

# Microwave Ovens

Turn off all electronic devices

## Observations About Microwaves

- Microwave ovens heat food internally
- They often cook foods unevenly
- They don't defrost foods well
- You shouldn't put metal inside them?!
- Do they make food radioactive or toxic?

## 4 Questions about Microwave Ovens

1. Why do microwaves cook food?
2. How does metal respond to microwaves?
3. Why do microwave ovens tend to cook unevenly?
4. How does the oven create its microwaves?

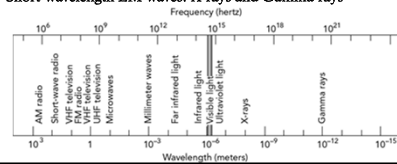
## Question 1

Q: Why do microwaves cook food?

A: Water in the food responds to their electric fields.

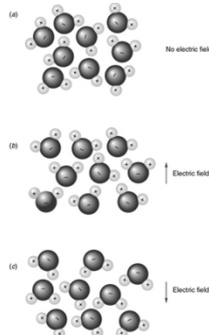
Microwaves are electromagnetic waves, w/fluctuating electric fields

- ◊ Long-wavelength EM waves: Radio and Microwave
- ◊ Medium-wavelength EM waves: IR, Visible, and UV light
- ◊ Short-wavelength EM waves: X-rays and Gamma-rays



## Water Molecules

- ◊ Water molecules are unusually polar
- ◊ An electric field tends to orient water molecules
- ◊ A fluctuating electric field causes water molecules to fluctuate in orientation



## Microwave Heating

- Microwaves have rapidly alternating electric fields
- Water molecules orient back and forth with those electric fields
- Liquid water heats due to molecular "friction"
- Ice doesn't heat well because its molecules are not free to rotate
- Steam doesn't heat due to a lack of molecular "friction"
- Food's liquid water content heats the food (in most cases)

### Question 2

Q: How does metal respond to microwaves?

A: Currents flow back and forth in the metal.

Non-conductors polarize in the microwaves

Conductors carry currents in the microwaves

- ◊ Good, thick conductors reflect microwaves
- ◊ Poor or thin conductors experience resistive heating
- ◊ Sharp conductors initiate discharges into the air

### Question 3

Q: Why do microwave ovens tend to cook unevenly?

A: Interference produces nonuniform electric fields.

Interference is when the fields add or cancel

- ◊ Adding fields are constructive interference
- ◊ Canceling fields are destructive interference

Reflections in a microwave oven lead to interference effects

Most ovens either "stir" the waves or move the food

### Question 4

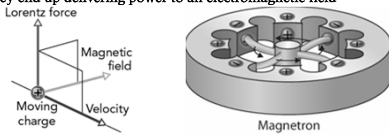
Q: How does the oven create its microwaves?

A: A magnetron tube radiates microwaves.

Magnetrons are vacuum tubes that were invented in WWII

Electrons travel through empty space in a vacuum tube

- ◊ Those electrons obtaining power from a strong electric field
- ◊ Their paths are bent by a strong magnetic field and the Lorentz force
- ◊ They end up delivering power to an electromagnetic field



### Generating Microwaves

In a magnetron tube:

- ◊ A large negative voltage is applied to a hot central filament
- ◊ Electrons stream outward from that filament toward higher voltage
- ◊ Tank circuits surrounding the filament produce oscillating voltages
- ◊ Electrons aim at the higher voltages, but are bent by the Lorentz force
- ◊ Electrons hit lower voltages instead, adding energy to the tank oscillations
- ◊ Most of the electric power becomes microwave power

A wire loop extracts energy from the magnetron's tank circuits

A short 1/4-wave antenna emits the microwaves into the oven

### Summary about Microwave Ovens

They cook food because of its water content

Polar water molecules heat in microwave fields

Thin or sharp metals overheat or spark

The microwaves are produced by a magnetrons