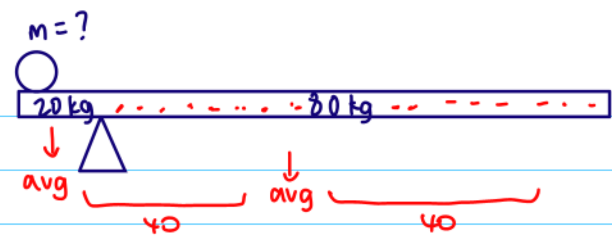
$$\tau_{ccw} = \tau_{cw}$$

$$F_1 \cos\theta \, L = F_2 \cos\theta \, R$$

$$F_1 L = F_2 R$$

$$\frac{F_1}{F_2} = \frac{R}{L}$$

Ex ② If the board weighs 100 kg and the pivot is placed at 20% of the length from one end. How much mass must be placed on one end to balance.




$$F_1 L = F_2 R$$

$$(mg_{ball}) L_{ball} + (mg_{board}) L_{board} = mg_{board} R$$

$$m(20) + (20)(10) = (80)(40)$$

$$20m + 200 = 3200$$

$$20m = 3000$$

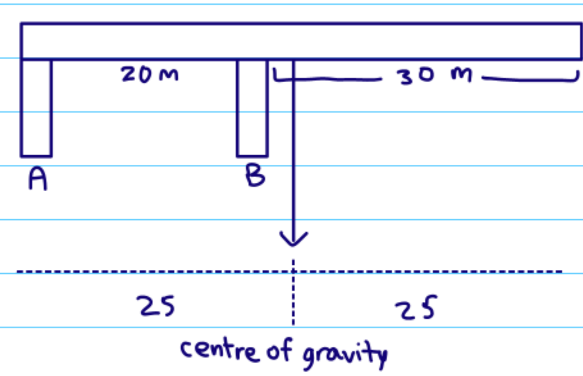
$$m = 150 \text{ kg}$$

Assignment Giancoli
p. 268 # 18-21

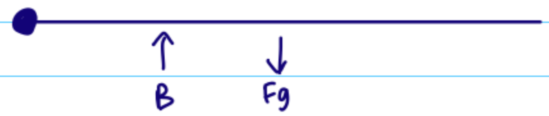
[redacted]

Oct 23 Ex ① If the beam is 1200 kg, what are the forces

$F_g$ beam $= 1200 \times 9.8$
$= 11760$ N



From pivot A



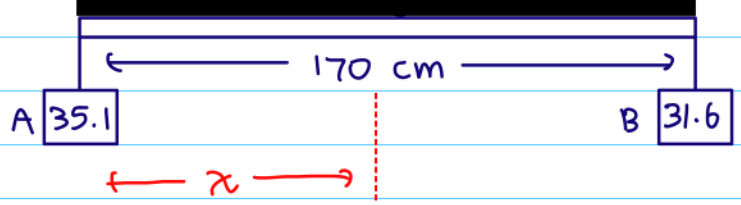

$$\tau_{cw} = \tau_{ccw}$$
$$11760(25) = F_B(20)$$
$$F_B = 14700\text{ N } [\uparrow]$$

$$\uparrow = \downarrow$$
$$F_B = F_A + F_g$$
$$14700 = F_A + 11760$$
$$F_A = 2940\text{ N}$$

Ex ② p 268 #25

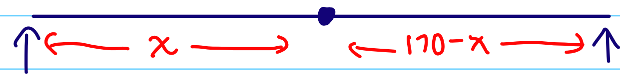
What is the centre of mass

[redacted]




let A be pivot

$$\tau_{cw} = \tau_{ccw}$$
$$(35.1 + 31.6)(9.8)(x) = (31.6)(9.8)(170)$$
$$x = 80.5\text{ cm}$$



