Marshmallows & The Speed of Light

Workshop

This workshop uses marshmallows to teach participants about waves and to calculate the speed of light.

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Number of Participants: 5-30

Audience: Elementary (ages 5-10) and up

Duration: 20-30 minutes

Difficulty: Level 1

Materials Required:

- Microwave
- Plate
- Mini marshmallows
- Ruler
- Rope or long spring (optional)

Setup:

1. Evenly spread out the marshmallows on a plate.
2. Remove the microwave's turntable and microwave the marshmallows.

Presenter Brief:

Practice melting the marshmallows in your microwave beforehand. Be sure to remove the turntable, as the demonstration relies on standing waves. Identify a reliable cooking time and note the frequency listed on the back of the machine before the demonstration, it is needed for calculations.

Vocabulary:

- Standing wave – A wave pattern that results from the interference from at least two waves; has regions of minimum and maximum intensity: nodes and antinodes, respectively.
- Wavelength – The distance between corresponding points, such as peak to peak.
- Node – Any point along a wave with no displacement.
- Anti-node – Any point along a wave that experiences the maximum intensity.

Physics & Explanation:

Elementary (ages 5-10):

Microwave ovens heat food by using light that is invisible to the human eye to excite water molecules inside the food and thereby warm up the food around the water. We can see the effects of this invisible light by looking at the hot and cold spots produced by the microwave in food. An easy to use food is marshmallow.

> Use diagrams, rope, or a long spring to illustrate a standing wave. Have the students identify maxima (anti-nodes) and minima (nodes). If there are many children, a large rope or rubber tube work well. Explain that this is a wave, unlike the microwaves, that they can see.
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> Arrange marshmallows so that they cover a plate. Using your pre-determined time, heat the marshmallows until melted spots form. Point out the hot and cold spots and mark the spots with a marker for hot and a different marker for cold spots. Explain that the hot spots are places that the waves add together and are maximum (anti-nodes), just like when you make standing waves on a rope or spring. We can see the maxima of light waves this way.

The cold and hot spots in the marshmallows let us know how big the waves of invisible light are that heats up our food.

Middle (ages 11-13) and general public:

Microwave ovens use light waves to cook food. These waves have more energy in each one than radio waves, which are also light that we cannot see. The waves inside the microwave oven heat the food by exciting the water molecules inside the food. The wavelength used is tuned specifically to water.

As the water is excited by the waves, friction is created and the food heats up.

Microwaves work by using light to create friction in the food at the molecular level.

After explaining the above, use diagrams or a long spring to illustrate a standing wave. Explain that standing waves are created in microwave ovens. At anti-nodes, where there is a maximum of light waves, the marshmallow gets hot. At nodes, the food does not heat up very much. This is why we have the rotating trays in many microwaves and why the food will sometimes heat unevenly.

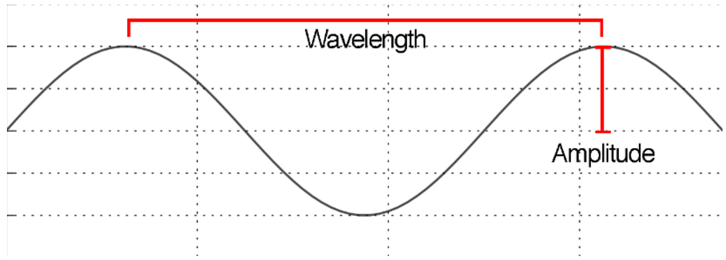

Figure 1

Since radio waves are part of the electromagnetic spectrum, they travel at the speed of light, like all electromagnetic waves.

The wave equation relates velocity, frequency, and wavelength of a wave.

$$v = f\lambda$$

Since the hot and cold spots in the food represent anti-nodes and nodes respectively, we can use food like marshmallows to observe the standing wave in the oven. Spread the marshmallows out evenly over a plate and cook in the microwave. One can also use other foods, such as chocolate, hot dogs, or even soft bread. The food just needs a little bit of water in it.

After heating the food until the cold and hot spots are visible, measure the distance between the hot spots and calculate the speed of light using the frequency indicated on the back of the microwave. Be sure to convert to metric units and remember that the distance between two hot spots is only one half of the wavelength ($\lambda/2$).

How does your answer compare the correct value of $c = 2.99 \times 10^8\ {}^{m}/_{s}$? What are some reasons your answer is off? Consider the "resolution" (size) of the marshmallows and uncertainties in your measurements.

We can see the standing radio waves produced by a microwave in the cold and hot spots in the marshmallows.

Additional Resources:

- 2014 SOCK https://www.spsnational.org/sites/default/files/files/programs/2014/sock/2014-sps-sock-manual-final.pdf
- HuffPost video https://www.youtube.com/watch?v=GH5W6xEeY5U

Useful Equations:

Wave equation	$v = f\lambda$

$v - velocity\ of\ wave$

$f - \ frequency$

$\lambda - wavelength\ of\ light$