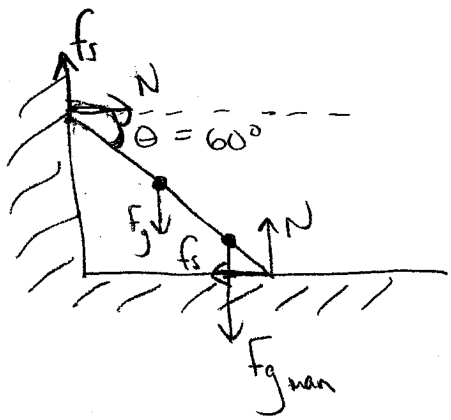
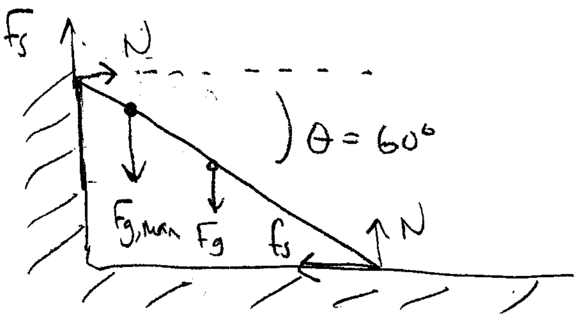
Homework #10

Ch 12

(Q4) To think about it, first draw free body diagrams for both situations

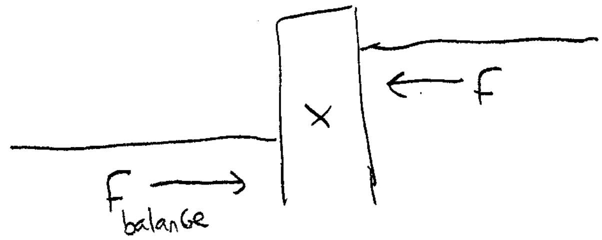




In order for the ladder to slip, the torques must be imbalanced. The torques provided by the normal forces / friction forces will be the same. Consider the pivot point to be the center of mass of the ladder. The torque provided by the weight of of the man will be the same (assuming he is the same distance from the center of mass in each case) because his weight and the angle are the same. Therefore, it is equally likely to slip in both cases.

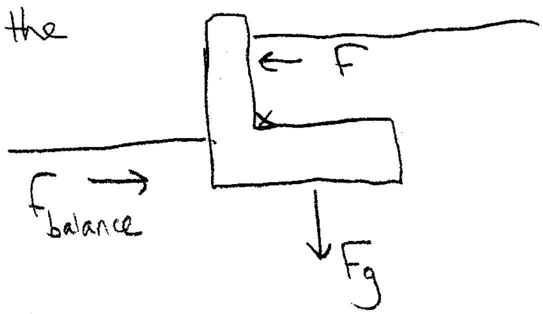
(Q5)

(a) In picture (a), it is the force from the earth on the other side of the wall that produces the torque to keep the wall from rotating.



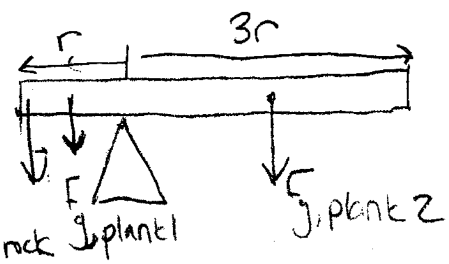
In picture (b), the weight of the ground above the lower leg of the wall also provides a torque to prevent rotation.

(The additional support may also reduce the torque caused by F by moving the center of mass of the wall [ie, the axis of rotation])



(b) Wall (b) would be much less likely to turn because there are more torques available to balance the torque caused by F. (It may also reduce the torque caused by F by changing the location of the center of mass.

