Measuring The Speed of Light

COLLEGE OF NATURAL SCIENCES
COLORADO STATE UNIVERSITY

Overview

You can use a plate of marshmallows to demonstrate the uneven heating of a microwave. By measuring the distance between areas of heating in the marshmallows, you can approximate the speed of light.

Theory

Microwave ovens heat food with microwaves, electromagnetic waves which, like visible light, travel at the speed of light. Inside the metal cabinet of the microwave oven, the waves set up a pattern of *standing waves*.

Within the microwave, there is a combination of two waves moving in opposite directions but with the same amplitude and frequency. The peaks and troughs of the wave are antinodes, which correspond to areas of heating. But there are also places where the wave has no amplitude—we call these nodes. At the nodes of the wave, there is no heating. The walls of the oven are areas of no electric field, and are nodes of the electromagnetic wave. By taking the turn plate out of the microwave oven and adding a plate of marshmallows, you can actually see the areas where the marshmallows are hot, and where they are not. The marshmallows expand when heated, and remain small when not heated. Measuring the distance between two areas of expanded marshmallows on the plate will give you the distance between two antinodes of the electromagnetic wave—and that lets you find the wavelength, and knowing the wavelength lets you calculate the speed of light!

Necessary materials:

- Microwave oven
- Microwave safe plate
- Marshmallows (mini size is preferable)
- Toothpicks or straws
- A ruler

Doing the experiment

Remove the turntable from your microwave. Completely cover a plate with marshmallows, spreading them out as evenly as possible. Place the plate of marshmallows in the microwave and let the microwave run for about 15 seconds, or until you can see the marshmallows growing; it will be extremely obvious! If necessary, place toothpicks or straws in the areas of heated marshmallow to give you more defined points to measure. Now, measure the distance between two consecutive areas of hot marshmallow. This measurement represents the distance between two antinodes of the standing electromagnetic wave.

Next, we calculate the speed of light using the relationship $c = \lambda f$, where c is the speed of light in meters per second, λ is the wavelength in meters, and f is the frequency in hertz (Hz).

To calculate the wavelength, first multiply your measure distance between marshmallow peaks by two.

(distance in cm) x 2 = wavelength in cm

Then, convert to meters: (wavelength in cm) ÷ 100 = wavelength in meters

To find the frequency, check the label on the back of your microwave oven. In our case, the frequency was 2450 MHz. Convert from MHz to Hz by multiplying by 10^6.

$$2450 \text{ MHz} = 2450 \times 10^6 \text{Hz}$$

Now, multiply these two numbers together to get c, the speed of light.

c= (wavelength in meters) x (frequency in Hz)

The speed of light is 3×10^8 m/s, and you should get a number that is close to this. Although you calculated the speed of the microwaves that warmed the marshmallow, microwaves are still electromagnetic waves. Since light is also an electromagnetic wave, they move at the same speed!

Summing up

This is a basic and simple way to demonstrate how waves work with a payoff—you can calculate the speed of light!

For more information

Colorado State University College of Natural Sciences: http://www.natsci.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu