

# PhyzLab: Ride My See-Saw\*

balancing torques created by unequal forces

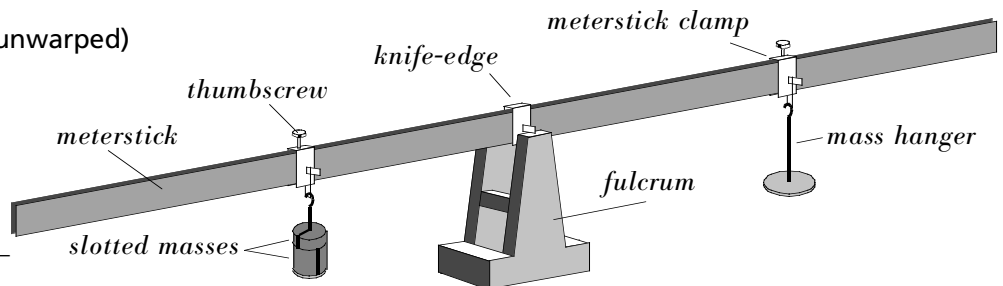
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|--------|----|--|--|
| PERIOD | 1. |  |  |
|        | 2. |  |  |
| GROUP  | 3. |  |  |
|        | 4. |  |  |

## • Purpose •

Did you know that it's possible to make a see-saw such that you could sit on one side and balance ten of your classmates on the other side? Indeed, see-saws could be made to balance nearly any weight with any other weight. See-saw riders exert opposing torques on the see-saw, but there's more to torque than force (or weight). Through this investigation, you will determine a method for balancing torques created by unequal forces.

## • Apparatus •

- \_\_\_ 1 meterstick (preferably unwarped)
- \_\_\_ 1 fulcrum
- \_\_\_ 1 knife edge
- \_\_\_ 2 meterstick clamps
- clamp mass = \_\_\_\_\_
- \_\_\_ 2 mass hangers
- hanger mass = \_\_\_\_\_
- \_\_\_ 1 set of slotted masses



## • Procedure •

### 1. SEEKING A BALANCE

a. Record the mass of the meterstick clamps and the mass hangers in the space above.

b. Attach the knife edge to the center of the meterstick. Set the knife edge—**thumbscrew side down**—on the fulcrum. Remove any clamps that may be attached to the meterstick. Find the balancing point (called the center of gravity, CG) of the meterstick by adjusting the position of the knife edge until the meterstick balances. Record the location of the CG.

CG = \_\_\_\_\_

c. Construct a hanging mass consisting of a 200 g slotted mass attached to a mass hanger. Construct a second hanging mass using a 100 g slotted mass. Record the total mass each will have when hung on to the meterstick (slotted mass + hanger mass + clamp mass).

$m_{200} =$  \_\_\_\_\_ (not 200g)     $m_{100} =$  \_\_\_\_\_ (not 100g)

d. Attach the masses to opposite sides of the balancing meterstick. Do not overtighten thumbscrews since this will damage the meterstick. Determine a simple experimental method to balance the large (~200 g) mass with the small (~100 g) mass. Explain your simple method (include a diagram) with values labeled.

e. Record the masses and positions as trial 1 on the data table on the following page. Continue taking more data on balancing mass/position combinations.

- i. For trials 1-2, use the "100 g" and "200 g" masses. Vary the location of one mass and then adjust the position of the other until equilibrium is again attained.
- ii. For trials 3-4, use a "200 g" mass and a "300 g" mass. Again, find an equilibrium configuration, record, and then change the position of one mass and adjust the other, record and repeat.
- iii. For trials 5-6, use a "100 g" mass and a "400 g" mass.

| Trial # | Small Mass*<br>$m_1$ ( ) | Lever Arm**<br>$d_1$ ( ) | Large Mass*<br>$m_2$ ( ) | Lever Arm**<br>$d_2$ ( ) |  |  |
|---------|--------------------------|--------------------------|--------------------------|--------------------------|--|--|
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|         |                          |                          |                          |                          |  |  |
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|         |                          |                          |                          |                          |  |  |

\*Mass of slotted weight(s) + mass of clamp + mass of mass hanger.

\*\*Lever arm is the distance from the fulcrum to the clamp holding the mass. DON'T record the "centimeter mark" location of the clamp here. You may wish to record the meterstick location on a sheet of scratch paper and have a member of the lab group compute the lever arm. All values of lever arm should be less than 50cm.

