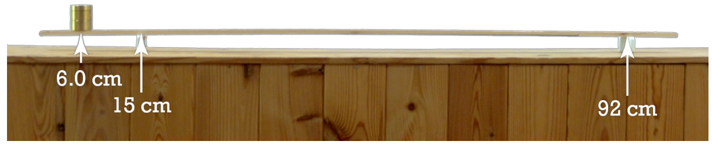
Flipping Physics Lecture Notes:

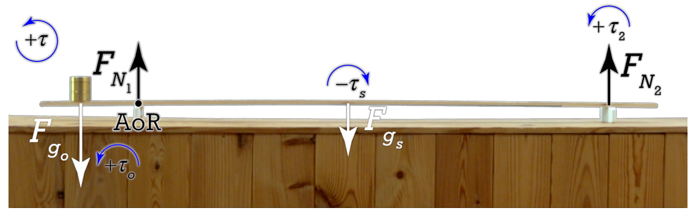
Introductory Rotational Equilibrium Problem

Example: A uniform 0.093 kg meterstick is supported at the 15 cm and 92 cm marks. When a 0.250 kg object is placed at the 6.0 cm mark, what are the magnitudes of the forces supporting the meterstick?



$$m_s = 0.093kg;\ m_o = 0.250kg;\ F_{N_1} = ?;\ F_{N_2} = ?$$

The system is at rest, so it is in both translational and rotational equilibrium. Therefore, the net force equals zero and the net torque about any axis of rotation equals zero. This special case is called *static* equilibrium.



Sum the forces in the y-direction on the meterstick.

$$\sum F_y = -F_{g_o} + F_{N_1} - F_{g_s} + F_{N_2} = ma_y = m(0) = 0$$

$$\Rightarrow -m_o g + F_{N_1} - m_s g + F_{N_2} = 0$$

Both force normals are unknowns, so we need to put this equation in our equation holster and sum the torques on the meterstick about force normal #1. Note: Counterclockwise or out of the page is positive.

$$\sum_{AoR\ @\ F_{N_1}} \tau_{meterstick} = \tau_o + \tau_1 - \tau_s + \tau_2 = I\alpha = I(0) = 0$$

Torque directions:

- The Force of gravity of the object would cause the meterstick to rotate counterclockwise or out of the page, so the torque caused by force of gravity of the object is positive.
- Force normal #1 acts right at the axis of rotation, therefore, the "r" value for force normal #1 is zero, and the torque caused by force normal #1 is zero and has no direction.
- The force of gravity of the stick and force of gravity 2 would both cause the meterstick to rotate clockwise or into the page, so the torques caused by force of gravity of the stick and force of gravity #2 are both negative.

$$\Rightarrow r_o F_{g_o} \sin\theta_o - r_s F_{gs} \sin\theta_s + r_2 F_{N_2} \sin\theta_2 = 0\ \&\ \theta_o = \theta_s = \theta_2 = 90^\circ\ \&\ \sin(90^\circ) = 1$$

$$\Rightarrow r_o m_o g - r_s m_s g + r_2 F_{N_2} = 0 \Rightarrow r_2 F_{N_2} = r_s m_s g - r_o m_o g \Rightarrow F_{N_2} = \frac{r_s m_s g - r_o m_o g}{r_2}$$

$$15 = 6 + r_o \Rightarrow r_o = 15 - 6 = 9cm \approx 0.09m\ \&\ 15 + r_s = 50 \Rightarrow r_s = 50 - 15 = 35cm$$

$$15 + r_2 = 92 \Rightarrow r_2 = 92 - 15 = 77cm$$

$$F_{N_2} = \frac{(35)(0.093)(9.81) - (9)(0.25)(9.81)}{77} = 0.12804 \approx \boxed{0.13N}$$

$$F_{N_2} = \frac{r_s m_s g - r_o m_o g}{r_2} \Rightarrow \frac{(cm)(kg)\left(\frac{m}{s^2}\right) - (cm)(kg)\left(\frac{m}{s^2}\right)}{cm} = (kg)\left(\frac{m}{s^2}\right) = N$$

And, going back to our equation holster:

$$-m_o g + F_{N_1} - m_s g + F_{N_2} = 0 \Rightarrow F_{N_1} = +m_o g - F_{N_2} + m_s g$$

$$\Rightarrow F_{N_1} = (0.25)(9.81) - 0.12804 + (0.093)(9.81) = 3.23679 \approx \boxed{3.2N}$$