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Experiment 1.07: Torque

Diego Castano
Nova Southeastern University, castanod@nova.edu

I. EXPERIMENT 1.07: TORQUE

A. Abstract

A meter stick is pivoted at a point and maintained horizontal by the appropriate placement of weights along its length. The measurements are compared to the theoretical predictions based on the two conditions for static equilibrium.

B. Formulas

$$\tau = rF\sin\theta \tag{1}$$

$$\text{static equilibrium:} \begin{cases} \sum_{\text{ext.}} \vec{F} = \vec{0} \\ \sum_{\text{any axis}} \vec{\tau} = \vec{0} \end{cases} \tag{2}$$

Equations (2) represent the two conditions necessary for static equilibrium.

C. Description and Background

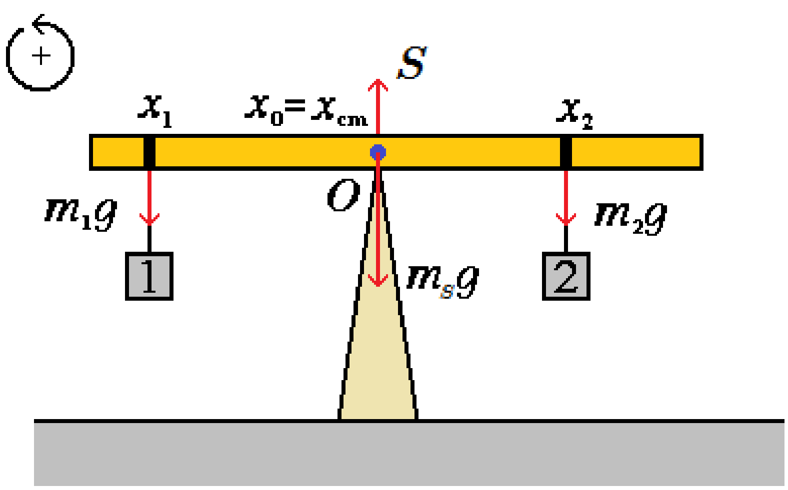

FIG. 1. Part I set-up.

Part I of the experiment is depicted in Figure 1. There are four forces on the meter stick. The fulcrum, or support, force is denoted, $\vec{S}$. The meter stick is pivoted at its center of mass (which may not be the 50 cm position). A mass, m_{11}, is hung from position $x_1 = 40$ cm, then another mass, m_{12}, is chosen and location x_2 is found experimentally so as to realize horizontal equilibrium for the meter stick system.

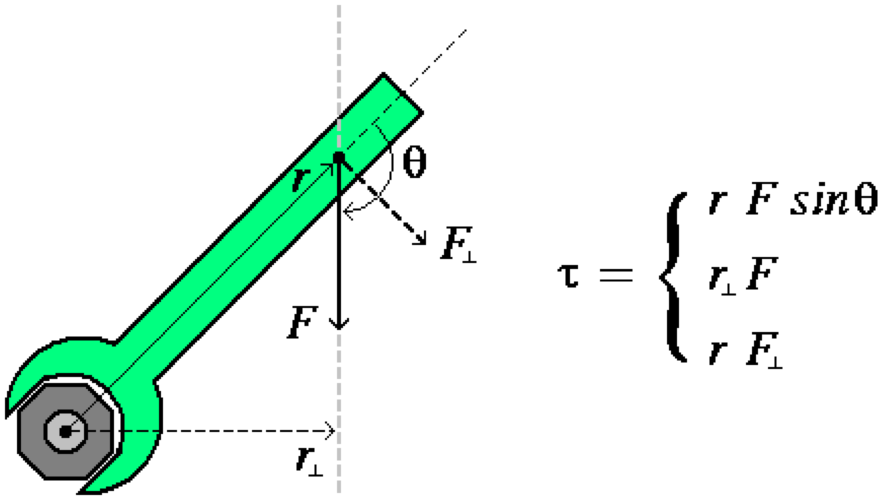

FIG. 2. Torque example.

Equation (1) is the general equation for the magnitude of a torque. An example of its use in determining the torque about the head of a bolt due to the application of a wrench is depicted in Figure 2. The torque direction is perpendicular to the plane of the figure and points into the plane as the right hand rule confirms.

