

INCREASING THE AVERAGE KINETIC ENERGY OF ELECTRIC DIPOLES AND NEIGHBOURING PARTICLES IN A DIELECTRIC MEDIUM THROUGH APPLICATION OF AN ALTERNATING ELECTRIC FIELD

Or

What happens when you put things in a microwave that you shouldn't put in a microwave?

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with

Oliver Barker (Science and History of Microwave Cooking)

Adam Theaker (Foam and Lightning)

Martin Stewart (Grape Plasma)

and James Begg (Marshmallows, and The Speed of Light)

ON THE MENU TODAY:

- 1. An introduction to the history and technology of the microwave oven.
- 2. Grape Plasma
- 3. Foam and Lightning
- 4. Marshmallows, and the Speed of Light

1. FIRST THINGS FIRST, A BIT OF REVISION:

THE ELECTRIC DIPOLE MOMENT

In the simplest case scenario of two point charges, one with charge $+q$, and one with charge $-q$, the electric dipole moment, \mathbf{p} , can be expressed as:

$$\mathbf{p} = q\mathbf{d},$$

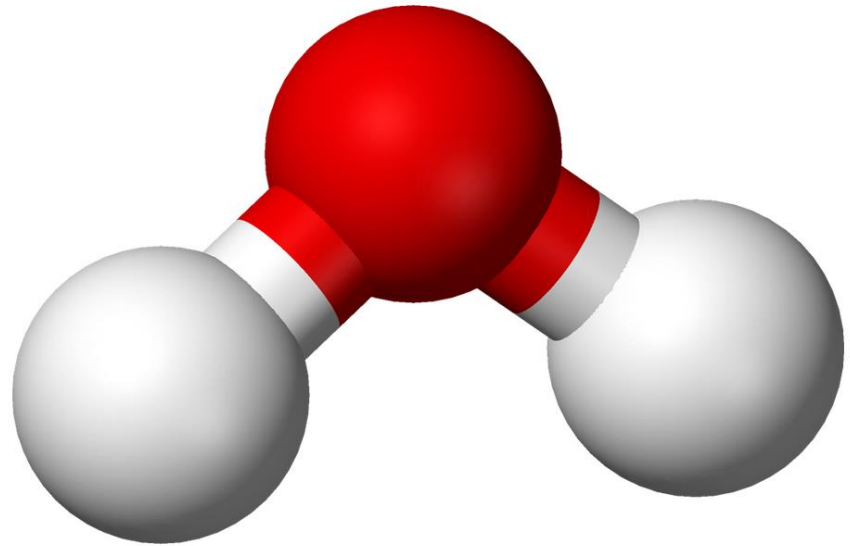
...where \mathbf{d} is the displacement vector between the charges.

In an electric field \mathbf{E} , each charge will experience a force in opposing directions, $q\mathbf{E}$, and the electric dipole moment will experience a torque, t , such that

$$t = \mathbf{p} \times \mathbf{E}$$

THE WATER MOLECULE

- The Oxygen atom has six outer shell electrons.
- Hydrogen atoms have one each.
- Electrons prefer to form up as a group of eight.
- Electrons bunch near the middle, partially exposing the nuclei, and creating +^{ve} and -^{ve} poles.

