Torque

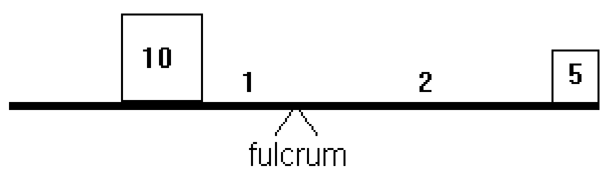
Introduction: Not everything moves in a straight line. In fact, an argument can be made that nothing moves in straight lines, but curved space is beyond the scope of this lab. The torques we will discuss are everyday phenomena, such as crowbars, see-saws, and steering wheels. However, your lab is not merely a practical but also an artistic endeavor: using string, tape, dowels, and *pretty* masses you will design and build a simple three beam mobile.

Theory: Force gives acceleration to a mass in the direction of the force, and when that force causes rotation about an axis we say a torque has been applied. Torque is a force acting over a distance. If all vectors are perpendicular this relationship is described mathematically as:

$$\Gamma = rF$$

where *r* is the distance from where the force *F* acts to the axis of rotation. The point of rotation is called the pivot or fulcrum, and the distance *r* is called the lever or moment arm. Forces never cause rotations when they act at the pivot, a fact that can simplify calculations.

In most common daily occurrences the force will be perpendicular to the lever arm and we can simply consider torque to be force times length. Such is the case with a see-saw. If the pivot is placed at the center of mass of the board, the weight of the board will produce no torque. A state of rotational equilibrium will occur when all the torques which cause clockwise rotations balance out the counter-clockwise torques. Examine the example below:



The 10 weight times the 1 distance balances the 5 weight times the 2 distance.

A mobile is a series of beams and masses suspended from other beams, all of which are is a state of rotational equilibrium. To keep the calculations easy each fulcrum (string) could be placed at the center of each beam. However, the weight of the beam will have to be included if you don't place the string at the center of the beam.

Task:

Start building a mobile with one small beam suspended from one of two medium beams. Then suspend the two medium beams from the long beam. **Do not dismantle the mobile until your lab instructor says that is OK to do so. <u>The pretty masses on the same beam must not have the same mass value.</u>**

Equipment:

- String

- Four beams
- Five pretty masses (bring these from home or work, *not* what you happen to find in your purse or pocket because you didn't read this lab in advance and forgot to bring from home!)

The Steps:

1. **Mass all your objects and all the beams.**
2. **Start with the smallest mass at the end of the first beam**. Place the fulcrum at the center of the beam. Calculate the position of the heavier object such that the system is in complete equilibrium.
3. Calculate the positions of each mass or mass system relative to the **fulcrum** of the beam which supports it **(See the calculations section below)**. Assume that the lighter mass is always at the end of the beam.
4. After you have done your calculations, create a design using the four beams and five pretty masses. **Include this master plan in your report**.
5. When you start building your mobile you will realize that the pretty masses may not all be at the ends of the beams, and the smaller beams may not be at the ends of the longer beams.
6. Remember, you are the artist! You can choose where on each beam you want the mass to hang relative to the fulcrum (point of suspension). You may choose the fulcrum to coincide with the center of mass of the beam or not. In any case, you will have three masses per beam (two pretty masses and the beam itself), and you will choose the positions for two of these three. Through calculations you will find the place to hang the third mass.
7. After the mobile is assembled, the beams should all be horizontal. If they are not, adjust the weight positions. What would cause a beam not to be horizontal?
8. Show the mobile to your instructor once the everything is balance. You must show the mobile to your instructor to get full credit in this lab. **Do not dismantle the mobile until your lab instructor says that is OK to do so.**

Calculations:

1. Starting with the lowest beam, and assuming you know all the masses, mathematically place the lighter pretty mass at the end of the smaller beam and calculate how far the heavier mass should be from the fulcrum, which is the center of the little beam.
2. Repeat for the other lower beams.
3. Add the two-pretty-mass + beam weight for all the lower beams. Suspend the lighter of the two sums from the end of the long beam, and calculate where you need to place the heavier two-mass + beam(s) weight on the long beam to balance the system.