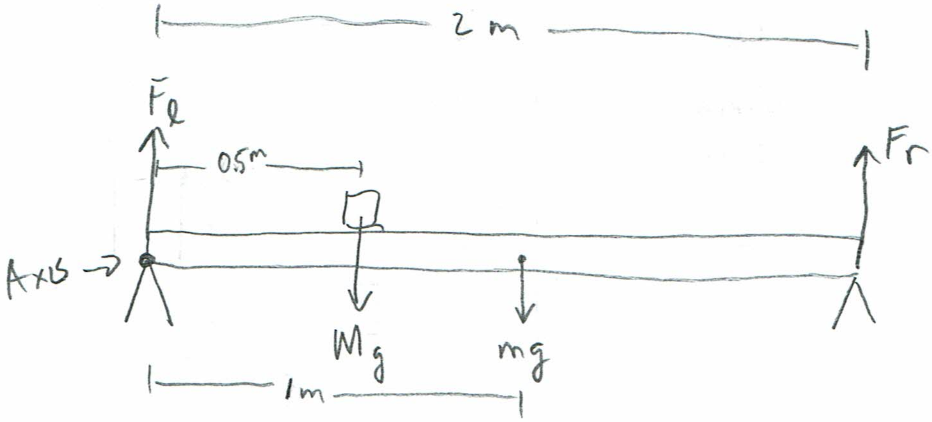


Choose the axis at the left so that F_l creates no torque

$$\tau_{net} = \underbrace{(2m \cdot F_r)}_{\text{CCW}} - \underbrace{(0.5m \cdot Mg)}_{\text{CW, so negative}} - \underbrace{(1m \cdot mg)}_{\text{CW, so negative}} = 0$$ ← static equilibrium

$$\Rightarrow F_r = \frac{0.5m \cdot Mg + 1m \cdot mg}{2m} = 17.15 N$$

And now $F_{net,y} = F_l + F_r - Mg - mg$

$$\Rightarrow F_l = Mg + mg - F_r$$
$$= 31.85 N$$

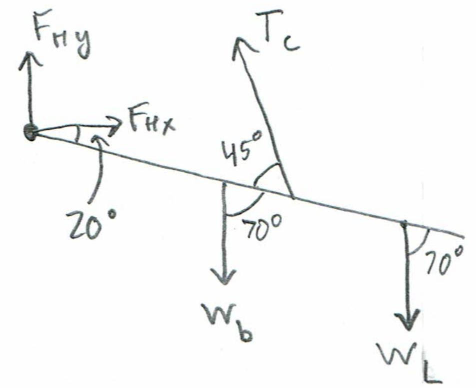
It makes sense, given that the "extra" mass M is to the left, that $F_l > F_r$

By choosing our axis at the location of F_l, we got a torque equation with only one unknown. this is a helpful strategy

Practice Problems solutions.

1. Take our system to be the bridge plus sir lost-a-lot

a)



Take the pivot at the hinge as shown.

$\tau_c = r_c T_c \sin\theta_c$ where $r_c = 5\,m$, $\theta_c = 45°$

$\tau_b = r_b w_b \sin\theta_b = r_b m_b g \sin\theta_b$

where $r_b = 4.0\,m$ (CM of bridge)

$\theta_b = 70°$, $m_b = 2000\,kg$

$\tau_L = r_L w_L \sin\theta_L = r_L m_L g \sin\theta_L$

where $r_L = 8m - 1m = 7m$

$m_L = 1000\,kg$ $\theta_L = 70°$

The 70° angles are the complement of the 20° angle.

