TEAM NEPTUNE(UGANDA)

CHOCOLATE AND SPEED OF LIGHT

QUESTION

A visual method to measure the speed of light is to place a chocolate bar in a microwave oven until chocolate starts to melt and measure the distance between hotspots. Study this effect and investigate the accuracy of this method.

INTRODUCTION

So what are these so called hotspots?

These are the small areas with a relatively higher temperature in comparison to their surroundings. Hotspots on food heated by a microwave oven develop because food rarely heat s evenly in the oven regardless of setting.

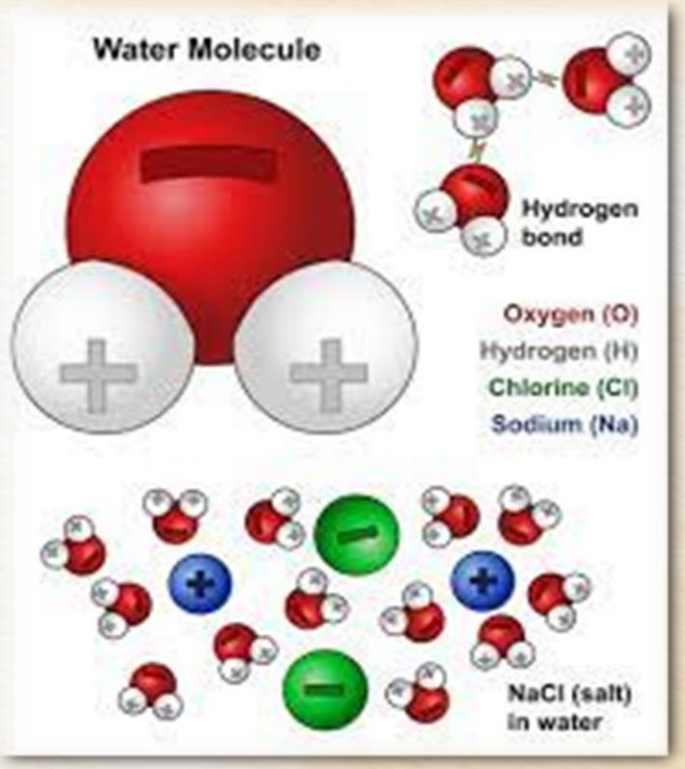
ASKING THE RIGHT QUESTIONS.

WHY DOES FOOD HEAT UNEVENLY?

WATER. The microwave was designed to work around water.

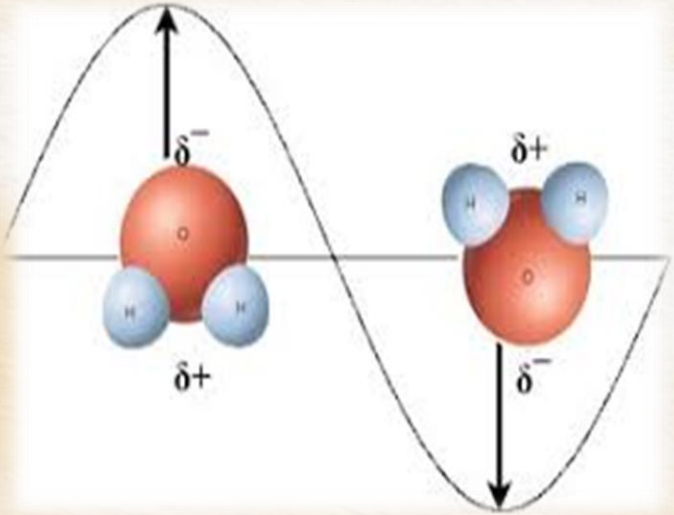
Water content

Foods with higher water content tend to absorb microwave energy with a higher efficiency while foods with a lower water content absorb heat more slowly causing uneven heating.