(Q10) The torques must balance

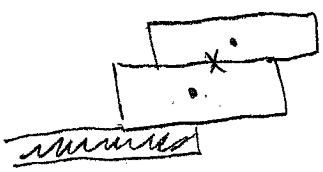


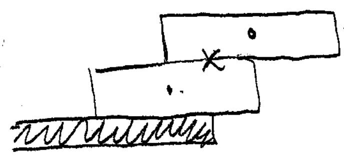
so $(mg)_{rock}\, r + \left(\frac{M}{4}g\right)_{plank} \frac{r}{2} = \left(\frac{3M}{4}g\right)_{plank} \frac{3r}{2}$

$m_r r = \frac{9M_p r}{8} - \frac{M_p r}{8} = \frac{8M_p r}{8}$

So $m_{rock} = M_{plank}$

(Q12) To figure out which configuration is most stable, I should look at the located of the center of mass. If the center of mass is past the edge of the table, the configuration will be unstable. The center of mass will lie in the center of the center of masses for each brick

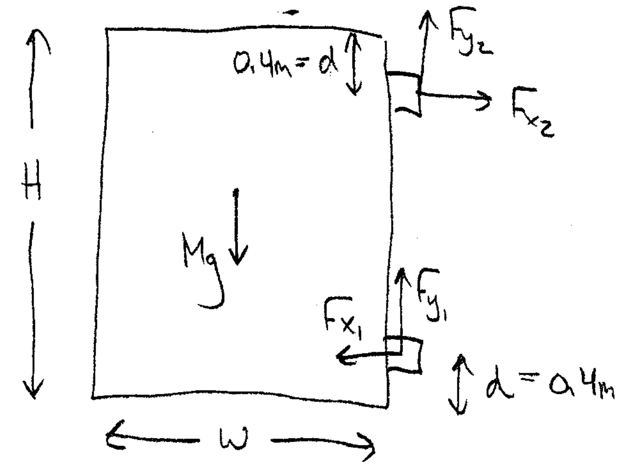

(a)


(b)

So it looks like config. (b) is more stable

(P15) This situation is static, so ΣF and $\Sigma \tau$ are zero.

I'll choose my coordinate system so that the origin is at the location of the lower hinge (This is so I don't have to figure out any angles)



$$\Sigma \tau = F_{x_2}(H-2d) - Mg\left(\frac{W}{2}\right) = 0$$

$$F_{x_2} = \frac{MgW}{2(H-2D)} = \frac{(13kg)(9.8m/s)(1.30m)}{2(2.3m - 2[0.4m])} = 55.2N$$

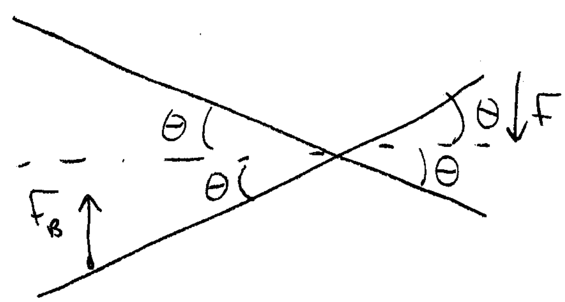
(see picture for direction)

$$\Sigma F_x = F_{x_2} - F_{x_1} = 0 \longrightarrow F_{x_1} = F_{x_2} = 55.2N$$ (in the opposite Direction)

$$\Sigma F_y = F_{y_2} + F_{y_1} - Mg = 0$$

Since each hinge holds half the weight $F_{y_2} = F_{y_1} = \frac{Mg}{2} = 63.7N$ upward

P16) $\tau = Fr\sin\theta$



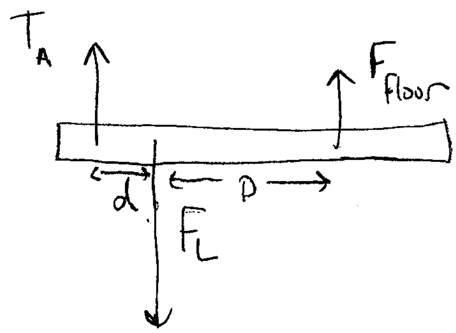
$$(Fr)_{long} = (Fr)_{short}$$

$$(F_B)r_{long} = F\, r_{short}$$

$$F = \frac{r_{long}}{r_{short}}(F_B) = \frac{8.50\,cm}{2.70\,cm}(11.0N) = 34.6\,N$$

(However, the net force is zero.)

(P19) The net torque and net force will be zero. I'll take the bottom of the leg bone as my pivot point.



① $\Sigma F = T_A + F_{floor} - F_L = 0$

② $\Sigma \tau = T_A d - F_{floor} D = 0$

$$F_{Floor} = T_A \frac{d}{D} = \frac{T_A}{2}$$

$D = 2d$

In equillibrium, $F_{floor} = mg$

(think Newton's 3rd Law ⟶ The force he exerts on the floor is the same force the floor exerts on him. If he's not accelerating, this force is equal in magnitude to his weight).

$$T_A = 2mg = 2(70kg)(9.8 m/s) = 1400\,N$$

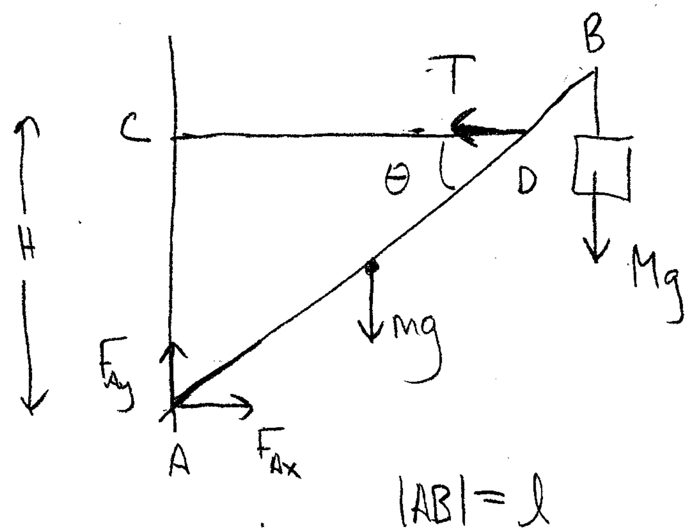
Plugging into eq. ①

$$T_A + \frac{T_A}{2} = \frac{3}{2} T_A = F_L$$

$$F_L = \frac{3}{2}(1400\,N) = 2100N$$

(P31)

(a) To find tension; I'll consider the motion of the aluminum pole rotating about point A



$$\sum F_x = F_{Ax} - T = 0$$

$$\sum F_y = F_{Ay} - Mg - mg = 0$$

$$\sum \tau = TH - Mg\,l\cos\theta - mg\frac{l}{2}\cos\theta = 0$$

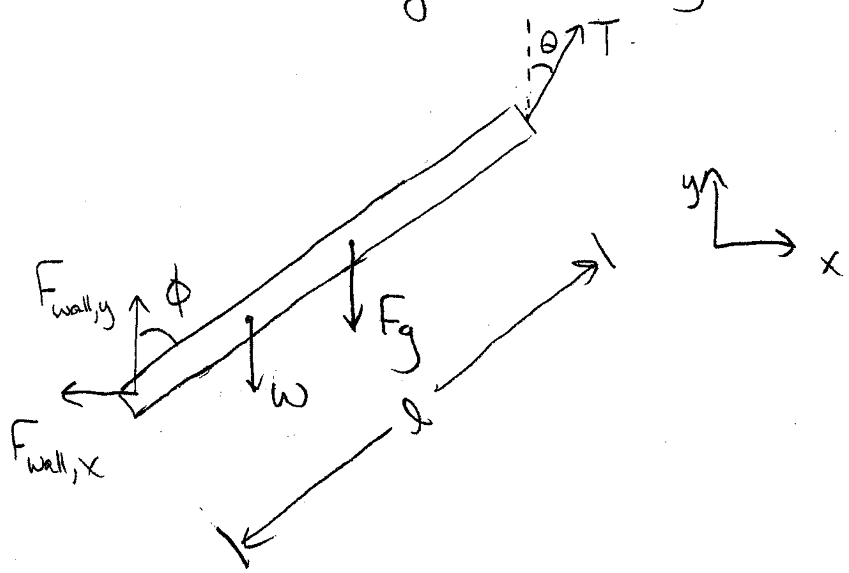
$$T = \frac{g\,l\cos\theta\left(M - \frac{m}{2}\right)}{H} = \frac{(9.8\,\text{m/s}^2)(7.5\,\text{m})\cos 37°\left(12\,\text{kg} + \frac{8\,\text{kg}}{2}\right)}{3.80\,\text{m}}$$

