

# Microwave Ovens

## Introductory Question

- If you put a CD in a microwave oven, it will
  - A. do nothing.
  - B. burn up the microwave oven.
  - C. burn up the CD.

## Observations About Microwaves

- Microwave ovens cook food from inside out
- 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?

## 3 Questions about Microwave Ovens

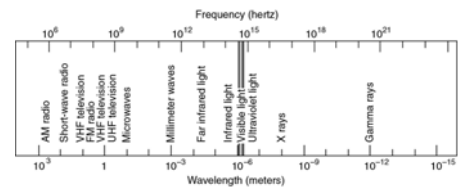
- Why do microwaves cook food?
- How does metal respond to microwaves?
- How does the oven create its microwaves?

## Question 1

- Why do microwaves cook food?

## Electromagnetic Spectrum

- Microwaves are a class of electromagnetic waves
  - Long-wavelength EM waves: Radio & Microwave
  - Medium-wavelength: IR, Visible, UV light
  - Short-wavelength: X-rays & Gamma-rays



### Clicker Question

- A US cell phone can communicate using waves at 850 MHz (35 cm wavelength). How long should a resonant cell phone antenna be?
- A. 35 cm (14 inches)
  - B. 17.5 cm (7 inches)
  - C. 8.7 cm (3.5 inches)
  - D. 4.4 cm (1.7 inches)

### Clicker Question

- Wireless internet (Wi-Fi) communication is done at 2.54 GHz (11.8 cm wavelength). How long is a resonant Wi-Fi antenna?
- A. 11.8 cm (4.6 inches)
  - B. 5.9 cm (2.3 inches)
  - C. 2.9 cm (1.2 inches)
  - D. 1.5 cm (0.6 inches)

### Clicker Question

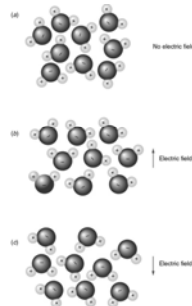
- As the communication wave from a Wi-Fi transmitter passes an electric charge, what happens to that electric charge?
- A. It accelerates away from the transmitter
  - B. It accelerates toward the transmitter
  - C. It shakes back and forth
  - D. Nothing

### Clicker Question

- As the communication wave from a Wi-Fi transmitter passes an electric dipole (a + charge attached to an equal – charge), what happens to that dipole?
- A. It shakes back and forth
  - B. It twists back and forth
  - C. It accelerates away from the transmitter
  - D. Nothing

### Water Molecules

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



### Microwave Heating

- Microwaves have alternating electric fields
- Water molecules orient back and forth
- Liquid water heats due to molecular “friction”
- Ice doesn’t heat due to orientational stiffness
- Steam doesn’t heat due to lack of “friction”
- Food’s liquid water content heats the food

### Clicker Question

- Popcorn kernels feel solid and dry, so how can those kernels pop in the microwave oven?
- A. Microwaves heat solid materials quite well
- B. Microwaves heat dry materials quite well
- C. Corn kernels contain some trapped liquid water

### Question 2

- How does metal respond to microwaves?

### Effects of Microwaves

- Non-Conductors: Polarization
  - Mobile polar molecules orient and heat
  - Immobile polar molecules do nothing much
  - Non-polar molecules do nothing much
- Conductors: Current flow
  - Good, thick conductors reflect microwaves
  - Poor conductors experience resistive heating
  - Thin conductors experience resistive heating
  - Sharp conductors initiate discharges in the air

### Clicker Question

- A microwave oven's cooking chamber has 6 sides. What are those sides made of?
- A. 5 are metal and 1 is plastic mesh
- B. 5 are plastic and 1 is plastic mesh
- C. 5 are metal and 1 is metal mesh
- D. 5 are plastic and 1 is metal mesh

### Interference

- Identical waves that overlap can interfere
- Interference is when the fields add or cancel
  - Adding fields are constructive interference
  - Canceling fields are destructive interference
- Reflections lead to interference in a microwave
- Interference causes uneven cooking
- Most ovens "stir" the waves or move the food

### Introductory Question (revisited)

- If you put a CD in a microwave oven, it will
- A. do nothing.
- B. burn up the microwave oven.
- C. burn up the CD.

### Clicker Question

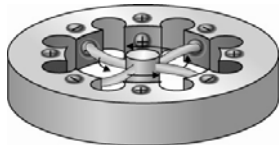
- If you put an ordinary wooden pencil in a microwave oven and turn the oven on, what will happen?
- A. The pencil will emit sparks
- B. The pencil will get warm but nothing else
- C. The pencil will burn up but nothing else
- D. The pencil will burn and emit plasma balls

### Question 3

- How does the oven create its microwaves?

### Generating Microwaves

- Magnetron tube has tank circuits in it
- Streams of electrons amplify tank oscillations
- A loop of wire extracts energy from tanks
- A short  $\frac{1}{4}$ -wave antenna emits the microwaves



Magnetron

### 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