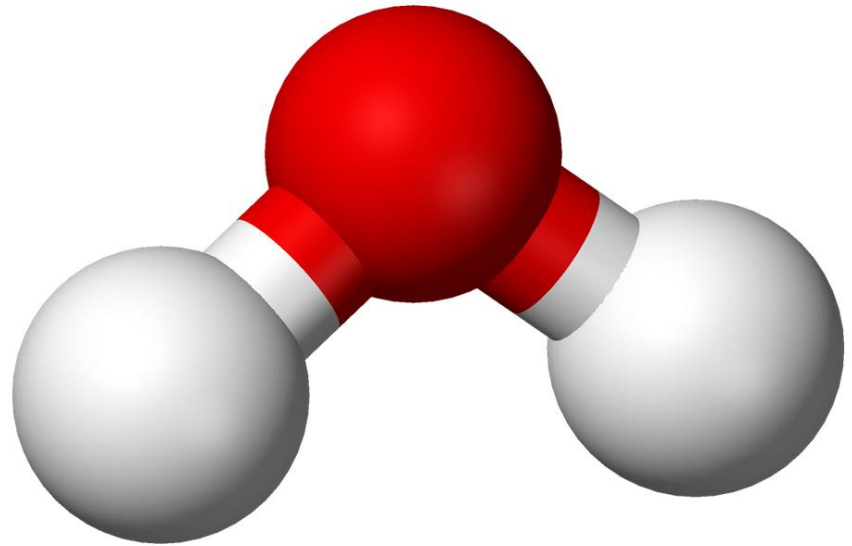


THE WATER MOLECULE

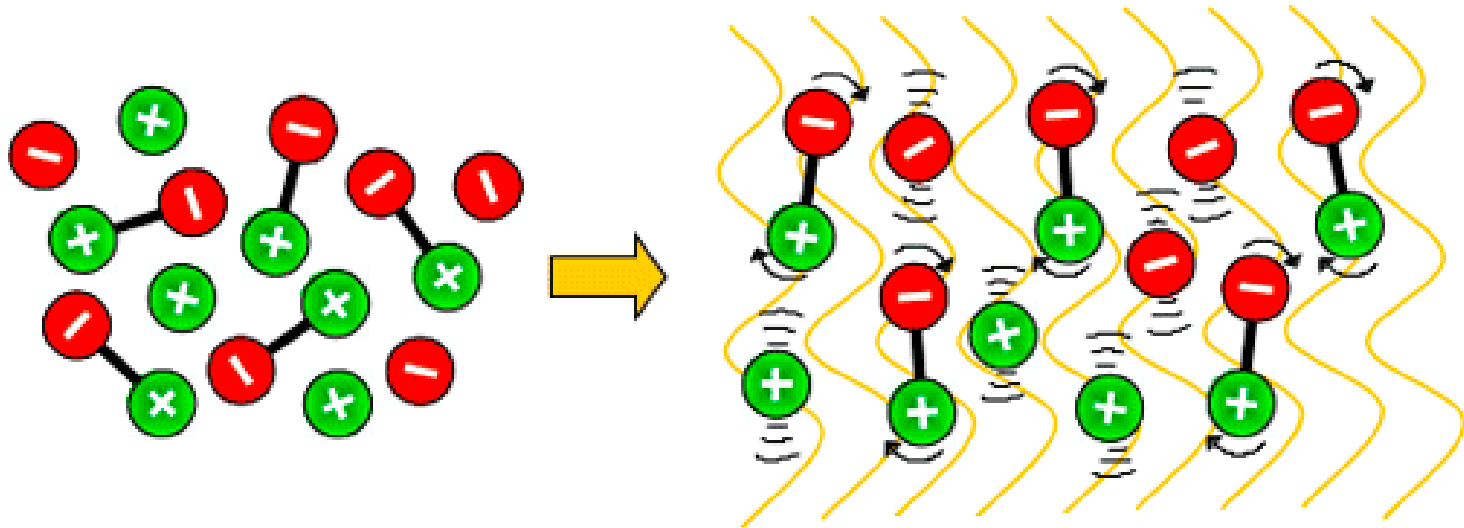
- Slightly positive at one end.
- Slightly negative at the other.
- $\mathbf{p} = q\mathbf{d}$

