Name:

Skill Sheet 16   Indirect Measurement

Have you ever wondered how scientists and engineers measure large quantities like the mass of an iceberg, the volume of a lake, or the distance across a river? Obviously, balances, graduated cylinders, and measuring tapes could not do the job! Very large (or very small) quantities are calculated through a process called indirect measurement. This skill sheet will give you an opportunity to try indirect measurement for yourself.

1. Using a shadow to find the height of a tree

Try this activity on a sunny day. You will need two meter sticks, a calculator, pencil and paper, and a tall tree to measure. (If there are no trees nearby, substitute a building, flagpole, statue, or other tall outdoor object.)

Ask a friend to hold the meter stick vertically, with one end touching the ground. Measure and record the length of the shadow formed by the meter stick.

An object twice as tall as the meter stick will create a shadow twice as long. An object six times as tall as the meter stick will create a shadow six times as long. Because there is a direct relationship between the height of objects and the length of their shadows, you can set up a proportion to figure out the height of an object based on the length of its shadow:

$$\frac{\text{height of meter stick}}{\text{length of meter stick shadow}} = \frac{\text{height of object}}{\text{length of object shadow}}$$

Now measure the length of the tree's shadow. Remember that shadow length changes throughout the day, so if more than a few minutes has passed since you measured the meter stick shadow, you will need to measure it again.

If the length of the meter stick shadow is 1.25 meters and the length of your tree's shadow is 4.25 meters, you would set up your proportion like this:

$$\frac{1.00 \text{ meter}}{1.25 \text{ meter}} = \frac{\text{height of tree}}{4.25 \text{ meter}}$$

Multiply both sides of your equation by the length of object shadow to find the height of the tree:

$$4.25 \text{ meter} \times \frac{1.00 \text{ meter}}{1.25 \text{ meter}} = \frac{\text{height of tree}}{4.25 \text{ meter}} \times 4.25 \text{ meter}$$

$$3.40 \text{ meters} = \text{height of tree}$$

Activity: Use your own measurements in the proportion above to find the height of your tree. This process is called **indirect measurement**, because rather than using a tool to measure the height directly, you measured something else and used that measurement to calculate the height. What is the height of your tree? Be sure to include units in your answer.

2. Measuring the width of a compact disk

Indirect measurement is also used to measure small quantities. It is difficult, for example, to get an accurate measurement of the width of one compact disk using a ruler. The CD is just too thin! However, if you had a stack of CD's, you could measure the height of the stack. Dividing this height by the number of CD's in the stack will tell you the width of one stack.

Activity: Locate a centimeter ruler and at least eight CD's. Calculate the width of one CD.

3. Using indirect measurement to solve problems

1. If you place one staple on an electronic balance, the balance still reads 0.0 grams. However, if you place 210 staples on the balance, it reads 6.80 grams. What is the mass of one staple?

2. A sculptor wants to create a statue. She goes to a quarry to buy a block of marble. She finds a chip of marble on the ground. The volume of the chip is 15.3 cm^3. The mass of the chip is 41.3 grams. The sculptor purchases a block of marble 30.0-by-40.0-by-100. cm. Use a proportion to find the mass of her block of marble.

3. The instructions on a bottle of eye drops say to place three drops in each eye, using the dropper. How could you find the volume of one of these drop? Write a procedure for finding the volume of a drop that includes using a glass of water, a 10.0-mL graduated cylinder, and the dropper.

4. A stack of 55 business cards is 1.85 cm tall. Use this information to determine the thickness of one business card.

5. A student wants to use indirect measurement to find the thickness of a sheet of newspaper. In a 50-centimeter tall recycling bin, she finds 50 sheets of newspaper. Each sheet in the bin is folded in fourths. Design a procedure for the student to use that would allow her to measure the thickness of one sheet of newspaper with little or no source of experimental error. The student has a meter stick and a calculator.

one sheet of newspaper

4 layers