$$T = 250\,\text{N}$$

$$F_{Ax} = T = 250\,\text{N}, \quad F_{Ay} = (M+m)g = 200\,\text{N}$$

(P34)

(a)



(b) To determine $F_{wall,y}$ and $F_{wall,x}$ I'll consider Forces.

$$\Sigma F_x = 0 \rightarrow T_x - F_{wall,x} = 0$$

$$F_{wall,x} = T\sin\theta = 70N \sin 37° = 42\,N$$

$$\Sigma F_y = 0 \rightarrow T_y + T_{wall,y} - F_g - W = 0$$

$$T_{wall,y} = F_g + W - T_y$$

$$= Mg + W - T_y$$

$$= (3.0\,kg)(9.8\,m/s^2) + 20N - (70N)\cos 37°$$

$T_{wall,y} = -6.5\,N \rightarrow$ So the hinge is actually pulling down on the rod.

I have enough information with forces alone to solve for the force from the hinge that I don't need to consider torques.

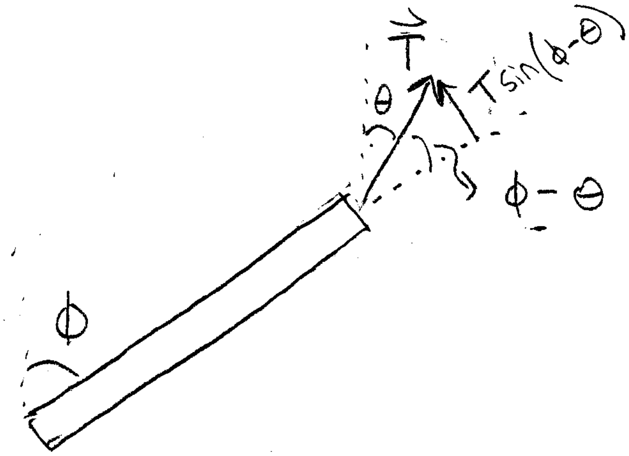
(c) $\Sigma\tau = 0 \rightarrow$ let the pivot point be the hinge

$$\Sigma\tau = \tau_W + \tau_{F_g} - \tau_T$$

$$\tau_W = x\sin\phi\, W$$

$$\tau_{F_g} = \frac{l}{2}\sin\phi\, mg$$

$$\tau_T = l\left[T\sin(\phi-\theta)\right]$$



$$\Sigma\tau = x\sin\phi\, w + \frac{l}{2}\sin\phi\, mg - l\,T\sin(\phi-\theta) = 0$$

$$x = \frac{l\,T\sin(\phi-\theta) - \frac{l}{2}\sin\phi\, mg}{\sin\phi\, w}$$

$$= l\left[\frac{T}{w}\frac{\sin(\phi-\theta)}{\sin\phi} - \frac{mg}{2w}\right]$$

$$= 5.0\,\text{m}\left[\frac{70\,\text{N}}{20\,\text{N}}\frac{\sin(16^\circ)}{\sin(53^\circ)} - \frac{(3.0\,\text{kg})(9.8\,\text{m/s}^2)}{2(20\,\text{N})}\right]$$