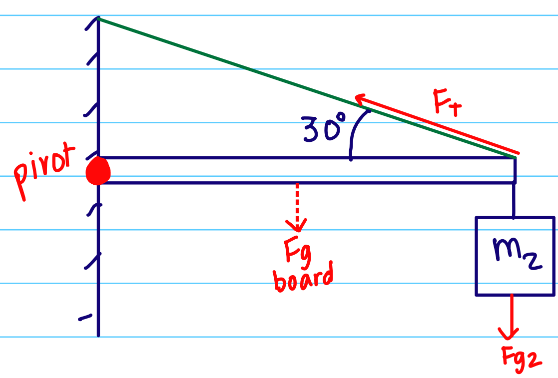

$$\tau_{cw} = \tau_{ccw}$$
$$(35.1)gx = (31.6)g(170-x)$$
$$35.1x = 5372 - 31.6x$$
$$66.7x = 5372$$
$$x = 80.5\text{cm}$$

Assignment Mathewson p 234-235 #1-8

Oct 27

## Snakes and ladders

Ex① Given the board is $m_1 = 25$ kg and $m_2 = 280$ kg




What is the tension of the plumbing snake if it makes an angle of 30° with the board?

Find the force between the wall and the board?

a)
$$\tau_{cw} = \tau_{ccw}$$
$$(F_{g\,board})\left(\frac{r}{2}\right) + (F_{g2})(r) = (F_T \sin 30^\circ)(r)$$
$$(m_{board}\,g)\left(\frac{1}{2}\right) + (m_2 g) = F_T \sin 30^\circ$$
$$(25)(9.8)(0.5) + (280)(9.8) = F_T \sin 30^\circ$$
$$F_T = 5733\text{ N}$$

b) $\Sigma F = 0$

$$F_{yup} + F_{up} = F_{g1} + F_{g2}$$
$$F_{yup} + 5733 \sin 30 = 245 + 2744$$
$$F_{yup} = 122.5\text{ N}$$

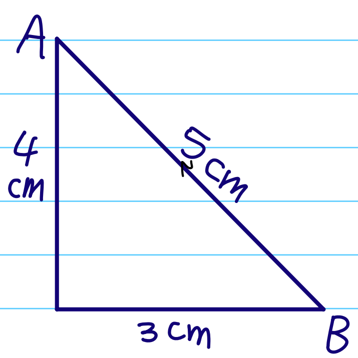
$$F_x = F_{Tx}$$
$$= F_T \cos 30^\circ$$
$$= 4964.9\text{ N}$$

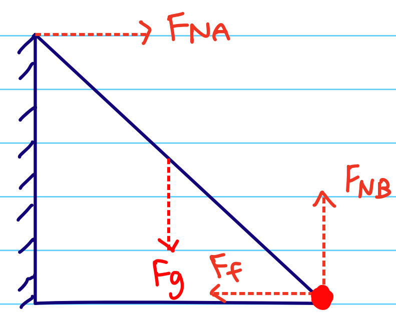
$F_{wall}$ resultant $= \sqrt{4964.9^2 + 122.5^2}$
$= 4966\ N$

$\tan\theta = \frac{122.5}{4964.9}$

$\theta = 1.41^\circ$ above horizontal

Ex② A 5.0 m long 12 kg uniform ladder leans against a frictionless wall at point A and is in equilibrium




a) Find all forces

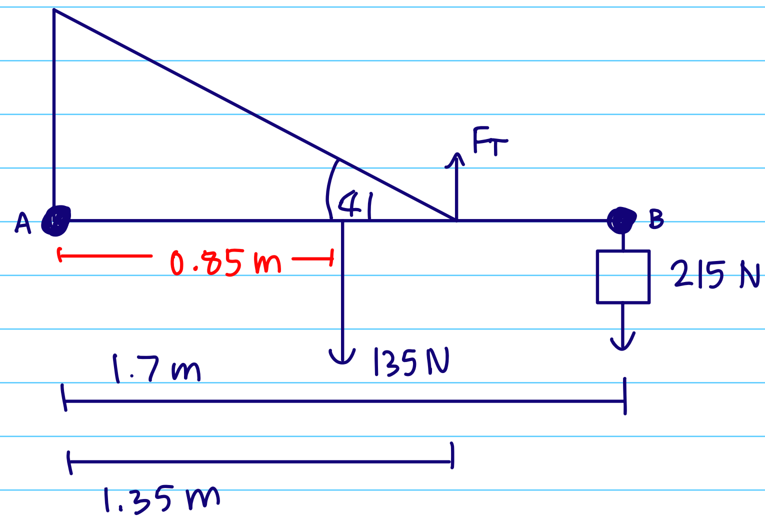
$F_g = F_{NB} = mg$
$= (12)(9.8)$
$= 117.6\ N$

