LAB INVESTIGATION ________

MOMENT OF FORCE LAB - (TORQUE LAB)
STATIC EQUILIBRIUM

Objective: To study the concept of moment of force and the condition that must be staisified for a body to be in rotational and translational equilibrium.

Method: The concept of moment of force is studied by applying known forces to a meter stick balanced at its center of gravity. The forces and their moment arms or lever arms are adjusted to place the system into equilibrium. The moments of force that that tend to produce clockwise rotation are compared with those tending to produce counterclockwise rotation. Other similar exercises are performed with different sets of forces and also where the axis of rotation is not at the center of gravity of the meter stick. The observed data are tested to check the "law of torques", that is, the condition of rotational equilbrium.

Theory: The effect of a force in producing rotation depends upon two factors: the magnitude and direction of the force and the location of the axis of rotation. The factor that determines the effect of a given force upon rotational motion is the perpendicular distance from the axis of rotation to the line of action of the force, a distance called the "moment arm" or "lever arm" of the force.

In considerations involving rotary motion, the acting forces and their moment arms are of equal importance. The product of these two quantities is called moment of force, also referred to as torque.

$$M = F \times L \qquad \text{or} \qquad T = F \times L$$

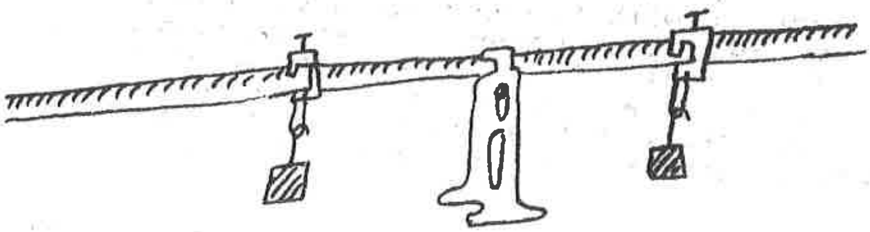
Since torque is a product of force and a distance, its unit is any force unit times any distance unit.

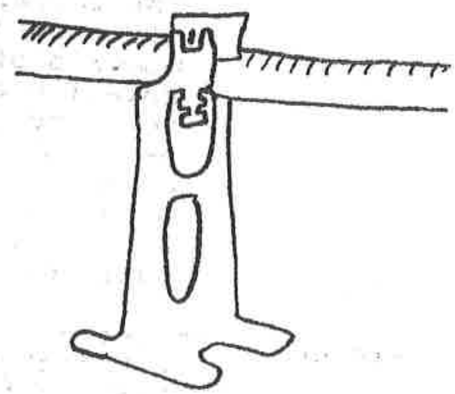
The most common force acting upon a body is its weight. For any ordinary object, no matter how irregular its shape, there exists a point such that the entire wieght may be considered as being concentrated at that point. This point is called the "center of gravity" of the body. The center of gravity may be either within or outside the body, depending upon the shape of the body. If a single force equal to the weight of the body and acting vertically upward could be applied at the center of gravity, it would support the body in equilibrium no matter how the body might te tipped about the center of gravity.

A knowledge of the position of the center of gravity is very useful in problems of equilibrium, for that place is the point of application of the force vector representing the weight. When the axis of rotation does not pass through the center of gravity the moment of force produced by the weight of the body must be taken into consideration.

The solution of problems involving static equilibrium is simplified by drawing a suitable diagram and the careful choice of an axis of rotation. The best choice is usually a point through which one or more unknown forces act. This point may or may not be the actual pivot, or the center of gravity of the body. Particular attention must be given to the correct evaluation of the moment arms of the various forces and to the algebraic signs of the torques.

Apparatus: The principal piece of apparatus is called a "demonstration balance". It consists of a meter stick supported on a "knife-edge" clamp in a heavy iron support. Weight hangars provided with set screws for lightly clamping to the meter stick, provide convenient methods for attaching forces the balance.