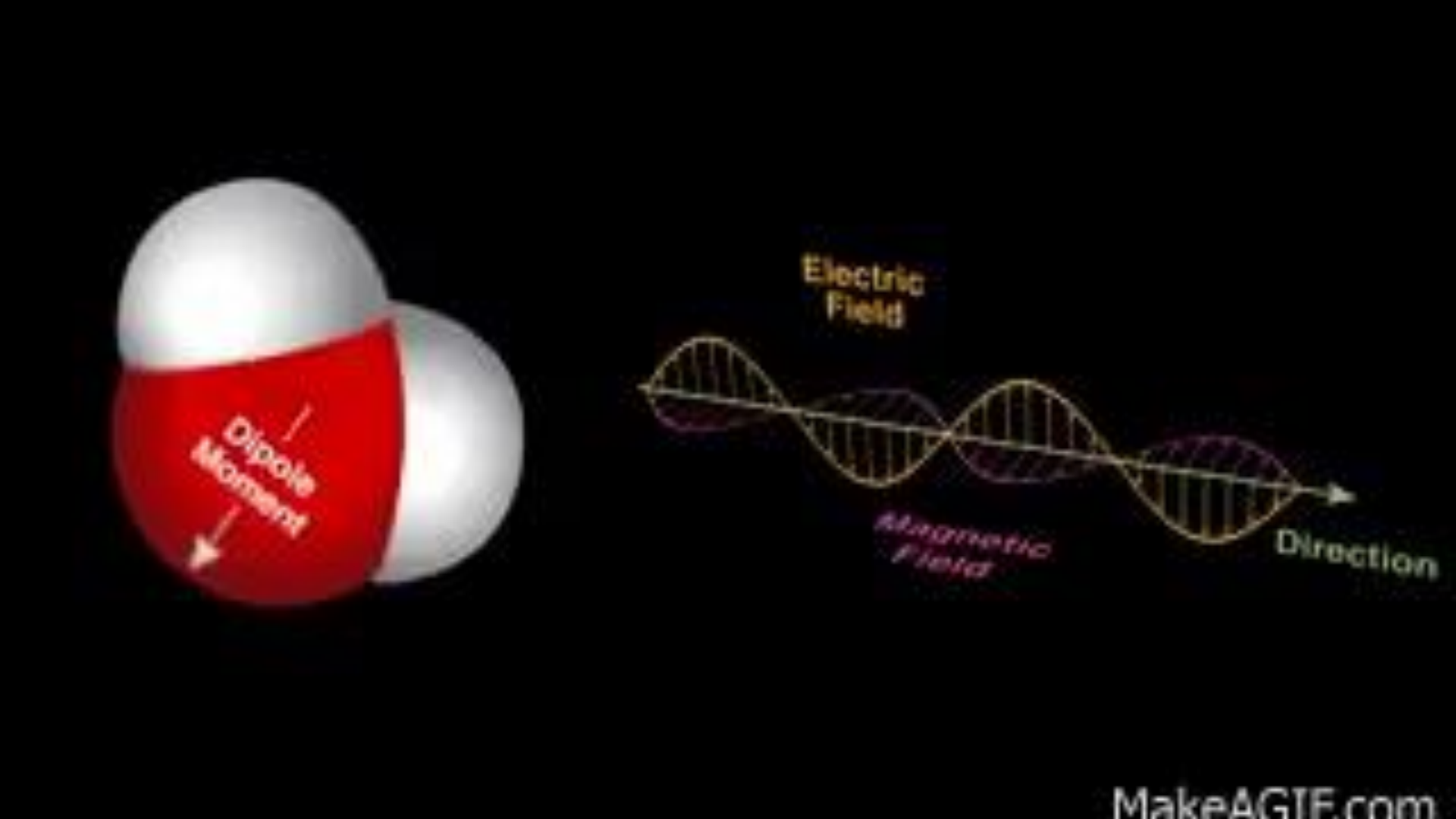


The different ingredients in a foodstuff often have varying rates of energy absorption, that is heat capacities, which can be observed clearly for the case of a berry pie where the berries have a higher water content hence heat up faster than the dry crust. This leaves us with the pie which is hot om the inside and relatively cold on the outside.

WHAT MAKES WATER SO SPECIAL?



1. The dipole that exists across a water molecule causes the negative and positive ends of the molecule to switch back and forth in the presence of oscillating electromagnetic fields, causing friction on the molecular level generating heat in a really short time. (take note of the standing wave produced by reflection by the walls of the microwave)


Dipole
Moment
Electric
Field
Magnetic
Field
Direction
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WHY CHOCOLATE WOULD BE GREAT FOR SUCH A STUDY

1. Chocolate is an amalgamation of various substances with the right balance of water and easily identifiable hotspots. We will be using crystallization type IV chocolate for our research.

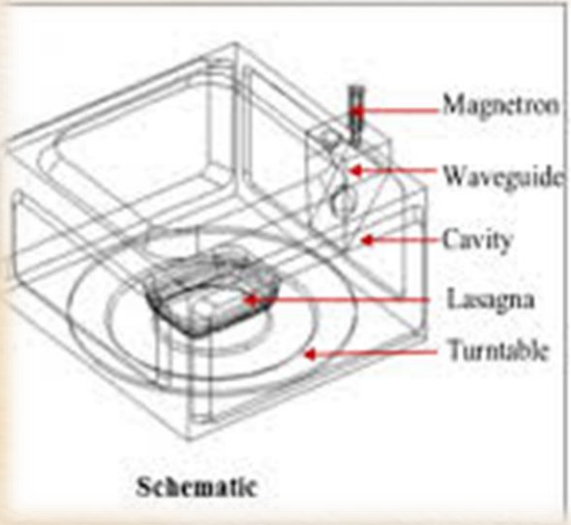
PHENOMENON TO INVESTIGATE

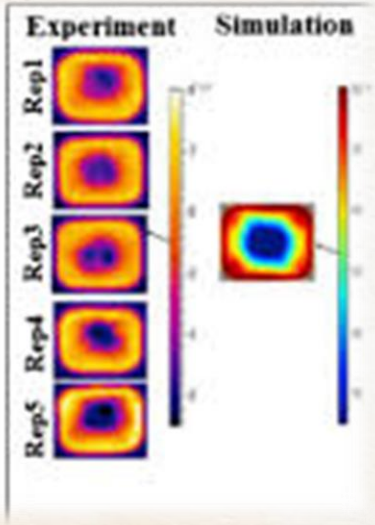
It was decided that somehow, speed of light can be calculated by measuring the distance between hotspots as previously described , so what could be the science behind the science?

THEORY BEHIND THE PHENOMENON

1. The theory rotates around the inner machinations of a microwave oven and the interaction of microwaves and food stuffs.

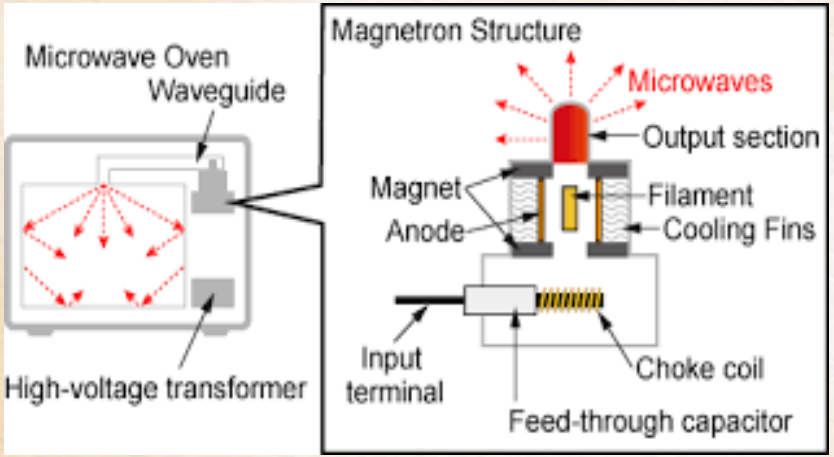
PARTS OF A MICROWAVE





1. Obviously there are only a few parts relevant to this study. The magnetron, walls , turn table and wave guide.

PURPOSE OF SAID PARTS



1. <u>MAGNETRON</u>
2. **Magnetrons** are specialty tubes that convert electron energy into radio (**microwave**) energy.