$$x = 2.4\,\text{m}$$

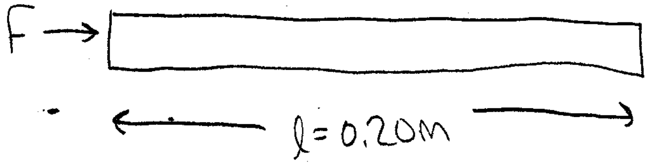
(P47) Use the Bulk modulus to find the pressure

$$\frac{\Delta V}{V_0} = -\frac{1}{B}\Delta P$$

$$\Delta P = -B\frac{\Delta V}{V_0} = -(90\times10^{9}\,\text{N/m})(-0.001)$$

$$= 90\times10^{7}\,\text{N/m}^2 = 9.0\times10^{2}\,\text{atm}$$

(P54)



$A = 3.6\ cm^2$

(a) Look at compressive strength

$$max = 170\times10^6\ N/m^2 > \left[\frac{(3.6\times10^4 N)}{3.6\times10^{-4} m^2} = 1.0\times10^8\ N/m^2\right]$$

The bone will not break

(b) Use Young's Modulus to find the change in length

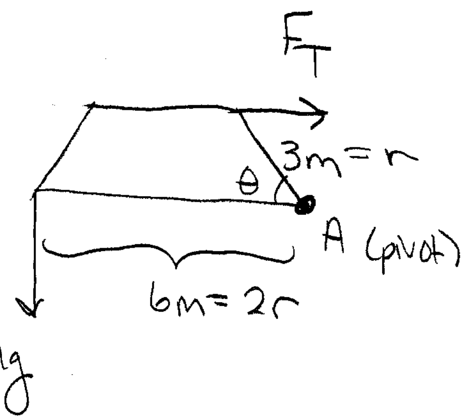
$$\Delta L = \frac{1}{E}\frac{F}{A}L_0$$

$$= \frac{(3.6\times10^4 N)(0.20m)}{(15\times10^9 N/m^2)(3.6\times10^{-4} m^2)} = 1.3mm$$

(P61)

(a) About point A

$$\Sigma\tau = 0$$



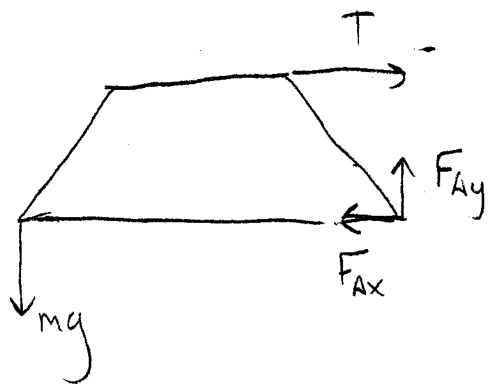
$$F_T r\sin\theta - 2rMg = 0$$

$$F_T = \frac{2Mg}{\sin\theta}$$ → since the trusses make equillateral triangles $\theta = 60°$

