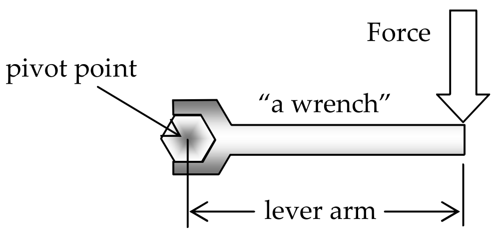
Static Equilibrium

Introduction:

In order to insure that objects remain at rest, two conditions of static equilibrium must be satisfied. The First Condition states that objects will not translate or vibrate so long as the outside forces are balanced. The Second Condition requires that *torques* balance so that objects do not rotate. Torque is defined as the product of the force of rotation and the *lever arm*:

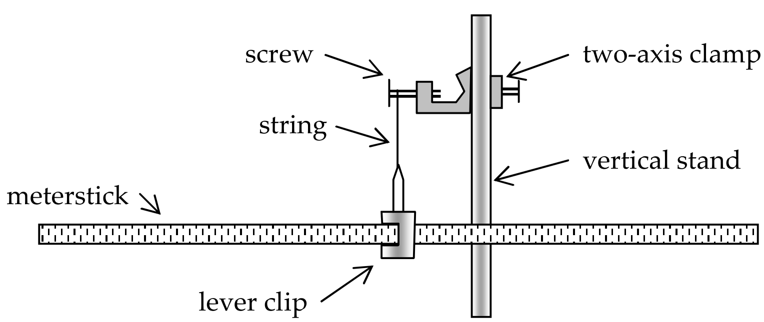


Torque = Force × lever arm

where the lever arm is defined as the shortest distance between the pivot point and the line of the force.

The purpose of this experiment is to test whether the Second Condition of Static Equilibrium holds in a simple experiment. Make sure your group has a vertical stand, a two-axis clamp, 3 lever clips, a set of hooked weights, a scientific calculator, a meterstick, and some string.

Preliminary Set-Up and Measurements:



1) Attach the two-axis clamp near the top of the vertical stand.
2) Use a piece of string to hang a lever clip off one of the screws protruding from the two-axis clamp. Slide the meterstick through the hanging clip. Screw the clip in place when the meterstick hangs horizontally at rest (see diagram above).
3) Read the location of the lever clip along the meterstick. Record the number of centimeters that line up with the center of the clip. This is the *center of gravity* of the meterstick, i.e. its natural pivot point.

Position of Center of Gravity = ______________________ cm

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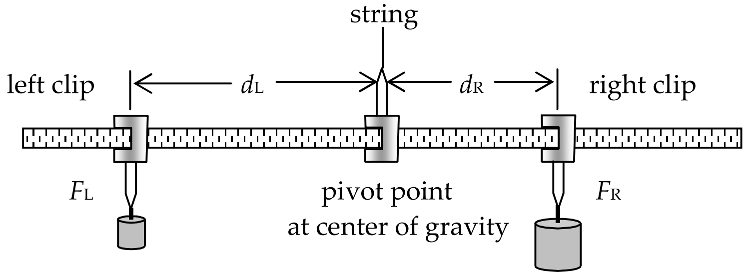
Data Collection:

Set-Up #1:



1) Mass the two remaining clips on the balance. Record their masses in grams below.
2) Hang a 50-gram weight from one of the clips and fasten it at the 10-cm mark on the meterstick. The total force F_L equals the mass of the clip plus 50 grams. (For convenience, we will be using grams to measure force in this lab.) Record F_L in the data table.
3) Hang a 100-gram weight from the remaining clip and slide it on the opposite (right) side of the meterstick. Find the position that levels the stick, i.e. where the system is in static equilibrium. The total force F_R equals the mass of the clip plus 100 grams. Record F_R in the data table.
4) Calculate the lever arms d_L and d_R and record their values (in *cm*) in the data table.
5) Calculate the left torque as $F_L d_L$ and the right torque as $F_R d_R$. The unit is gram-centimeters.
6) Now hang a 100-gram weight from the left clip and fasten it at the 35-cm mark on the meterstick. Record total force F_L in the data table.
7) Hang a 50-gram weight from the right clip. Find the position that levels the stick. Record total force F_R in the data table.
8) Repeat Steps 4 – 5 above.