METAL CAVITY

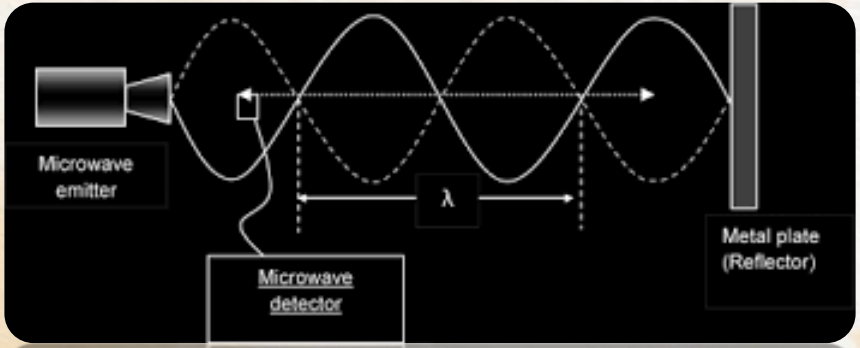
1. A microwave cavity or radio frequency (RF) cavity is a special type of resonator, consisting of a closed (or largely closed) metal structure that confines electromagnetic fields in the microwave region of the spectrum. The structure is either hollow or filled with dielectric material.

SUMMARY

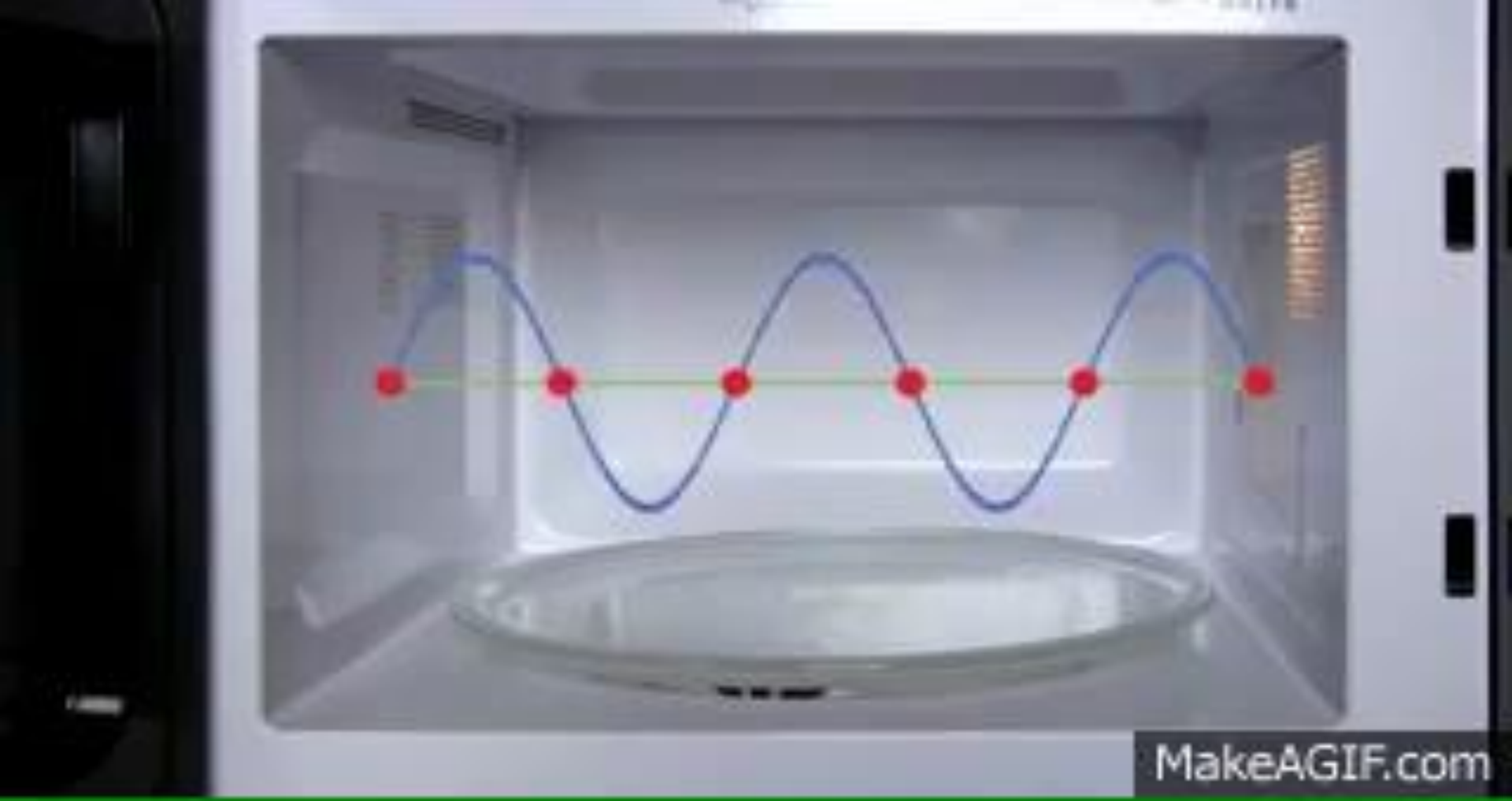
1. The microwave oven uses a magnetron to generate microwave energy. The microwave energy travels through a waveguide and is distributed into a metal cavity where the food is cooked.
2. The turntable plays a very important role in this study as it is quickly removed and discarded.