$$= \frac{2(56.0\times10^3 N)}{\sin(60°)} = 1.29\times10^5 N$$

Use Newton's Laws to find the Force at A

$\Sigma F = 0$

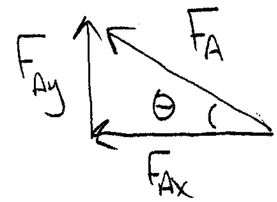


$F_{Ax} - T = 0$

$F_{Ax} = 129 \text{ kN}$

$F_{Ay} - mg = 0$

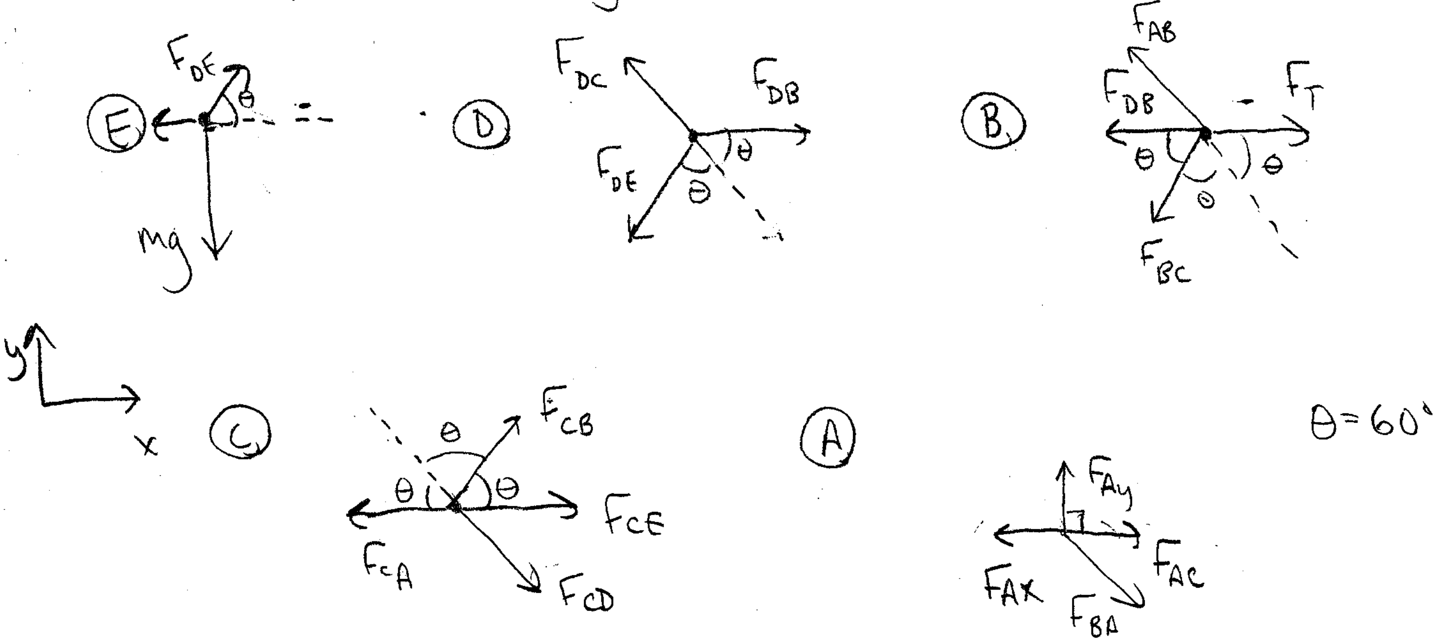
$F_{Ay} = mg = 56 \text{ kN}$



$|F_A| = \sqrt{(F_{Ax})^2 + (F_{Ay})^2} = 141 \text{ kN}$

$\theta = \tan^{-1}\left(\frac{F_{Ay}}{F_{Ax}}\right) = \tan^{-1}\left(\frac{56 \text{ kN}}{129 \text{ kN}}\right) = 23.5°$ above horizontal

(b) Draw seperate force diagrams for each junction:



Remember, the indices are interchangable, so $|F_{DE}| = |F_{ED}|$, etc.

Now, write down Newton's 1st Law for each junction in both directions

(E)

$$F_{DE} \sin\theta - mg = 0 \rightarrow F_{DE} = \frac{mg}{\sin\theta} = \frac{56\text{ kN}}{\sin 60°} = \boxed{64.7\text{ kN} = F_{DE}}$$

$$F_{DE}\cos\theta - F_{EC} = 0 \rightarrow F_{EC} = +F_{DE}\cos\theta = +(64.7\text{ kN})\cos 60°$$

$$\boxed{F_{EC} = +32.3\text{ kN}}$$

(D)

$$F_{DE}\sin\left(\frac{\theta}{2}\right) + F_{DC}\sin\left(\frac{\theta}{2}\right) = F_{DB}$$

$$F_{DE}\cos\left(\frac{\theta}{2}\right) = F_{DC}\cos\left(\frac{\theta}{2}\right) \rightarrow F_{DE} = \boxed{F_{DC} = 64.7\text{ kN}}$$

$$\rightarrow 2F_{DE}\sin\left(\frac{\theta}{2}\right) = F_{DB} = 2(64.7\text{ kN})\sin 30° = \boxed{64.7\text{ kN} = F_{DB}}$$

