Speed of Light

Overview: One of the biggest challenges with measuring the speed of light is that the photons move *fast,* too fast to watch with our eyeballs. So instead, we're going to watch the effects of microwave light and base our measurements on the effects the light has on different kinds of food.

What to Learn: Today you get to think and act like a real scientist by doing an experiment, taking measurements, using math to figure out an answer, and test different materials to see which gives you the best result.

Materials

- chocolate bar (extra-large bars work best)
- mini marshmallows
- chocolate chips
- American sliced cheese (the kind that comes individually wrapped)
- paper plates
- ruler
- calculator
- pencil and paper
- microwave (You'll only need one of these for the entire group.)

Experiment

1. First, you'll need to find the "hot spots" in your microwave. The video will demonstrate this for you, but here are the steps:
2. Remove the turntable from your microwave and place a naked bar of chocolate on a plate inside the microwave. (Make sure the chocolate bar is the BIG size – you'll need at least 7 inches of chocolate for this to work.)
3. Turn the microwave on and wait a few minutes until you see small parts of the chocolate bar start to bubble up, and then quickly open the door (it will start to smoke if you leave it in too long).
4. Look carefully at the chocolate bar without touching the surface… you are looking for TWO hotspots, not just one – they will look like small volcano eruptions on the surface of the bar.
5. If you don't have two, grab a fresh plate (you can reuse the chocolate bar) and try again, changing the location of the plate inside the microwave. You're looking for the place where the microwave light hits the chocolate bar in two spots so you can measure the distance between the spots.
6. Open up the door or look on the back of your microwave for the technical specifications. You're looking for a frequency in the 2,000-3,000 MHz range, usually about 2450 MHz. Write this number down on a sheet of paper – this tells you the microwave radiation frequency that the oven produces, and will be used for calculating the speed of light.
7. When you're ready to take a measurement, pop in the first food type on a plate (without the turntable!) into the best spot in the microwave, and turn it on. Remove when both hotspots form, and being careful not to touch the surface of the food, measure the center-to-center distance using your ruler in centimeters. TIP: If you're using mini-marshmallows or chocolate chips (or other smaller foods), you'll need to spread them out in an even layer on your plate so you don't miss a spot that could be your hotspot!
8. Note that when you measure the distance between the hotspots, you are only measuring the peak-to-peak distance of the wave… which means you're only measuring *half* of the wave. We'll multiply this **number by**

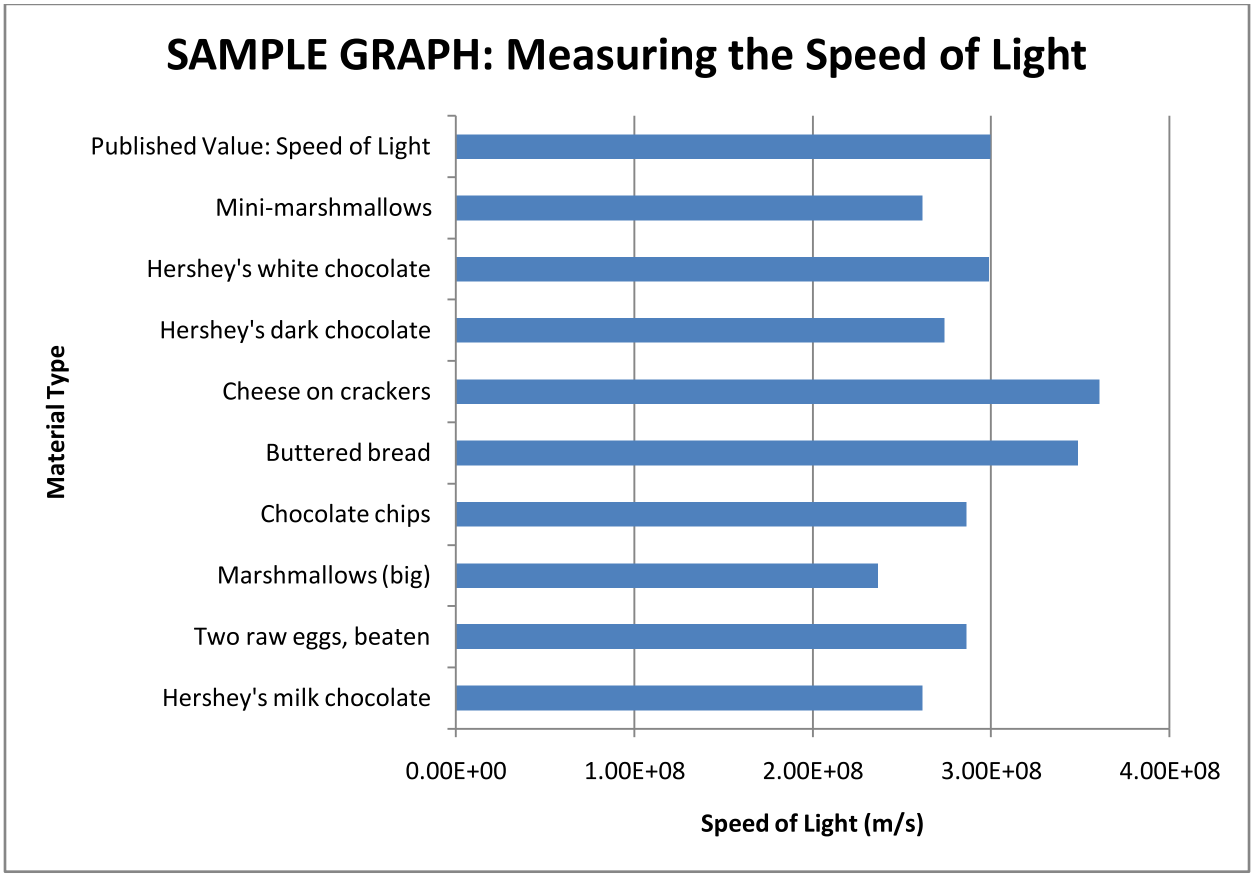
two to get the actual length of the wave (wavelength). If you're using centimeters, you'll also need to convert those to meters by dividing by 100.

