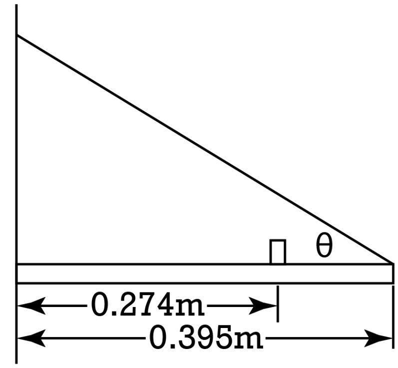
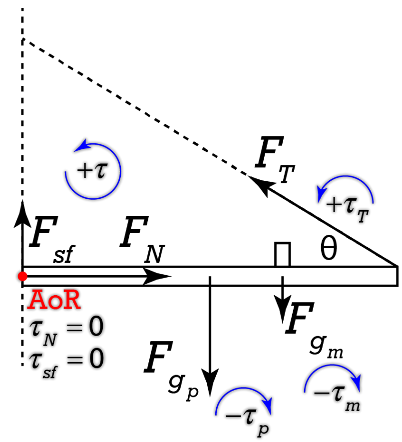
Flipping Physics Lecture Notes:

Torque - Mass on Plank with String



Example: A 0.300 kg mass rests on a 0.395 m long, 0.764 kg, uniform wooden plank supported by a string as shown in the figure. If the mass is 0.274 m from the wall and the angle between the string and the plank is 32.1°, (a) What is the force of tension in the string? and (b) What is the normal force from the wall?

The wood plank is at rest and not rotating, therefore it is in static equilibrium, therefore the net force acting on the plank equals zero and the net torque acting on the plank equals zero about any axis of rotation. The first thing we need to do is to draw the free body diagram of the forces acting on the plank.



Now that we have the free body diagram, we can sum the torques on the plank with an axis of rotation about the left end of the plank. Notice both the force normal and the force of static friction act at the axis of rotation and therefore cause no torque on the plank. (This is why we chose the left end as our axis of rotation. Notice how two out of our three unknown forces cause no torque with that axis of rotation. Helpful, eh?) We can make out counterclockwise, or out of the board, positive, therefore the torque caused by the force of tension is positive and the torques caused by the force of gravity of the plank and the force of gravity of the mass are both negative.

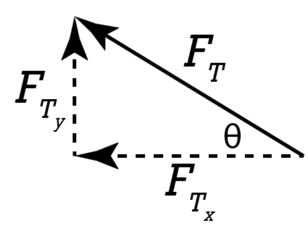
Knowns: $m_p = 0.764kg;\ m_m = 0.300kg;\ r_p = \dfrac{0.395m}{2} = 0.1975m;\ r_T = 0.395m;\ r_m = 0.274m;$
$\theta = 32.1°;\ (a)F_T = ?\ (b)F_N = ?$

$$\sum_{\substack{\text{AoR@left end}}} \vec{\tau}_{plank} = -\vec{\tau}_p - \vec{\tau}_m + \vec{\tau}_T = I\vec{\alpha} = I(0) = 0 \Rightarrow \vec{\tau}_T = \vec{\tau}_p + \vec{\tau}_m$$

$$\Rightarrow r_T F_T \sin\theta_T = r_p F_{g_p} \sin\theta_p + r_m F_{g_m} \sin\theta_m \Rightarrow r_T F_T \sin\theta_T = r_p m_p g \sin(90) + r_m m_m g \sin(90)$$

$$\Rightarrow F_T = \frac{r_p m_p g + r_m m_m g}{r_T \sin\theta_T} = \frac{(0.1975)(0.764)(9.81) + (0.274)(0.300)(9.81)}{(0.395)\sin(32.1)} = 10.8937 \approx \boxed{10.9N}$$

Next we are going to sum the forces in the x-direction, however, before we can, we need to break the force of tension in to its components. Actually, all we really need is the force of tension in the x-direciton.



$$\cos\theta_T = \frac{A}{H} = \frac{F_{T_x}}{F_T} \Rightarrow F_{T_x} = F_T \cos\theta_T$$

$$\sum F_x = F_N - F_{T_x} = ma_x = m(0) = 0 \Rightarrow F_N = F_{T_x} = F_T \cos\theta_T = (10.8937)\cos(32.1)$$
$$\Rightarrow F_N = 9.2283 \approx \boxed{9.23N}$$

P.s. I know we did not solve for the force of static friction (or, for that matter, the minimum coefficient of static friction to hold the plank on the wall), however, you are welcome to sum the forces in the y-direction, or pick a different axis of rotation and sum the torques on the plank, and you will be able to solve for that. Enjoy!