Procedure:

1. Locate the center of gravity of the meter stick by placing it in the clamp (do not tighten the screw to tight, you may damage the wood by over tightening!!) and adjusting it until the stick is in equilibrium. Record this position as the center of gravity of the meterstick system and the meter stick number. Draw a diagram of the set-up in the space below.

2. Attach a load of about 200 grams on the meter stick at a distance of about 15 cm from the fulcrum, (include the weight of the clamp!!) Then attach a weight of about 100 grams to the other side of the fulcrum and adjust the position of its clamp until equilibrium is restored. Draw a diagram of the set-up in the space below, label all distances and forces!!!!!

3. Calculate and record the clockwise torque and the counterclockwise torque from procedure 2. Determine the percentage difference between them.

Clockwise Torque	=	Counter Clockwise Torque	% Difference
____________	=	____________	$\% D = \frac{\text{difference}}{\text{Average}} \times 100$

4. Slide the meterstick as far as possible toward the zero end through the knife-edge clamp (about to the 1 cm mark). Record this position as the axis of rotation. With a loop of string and a spring balance apply a force near the 100 cm end of the meterstick. Lift up on the spring scale and record the force exerted by the spring balance and its moment arm. The opposing force in this case is the weight of the meter stick as previoulsy located at the center of gravity. Record the moment arm of this weight. From the law of moments(torques) calculate the weight of the meter stick. Draw a diagram of this procedure in the space below! Label all units and distances.

5. Weigh the meter stick on a precision scale.

Meterstick number ____________ Meterstick weighs ____________ N

____________ grams

6. In the space below determine the percentage of error between the calcuated weight of the meter stick (procedure 4) and the accepted weight of the meter stick (procedure 5).

$$\frac{O - A}{A} \times 100\% \quad = \quad \%\ \text{Error}$$

7. With the fulcrum arranged as in step 4, hang a force of about 300 grams at a distance of about 20 cm from the fulcrum. Then use the spring balance at a distance of about 75 cm from the fulcrum to exert a force that will produce equilibrium. Record the observed values. Taking into account the measured weight of the meterstick (the accepted value in procedure 5). Check the law of moments(torques). Draw a diagram of this procedure, label ALL forces and distances!! Calculate the percent difference!!!!

8. Use the same set up in this procedure as used in procedure 7. Place the spring scale and the loop of string at about the 40 cm mark to support the meter stick. Place about 500 grams at about the 90 cm position on the meter stick. Raise the spring balance until the meter stick is horizontal and record its reading. (You will have to hold the meter stick down with your finger at the point of rotation, do so carefully and lightly so as to not add any additional torque).

* An alternative methoc is to attach a loop of string near the zero end of the meterstick around a fixed object on the lab table then place the spring scale and string at the 40 cm mark and then attach the 500 grams at about the 90 cm mark.

Draw a diagram of this procedure in the space below. Label all units and distances. Check the law of torques, using the accepted or actual weight of the meterstick as found on the scale. Determine the percentage difference!

Postlab Questions: Answer each as completely as possible and in complete sentences!!!!!

1. Where is the center of gravity of a doughnut? Cxplain your reasoning.

2. What relationship exists between a force and its lever(moment) arm when the force is varied so as to maintain a constant torque?

3. Describe two ways by which an experimenter could locate the center of gravity of an irregularly shaped object?

4. Use the data from the first part of procedure 2 of this experiment. What is the upward force exerted by the fulcrum? How did you get this value?

5. Well-made beam balances, or trip scales, are carefully manufactured so that the lever arms are identical. Suppose the two-pan balance of a grocer's scales are poorly made, so the balance arm on the right is longer than that on the left. To compensate for this the grocer adds a lead weight the the underside of the pan on the left. When groceries are placed on the left pan balance by weights on the right pan, is anyone cheated? If so, Who! If not, why not?

6. Explain why a dressmaker's scissors have long blades and short handles and the reverse is true for a tinsmith's shears.

Name: ______________________________
Partner: ___________________________
Hour: _________ Date ___________

	Score Weight
______	10 Lab Technique
______	24 Data/ Diagrams
______	12 Postlab
______	4 Clean up
______	50 TOTAL