Lever: Equilibrium and Torque

Main Topic	Forces
Subtopic	Simple Machines
Learning Level	High
Technology Level	Low
Activity Type	Student

Description: Investigate torque and equilibrium in centered and off-center lever systems.

Required Equipment	Physics Workshop Lever, Workshop Stand, Hooked Masses
Optional Equipment	Spring Scale or Electronic Balance

Educational Objectives

- To investigate equilibrium using a lever in two activities.

Concept Overview

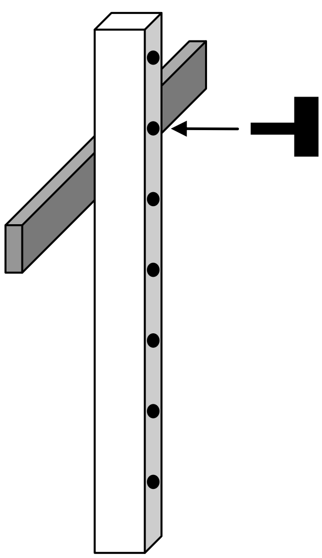
In the first lab, students will investigate the arrangements of weights that result in equilibrium (balance) in the lever system. They will use the concept of torque (force times fulcrum length) to predict the arrangement of weights that will produce equilibrium.

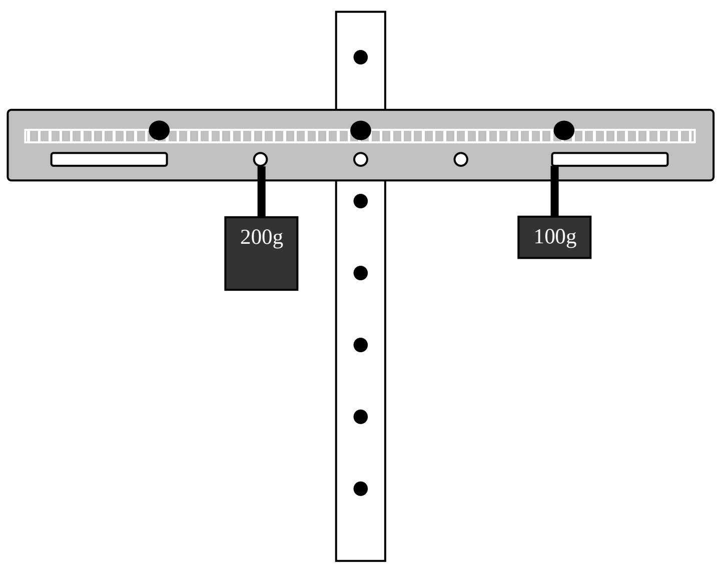
In the second lab, students will hang the lever off-center, so that it does not balance when unweighted. They will use inquiry and calculations to determine the weight of the lever itself.

Lab Tips

Assembly:

1. Push the attachment bolt through the Workshop Stand at approximately eye level.
2. Screw the bolt into center of the Lever from the back, so that students can see the printed scale.
3. Tighten the bolt and check to see that the lever pivots freely.
4. Hang Hooked Masses in the holes so that the Lever balances.





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Lever: Torque and Equilibrium

Objective: To investigate equilibrium using a lever.

Materials: Workshop Stand, Lever, Bolt, Hooked Masses.

Background:

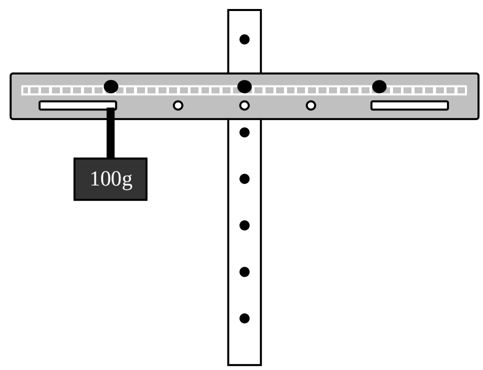
A system is in equilibrium when the net force is zero. In the case of the lever, equilibrium is synonymous with balance.

In a rotational system such as the lever, it is important to consider both the force and the lever arm (the distance from the fulcrum to the force). The product of the force and the lever arm is called torque. Torque in rotational systems behaves like force does in linear systems. Equilibrium in rotational systems occurs when the net torque is zero.

$$\mathrm{T} = Fd$$

Procedure:

1. Use the bolt to attach the Lever to the Workshop Stand, so that the lever is at eye level. Use the center pivot.
2. Check to make sure that the lever balances when empty.
3. Hang a 100g mass at the 20cm mark on the left side of the lever.
4. Hang a 200g mass at a point that causes the lever to balance. Where did you place the 200g mass? ______________________________
5. Calculate the torque on the left side of the fulcrum.