Part II of the experiment is depicted in Figure 3. The meter stick is now pivoted at $x_0 = 25$ cm. A mass, m_{21}, is chosen and hung at x_1 (located experimentally) so as to realize horizontal equilibrium for the meter stick system.

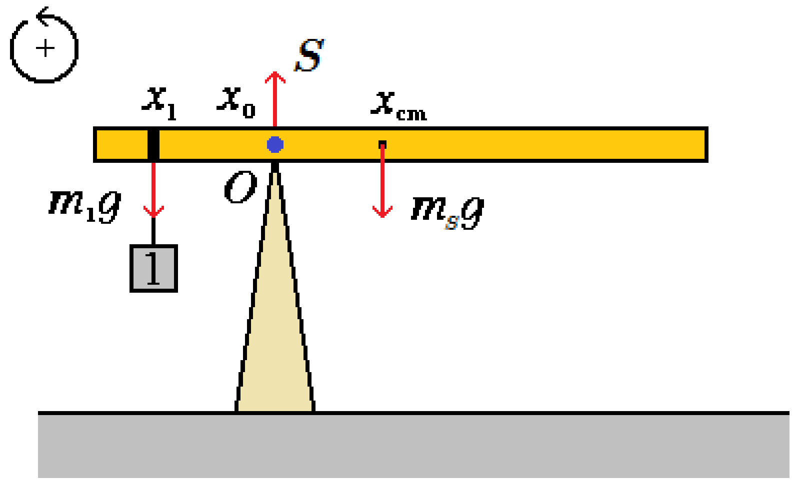

FIG. 3. Part II set-up.

D. Procedure

1. Part I

1. Locate the center of mass of the meter stick. Support the meter stick at this point.

2. Hang a weight at the $x_1 = 40.00\ cm$ mark on the meter stick. Record the hanging mass (m_{11}). The recorded hanging mass should include the clamp mass.

3. Using a second, different hanging mass (m_{12}), determine the location (try to measure down to the half millimeter) along the meter stick that achieves static equilibrium (x_2).

2. Part II

1. Support the meter stick at the 25.00 cm mark.

2. Determine the required hanging mass (m_{21}) and its location (try to measure down to the half millimeter) to achieve static equilibrium in this case.

E. Measurements

mass of the meter stick, m_{stick} [*gram*]	
location of meter stick's c.m., x_{cm} [*cm*]	

part	x_0 [*cm*]	total mass 1 [*gram*]	location 1 [*cm*]	total mass 2 [*gram*]	location 2 [*cm*]
I			40.00		
II	25.00			N/A	N/A

F. Instructions

1. Calculate the (Part I) torque about the pivot due to m_{11}, $\tau_{\odot}$ [$N \cdot m$].
2. Calculate the (Part I) torque about the pivot due to m_{12}, $\tau_{\otimes}$ [$N \cdot m$].
3. Calculate the percent difference in the two opposing torques in Part I.
4. Calculate the (Part II) torque about the pivot due to m_{stick}, $\tau_{\otimes}$ [$N \cdot m$].
5. Calculate the (Part II) torque about pivot due to m_{21}, $\tau_{\odot}$ [$N \cdot m$].
6. Calculate the percent difference in the two opposing torques in Part II.
7. Calculate the uncertainties in each of the four calculated torques using

$$\delta\tau^2 = \tau^2 \left[\left(\frac{\delta r_\perp}{r_\perp} \right)^2 + \left(\frac{\delta m}{m} \right)^2 \right]$$

   where $\delta m = 0.1\ g$ and $\delta r_\perp = 0.05\ cm$. Enter these into the table.

8. Given the uncertainties, are the opposing torques in Part I equal?
9. Given the uncertainties, are the opposing torques in Part II equal?

G. Calculations

part	$\tau_\odot$ [$N \cdot m$]	$\delta\tau_\odot$ [$N \cdot m$]	$\tau_\otimes$ [$N \cdot m$]	$\delta\tau_\otimes$ [$N \cdot m$]	%-Diff $(\tau_\odot, \tau_\otimes)$
I					
II					

part	$(\tau_\odot - \delta\tau_\odot, \tau_\odot + \delta\tau_\odot) \cap (\tau_\otimes - \delta\tau_\otimes, \tau_\otimes + \delta\tau_\otimes) \neq \varnothing$
I	YES or NO
II	YES or NO