Mass of left clip = ___________________ grams

Mass of right clip = _________________ grams

F_L [grams]	d_L [cm]	F_R [grams]	d_R [cm]
50		100	
100		50	

Left Torque [gram-cm]	Right Torque [gram-cm]

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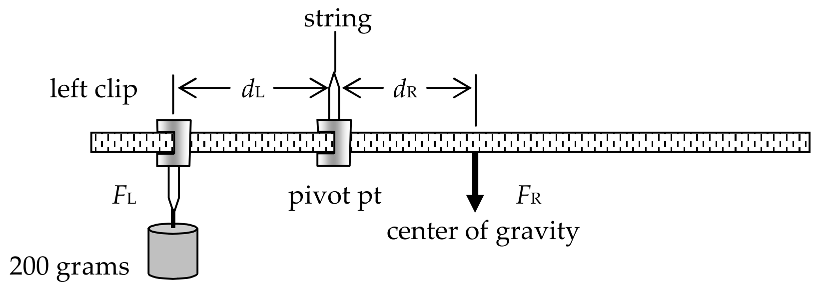
Set-Up #2:



1) Hang a 200-gram weight from the left clip and fasten it at the 20-cm mark on the meterstick. Record total force F_L in the data table.
2) Fasten the pivot point (the clip attached to the string) to the 30-cm mark on the stick. The center of gravity now causes an opposing torque on the right side of the stick. Move the meterstick until it balances. The total force F_R equals the mass of the meterstick.
3) Calculate the lever arms d_L and d_R and record their values (in *meters*) in the data table.
4) Calculate the left torque as F_Ld_L and set your result equal to the right torque as F_Rd_R. Solve for F_R. Record your result as the calculated F_R.
5) Now mass your meterstick using the balance. You may need to add extra weight to one of the pans of the balance in order to obtain a measurement. Record your result as the measured F_R.

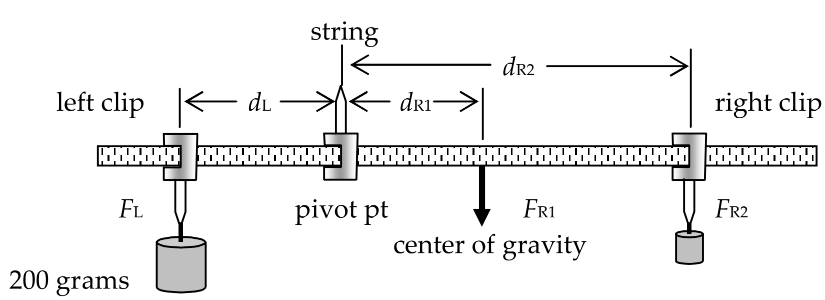
F_L [grams]	d_L [cm]	d_R [cm]
200	**20**	

Left torque = F_Ld_L = ____________________ gram-cm

Calculated F_R = mass of meterstick = ____________________ grams

Measured mass of meterstick = ____________________ grams

Set-Up #3:



1) Keep the 200-gram weight hanging from the left clip at the 20-cm mark on the meterstick.

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2) Hang a 50-gram weight from the right clip and fasten it at the 80-cm mark.
3) Move the pivot point until the stick is level.
4) Record total force F_L in the data table. Record F_{R1} (use the measured mass of the meterstick) and F_{R2} (the total mass of the right clip plus 50 grams).
5) Calculate the lever arms d_L, d_{R1}, d_{R2} and record their values.
6) Calculate the left torque as $F_L d_L$ and the right torque as $F_{R1}d_{R1} + F_{R2}d_{R2}$.

F_L [grams]	d_L [cm]	F_{R1} [grams]	d_{R1} [cm]	F_{R2} [grams]	d_{R2} [cm]
200	**20**				

Total left torque = ________________________________ gram-cm

Total right torque = ______________________________ gram-cm

Questions: Please answer neatly in complete sentences. Use an additional sheet if necessary.

1) How does the left torque compare with the right torque in Set-Up #1? Based on your data, can you conclude that the Second Condition of Static Equilibrium holds? Why?

2) How does your calculated value for the mass of the meterstick compare with its measured value in Set-Up #2? Based on your data, can you conclude that the Second Condition of Static Equilibrium holds? Why?

3) How does the left torque compare with the right torque in Set-Up #3? Based on your data, can you conclude that the Second Condition of Static Equilibrium holds? Why?

4) Describe at least two ways to improve the precision of this experiment.

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