6. Calculate the torque on the right side of the fulcrum.

7. Compare the two torques. What does that mean for the lever overall?

8. Remove the masses. Place a 1000g mass at the 10cm mark. Predict the placement of a 500g mass to establish equilibrium.

9. Test your prediction. Describe the results.

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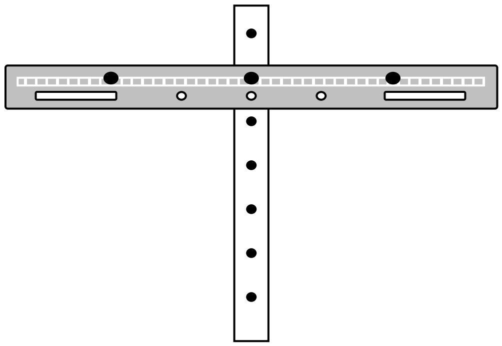
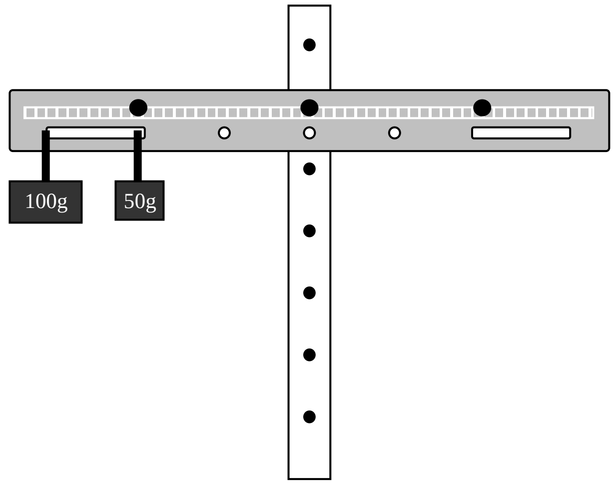
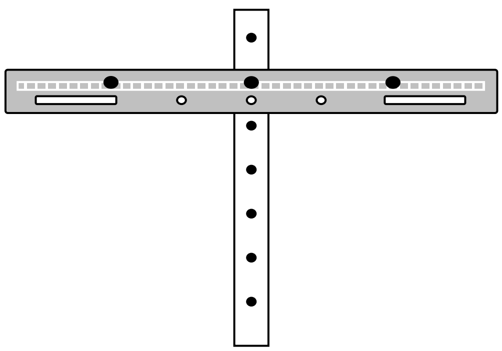


10. On the diagram at left, draw force vectors representing the forces on the lever in #9. Remember to draw the vectors of the correct relative length and to label them in units of force (not mass).

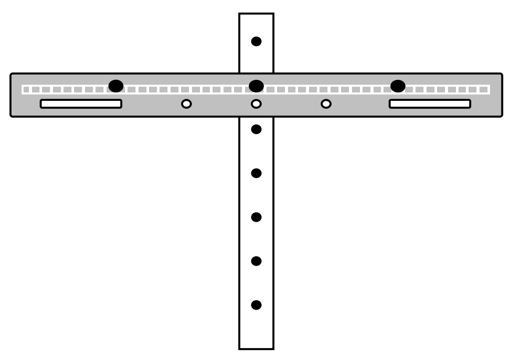
11. Hang a 50g mass and a 100g mass on the left side of the lever as shown. Predict the placement of a 200g mass on to produce equilibrium. Test your prediction and add the 200g mass to the diagram.





12. Draw force vectors to represent the arrangement in #11.

13. Suggest an arrangement of one 500g mass and two 200g masses that would produce equilibrium. Describe the arrangement in a statement and as a force diagram.



Lever: Finding an Unknown Mass

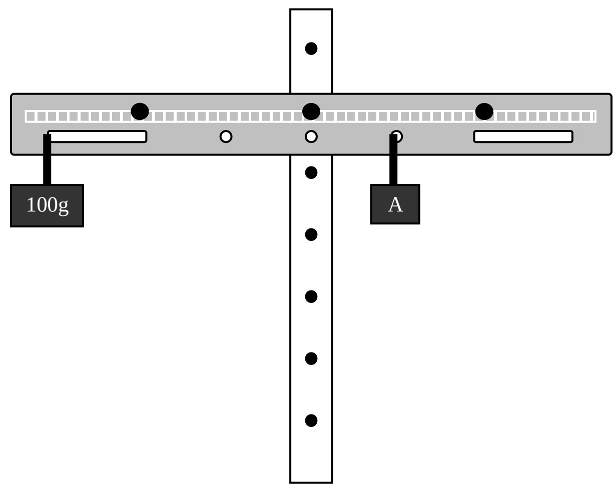
Objective: To use the concepts of torque and equilibrium to find an unknown mass.