$\tau_{ccw} = \tau_{cw}$
$F_g(\frac{3}{2}) = F_{NA}(4)$
$117.6(\frac{3}{2}) = F_{NA}(4)$
$F_f = F_{NA} = 44.1 N$

b) Find $\mu$

$F_f = \mu F_N$
$44.1 = \mu(117.6)$
$\mu = 0.38$

Ex③




at pivot ● A

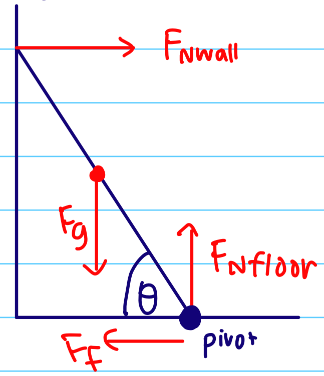
$$F_{cw} = F_{ccw}$$
$$(135 \times 0.85) + (215 \times 1.7) = F_T \times 1.35$$
$$F_T = 355.74 \text{ N}$$

at pivot ● B

$$F_{cw} = F_{ccw}$$
$$355.74 \times 0.35 = (135 \times 0.85) + (F_{wall\,y} \times 1.7)$$
$$F_{wall\,y} = 5.74 \text{ N} \downarrow$$

## Ladders & Wheels

Ex① Ladder length L makes angle $\theta$ with the ground. If the wall is friction and there is a $\mu_s$ between ladder and ground. Solve $\theta$




$$\tau_{ccw} = \tau_{cw}$$
$$F_{Nwall}(L)\sin\theta = F_g\left(\tfrac{L}{2}\right)\cos\theta$$
$$F_f(L)\sin\theta = F_{Nfloor}\left(\tfrac{L}{2}\right)\cos\theta$$
$$\mu_s F_{Nfloor}(L)\sin\theta = F_{Nfloor}\left(\tfrac{L}{2}\right)\cos\theta$$
$$\frac{1}{2\mu_s} = \frac{\sin\theta}{\cos\theta}$$

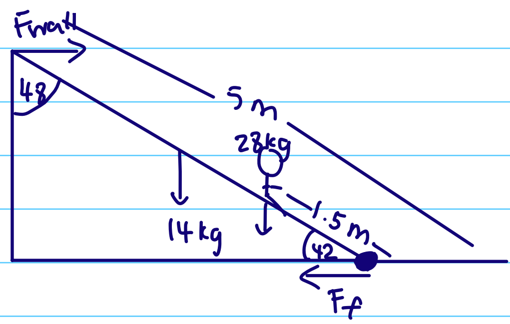
$$\tan\theta = \frac{1}{2\mu_s}$$

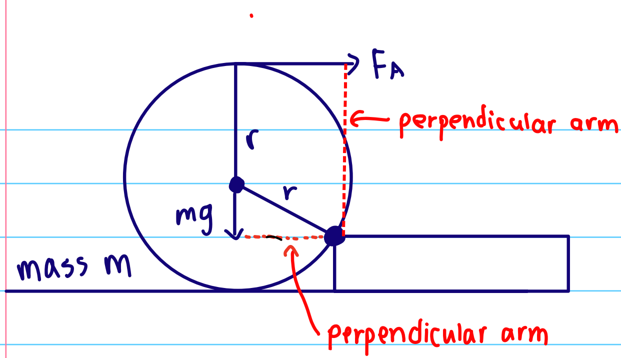
$$\theta \geqslant \tan^{-1}\left(\frac{1}{2\mu_s}\right)$$

Assignment:

Point p. 94 #28-32

NOV 8






$$F_g(L_g) = F_A(L_A)$$

$$mg\left(\sqrt{r^2-(r-h)^2}\right) = F_A(2r-h)$$

$$\frac{mg\left(\sqrt{2rh-h^2}\right)}{2r-h} = F_A$$

$$\frac{mg\sqrt{h(2r-h)}}{2r-h} = F_A$$

$$\frac{mg\sqrt{h}}{\sqrt{2r-h}} = F_A$$