It is also important to note that microwaves are reflected by metal and by sheer coincidence, the walls of our microwave oven are made of a reflecting metal.

REFLECTION OF MICROWAVES



1. Microwaves in a microwave oven are produced by the magnetron and would travel in all directions if not guided by the wave guide. The microwaves travel to the opposite end of the microwave where they are reflected. Microwaves travel as transverse waves and the reflected waves are of the same frequency and wave length and speed and superpose with the waves produced by the magnetron to produce standing wave of increased amplitude but does not travel. It is fixed in place and only oscillates.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THE STANDING WAVE MAKES THE REST SO EASY

1. Regions of high amplitude and low amplitude are formed(also known as antinodes and nodes) which helps to explain why food does not heat evenly in a microwave oven unless fitted with a turntable. The antinodes are regions of maximum oscillation of the wave hence the most heating(excitation of water molecules occurs in this such reasons, hence a need for a turntable that turns with just the right speed that most parts of the food pass through these hot regions.

EXPERIMENTS

EXPERIMENT

1. <u>REQUIREMENTS</u>

a) Chocolate

1. Milk chocolate and dark chocolate (Cadbury and E Wedel)
2. Preferably no nuts or extra ingredients of that sort
3. Preferably no fancy patterns and a relatively even and flat surface.

Foot ruler, measuring tape

Microwave oven of known frequency
(preferably not a convention oven)

Infrared camera or pointed object.


SINCE 1851
E. Wedel
PREMIUM
MILK CHOCOLATE
CHOCOLAT AU LAIT
Net Weight/
Poids Net
220 g (7.76 OZ)
STORY EDITION
Cadbury
DAIRY MILK
MILK CHOCOLATE
THE CLASSIC CREAMY TASTE
Scan the QR Code to bring this story to life!
#Homegrownstories
Was everything BIGGER or was Akinyi now just MUCH smaller? Then she heard whispers...
80 g
STORY EDITION
Cadbury
DAIRY MILK
MILK CHOCOLATE
THE CLASSIC CREAMY TASTE
Scan the QR Code to bring this story to life!
#Homegrownstories
Denzil has 5 hours to do 10 acts of kindness. If he wants that toy drone, he better act FAST...
4:59
80 g

PRECAUTIONS FOR THE TESTS

a) Use a traditional microwave oven, not a convention one.
b) Use a reasonable microwave setting to prevent burning of the chocolate.
c) Use a trusted microwave oven from a trusted company(ensure wavelength of microwave does not change with change in setting and frequency of microwaves is as indicated on the oven)
d) Chocolate should be placed in line with wave guide
e) Use microwave safe utensils
f) Do not unnecessarily touch chocolate before or during the experiment.

EXPERIMENT for real this time

TIME TESTS

<u>Procedure</u>

The chocolate is placed in the microwave and heated for varying values of time, t=20s keeping the chocolate type, brand, microwave oven, setting and elevation constant.

The distances of hotspots for different values of t are measured and recorded in meters.