(C)

$$F_{CA} - F_{DC}\sin\theta - F_{CB}\sin\theta - F_{CE} = 0$$

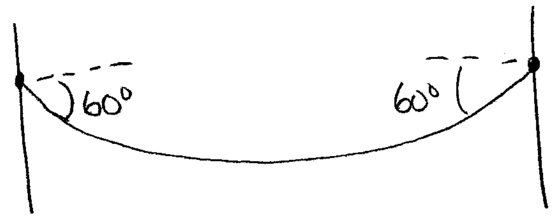
$$F_{CB}\cos\theta - F_{CD}\sin\theta = 0 \rightarrow F_{CD} = \boxed{F_{CB} = 64.7\text{ kN}}$$

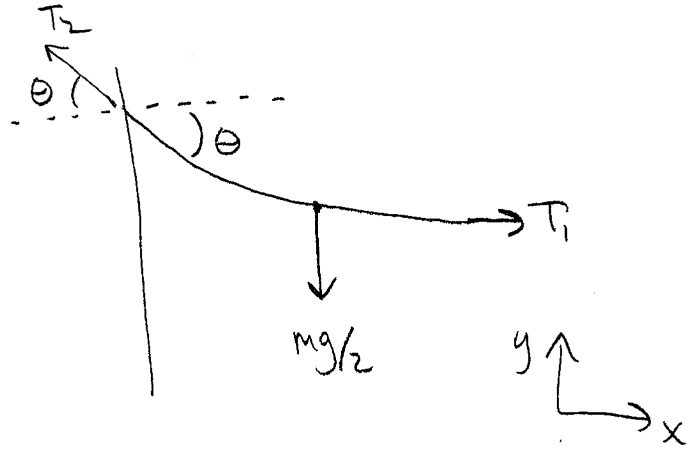
$$F_{CA} = 2F_{DC}\sin\theta - F_{CE} = 2(64.7\,kN)\sin 60° + 32.3\,kN$$

$$\boxed{F_{CA} = 97\ kN}$$

(B) $F_{AB}\sin\theta - F_{BC}\sin\theta = 0 \rightarrow \boxed{F_{AB} = F_{BC} = 64.7\,kN}$

(P80) Select half the rope as our system





$\Sigma F_x = 0$

$T_1 - T_2\sin\theta = 0$

$T_1 = T_2\cos\theta$

$\Sigma F_y = 0$

$T_2\sin\theta - \frac{mg}{2} = 0$

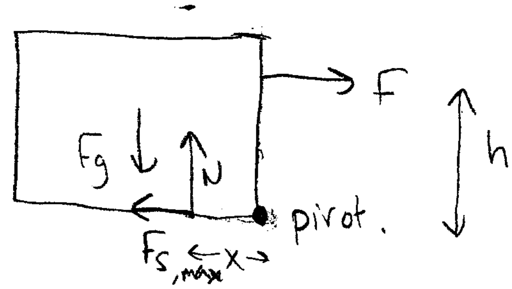
(b) $T_2 = \frac{mg}{2\cos\theta}$

(a) $T_1 = T_2\sin\theta = \frac{mg}{2\tan\theta}$

(c) The direction of the tension is horizontal at the lowest point and $\theta = 60°$ into the wall at the attachment point.

(P86) The box will begin to tip if the net torque is zero

Assume that the friction force acts in the same location as the normal force.