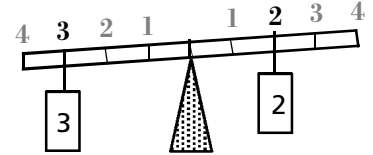
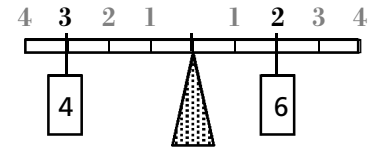
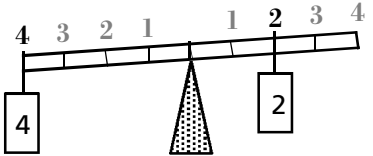
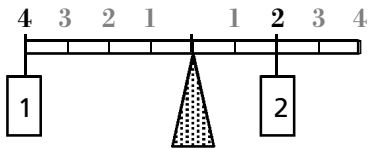
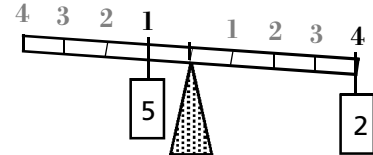
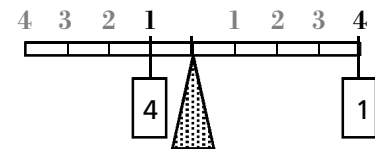
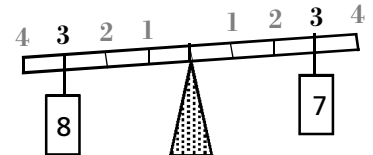
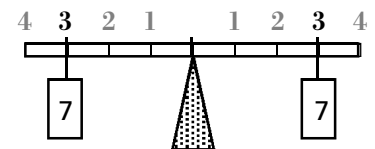
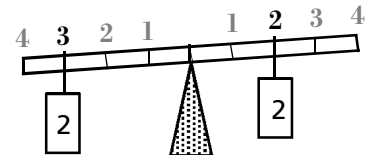
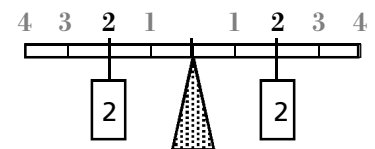
f. The diagrams to the right show some idealized lab arrangements.

The masses of the suspended objects are indicated by the numbers written on them, and the "meterstick" has eight divisions as shown.

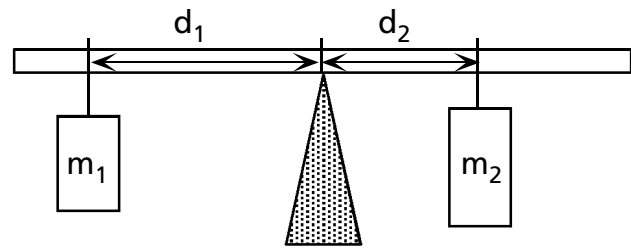
Ten examples are shown: all cases in the first column balance, all the cases in the second column do not balance.

Examine the evidence here and in your findings above to determine the conditions under which the see-saw will balance.

Upon determining the condition write it down **in words**.



g. Write the relationship using symbols: write **an equation**. Your equation will include  $m_1$ ,  $m_2$ ,  $d_1$ , and  $d_2$ .



## 2. USE YOUR SEE-SAW

Using principles discovered in the "Ride My See-Saw" lab, determine the mass of an unmarked object. Use the same apparatus as in the "Ride My See-Saw" lab with two exceptions:

- I. You can use **only** the 200 g mass from your set of slotted masses. No other slotted masses can be used.
- II. You will need an object whose mass is unknown. Get this from your instructor.

Describe and sketch the object (indicate color, shape, size, and any other distinguishing characteristics).

a. Write out a procedure on **separate** sheets of paper. A word to the wise: Try your procedure using the 100 g slotted mass as your unknown. Attached to the mass hanger and meterstick clamp, you know its mass to be about 165 g. If your procedure yields a value close to 165 g, you know the procedure is valid. In the description of your procedure, include the following:

- i. A brief written description of the procedure.
- ii. A diagram (not a picture) of the apparatus in use, labeling all appropriate features and quantities.
- iii. Data from at least five different trials neatly recorded on a well-organized and labeled table.
- iv. A sample calculation solving for the unknown mass in terms of other quantities measured in the lab.
- v. The final, settled upon value for the unknown mass that was given to you. You're so sure of this value that you're willing to bet your grade on it.

b. Error analysis.