Equilibrium requires $\tau_{net} = 0 = \tau_c - \tau_b - \tau_L$

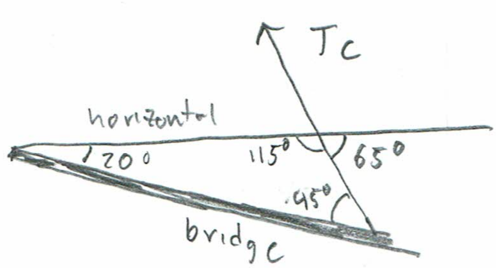
$$\Rightarrow \quad 0 = r_c T_c \sin\theta_c - r_b m_b g \sin\theta_b - r_L m_L g \sin\theta_L$$

$$\Rightarrow \quad T_c = \frac{r_b m_b g \sin\theta_b + r_L m_L g \sin\theta_L}{r_c \sin\theta_c} =$$

$$= \frac{4\,m \cdot 2000\,kg \cdot 9.8\,m/s^2 \cdot \sin 70° + 7\,m \cdot 1000\,kg \cdot 9.8\,m/s^2 \cdot \sin 70°}{5\,m \cdot \sin 45°}$$

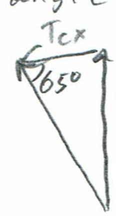
$$= 39070\,N.$$

b) Now $F_{net,y} = 0$ and $F_{net,x} = 0$ because this is static equilib. This is we have to find the components of T_c. This is a tad ~~to~~ tricky - what direction is T_c?



Some geometry shows that T_c is at an angle of 65° from the horizontal.

so



$T_{cy} = T_c \sin 65° = 35409\,N$

$T_{cx} = T_c \cos 65° = 16512\,N$

1b, continued.

So $F_{net,x} = F_{Hx} - T_{cx} = 0$

$\Rightarrow F_{Hx} = T_{c,x} = 16512\,N$

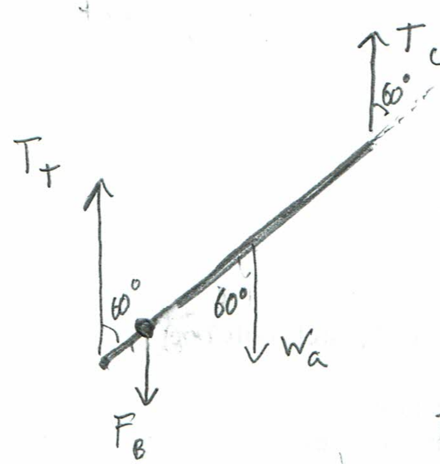
$F_{net,x} = F_{Hy} + T_{cy} - W_b - W_L$

$\Rightarrow F_{Hy} = W_b + W_L - T_{cy} = m_b g + m_L g - T_{cy}$

$F_{Hy} = -6009\,N$

The negative here indicates we guessed wrong about the direction of F_{Hy}. In fact, it is downwards with a force of 6009 N.

2. Consider the arm to be the system, and the point where the bones touch the pivot,



$\tau_c = r_c T_c \sin\theta_c$, and $r_c = 0.35\,m$, $T_c = m_w g$ and $\theta_c = 60°$

$\tau_T = r_T T_T \sin\theta_T$, and $r_T = 0.025\,m$ $\theta_T = 60°$

$\tau_a = r_a W_a \sin\theta_a$, and $r_a = 0.15\,m$ $\theta_a = 60°$ and $W_a = m_a g$

Since its equilibrium

note this is CW, so negative

$\tau_{net} = 0 = \tau_c - \tau_a - \tau_T$

The 60° angles complement the 30 angle.

$\Rightarrow 0 = r_c T_c \sin\theta_c - r_a W_a \sin\theta_a - r_T T_T \sin\theta_T$

$$\Rightarrow T_T = \frac{r_c m_w g \cancel{\sin 60°} - r_a m_a g \cancel{\sin 60°}}{r_T \cancel{\sin 60°}}$$

$$T_T = \frac{(0.35\,m)(15\,kg)(9.8\,m/s^2) - (0.15\,m)(2.0\,kg)\,9.8\,m/s^2}{0.025\,m}$$

$= 1940.4\,N$. A big force!

To find the force from the bone ~~one~~ downwards, recall that

$F_{net,y} = 0$ in equilibrium ~~and~~ so

$$F_{net,y} = T_c + T_T - F_B - W_a = 0$$

$$\Rightarrow F_B = T_c + T_T - W_a = 0$$

$$= (15\ kg)g + 1940.4N - (2\ kg)(g)$$

$$= 2067\ N$$

also a big force!