

## Investigation

# Comparing Light Sources

Many types of lights can be found in a hardware store. There are energy-saver incandescent bulbs, fluorescent bulbs, long-life bulbs, low-cost light bulbs, and specialty lights of all kinds. Work with a team to examine a collection of light bulbs. Find the wattage printed on them. If the packaging of the bulbs is available, see what it says. Do any of them claim that they are better light bulbs than the others? Decide on a question comparing the brightness of two bulbs. Here are some examples:

- Are all 75-watt incandescent bulbs alike? A reflector bulb sends out its light differently from a standard light bulb; but they use energy at the same rate. Do they provide the same amount of illumination?
- According to the packaging, a 15-watt compact fluorescent light is supposed to replace a 60-watt incandescent bulb. Is it really just as bright?

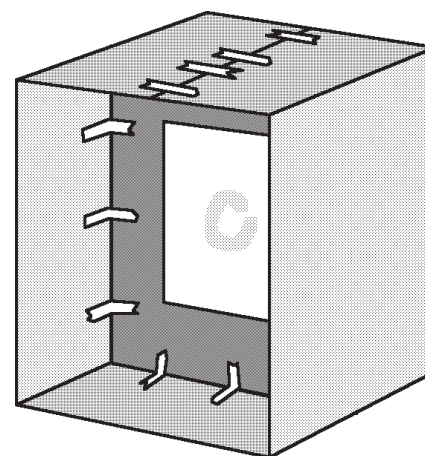
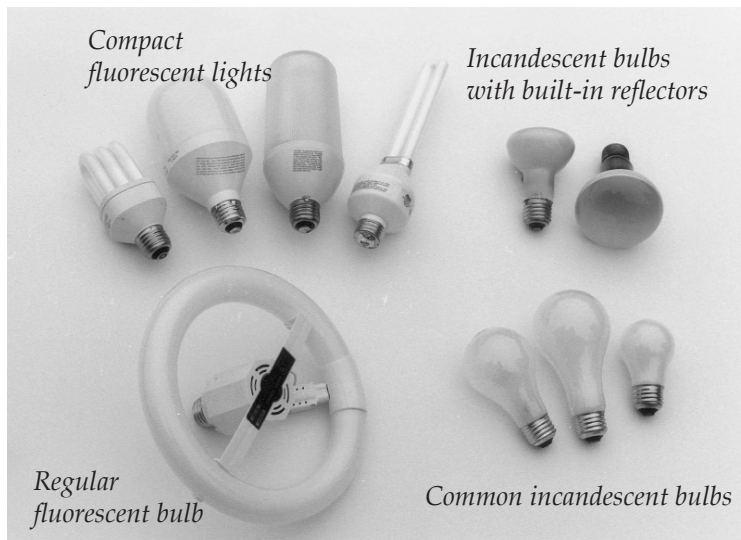
When you have decided on a question, build an *oil-smudge photocomparator* so you can compare brightness of lights. Here's how ....

## Assemble the Oil-Smudge Photocomparator

### Materials

- 1 sheet of white typing paper, 8  $\frac{1}{2}$ " x 11"
  - 1 sheet of cardboard, 10" x 12"
  - 1 sheet of cardboard, 14" x 44"
  - Small amount of oil (mineral oil, baby oil, or cooking oil)
  - Scissors
  - Masking tape
1. Cut a six inch square hole in the center of the 10" x 12" cardboard.
  2. Fold the 14" x 44" cardboard to fit around the 10" x 12" cardboard as shown. Tape it together so it forms a box with open ends. Tape the smaller piece of cardboard inside so it divides the box into two equal sections.
  3. With your finger, smear some oil onto the center of the typing

ALL THESE LIGHTS SCREW INTO AN ORDINARY SOCKET



*The exact size of the parts is not critical. You may need to tape a few pieces of cardboard together for the larger piece.*

paper in the shape of an “O” about two inches across. Use just enough oil so it soaks into the paper without running. Tape the smudged paper to the cardboard so the oil smudge is in the center of the box.

### Test the Photocomparator

Hold the photocomparator so it is between you and a bright light source. Look at the oil smudge. It should appear bright against a darker background. Now, hold the photocomparator so you are between it and a bright light source. Make sure your shadow is not blocking the light. Look at the oil smudge. It should appear dark against a lighter background. Can you explain why?