... in this case $q = 10e$, and $\mathbf{d} = 0.0039 \text{ nm}$

$$\mathbf{p} = 6.2 \cdot 10^{-30} \text{ C}\cdot\text{m}$$

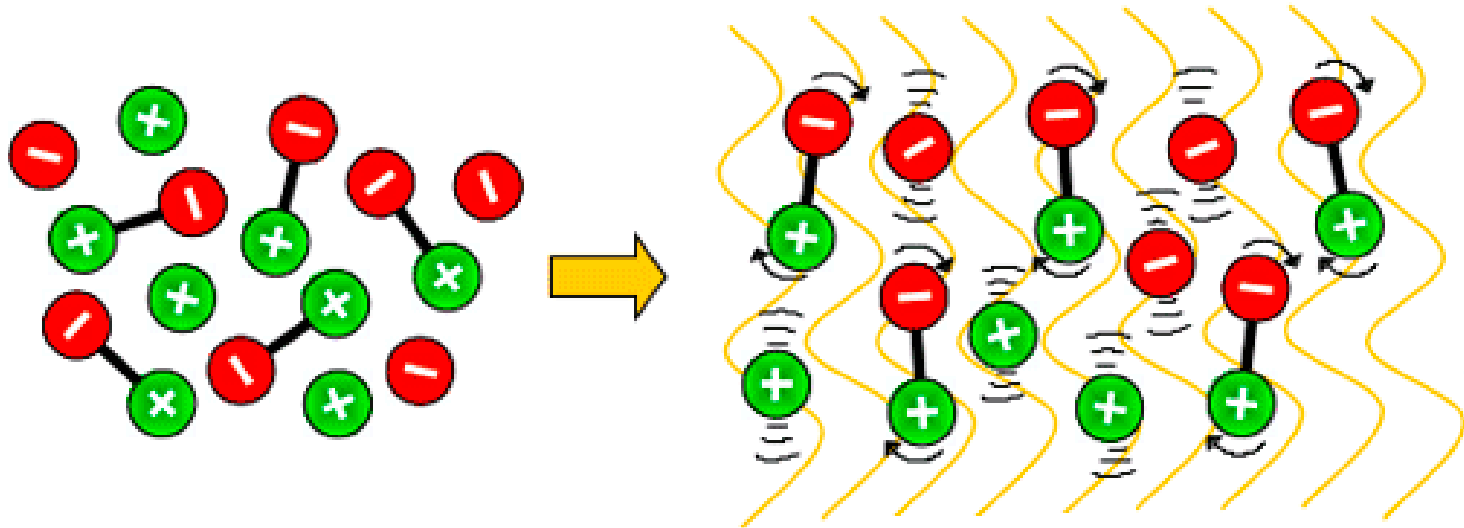


APPLICATION OF AN ELECTRIC FIELD



- Electric field pushes positive and negative ends of the water dipole in opposite directions, creating a torque, $t = \mathbf{p} \times \mathbf{E}$
- Dipoles align with the field.

ALTERNATING THE ELECTRIC FIELD



- Dipoles rotate constantly to align with the field, which gives them kinetic energy.
- They push, pull and collide with other particles, transferring kinetic energy, thereby increasing the average kinetic energy of all the particles.
- Dinner is cooked.

REALLY QUICK HISTORY OF THE MICROWAVE

- 1945: heating effect discovered by accident when radar engineer Percy Spencer melted a candy bar in his pocket.
- First food deliberately cooked by microwaves was popcorn, followed by an egg...
- Spencer verified his finding with a prototype “Magnetron Cooker”, tested in a restaurant.
- 1947: First commercial use of the technology was in the “Speedy Weeny” vending machine at Grand Central Station in New York.
- First commercially available model came out later that year. Cost about \$5000 (equivalent to ten times that now) and weighed half a ton.



THAT'S ALL FROM OLIVER...





FOAM AND LIGHTNING WITH ADAM THEAKER

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FOAM

- Soap contains small pockets of air containing water vapour.
- High pressure inside soap pushes through softened outer shell of the soap.
- Hence the foamy expansion.
- Demonstrates Charles' Law.

FOAM



FOAM

- No chemical change – only physical change.
- As it cools foam becomes brittle.



LIGHTNING

- Compact Discs (CDs) are polycarbonate plastic with a thin aluminium coating.
- Microwaves induce a large current which vapourises the metal.
- Discharging occurs over vapourised area.
- Combination of large current and electrical discharge causes the patterns

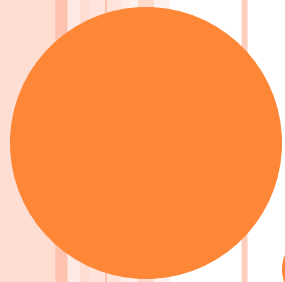
LIGHTNING



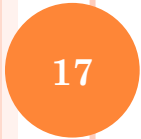
LIGHTNING

- Fractal pattern is caused by 'arcing'.
- Fractals mostly etched radially or uniformly against the azimuthal angle.



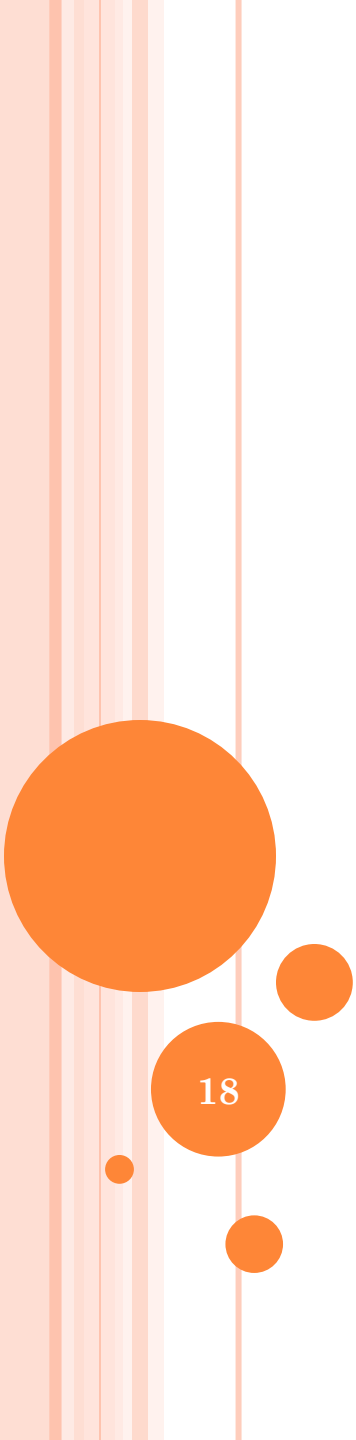


THAT'S ALL FROM ADAM...



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GRAPE PLASMA WITH MARTIN STEWART

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PREPARATION

- Cut the grapes in half.
- Cut in half again leaving a small amount of skin connecting the quarters.
- Use kitchen paper to dampen the grapes.
- Place the grapes in one of the microwaves hotspots which can be found using thermal sheets.
- Turn the microwave on for 10-15 seconds...



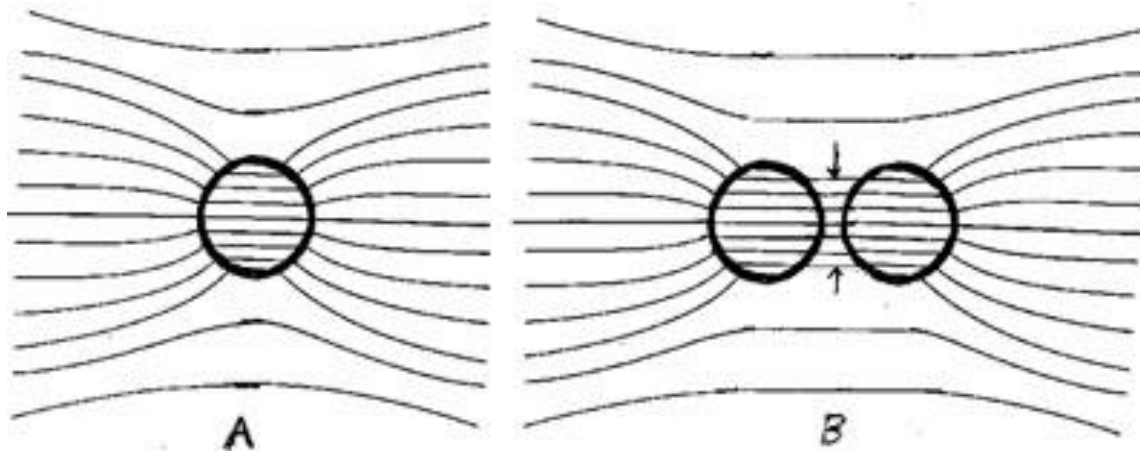
HOW IT WORKS...

