Let There Be Light, or…Heat?

Purpose:

The purposes of this lab are for students to determine which type of light bulb, compact fluorescent or incandescent, is more efficient at converting electrical energy to light instead of heat and for students to calculate the amount and cost of electricity used to power each type of light for 28 hours per week for a year.

Key Science Topics:

- Heat vs. temperature
- Power dissipated by a device

Grade Level:

- Physics, Grades 11-12

Student Prior Knowledge:

- Students should be able to calculate the power in Watts dissipated by a device when voltage and current are measured.
- Students should know how to calculate kilowatt-hours.
- Students should recognize that infrared radiation is heat.

Materials:

- Radiometer
- Compact fluorescent light bulbs, with lamp base
- Incandescent Light bulbs, with lamp base
- Kil-A-Watt meter (see suggestions, below)

Suggestions:

Ideally, this activity is to be done with students visiting stations. I usually have six groups of three to four students. For this lab, each group gets their own radiometer and I have three lamp bases with a CFL plugged into a Kil-A-Watt meter and three lamp bases with an IL plugged into a Kil-A-Watt meter. Students start at one type of light bulb, and then switch to the other.

Kil-A-Watt meters are available for about $30.00. If this is cost prohibitive, one Kil-A-Watt meter could be used by the teacher and the students could record the voltage and current data. Another possibility is to write to your local power company to see if they would donate Kil-A-Watt meters. If no Kil-O-Watt meter is available, feel free to provide the students with the sample voltage, current, and power data given in the Teacher Answer Key.

I have students measure the power on the Kil-A-Watt meter. They can calculate the power from the voltage and current measured, but it will not be the same value because the light bulbs are non-Ohmic; in other words, the resistance of the light bulb changes as the filament increases in temperature.

Background:

Students will examine whether a compact fluorescent light bulb or an incandescent light bulb produces more heat in two different activities. Students will hold a radiometer in front of each type of light bulb to observe which bulb makes the radiometer spin faster. Then, students will record data obtained from a Kil-A-Watt meter to determine which type of bulb uses more electricity.

Lowes rates light bulbs based on four hours of usage per day (www.lowes.com). Thus, the use per week is 28 hours. Students may comment that they use lights more or less often. Encourage them to think about how often lights are left on in rooms no one is using. As used in the teacher answer key, the price of electricity in Ohio, as of this writing, is $0.11 per kilowatt hour. Encourage your students to find out what is the local price for electricity prior to working on this activity.

Please remind students that their results are for only one light bulb. Encourage them to think about how many IL and CFL bulbs are in their house. Perhaps as an extension to this activity, you may want to have your students count each type of light bulb.

Additional Resources:

- Let There Be Light, or…Heat? PowerPoint file that shows the IR image of the compact fluorescent light bulb and the incandescent light bulb. This may be shown on a projector so students can see the temperature scale in color instead of a grayscale copy.

Common Core Standards

Insert applicable common core standards here.

Next Generation Science Standards

Insert applicable NGSS here.

Student Handout

Let There Be Light, or…Heat?

Name:_____ Date:_____

Electrical energy is converted into thermal energy, or heat, when you use objects such as electrical stove heating elements, toasters, hair dryers, or even light bulbs. Converting electrical energy to heat makes sense for some appliances, but not for light bulbs. When we turn on a light, we want to illuminate our surroundings, not heat them up. Some light bulbs convert up to 90% of the electricity used into heat leaving only 10% that is producing light. That means 90% of the electricity used was wasted. In this activity, you will determine which type of bulb is a light bulb and which type is more like a heat bulb.

Part 1

1) Place a radiometer 0.5m away from a compact fluorescent light (CFL) light bulb and an incandescent light (IL) bulb. Which type of light bulb made the radiometer spin faster?

Compare the two images below. Your teacher may have these available in color as a PowerPoint.

2) What is the maximum temperature of the following in °F?
   a. The IL bulb

   b. The CFL bulb

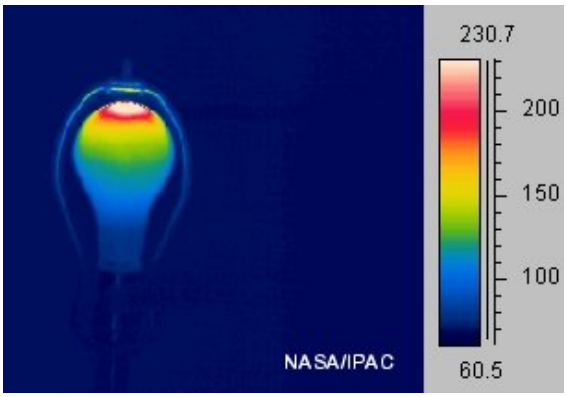


Figure 1: Infrared image of a compact fluorescent light bulb.

