Activity 2. Chocolate Light: Observing light as a wave

Learning Intentions
Students can observe that light can act and travel as a wave and that it has energy – enough to melt chocolate in this instance. Students can begin to conceptualize that light has a speed that can be measured (albeit crudely in this instance).

Before the experiment:
Using a microwave and a block of chocolate, students can measure the wavelength and even measure the speed of light by observing and measuring hotspots in the chocolate. Then you get to eat the chocolate…it's for science. And because it is science you may have to repeat the experiment. The same result can be achieved with bread that is spread with a reasonable thickness of butter.

Your hypothesis
First question to ask is what do you think will happen when you put the chocolate in the microwave and turn it on?

What do you think you will observe and what can you measure?

What is causing your predicted effect?

If microwaves are light, how can we use this knowledge and what we observe with the chocolate to measure the speed of light?

Materials

- Microwave
- Block of chocolate
- 3 or 4 small microwave safe cups/containers/blocks to sit over the carousel rotating mechanism
- Microwave-safe plate to sit the chocolate on
- Ruler

Teacher Notes	**Teaching Notes: Running the activity**
Teachers can demonstrate this experiment to younger students to observe light as a wave and to measure wavelength. Older students can conduct the experiment themselves and include the calculation of light speed. Students can measure the distance between their blobs of chocolate and calculate the wavelength of the microwaves. If you are doing this as a demonstration, complete the steps outlined in the Method section for about 6-8 blocks of chocolate to get a range of measurements. How close to the known speed of light is each student's calculation?	**Method** Remove the carousel (rotating plate) from the microwave and position the 3 or 4 supports for the chocolate around the rotating mechanism in the base of the microwave. Place plate on the supports and the chocolate on the plate. The idea is to avoid the chocolate rotating. It must remain still in the microwave. Turn the microwave on for about 15 seconds (med-high) and check the chocolate block. You are looking for soft blobs or spots on the chocolate that have just started to melt. Continue in short bursts until you achieve this. You want to avoid completely melting the chocolate. The length of time required to achieve the

There will likely be differences in each calculation. Get students to think why such differences occur.

There are ways to improve accuracy and rigour of the experiment. These include ensuring students are measuring their distance between the melted chocolate in a standardised way; ensuring the time in the microwave for each block of chocolate is exactly the same (once you have worked out the optimum time), the chocolate used is the same type and repeat the experiment a lot more times – yummy.

Combine the data from each repetition and get students to calculate the average and median speeds of light and compare these against the actual speed of light. Get students to compare the different outcomes and think about why these figures differ. How does repeating the experiment improve the statistical rigour of the outcome? This is equivalent to flipping a coin to understand the probability of getting a heads or tails. The more times you flip the coin the closer you will get to a 50:50 outcome of heads and tails.

What is happening

Microwaves are light and therefore travel at the speed of light. Microwaves heat food using a standing electromagnetic wave. A standing wave is one that is not travelling, it just oscillates (moves up and down) in one place. To see an animation of a standing wave, check this clip.

The part of the wave moving up and down from peak to trough is called the anti-node. Where the wave does not move is called the node. See Figure 1 below. The anti-nodes are where most of the heating occurs and it is where the spots of melted chocolate will be. As noted, the distance between two anti-nodes – or two melted chocolate spots – represents only half of one wavelength. We use this measurement, plus the known frequency of the microwave to calculate the speed of light.

Extended thinking

Students can cross check the frequency of their microwave specifications by

optimum melt will depend on the strength of your microwave, so there will be a bit of trial and error here. But the sacrifices you might have to make (eating the failed experiment) in the name of science are worth it.

Success will look like a block of chocolate with a line of soft, semi-melted spots along it.

The hot spots (melted chocolate) correspond to the crests and troughs of the light waves (microwaves). The distance between each blob represents half a wavelength. To determine the wavelength, you need to measure the distance between the centre of two melted blobs of chocolate and double the distance. See Figure 1.

Note that blobs of choc melt rather than the whole block. This is the reason you get hot and cold spots in your food when it is microwaved and the reason you need to stir it as you go.

Light speed is measured in metres per second. The formula to determine the speed of light is, speed of light (m/s) = wavelength x frequency.

The frequency of the wavelength is how fast it oscillates in a period of time and we can determine this by reading the technical panel on microwave. See Figure 2. The frequency of microwaves is usually measured in megahertz (MHz). In the example in Figure 2., the frequency is 2450 MHz

Our first job is to convert the wavelength from centimetres to metres and the frequency from megahertz to hertz so we can determine light speed in metres per second, units that are easier to conceptualize.