9. So, if you measure 6.2 cm between your hotspots, and you want to calculate the speed of light and compare to the published value which is in meters per second, here's what you do:
   2,450 MHz is really 2,450,000,000 Hz or 2,450,000,000 cycles per 1 second
10. Find the length of the wave (in cm): 2 * 6.2 cm = (12.4 cm) /(100 cm/m) = 0.124 meters
11. Multiply the wavelength by the microwave oven frequency:
    0.124 m * 2,450,000,000 Hz = **303,800,000 m/s**
12. The published value for light speed is 299,792,458 m/s = 186,000 miles/second = 671,000,000 mph
13. Calculate % Difference by using this simple formula:
    % Diff = **|** Measured Value – Published Value **|** ÷ Published Value x 100

Speed of Light Data Table

Food Type	**Hotspot Distance** *(cm)*	**Calculated Speed of Light** *(m/s)*	**% Difference**

Graphing: Use the data from your table to make a graph of your results, putting the different types of food on the vertical axis and the measured (calculated) speed of light value on the horizontal axis. Refer to the sample while you create your own. In the graph sample, note that "3.00 E+08" means 3 with eight zeros after it, or 300,000,000 meters per second.



Reading

When you warm up leftovers, have you ever wondered why the microwave heats the food and not the plate? (Well, some plates, anyway). It has to do with the way microwave ovens work.

Microwave ovens use dielectric heating (or high frequency heating) to heat your food. Basically, the microwave oven shoots light beams that are tuned to excite the water molecule. Foods that contain water will step up a notch in energy levels as heat. (The microwave radiation can also excite other polarized molecules in addition to the water molecule, which is why some plates also get hot.)

One of the biggest challenges with measuring the speed of light is that the photons move *fast,* too fast to watch with our eyeballs. So instead, we're going to watch the effects of microwave light and base our measurements on the effects the light has on different kinds of food. Microwaves use light with a wavelength of 0.01 to 10 cm (that's the "microwave" part of the electromagnetic spectrum). When designing your experiment, you'll need to pay close attention to the finer details such as the frequency of your microwave oven (found inside the door), where you place your food inside the oven, and how long you leave it in for.

Exercises

1. What would happen if you used cheese instead of chocolate?
2. Does it matter where in the microwave the chocolate is located? Does placement of the chocolate affect the wavelength?
3. Can you explain what the burn marks on the chocolate bar are from?

Answers to Exercises: Speed Of Light

1. What would happen if you used cheese instead of chocolate? (If it's soft and melty, it will work!)
2. Does it matter where in the microwave the chocolate is located? Does placement of the chocolate affect the wavelength? (Yes, it does matter, which is why most microwaves have turntables to ensure heating and reduce the hotspots on food where the energy is focused.)
3. Can you explain what the burn marks on the chocolate bar are from? (The focused energy from the microwave.)