**Whenever the sheet of paper is being illuminated by the same amount on each side, the smudge will be neither lighter nor darker than the background.** The smudge may hardly show up at all.



In your experiments, you will shine lights from different sources onto opposite sides of the photocomparator. When the smudge hardly shows up at all you know the photocomparator is receiving equal amounts of light from each side. The distance of each light to the photocomparator will help you determine which light is brighter. You will need to shade your oil smudge from all other lights not involved in this experiment.

### Set Up Your Work Space

#### Additional Materials

- Measuring tape or meter stick
- Oil smudge photocomparator
- Light bulbs to compare
- Fixtures and clamps to hold the bulbs

The room you work in should be nearly dark. Be sure the light from one team’s bulbs is not shining directly into the photocomparator of another team. It may be necessary to put objects around your work area to block the light.

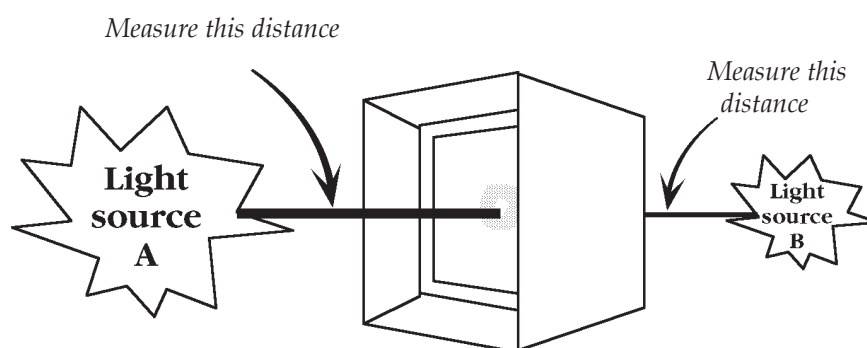
Set up your two lights at least two meters apart. If there is space, it is better to have the lights three or four meters apart. You will be measuring the distances between the photocomparator and each of the lights.

### Gathering the Data

1. On a blank sheet of paper prepare a data table like the one shown on the next page. Fill out the data table with information from the packaging, including cost, wattage, and any comments about the bulbs. If you have no information about the lifetime of a bulb, you can estimate 1,000 hours for a typical incandescent bulb, and 10,000 hours for a compact fluorescent bulb.
2. Have one team member hold the photocomparator between the two lights, A and B. Other team members should stand near lights A and B. They should tell the person holding the photocomparator to move it back and forth between A and B until they agree the oil smudge hardly shows at all. Then measure the distance from each light source to the oil smudge, and write the distances in the table.
3. If there is time, exchange experiments with another team. Make a new data table, and repeat the measurements to confirm the accuracy of each team’s data.

## Investigation *continued*

Description of bulb	Distance to photocomparator	Cost of bulb	Wattage of bulb	Lifetime (in hours)	Other information
15-watt compact fluorescent	<b>SAMPLE</b>				
60-watt soft light incandescent					



### Interpreting the Data

1. Which light source illuminated the photocomparator the brightest? By noting which distance is greater, you can tell which light is brighter. The dimmer light will be closer to the photocomparator.

It is possible to compare quantitatively the brightness of two lights, A and B, with the following formula:

$$\frac{\text{brightness of A}}{\text{brightness of B}} = \frac{(\text{distance to A})^2}{(\text{distance to B})^2}$$

Use your data to compute the brightness ratio. If one light is considerably brighter than the other, how many times brighter is it?

2. Which light source is more energy efficient? Find the ratio of the wattages of the two bulbs by dividing the wattage of bulb A by the wattage of bulb B. You can find out which bulb is more efficient by comparing the brightness ratio with the wattage ratio.

$$\frac{\text{wattage of A}}{\text{wattage of B}} \quad \text{— Compare —} \quad \frac{\text{brightness of A}}{\text{brightness of B}}$$

#### Sample

If A is 100W and B is 20W, the wattage ratio is  $100\text{W}/20\text{W} = 5$ . If bulb A is five times brighter than bulb B, the brightness ratio is also 5, so A and B are equally efficient. But if bulb A is just twice as bright as bulb B, the brightness ratio is 2. That means that bulb B is  $2^{1/2}$  times more efficient than A.

If the bulbs are equally efficient the ratios will be equal. If the brightness ratio is *higher* than the wattage ratio, then light A is more efficient. If the brightness ratio is *lower* than the wattage ratio, then light B is more efficient.