To convert the units, use the following formula.

Wavelength (the distance between melted blob multiplied by 2): X cm /100 = x metres

Frequency: Megahertz × 1,000,000 = hertz

manipulation of the formula to calculate the speed of light. [Speed of light (c) = wavelength x frequency] They have the wavelength they measured and they know the speed of light in air. The calculation to determine the frequency of their microwave wavelength is c/wavelength = frequency. They will have to convert the frequency which will be in hertz back into megahertz (divide the answer by 1,000,000). Again, the variable will be the accuracy of the measurement of the distance between the chocolate blobs. How close was the students' calculation to the actual microwave's frequency?	Now that we have frequency and wavelength in compatible units, we can calculate the speed of light. [Speed of light (c) = wavelength x frequency] The speed of light through air is about 300 million metres per second (m/s). How close to the known speed of light is your calculation? How does your result compare to the others in your class? How could you increase the accuracy of your result?

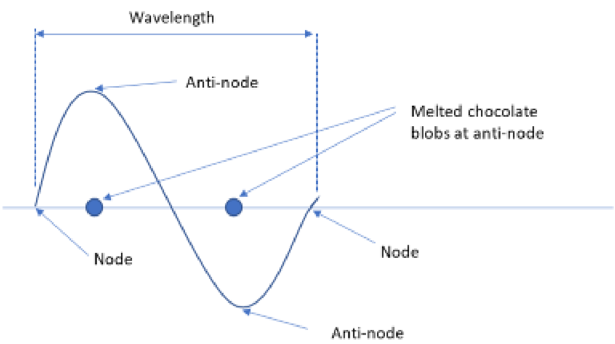

Figure 1. The microwave energy is greatest at the nodes of the wavelengths. The distance between two nodes equals half of a wavelength. To determine the wavelength of the microwaves (light) you need to double the distance you measure between each node (melted blob of chocolate).

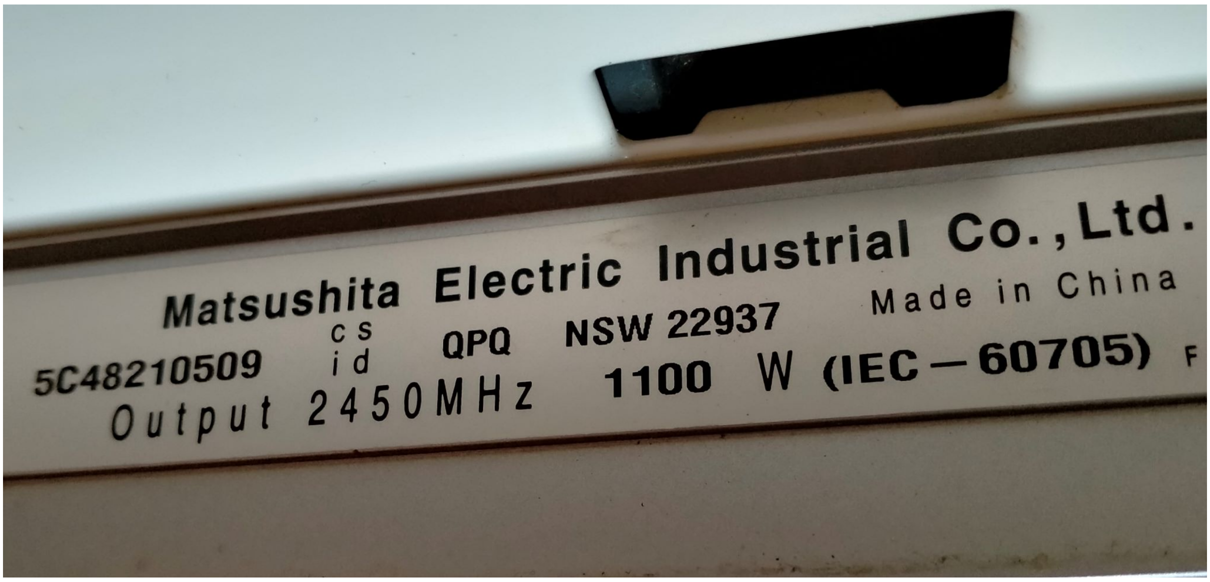

Figure 2. The technical specification on a microwave panel that show the microwave frequency in Megahertz (MHz).