Experiment 7

TORQUES (Fall 2023 version 2)

EQUIPMENT

1 meter stick	*1 ERROR program*
1 balance support	*1 sliding knife-edge clamp*
2 mass hangers	*2 sliding hanger clamps*
1 triple beam balance	*1 set of masses*
calculator	*1 rock with string or rubber band & paper clip*

INTRODUCTION

The purpose of this experiment is to study the concepts of center of gravity and torque *(the rotational counterpart of force)* and to apply these concepts to determine the value of an unknown mass.

Torque is defined as the product of a **force** and a **lever arm distance** that tends to produce rotation. The lever arm is the perpendicular distance from the axis of rotation to the line along which the force acts.

The **center of gravity** of an object is the average position of its weight. The force of gravity on the entire object can be considered to act at this point. For instance, the center of gravity of a uniform meter stick would be at its midpoint (the 50-cm mark).
In this experiment you will observe and calculate the torque produced by objects suspended from a meter stick supported at its center of gravity (see Figure 1).

The torque produced by each object suspended from the meter stick is found by multiplying its distance from the fulcrum times the force of gravity on that object. In other words:

$$T = F \times D$$

Where D is the distance from the fulcrum.
From your observations and calculations, you will determine the value of an unknown mass and explore the concept of a “solitary seesaw”.

PROCEDURE

A. Investigation of Torque

1. Hold a meter stick in your hand near the end marked 0–cm.
2. Place a sliding hanger clamp on the meter stick and slide it to the other 20-cm (0.2 m) mark. *Tighten the screw*. Suspend a mass hanger from the clamp. Place a 500-g (.5 kg) mass on the mass pan and attempt to rotate the stick up and down.

3. Slide the hanger clamp with the mass hanger and the 500-g mass to the 40, 60, 80, and then the 95-cm mark. At each mark attempt to rotate the stick up and down. How does the difficulty of holding the meter stick change as the mass is moved away from your hand? Remove the masses and hanger clamps.

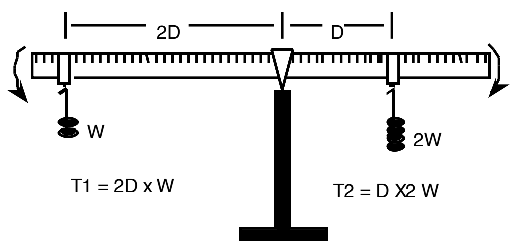


Figure 1
T1 =T 2

B. Calculation of Torque

4. Slide the knife edge clamp onto the meter stick so that the screw adjustment is at the **bottom edge** of the meter stick (refer to Figure 1). Slide the clamp until it is near the 50-cm mark.
5. Place the knife-edge clamp and meter stick in the balance support. Notice that the clamp serves as a fulcrum and allows the meter stick to rotate. Carefully adjust the position of the clamp until the meter stick is balanced in a horizontal position. This is the position of the center of gravity of the meter stick. This is also the position of the fulcrum when the meter stick is balanced with no additional masses on it. Record this position.
6. Measure and record the combined mass of a sliding hanger, mass hanger, and 500-g mass in kilograms. Calculate and record the combined weight. Remember **weight = mg.**

7. Place the sliding mass hanger onto the meter stick and position it 20 cm (0.2 m) to the right of the fulcrum. Use the screw to secure the sliding hanger in position. Suspend a mass hanger and 500 g (0.5 kg) mass from this hanger.

8. Measure and record the combined mass of the other sliding hanger, mass hanger, and 250-g mass in kilograms. Calculate and record the combined weight.

9. Place the second sliding mass hanger onto the other end of the meter stick and suspend the mass hanger and 250-g (0.25 kg) from it.

10. Adjust the position of the second sliding hanger until the meter stick is balanced in a horizontal position. Record the distance between the position of the hanger and the fulcrum in meters.

11. *Definition*: When the meter stick is balanced in the horizontal position, it is said to be in **equilibrium**. That is, all of the forces and torques cancel one another, resulting in no acceleration.

12. Use the torque formula to calculate the two torques acting on the meter stick. Record the results. Ideally you should find that the torques are equal in magnitude.

C. Determination of an Unknown Mass

13. . Suspend the rock from a string at a position 20 cm (0.2 m) to the right of the fulcrum. Record this distance.

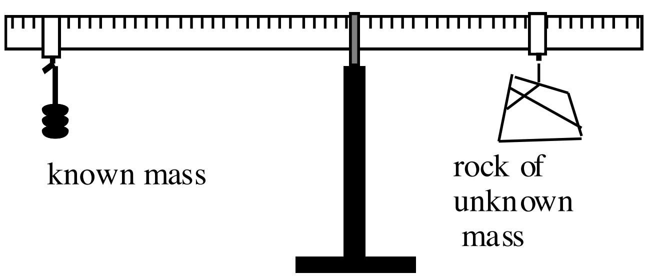


Figure 2

14. a. Measure and record the combined mass of sliding hanger, mass hanger and 100-g mass in kilograms. This is the known mass referred to in Figure 2. b. Calculate and record the weight of this combination.

