8 Torque

Apparatus

- meter stick with holes drilled in it
- 1/group
- spring scales, calibrated in newtons
- slotted weights (in lab benches in 415)
- holder for slotted weights
- string
- protractors
- hook clamps
- Ohaus balances

Goal

Test whether the total force and torque on an object at rest both equal zero.

Introduction

It is not enough for a boat not to sink. It also must not capsize. This is an example of a general fact about physics, which is also well known to people who overindulge in alcohol: if an object is to be in a stable equilibrium at rest, it must not only have zero net force on it, to keep from picking up momentum, but also zero net torque, to keep from acquiring angular momentum.

Observations

Weigh your meter stick before you do anything else; they don’t all weigh the same amount.

Construct a setup like the one shown above. Avoid any symmetry in your arrangement. There are four forces acting on the meter stick:

\[
\begin{align*}
F_H & = \text{the weight hanging underneath} \\
F_M & = \text{Earth’s gravity on the meter stick itself} \\
F_L & = \text{tension in the string on the left} \\
F_R & = \text{tension in the string on the right}
\end{align*}
\]

Each of these forces also produces a torque.

In order to determine whether the total force is zero, you will need enough raw data so that for each torque you can extract (1) the magnitude of the force vector, and (2) the direction of the force vector. In order to add up all the torques, you will have to choose an axis of rotation, and collect enough raw data to be able to determine for each force (3) the distance from the axis to the point at which the force is applied to the ruler, and (4) the angle between the force vector and the line connecting the axis with the point where the force is applied. Note that the meter stick’s own weight can be thought of as being applied at its center of mass.

The meter stick has holes drilled in it that you can use to attach the strings. You can make your analysis simpler by tying the knots as shown below, so that all the forces act at points along the center-line of the stick.

You have a selection of spring scales, so use the right one for the job — don’t use a 20 N scale to measure 0.8 newtons, because it will not be possible to read it accurately. Optimize your precision by choosing conditions that come as close as possible to maxing
out the scales. For each spring scale, hang a known weight from it, and adjust the calibration tab so that the scale gives the correct result. If you need to swap in a new spring scale, don’t forget to calibrate it.

**Prelab**

The point of the prelab questions is to make sure you understand what you’re doing, why you’re doing it, and how to avoid some common mistakes. If you don’t know the answers, make sure to come to my office hours before lab and get help! Otherwise you’re just setting yourself up for failure in lab.

**P1** You have complete freedom in defining what point is to be considered the axis of rotation — if one choice of axis causes the total torque to be zero, then any other choice of axis will also cause the total torque to be zero. It is possible to simplify the analysis by choosing the axis so that one of the four torques is zero. Plan how you will do this.

**P2** All the torques will be tending to cause rotation in the same plane. You can therefore use plus and minus signs to represent clockwise and counterclockwise torques. Choose which one you’ll call positive. Using your choice of axis, which of the four torques, $\tau_H$, $\tau_M$, $\tau_L$, and $\tau_R$, will be negative, which will be positive, and which will be zero?

**Analysis**

Determine the total force and total torque on the meter stick. Do error analysis for the total torque computed using one choice of axis. Do not use the max/min technique, but rather combine errors in quadrature as explained in appendix 3.

Finally, repeat your calculation of the total torque using a different point as your axis (with errors). Present both results in your own abstract.