The location of the normal force will change so that the torques balance (assuming the max static friction force is reached - remember, the friction force does not contribute to the net torque)

The block will tip when the normal force is acting at the pivot point ($x \to 0$)

$$\sum F_x = F - f_s = 0 \rightarrow F = F_{s\,max}$$

$$\sum F_y = N - mg = 0 \rightarrow N = mg$$

$$F_{s,max} = \mu_s mg = F$$

$\rightarrow$ This is just telling me that how hard I can pull on the box before it tips depends on the max static friction force.

$$\sum \tau = 0$$

$$Fh + Nx - Mg\frac{l}{2} = 0$$

$$\mu_s mgh + mgx - mg\frac{l}{2} = 0$$

To find μ_s, solve for x and then let $x \to 0$

$$x = \frac{mg\frac{l}{2} - \mu_s mgh}{mg} = l - 2\mu_s h$$

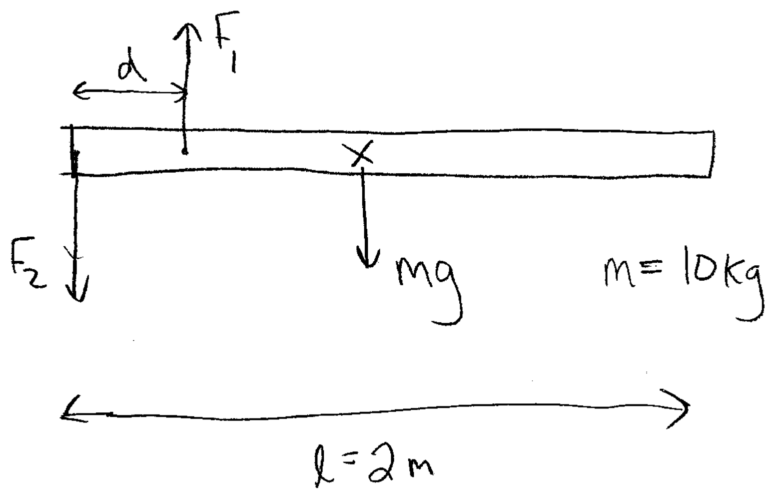
$$0 = l - 2\mu_s h$$

$$\mu_s = \frac{l}{2h}$$

→ so, the box will slide if $\mu_s \leq \frac{l}{2h}$

→ the box will tip if $\mu_s \geq \frac{l}{2h}$

(P89)



I need to consider both forces and torques

$$\Sigma F = 0$$

$$F_1 - F_2 - mg = 0$$

$\Sigma \tau = 0$ (pivot around the center of mass)

$$F_2 \frac{l}{2} - F_1\left(\frac{l}{2} - d\right) = 0$$

$$F_2\left(\frac{l}{2}\right) - (F_2 + mg)\left(\frac{l}{2} - d\right) = 0$$

$$F_2\left(\frac{l}{2}\right) - F_2\left(\frac{l}{2} - d\right) - mg\left(\frac{l}{2} - d\right) = 0$$

$$F_2\left(\frac{l}{2} - \frac{l}{2} + d\right) = mg\left(\frac{l}{2} - d\right)$$

$$F_2 = mg\left(\frac{l}{2d} - 1\right)$$

$$= (10\,kg)(9.8\,m/s^2)\left(\frac{2.0\,m}{2(0.3\,m)} - 1\right)$$

$$F_2 = 230\,N$$

$$F_1 = F_2 + mg = 230N + (10kg)(9.8\,m/s^2) = 330\,N$$

(b) The hand closest to the center must have the larger force so try moving F_1

$$F_1 = F_2 + mg = mg\frac{l}{2d} - mg + mg = \frac{mgl}{2d}$$

$$d = \frac{mgl}{2F_1} = \frac{(10kg)(9.8\,m/s^2)(2m)}{2(150N)}$$

$F_1 = 0.65\,m$ from the right hand.

(c) $$d = \frac{mgl}{2d} = \frac{(10kg)(9.8\,m/s^2)(2m)}{2(80N)}$$

$= 1.23\,m$ from the right hand

Now, check to see if the right hand is still less than 80N

$$F_2 = (10kg)(9.8\,m/s^2)\left[\frac{2m}{2(1.23m)} - 1\right] = -18.3\,N \checkmark$$