- i. When you are satisfied that you have determined an accurate value for the mass of your object, write it in the space below and bring the object to the instructor for "massing" on the precision balance (e.g. triple beam or electronic balance)..

VALUE CALCULATED IN LAB:  $m =$  \_\_\_\_\_ g (**Write this value in ink.**)

PRECISION BALANCE:  $M =$  \_\_\_\_\_ g

ii. Determine the percent error in your calculated value using the equation to the right.  
SHOW CALCULATION:

PERCENT ERROR = \_\_\_\_\_

iii. On your procedure sheet, list sources of error. Describe how each source would have affected your final determination of the mass of the object (would a given type of error lead to a calculated mass that was higher or lower than the actual mass, or would the error vary in its effect from trial to trial). Describe what could have been done to eliminate or minimize that source of error. **DO NOT LIST MISTAKES!** Mistakes are correctable. If you make a mistake, you do it over. Error sources are inherent in the apparatus or environment and cannot be corrected.

• **Post-Lab Questions** •

1. A question of balance\*. The following questions refer to individual weights. Due to the highly sensitive (psychotic?) nature of weight in our society, it is acceptable to reveal only your ideal weight to your group members. "Ideal weight" is whatever **you** think your weight should be. Record the weight of the smallest member of the group and convert it to mass in kilograms by dividing by 2.2.

$$W_{\text{SMALLEST}} = \text{_____ lbs} \div 2.2 = \text{_____ kg} = m_{\text{SMALLEST}}$$

Repeat with the sum of everyone else's weight to determine the combined mass of the others in the group.

$$W_{\text{OTHERS}} = \text{_____ lbs} \div 2.2 = \text{_____ kg} = m_{\text{OTHERS}}$$

If you had a very long plank that were balanced at its center and everyone in the lab group (except the smallest member) were standing about 3 m from the fulcrum, where would the smallest member of the group have to stand to balance with them? (Show calculation, box answer, draw diagram.)

2. The best way to play on a see-saw is to have it balanced by the riders so that each rider can gently push off the ground and be lifted to full height. If the riders do not balance, one will tend to stay in the air while the other tends to stay on the ground. If you are heavier than your see-saw partner, what adjustments could you make to improve the game? List and diagram at least two.

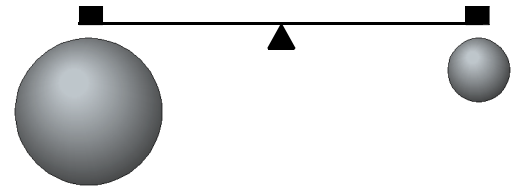
\*"Ride My See-Saw" and *A Question of Balance* are titles of works by which artist?

3. Would you get the same results in this lab if it were performed on the **moon**? If so, why; if not, how would the results vary?

4. Would you get the same results in this lab if it were performed in a **zero-g** environment? If so, why; if not, how would the results vary?

5. Considering your answer to the last question, is it the **mass** of the hanging objects or the **weight** of the hanging objects that is important in this lab? Explain.

6. Consider the situation depicted in the diagram. A plank extends from the earth to the moon. The center point can pivot but cannot otherwise move (it is the fulcrum). A 100 kg mass is placed at each end of the plank. Will it balance, lean downward on the earth side, or lean downward on the moon side? Explain!



• **Extension** •

SEE-SAW SOLO: DETERMINE THE MASS OF THE METERSTICK

1. Record the location of the center of gravity of your meterstick. CG = \_\_\_\_\_

2. Place the fulcrum at the 85 cm mark.

3. Use your apparatus to determine the mass of the meterstick. (Recall that you can assume all the mass of the meterstick acts at the meterstick's center of mass.)

a. Draw the arrangement and label the important quantities below.

b. Briefly describe your procedure.

c. Record your calculation(s).

$m_{\text{MEASURED}} =$  \_\_\_\_\_

4. Determine the actual mass of the meterstick using a calibrated scale (electronic or triple beam balance, for example).

$m_{\text{ACTUAL}} =$  \_\_\_\_\_

5. Calculate the percent error.

%E = \_\_\_\_\_