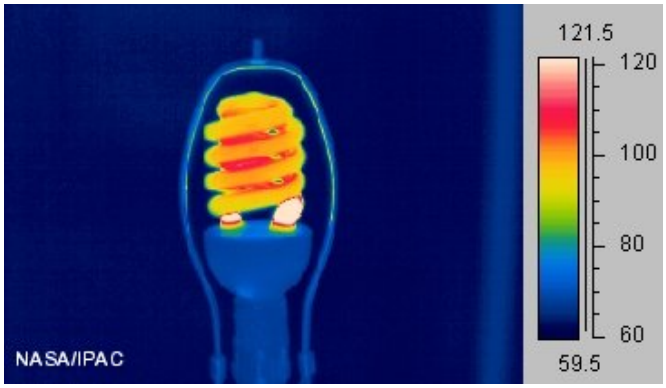


Figure 2: Infrared image of an incandescent light bulb.

3) Are these temperatures consistent with your results? Explain.

Part II:

Visit the station with the CFL plugged into the Kil-A-Watt meter and record the voltage, current, and power in the chart below. When finished, visit the station with the IL plugged into a Kil-A-Watt meter and record the voltage, current, and power in the chart below. If you do not have access to a Kil-A-Watt meter, please record the voltage, current, and power data from your teacher. Next, calculate the kilowatt-hours (kWhr) used per week, then used per year. Finally, calculate the cost to run each light bulb

Table 1

	Voltage (V)	Current (A)	Power (W)	Power in (kW)	Hours Used Per Week	kWhr Used Per Week	kWhr Used Per Year	Cost per kWhr	Electricity Cost Per Year
IL					28				
CFL					28				

4) Which light bulb costs has higher electrical costs based on average use for one year?

5) Why does this type of bulb use more electricity, and thus cost more?

6) Your friend argues that IL bulbs are much cheaper to purchase and use. She says that she can buy an IL bulb for $0.50. She would rather do that than pay $3.00 for a CFL. Complete the following calculations to determine if your friend is really saving money by purchasing the IL bulb.
   A. A CFL lasts, on average, 4 years. An IL lasts 0.5 years (based on 4 hours per day usage). How many IL bulbs will you have to purchase to equal one CFL bulb?
      _____
   B. To calculate how much money your friend needs to spend on IL bulbs to equal one of your CFL bulbs, multiply the number of IL bulbs you calculated in Part A by the cost of an IL bulb:
      _____ x $0.50 = _____
   C. Is your friend saving money so far? _____

Next, let's look at the total cost in electricity.

D. Multiply the CFL electricity cost per year you calculated in Table 1 above by 4, since CFL bulbs last four years.

_____x_____ =_____

E. Multiply the IL electricity cost per year you calculated in Table 1 above by 4, to compare with the electrical cost associated with an IL bulb.

_____x_____ =_____

F. Complete the following table to see how much it costs to use each type of bulb for four years.

	CFL	IL
Cost of enough bulbs to last 4 years		
Electricity costs for four years		
Total Cost		

G. So, is your friend saving money by buying an IL?

Teacher Answer Key

Let There Be Light, or…Heat?

Name: Key Date: _____

Electrical energy is converted into thermal energy, or heat, when you use objects such as electrical stove heating elements, toasters, hair dryers, or even light bulbs. Converting electrical energy to heat makes sense for some appliances, but not for light bulbs. When we turn on a light, we want to illuminate our surroundings, not heat them up. Some light bulbs convert up to 90% of the electricity used into heat leaving only 10% that is producing light. That means 90% of the electricity used was wasted. In this activity, you will determine which type of bulb is a light bulb and which type is more like a heat bulb.