Materials: Workshop Stand, Lever, Bolt, Hooked Masses.

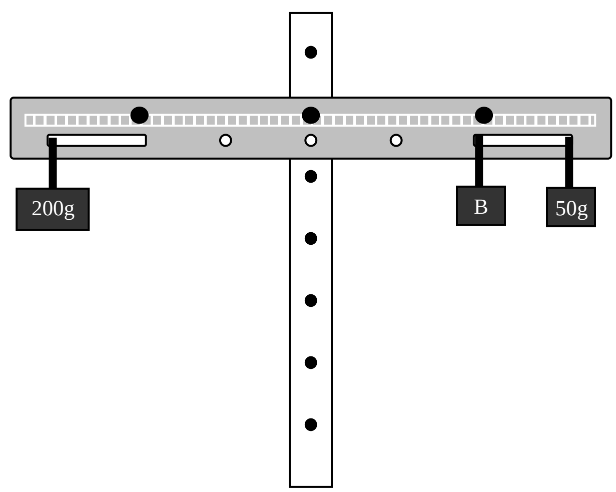
Pre-lab Exercise:

Predict the mass of the unknown object in each of the following situations. Show your calculations and record the mass in the blank.

1. Mass A = __________



2. Mass B = ____________

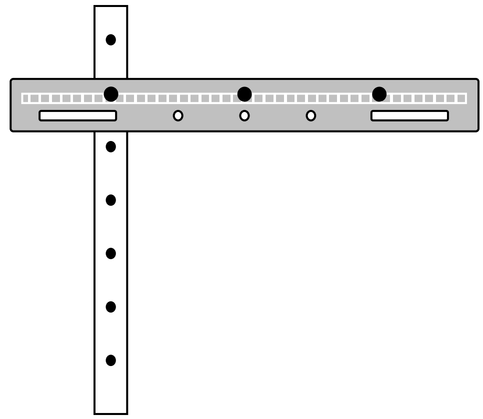


Background:

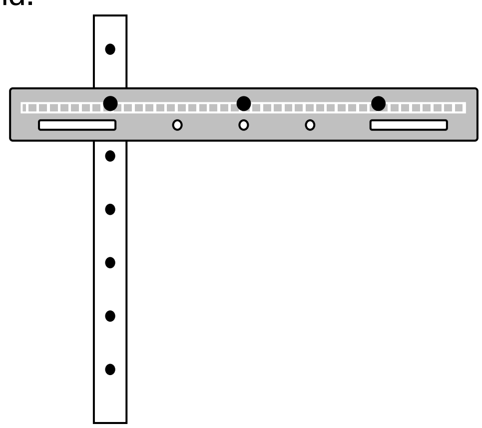
In activity B1, it was convenient to ignore the <u>mass</u> of the lever itself. Since the lever was centered, the weight of one side balanced the other. In this activity, you will estimate the mass of the lever by balancing it off-center.

An object's weight can be represented by a single downward force vector at its center of mass.

Procedure:



1. Draw force vectors representing the forces on the lever caused by its own mass. (Approximate that the mass is evenly distributed over the length of the lever.) Be sure to draw a force vector for the portions of the lever on each side of the fulcrum. Do not worry about the lengths of the vectors at this point, only their locations and relative sizes (which is larger).
2. If the weight of each portion of the lever was concentrated at one point, exactly how far from the fulcrum would each vector be? (Don't forget about the part of the lever beyond the printed scale.) Left side: __________________ Right side: ___________________
3. Use the bolt to attach the Lever to the Workshop Stand as shown, so that the lever is at eye level. Use the pivot near the left end.



4. Experiment with different hanging masses until you find a combination that will cause the lever to balance. Draw corresponding force vectors on the diagram at right.
5. Transfer the force vectors from the upper diagram to the lower diagram. Label the unknown masses "L" (for left) and "R" (for right).
6. Write an expression for the total torque on the right side of the fulcrum.

7. Write an expression for the total torque on the left side of the fulcrum.

8. Assume again that the mass of the lever is evenly distributed across its length. Consider the relative sizes of the left and right sides, and write an expression for the mass of the right side ("R") in terms of the mass of the left side ("L").

9. Substitute the expression from #8 into the torque expression from #6.

10. Since the lever is in equilibrium, the two total torques should be equal. Use your expressions from #9 and #7 to solve for the mass of the left side of the lever, “L.”

11. What is your estimate for the total mass of the lever?

12. Find the actual mass of the lever using a triple-beam or electronic balance and calculate the percent error.

    Actual mass = ____________________

    $$\%error = \frac{(actual - measured)}{actual} * 100\% =$$

13. Is that error acceptable under normal conditions? If not, identify reasons for the error and recalculate the experimental mass below.