SCIENCE FRIXION STEM LESSON PLANS

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High School

LIGHT MOVES FAST!

Using just a few sheets of paper, some FriXion erasable pens, and a household microwave, students learn about the fundamentals of heat transfer via radiation, as well as make measurements to approximate the speed of light!

LEARNING OBJECTIVES

After this activity, students should be able to:

- Define the component parts of an electromagnetic wave.
- Explain how microwaves heat objects.
- Analyze measurements to calculate the speed of light.
- Explain why FriXion ink is a useful tool for demonstrating the effects of heat transfer and measurement of fundamental properties of light.

Developed by

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MATERIALS

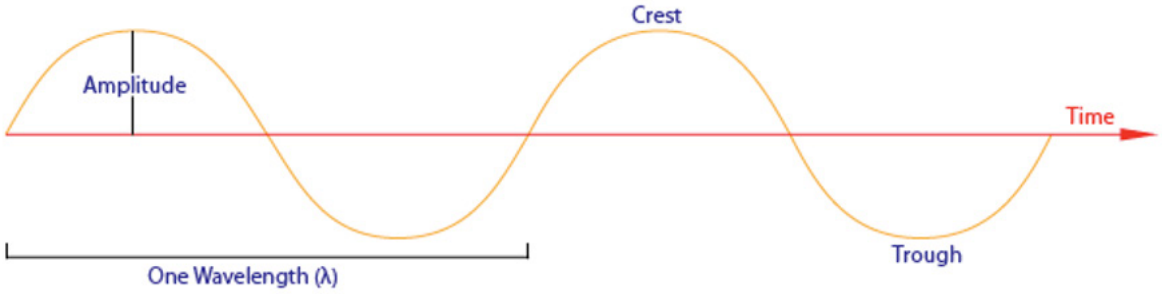
To share with the entire class (teacher demonstration):

- FriXion pens
- G2 pen (for circling spots where ink has disappeared)
- paper
- tape
- microwave (1200W)
- centimeter ruler

INTRODUCTION/MOTIVATION

If you've ever stood outside on a sunny day wearing dark clothing, you have felt heat transfer via radiation. The energy carried by the electromagnetic waves of light produced by the sun are absorbed by the dyes in the fabric of your dark clothing and converted into thermal energy, or heat.

The process behind heating food in a microwave is surprisingly similar. The microwave oven emits only one type of electromagnetic energy: microwaves. When these microwaves strike food, they cause molecules inside to rotate, spin, and bump into one another, generating heat. There is a common problem associated with microwave ovens however, uneven heating. Microwaves tend to have long wavelengths, and only the crests and troughs of the wave produce heating.



This means that a microwave oven has hot spots where there are crests and troughs and cold spots in between. Part of this issue is remedied by the use of a mechanical turntable that rotates the food through the hot spots and results in more even overall heating.

In this experiment, we will use the thermo-sensitive ink in Pilot FriXion pens to identify crests and troughs as well as measure the corresponding wavelength of the microwaves produced by the oven. Once the wavelength has been measured, the speed of light can be calculated using the equation **$c=\lambda\nu$**, where c = the speed of light in meters per second (m/s), λ is the wavelength of the microwaves in meters (m), and λ is the frequency of the microwave in Hertz (Hz).

PROCEDURE

Before the Activity

- Gather materials for the teacher demonstration.

With the Students (Teacher Demonstration)

1. Have students read the introduction above and provide them with the fundamental equations (from the introduction) and microwave frequency (found on the back of the microwave or online based upon the model).
2. Pass out paper and FriXion pens to students in the class.
3. Have students use the FriXion pens to draw tight grids of lines on one side of the page of paper.
4. Open the microwave and remove the rotating base plate.
5. Using the pages created by the students, tape and trim pages together until you have a single sheet of paper that exactly fits the interior of the microwave.
6. Heat the paper inside the microwave in small increments of a few seconds, opening the door and testing to see if any spots have developed where the FriXion ink has disappeared.
7. As spots appear, use a Pilot G2 pen to circle the spots.
8. Continue heating the paper in the microwave until multiple spots are visible on the page.
9. Once several spots are visible, photocopy the results and pass out copies to each student.

Student Analysis

1. Carefully mark the center of each spot where the FriXion ink has disappeared.
2. Using a ruler, measure the distance between center spots. Label the distances on the page in centimeters.
3. Calculate the average distance between center spots in centimeters.
4. Following your instructor's guidance, use your average distance to calculate the speed of light in meters per second (m/s).

DISCUSSION QUESTION

- Why was it important to remove the rotating base plate?
- Why was it important to take multiple measurements from different places where the FriXion ink disappeared?
- How did your calculated speed of light compare to the accepted value of 2.99 x 108 m/s?
- What may have caused some errors in the measurements involved in this experiment?