15. Place this sliding mass hanger on the other end of the meter stick and suspend a mass hanger.

16. Place the 100-g (0.1 kg) mass on the mass hanger.

17. Adjust the position of the sliding hanger until the meter stick is horizontally balanced. At this position, the torque produced by the known mass is equal to the torque produced by the rock and its sliding hanger. Record the distance between the sliding hanger and the fulcrum in meters.

18. Use the torque formula to find the torque caused by the known mass. Record the result.

19. Below is an equation that shows how one calculates the weight of the rock and hanger given the known weight and length of each lever arm.

20. Make sure you understand how this equation was derived. In this part of the lab,

$$\text{Torque} = \text{Weight} \times \text{Length of lever arm}$$

or

$$T = WL.$$

Because the meter stick is in equilibrium, we know the magnitude of the torques are equal and oriented in opposite directions, so

$$T_{\text{Known}} = T_{\text{rock}}$$

Using our definition of torque,

$$W_{\text{Known}} \times L_{\text{Known}} = W_{\text{R}} \times L_{\text{R}} \;.$$

Finally, we solve for the weight,

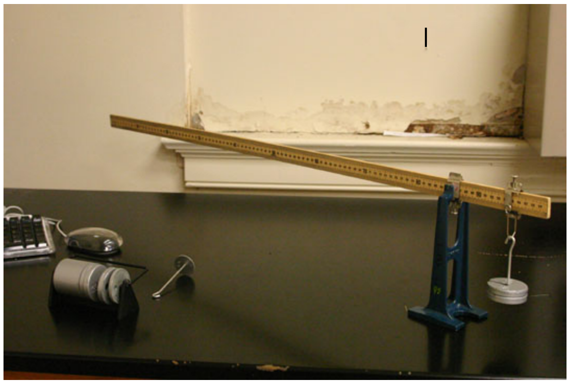
$$W_{\text{R}} = \frac{W_{Known} \times L_{Known}}{L_R}.$$

21. a. From this equation, calculate the weight of the rock with its hanger. Record this weight. Then calculate and record the mass of the rock and its hanger.

22. Use the triple beam balance to find the mass of the rock and hanger. Record the result.

23. Use the ERROR program to find the percent error as compared to the mass found with the triple beam balance, using the triple beam balance as the true value.

D. Investigation of a "Solitary Seesaw"



24. Remove all clamps & knife edge. Use the triple beam balance to determine the mass of your meter stick. Record this mass in kilograms.
25. Slide the knife-edge clamp onto the meter stick and position it near the 90-cm mark. Tighten the screw.
26. Place a knife edge clamp and meter stick in the balance support. Notice that the meter stick does not balance with the fulcrum in this position.
27. Slide a mass hanger onto the meter stick and securely position it at the 95-cm mark. Suspend a mass pan from the hanger. Place 200-g (0.200 kg) on the pan.
28. Loosen the screw on the knife edge clamp and adjust its position until the meter stick is horizontally balanced. Record the position of the fulcrum and the distance between the fulcrum and the mass hanger.

Experiment 7

DATA SHEET

Name: ___________________________________ Section:_________

A. Observations: As you slide the mass further down the meter stick, how does the difficulty of holding the meter stick change?____
____

____

B. Calculation of Torque

position of fulcrum = _________________ cm mark

Combined mass of sliding hanger, mass hanger and mass (kg)	combined weight (N)	distance from fulcrum (m)	Calculated Torque (N*m)

C. Determination of an Unknown Mass

Step13: distance from rock and hanger to fulcrum ________________ m

Step 14 a: known mass of sliding hanger, mass hanger, and 100g ______________kg

Step 14 b: known weight of sliding hanger, mass hanger, and 100g _______________N

Step 17: distance from known mass to fulcrum when balanced _____________m

Step 18: calculated torque caused by known mass _____________N * m

Step 21 a: calculated weight of rock and sliding mass hanger ____________N

Step 21 b: calculated mass of rock and sliding mass hanger ____________kg

Step 22: mass of rock and mass hanger measured by triple beam balance _____________kg

Step 23: percent error of calculated mass of rock and hanger ________________ %

D. Investigation of a "Solitary Seesaw"

mass of meter stick ________________ kg

final position of fulcrum ________________ cm mark

distance between fulcrum and mass _____________cm

QUESTIONS

1. Define **torque** and draw a diagram that illustrates the definition, labeling where the fulcrum is located and where the distances are measured.

2. In part A, why did it become more difficult to rotate the meter stick each time you repositioned the mass?

3. After the meter stick was balanced in part B, the system was in **equilibrium**. Define equilibrium. Since forces were acting on the meter stick, explain why the meter stick was in equilibrium.

4. In part D, there was a mass placed on one side of the fulcrum that caused a torque. When the fulcrum was positioned so that the system was in equilibrium, there must have been a second torque to counteract the first. What produced this second torque?

5. At what position along the meter stick did this torque act?

6. A mass of 1 kg is located at the 0-cm end of the meter stick. If the meter stick is suspended at its center, what mass must be placed at the 75-cm mark to balance the stick? Explain your answer.

7. Why is it easier to open a door by pushing on the edge of the door nearer the knob than the hinges?

8. Identify a measurement device we have been using in this laboratory that makes use of torque. Draw a picture of the device identifying the fulcrum and lever arm distances.