Name: _____ Name: _____

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Static Equilibrium
Using a Meter Stick to Determine an Unknown Mass

Note on grading: Your lab score in large part will be based on how accurately your group performs the lab's activities. Cheating during any part of the lab activity will result in a grade of zero. *Only the TA may weigh the unknown mass and the meterstick to determine the actual mass of each.*

DO NOT Write or Draw on the Meterstick

Purpose:

Applying the principle $\sum\tau = 0$ for a rigid body in static equilibrium, the students will use a meterstick and some known masses to predict the mass of an unknown object and determine the mass of the meterstick without weighing either the unknown mass or the meterstick.

Part I – A Rough Estimate of the Meterstick's Mass

Hints:

1. Determine the meterstick's center of mass.
2. Typically, the meterstick's center of mass is not located at 50cm.
3. The piece of provided angle will be used as a fulcrum. Place the fulcrum on a book to help prevent it from sliding on the bench top.
4. Use the provided loop of string to hang the known mass.
5. The mass hanger has a mass of 5g.
6. It may be difficult to get the meterstick to balance perfectly; a very slight amount of rotation is OK.
7. In general, torque has units of Newton-meters.

Students may not use a scale or balance for Part I, Part II, Part III, or Part IV to weigh the unknown or the meterstick.

With the 10cm and 60cm mark located over the bench, place the fulcrum under the 60cm mark of the meterstick. Hang and carefully position 40g on the portion of the meterstick that is extended over the edge of the bench such that the meterstick is balanced while the 60cm mark remains positioned over the fulcrum.

The lab group should thoroughly discuss the concepts that allow the meterstick to balance.

Part I – A Rough Estimate of the Meterstick's Mass (continued)

Estimate the mass of the meterstick. Provide an appropriately labeled diagram and show all work.

Part II - Determining the Mass of the Meterstick

Students may not use a scale or balance for Part I, Part II, Part III, or Part IV to weigh the unknown or the meterstick.

Create a scatter plot with the torque due to the known mass on the x-axis and the lever arm from the fulcrum to the meterstick's center of mass on the y-axis. Collect a minimum of 6 data points to create an appropriate scatter plot to determine the mass of the meterstick.

Hints

1. The position of the fulcrum will have to be varied.
2. The location of the fulcrum should remain in between the known mass and the meterstick's center of mass.
3. Maximizing the length of the lever arms will result in less error.
4. In general, torque has units of Newton-meters.
5. Appropriately utilize any of the Hints from Part I.

Attach the Scatter Plot and Data Table: The scatter plot requires appropriate labels. (20 points)

The predicted mass of the Meterstick recorded below must be related to the scatter plot's fit equation.

Predicted Mass of Meterstick in grams (a)	Actual Mass of Meterstick in grams (b)	Percent Difference $= \frac{\lvert a-b \rvert}{b} x100\%$	Score from Table Below

Percent Difference	<=1.7%	<=2.0%	<=2.2%	<=2.5%	<=3.2%	<=3.7%	>3.7%
Points	25 (100%)	24 (96%)	22 (88%)	21 (84%)	19 (76%)	18 (72%)	15 (60%)

Before beginning Part III, request the TA to weigh the meterstick and determine your percent difference.

Part III – Estimating the Mass of the Unknown using a Single Data Point

Students may not use a scale or balance for Part I, Part II, Part III, or Part IV to weigh the unknown or the meterstick.

Hints:

1. Place the unknown mass and a known mass on opposite sides of the fulcrum.
2. Maximizing the length of the lever arms will result in less error.
3. Position the fulcrum and meterstick diagonally on a corner of the bench such that items can be hung on both sides of the meterstick.

Briefly explain how the mass of the meterstick can be made irrelevant based on the selection of the position of the fulcrum and the chosen pivot point. (5 points)

Using the meterstick and 30 grams of known mass, estimate the mass of your unknown object.

Estimate the mass of the unknown mass. Provide an appropriately labeled diagram and show all work. (5 points)	
Estimate of Unknown Mass (g)	

Part IV – Determining the Mass of the Unknown using Multiple Data Points

Students may not use a scale or balance for Part I, Part II, Part III, or Part IV to weigh the unknown or the meterstick.

The torque produced by the known masses will be varied to collect a minimum of 8 data points. Therefore, the torque produced by the known masses will be considered the independent variable and shall correspond to the x-axis. Create a scatter plot of "Lever Arm to Unknown" vs "Torque Produced by Known Masses".

Hints

1. Use a minimum of 10g for the known mass.
2. To vary the torque produced by the known mass, both the known mass and the lever arm of the known mass may be varied.
3. The lever arm of the unknown mass should not be allowed to remain constant.
4. The location of the fulcrum ***must*** remain constant for all data collected.
5. The chosen pivot point ***must*** also remain constant for all data collected.
6. The mass of the unknown can be found with a fair amount of precision with carefully taken measurements. The largest source of error is not keeping the location of the fulcrum constant. A percent difference of 0.5% or less is obtainable.

Predict the mass of the unknown mass using the scatter plot. The predicted mass of the Unknown recorded below must be related to the scatter plot's fit equation.

Attach the Scatter Plot and Data Table: The scatter plot requires appropriate labels. (20 points)

Considering the experience that was gained with Part I, Part II and Part III, more precise results are expected for Part IV. Therefore, the percent difference has been tightened.

Predicted Mass of Unknown in grams (a)	Actual Mass of Unknown in grams (b)	Percent Difference $= \frac{\lvert a-b \rvert}{b} x100\%$	Score from Table Below

Percent Difference	<=1.2%	<=1.4%	<=1.6%	<=2.0%	<=2.4%	<=2.7%	>2.7%
Points	25 (100%)	24 (96%)	22 (88%)	21 (84%)	19 (76%)	18 (72%)	15 (60%)