The experiment is repeated for different values of t=25,30,35s

TABLE OF RESULTS

T(s)	L(m)
20.0	0.059
25.0	0.061
30.0	0.063
35.0	0.065

TYPE TESTS

1. **PROCEDURE**
2. The chocolate is placed in the microwave oven .
3. It is heated for 25 seconds keeping the microwave oven, brand, setting and elevation constant.
4. The experiment is repeated for milk, dark and white chocolate

RESULTS

1. The white chocolate melted way too easily and it was difficult to locate hotspots if any
2. The dark chocolate and milk chocolate had almost no difference in results proving that they were both ideal for the experiment.

EXPLANATION

1. The milk and dark chocolate have a convenient amount of water hence they do not melt as easily and it is relatively easier to identify hotspots.
2. The white chocolate on the other hand has a high water content due to its high milk content making it melt way too easily hence making it difficult to identify hotspots and leading to possible errors and unreliability of such an experiment.

MICROWAVE TESTS

PROCEDURE

The chocolate is placed in the LG microwave oven.

It is heated for 25 seconds keeping the chocolate type , brand, setting, frequency and elevation constant.

The experiment is repeated for microwaves of midea, Panasonic, and Toshiba.

RESULTS

1. There were only very slight differences in lengths of hotspots recorded which could be accounted for by random errors.
2. Perhaps maybe the different companies have got slightly different frequency of microwave from what is recorded on the oven.

ELEVATION

PROCEDURE

The chocolate is placed at varying distances above or below the magnetron and heated for 25s keeping the chocolate type and brand , microwave oven and setting, and frequency constant.

RESULTS

1. Again, the results of this experiment were inconclusive as there was not a big enough gap between values to classify elevation as a determining factor. The differing values can still be accounted for by random errors.

FINAL TESTS

1. **PROCEDURE**
2. The chocolate is placed in the microwave oven an dis heated keeping all favorable factors constant this time round.
3. That is the chocolate type, brand, microwave oven, setting, frequency, elevation.
   The experiment is repeated three times and the average distance between hotspots is calculated.

TABLE OF RESULTS

1	**0.060 m**
2	0.061 m
3	0.061 m

CALCULATION

1. From $V = f\lambda$ where v stands for velocity, f stands for frequency and λ stands for wave length.
2. We can calculate the speed of microwaves since we have the distance between antinodes in meters(average of the three obtained values), the frequency of the microwaves in hertz.
The distance between antinodes is half a wave length though so this value will be multiplied by 2.

SPEED OF LIGHT

1. The speed of light is equal to the speed of all electromagnetic waves including that of a microwave hence we can obtain speed of light through our calculation.
2. From $V = f\lambda$
3. V= 2,450,000,000*0.122
4. V=298,900,000 m/s

5. This value is very close to the value of speed of light
6. (299 792 458 m / s)
7. With a percentage error of 0.002976919%

ACCURACY AND PRECISION

The accuracy of this method isn't too questionable because values very close to the accepted value were obtained very often. The average of these values was also close to the accepted value hence the experiment is mathematically accurate.

The precision of this experiment is questionable even though measurements were very close to each other.

VALIDITY AND RELIABILITY

Its validity is up for debate. The apparatus used is indeed questionable as a ruler only measures accurately to one decimal place and is prone to all sorts of errors namely zero error, parallax error and scale error. A better material than chocolate would be preferred such as spaced grated cheese whose heated regions would not easily spread heat to other reasons and tamper with the accuracy of the experiment. A better way to visualize the hotspots could also be suggested such as the use of an infra red camera to accurately pinpoint the centers of the hotspots as this is believed to be the most heated region.

We could justify this experiment though because no more than one variable is being varied at the same time. But then again, the assumptions made such as no heat transfer within the chocolate cannot be justified. This leads to a lot of random errors in measuring the distance between hotspots however slight.

ERRORS

The random errors decrease the reliability of this experiment because they decrease the repeatability. This experiment is also prone to systematic error such as the zero error or scale error and can easily be affected by human error if not accurately done

CONCLUSION

The experiment is relatively accurate, has got questionable validity and precision, conflicted reliability and is prone to a lot of errors. Therefore we would not recommend using this experiment to get values used in an experiment though it is quite fun and tasty.

THANKS FOR LISTENING!

REFERENCES

1. planetscience.com
2. instructables.com
3. onlyphysics.org

CLOSING REMARKS

1. THANKS FOR LISTENING!!!!!!!
2. GREETINGS FROM UGANDA.