Student Sheet

In this practical I will be:

- Carefully measuring and recording the findings of the experiment.
- Calculating the speed of light using recordings from my experiment.
- Analysing the method for the experiment in order to improve the accuracy of my calculated value.

Introduction:

The Egyptian pharaoh Akhenaten has declared there is only one god and that is Aten the sun-disk. The Sun is the source of our light and is important for our lives in Egypt. The ancient Egyptians had strange stories to explain the light and dark of day.

The Sun in the sky seems to be a long way away. If it was not we would be burnt by the heat of the Sun so light must travel from the Sun to Earth. You can find out how fast light travels using the following method.

Equipment:

- Access to a microwave oven
- 1 large plate or shallow bowl
- 1 flat, non-metal plate or board
- 4 approximately equally thick slices of bread from a rectangular loaf
- A knob of butter or margarine
- 1 dinner knife
- 1 ruler (30 cm long)
- Calculator
- Paper towelling

Hazard warnings:

Make sure there is no metal on the bread when put into the microwave oven and be careful of the butter or margarine since it can be very hot when it comes out of the microwave oven.

Method:

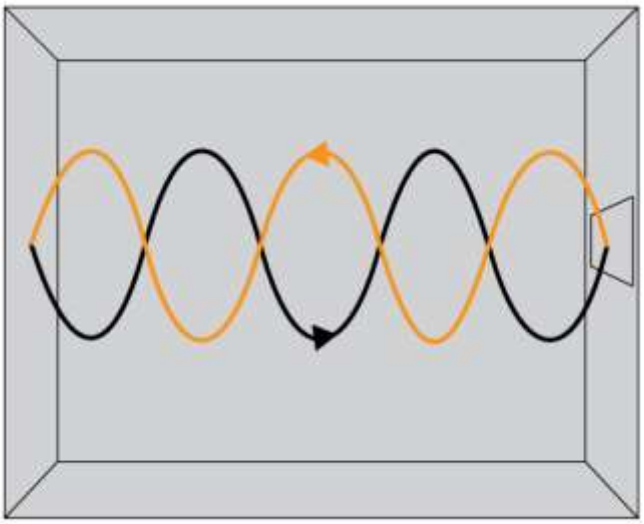
1. Remove the turntable from the microwave oven. Or you may be able to use the turntable by placing it upside down over the rotating parts. Ensure that it does not turn before using it.

2. Check the back or door lip of the microwave oven for the frequency of the wave. It will be in megahertz (MHz) or gigahertz (GHz). It should be about 2,450 MHz or 2.45 GHz.
3. Put the large plate or bowl over the rotating parts so the plate or bowl cannot turn when the microwave oven is turned on. Or use the turntable upside down as mentioned in point 1.
4. Take the four slices of bread. Using the dinner knife spread the butter or margarine evenly but thickly on one side and right up to the crust edge.
5. Lay the bread slices on the flat plate or board in a 2 x 2 slices square edge to edge, so it forms a bread sheet.
6. Add some butter to the edges to create a continuous butter surface.
7. Carefully put the flat plate with the bread on into the centre of the microwave oven. Turn on and heat the bread until the butter starts to melt. This should take about 10-15 s, but just in case check every 5 s.
8. When you see the butter or margarine has melted in parallel strips separated by unmelted strips, stop the microwave oven.
9. Use your ruler to measure the distance, in centimetres, between the melted strips.
10. Multiply this figure by 2 to get the wavelength of the microwave oven. It is likely to be about 12 cm.
11. The frequency of a wave is the number of waves produced per second Take the frequency figure for the microwave and multiply it by the wavelength. If the frequency is in megahertz you will then need to multiply by 1 million (1,000,000) and if using gigahertz multiply by 1 billion (1,000,000,000).
12. This will give you the approximate speed of light in centimetres per second. To convert it to metres per second, divide by 100. Find the actual speed of light, compare your answer, and try to work out how accurate your method was.
13. How could you make it more accurate?

Theory:

The microwave oven works by producing microwaves, a type of electromagnetic wave, from a device called a magnetron.

The magnetron is typically on the right hand side of the inside of the microwave oven, covered by a grill. The microwaves enter the cabinet of the microwave oven through this grill. The waves are large and travel across the cabinet, reflecting off of the opposite wall. This creates a standing wave where two waves going in opposite directions as shown in the diagram 1 below:



These two waves interact to make huge vibrations at some points and in other places there is no vibration.

This means molecules will be vibrated very powerfully where there is a large vibration, and because the kinetic energy of the molecule is high the temperature increases. In the areas where the vibration is very low the kinetic energy of the molecules will be low so the temperature is lower. These two different areas are separated by half a wavelength.

The turntable in a microwave oven is there to turn the food round so the food cooks evenly.

If you put the buttered bread in the microwave the butter will first melt where the microwaves are the most intense, so the distance between these will be half a wavelength.

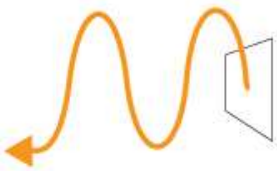
So what has the wavelength got to do with the speed of light?

Your microwave oven is producing microwaves vibrating at a certain frequency. This frequency can be found written on the back of your microwave oven.

The wavelength depends on how rapidly the wave is vibrating (the frequency) and how fast it is moving. As it is a type of light it moves at the speed of light.

Speed, wavelength and frequency are closely related, as described in diagram 2:

For a wave travelling at a fixed frequency (a certain number of vibrations per second);



if it moves slowly it will travel less far between vibration so the wavelength will be less;

if it moves faster the wavelength will be longer.

So this means that if the wave has a frequency of 100 Hz it will travel its wavelength 100 times in a second. So the speed of a wave is its frequency multiplied by its wavelength.

Because microwaves are a type of light you have just measured the approximate speed of light.