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:

\[
\text{Torque} = \text{Force} \times \text{lever arm}
\]

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.

\[
\text{Position of Center of Gravity} = \underline{\text{____________________ cm}}
\]
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

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<thead>
<tr>
<th>$F_L$ [grams]</th>
<th>$d_L$ [cm]</th>
<th>$F_R$ [grams]</th>
<th>$d_R$ [cm]</th>
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<td>50</td>
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Left Torque [gram-cm] | Right Torque [gram-cm]
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 $F_L d_L$ and set your result equal to the right torque as $F_R d_R$. 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 $F_R$.

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<tr>
<th>$F_L$ [grams]</th>
<th>$d_L$ [cm]</th>
<th>$d_R$ [cm]</th>
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Left torque = $F_L d_L = \text{gram-cm}$

Calculated $F_R = \text{mass of meterstick} = \text{grams}$

Measured mass of meterstick = $\text{grams}$

Set-Up #3:

1) Keep the 200-gram weight hanging from the left clip at the 20-cm mark on the meterstick.
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 $F_Ld_L$ and the right torque as $F_{R1}d_{R1} + F_{R2}d_{R2}$.

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<tr>
<th>$F_L$ [grams]</th>
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<th>$F_{R1}$ [grams]</th>
<th>$d_{R1}$ [cm]</th>
<th>$F_{R2}$ [grams]</th>
<th>$d_{R2}$ [cm]</th>
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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.