University Physics 1A

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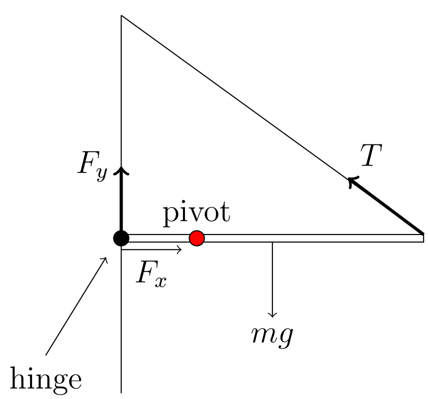
Torque Concepts

If an object is in static equilibrium, its acceleration is 0. The net force on the object is 0 and the object is not rotating around any point. When calculating torque, it is important what point you choose as the pivot point or reference point because the torque calculated is different for each reference point.

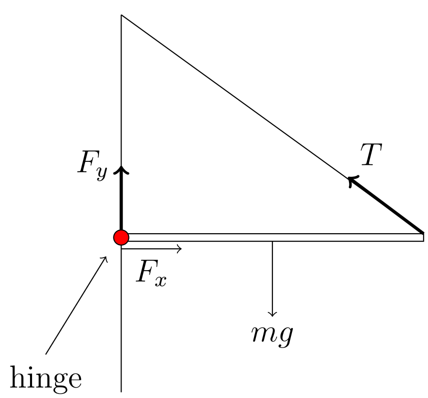
Example

Suppose we have a rod of mass m and length L a hinge and suspended by a string. Choosing the point $\frac{L}{4}$ as our pivot point in the problem gives the following equations.



$$
\begin{aligned}
F_{net\ y} &= F_y - mg + T\sin\theta = 0\\
F_{net\ x} &= F_x - T\sin\theta = 0\\
\tau_{net} &= -F_y\frac{L}{4} - mg\frac{L}{4} + T\sin\theta\frac{3L}{4} = 0\\
0 &= -(mg - T\sin\theta)\frac{L}{4} - \frac{mgL}{4} + \frac{3TL}{4}\sin\theta\\
&= -mg\frac{L}{4} + \frac{TL}{4}\sin\theta - \frac{mgL}{4} + \frac{3TL}{4}\sin\theta\\
mg\frac{L}{4} + mg\frac{L}{4} &= \frac{TL}{4}\sin\theta(4)\\
\frac{1}{2}mgL &= TL\sin\theta\\
T &= \frac{mg}{2\sin\theta}
\end{aligned}
$$

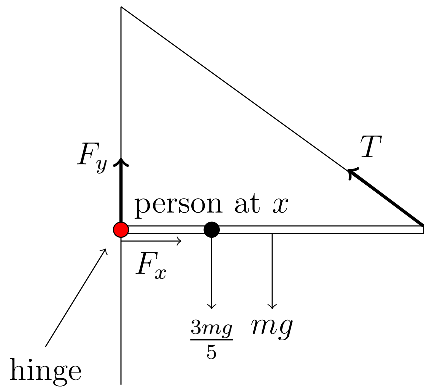
It is much easier to choose the pivot point at the location of an unknown force to simplify the algebra. Suppose we choose the hinge as our pivot point.



The force equations remain the same no matter what, but the net torque becomes:

$$
\begin{aligned}
\tau_{net} &= 0 = 0 - mg\frac{L}{2} + T\sin\theta\\
T &= \frac{mg}{2\sin\theta}
\end{aligned}
$$

Suppose the weight supported by the string is 1.5 times the tension calculated. How far can a person with weight $\frac{3m}{5}$ walk along the rod before the string snaps?



$$
\begin{aligned}
T_{max} &= \left(\frac{3}{2}\right)\left(\frac{mg}{2\sin\theta}\right) \\
F_{net\ y} &= F_y - mg + T\sin\theta - \frac{3mg}{5} \\
F_{net\ x} &= F_x - T\cos\theta = 0 \\
\tau_{net} &= 0 - mg\frac{L}{2} + T_{max}sin(\theta)L - \frac{3}{5}mgx = 0 \\
&= -\frac{mgL}{2} + \frac{3}{2}\frac{mg}{2\sin\theta}\sin\theta L - \frac{3}{5}mgx \\
\frac{mgL}{2} - \frac{3}{4}mgL &= -\frac{3}{5}mgx \\
x &= -\frac{5}{3}\left(\frac{L}{2} - \frac{3}{4}L\right) \\
&= \frac{5}{12}L
\end{aligned}
$$

The person can only walk $\frac{5}{12}$ of the way along the rod.

You can find all my notes at `http://omgimanerd.tech/notes`. If you have any questions, comments, or concerns, please contact me at alvin@omgimanerd.tech