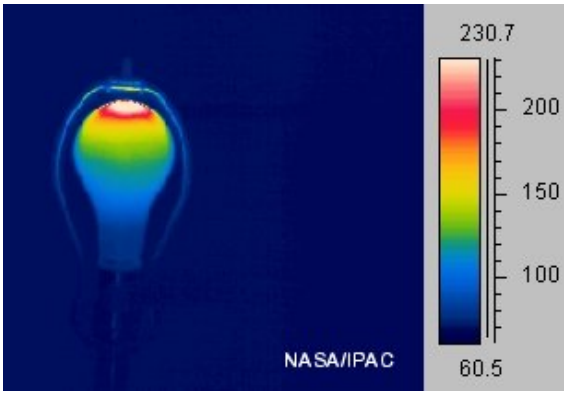
Part 1

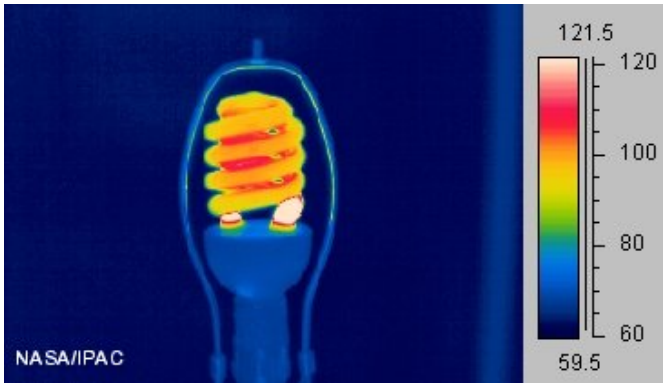
1) Place a radiometer 0.5m away from a compact fluorescent light (CFL) light bulb and an incandescent light (IL) bulb. Which type of light bulb made the radiometer spin faster?
   The incandescent light bulb made the radiometer spin faster.

Compare the two images below. Your teacher may have these available in color as a PowerPoint.

Note: You may want to point out the range of temperatures on each image.

2) What is the maximum temperature of the following in °F?
   a. The IL bulb
      Max temperature is 230.7°F. While not asked for, the minimum temperature is 100°F—compare to the max temperature of the CFL.
   b. The CFL bulb
      Max temperature is 121.5°F, but the majority of the bulb is about 110°F.





3) Are these temperatures consistent with your results with the radiometer? Explain.
   Yes. Radiometers require both infrared and visible light to move. The more infrared and visible light produced by a given source, the faster the radiometer spins.

Part II:

Visit the station with the CFL plugged into the Kil-A-Watt meter and record the voltage, current, and power in the chart below. When finished, visit the station with the IL plugged into a Kil-A-Watt meter and record the voltage, current, and power in the chart below. If you do not have access to a Kil-A-Watt meter, please record the voltage, current, and power data from your teacher. Next, calculate the kilowatt-hours (kWhr) used per week, then used per year. Finally, calculate the cost to run each light bulb

Table 1

	Voltage (V)	Current (A)	Power (W)	Power in (kW)	Hours Used Per Week	kWhr Used Per Week	kWhr Used Per Year	Cost per kWhr	Cost For Year
IL	120	0.52	64	0.064	28	1.792	93.184	$0.11	10.25
CFL	120	0.28	21	0.021	28	0.588	30.576	$0.11	3.36

4) Which light bulb costs has higher electrical costs based on average use for one year?
The incandescent light bulb has higher electrical costs

5) Why does this type of bulb use more electricity, and thus cost more?
Incandescent light bulbs use electricity to heat a tungsten filament so hot it glows in the visible part of the spectrum. Things that heat up, like toasters and stoves, require a lot of electricity.

6) Your friend argues that IL bulbs are much cheaper to purchase and use. She says that she can buy an IL bulb for $0.50. She would rather do that than pay $3.00 for a CFL. Complete the following calculations to determine if your friend is really saving money by purchasing the IL bulb.
   H. A CFL lasts, on average, 4 years. An IL lasts 0.5 years (based on 4 hours per day usage). How many IL bulbs will you have to purchase to equal one CFL bulb?
   8 bulbs
   I. To calculate how much money your friend needs to spend on IL bulbs to equal one of your CFL bulbs, multiply the number of IL bulbs you calculated in Part A by the cost of an IL bulb:
   8 bulbs x $0.50 = $4.00

   J. Is your friend saving money so far? No.

Next, let's look at the total cost in electricity.

K. Multiply the CFL electricity cost per year you calculated in Table 1 above by 4, since CFL bulbs last four years.
$3.36 x 4 =$13.44

L. Multiply the IL electricity cost per year you calculated in Table 1 above by 4, to compare with the electrical cost associated with an IL bulb.
$10.25 x 4 = $41.00

M. Complete the following table to see how much it costs to use each type of bulb for four years.

	IL	CFL
Cost of enough bulbs to last 4 years	$4.00	$3.00
Electricity costs for four years	$41.00	$13.44
Total Cost	$45.00	$16.44

N. So, is your friend saving money by buying an IL bulb?
No! Your friend is spending an extra $28.56 by using an incandescent light bulb.