- Microwaves typically operate in a power range of 500W to 1000W.
- The microwaves emitted in the cavity of the magnetron have a frequency of around 2400 MHz.
- This corresponds to a wavelength of 0.125m.
- This wavelength roughly corresponds to the dimensions of the grapes.
- This will lead to a resonating effect.



HOW IT WORKS...

- The grapes form an electric dipole, with a potential difference between the segments of around 3000V, and consequently electrical arcs form between them.
- Heat from this arc creates temperatures of around 3000C, vaporising solutes in the grape, which then ionise.
- The resulting plasma is kept hot by incoming microwaves, and rises.

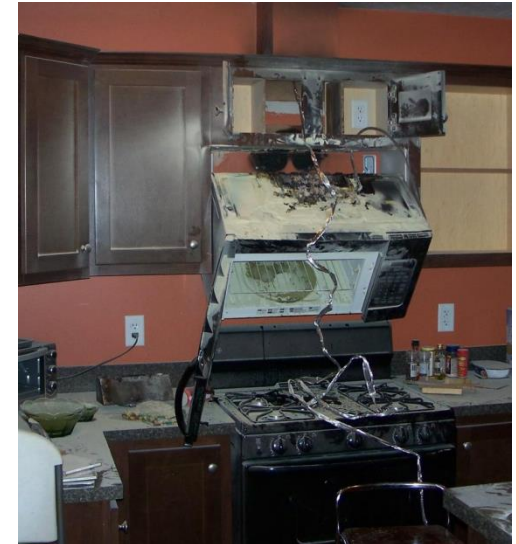


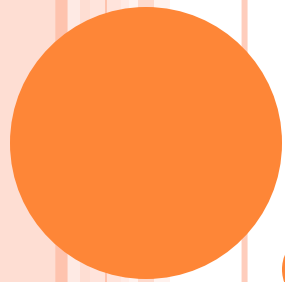
VIDEO



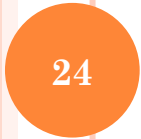
WHY IS THIS EXPERIMENT UNSAFE?

- The grapes need the full power of the microwave.
- If the grapes dry out fully, which takes around 15s, the microwaves will have nothing to act on but the magnetron itself.
- This will result in the microwave's destruction.
- So if you wish to do this experiment your microwave will be at serious risk.





THAT'S ALL FROM MARTIN...



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**MARSHMALLOWS, AND THE SPEED
OF LIGHT
WITH JAMES BEGG**

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THE MANY USES OF MARSHMALLOWS

- Is it possible to estimate the speed of light using Marshmallows?
- Do all Marshmallows behave the same?

MARSHMALLOW EXPERIMENT : METHOD

- Step 1: Place Marshmallows in a dish.