## Investigation *continued*

3. Did the package make any claims you can evaluate from this investigation? If so, did the bulbs live up to the advertising on the packaging?
4. How do these lights serve your needs? Is there anything about the look of a light bulb, its size, the color of its light, or the direction it casts its light that makes it suitable for some purposes but not for others?
5. Summarize what you did, what you found, and your recommendations in a report.

## Efficiency, Costs, and Savings

Suppose you find that a 60-watt incandescent bulb is just as bright as a 15-watt compact fluorescent light. They give similar light and fit the same fixture. For energy efficiency the one with lower wattage is best. But what about the **total** cost of the light? A 60-watt light bulb costs about 60¢ and lasts for about 1000 hours. A 15 watt compact fluorescent bulb costs about \$12 and lasts for 10,000 hours. Electricity costs, for example, about 10 cents per kilowatt-hour. On the next page are two ways to use this information to compare the costs of the lights. Try them both to see which is the better bargain.

## Paybacks from Changing a Light Bulb

Imagine yourself in the hardware store buying a bulb to replace one that burned out. You see the regular incandescent bulbs and you see the compact fluorescent bulbs. One costs less than the other initially, but the other is more energy efficient.

- Which one will you choose?
- What difference will your choice make?



Image courtesy of [www.wikipedia.org](http://www.wikipedia.org)

## Payback to Households

Suppose you select the more expensive compact fluorescent bulb. There will come a time when the savings on the electricity bill exactly matches the extra money you paid. That is the payback time. At the payback time you have neither gained or lost, as far as money is concerned—except for one thing: The energy efficient light bulb is now paid for, and still working for you. From this point on, all energy savings are also money savings.

## Investigation

# Method 1: Life Cycle Cost

The *life cycle cost* of a light bulb includes the purchase price and the cost of energy use during its entire lifetime. Since a compact fluorescent bulb lasts 10 times longer than an incandescent bulb, let's compare one compact fluorescent bulb to 10 incandescent bulbs over a 10,000 hour cycle.

**INCANDESCENT: Material cost** of ten 60 W incandescent bulbs = \$ \_\_\_\_\_

**Energy used over life cycle** is 60 W x 10,000 hrs = \_\_\_\_\_ watt-hours  
divided by 1000 watt-hours/kilowatt hour = \_\_\_\_\_ KW-hours

**Operating cost over lifecycle** = \_\_\_\_\_ KW-hours  
times \$0.10/ kilowatt hours = \$ \_\_\_\_\_

**Total Cost** (material cost plus operating cost) of  
ten 60-watt incandescent bulbs = \$ \_\_\_\_\_

**COMPACT FLUORESCENT LIGHT (CFL): Material cost** of one 15-watt CFL = \$ \_\_\_\_\_

**Energy used over life cycle** is 15 W x 10,000 hrs = \_\_\_\_\_ watt-hours  
divided by 1000 watt-hours/kilowatt hour = \_\_\_\_\_ KW hours

**Operating cost over lifecycle** = \_\_\_\_\_ KW-hours  
times \$0.10/ kilowatt hours = \$ \_\_\_\_\_

**Total Cost** (material cost plus operating cost) of one 15-W CFL = \$ \_\_\_\_\_

	15 watt compact fluorescent	60 watt incandescent
Initial cost	\$12.00	\$ 0.60
Cost after 1 month	<i>The results of your calculations should go on a table like this one.</i>	
Cost after 2 months		
Cost after 3 months		

## Method 2: Payback Time

Buying the energy efficient light bulb means spending more money at the start, but it also means saving a little money every time you have the light on. A time will come when the savings are enough to pay back the extra cost of the energy efficient light. That time is called the **payback time**.

To find the payback for choosing a compact fluorescent bulb over an incandescent bulb, make a table showing the total cost for each kind of bulb month by month as time goes by. The payback time comes during the month when the total cost of using an incandescent light bulb catches up to the cost of using the energy efficient compact fluorescent bulb.

At the beginning of the first month the cost is simply the price of the light bulb. For each month after that add on a month's worth of energy costs. Assume the light is on for four hours a day. Use the wattage of the bulb and the energy cost (10¢ per kilowatt-hour) to calculate the monthly energy cost. Whenever the operating time of the bulb reaches the bulb's lifetime, add in the cost of a new light bulb. Make a graph of cost versus time. Plot the data for both light bulbs on the same graph. Where the two lines cross is the payback time.