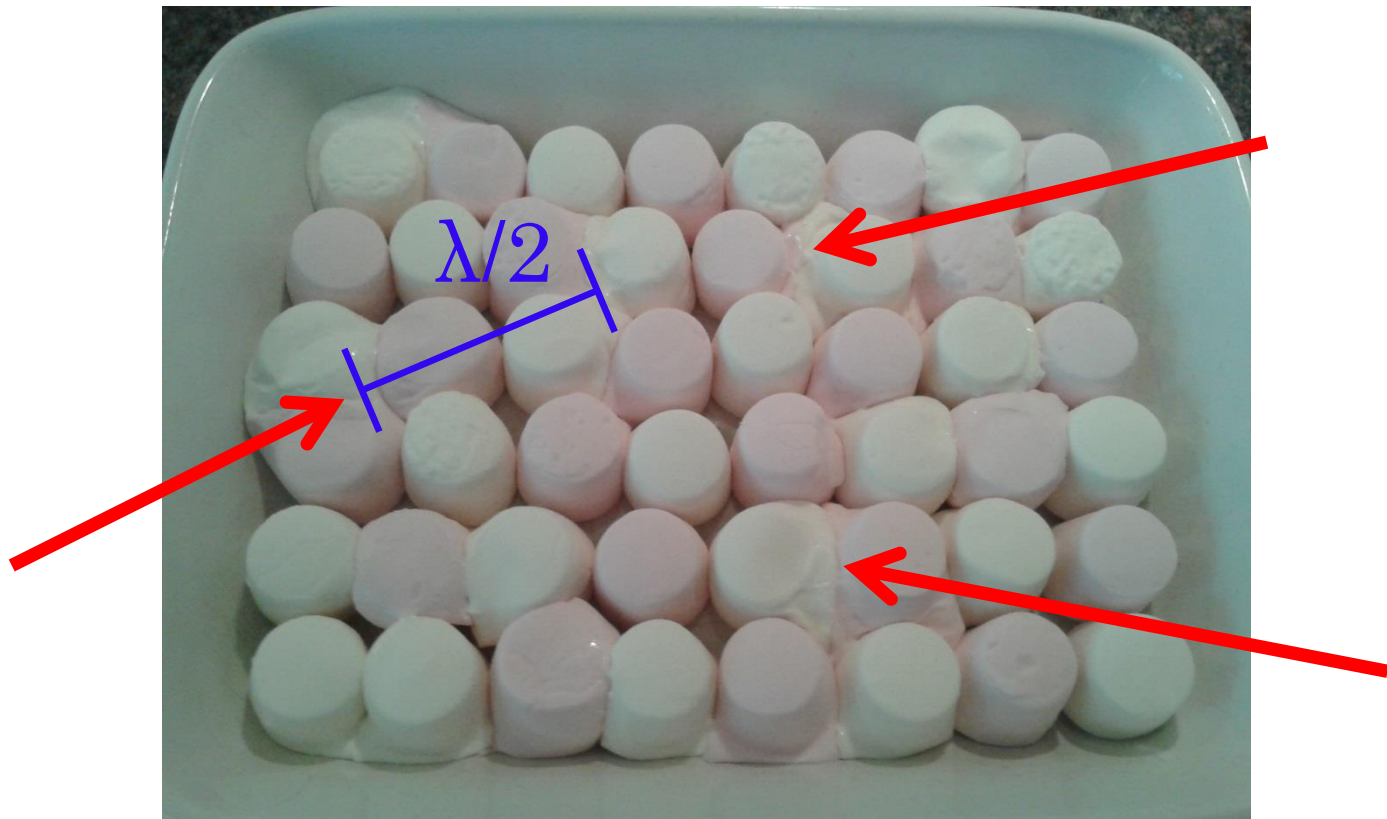


- Step 2: Place dish in a Microwave Oven and heat.



MARSHMALLOW EXPERIMENT : METHOD

- Step 3: Remove dish and measure.



MARSHMALLOW EXPERIMENT : RESULTS

- $\lambda/2 \approx 6 \text{ cm}$
- $f = 2450 \text{ MHz}$
- $v = f \cdot \lambda$
 - $v \approx 2.45 \times 10^9 \times 0.12$
- $v \approx 2.94 \cdot 10^8 \text{ m} \cdot \text{s}^{-1}$



MARSHMALLOW EXPERIMENT : FLUMPS

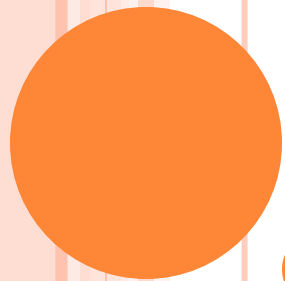
- Repeated experiment with Flumps
- Flumps did not display clear pattern



- Flumps mysteriously disappeared

SUMMARY

- Don't try this at home.



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THANK YOU FOR LISTENING

We will now take your questions.