Electromagnetic Waves

Chp. 12 Section 1

What are electromagnetic waves?

Electromagnetic Waves

- Section 1 slides 3- 31
- What are electromagnetic waves?
- Section 2 slides 32-59
- The Electromagnetic Spectrum
- Section 3 slides 60-69
- Radio Communication

What are electromagnetic waves?

- How electromagnetic waves are formed
- How electric charges produce electromagnetic waves
- Properties of electromagnetic waves

Electromagnetic Waves…

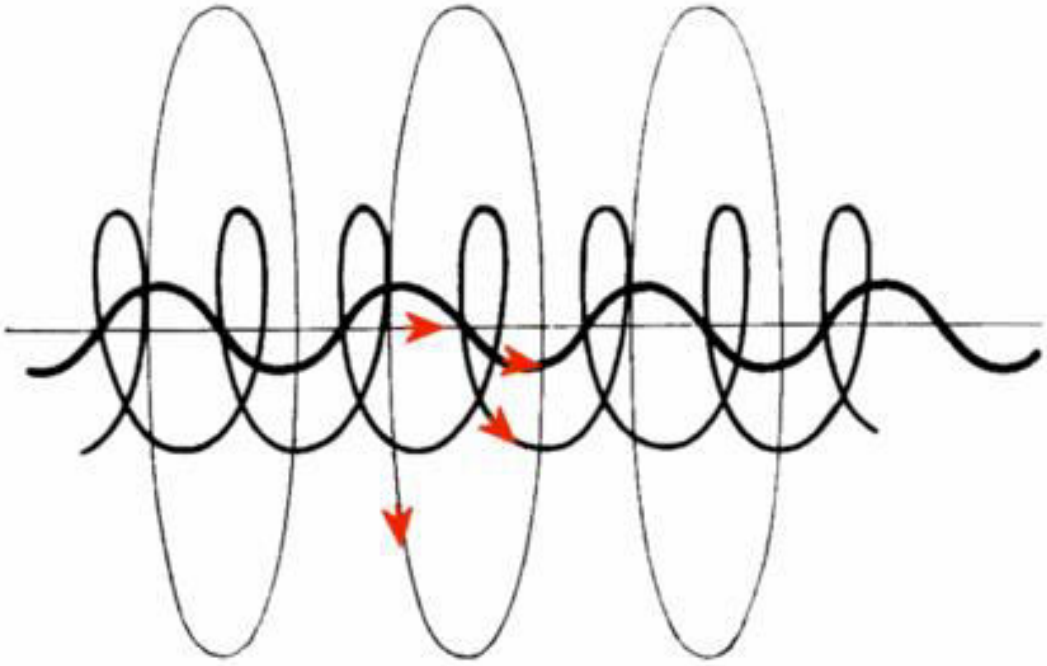
- Do not need matter to transfer energy.

Electromagnetic Waves…

- Do not need matter to transfer energy.
- Are made by vibrating electric charges and can travel through space by transferring energy between vibrating electric and magnetic fields.

How do moving charges create magnetic fields?

- Any moving electric charge is surrounded by an electric field and a magnetic field.



What happens when electric and magnetic fields change?

- A changing magnetic field creates a changing electric field.

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- A changing magnetic field creates a changing electric field.
- One example of this is a transformer which transfers electric energy from one circuit to another circuit.
  - In the main coil changing electric current produces a changing magnetic field
  - Which then creates a changing electric field in another coil producing an electric current
  - The reverse is also true.

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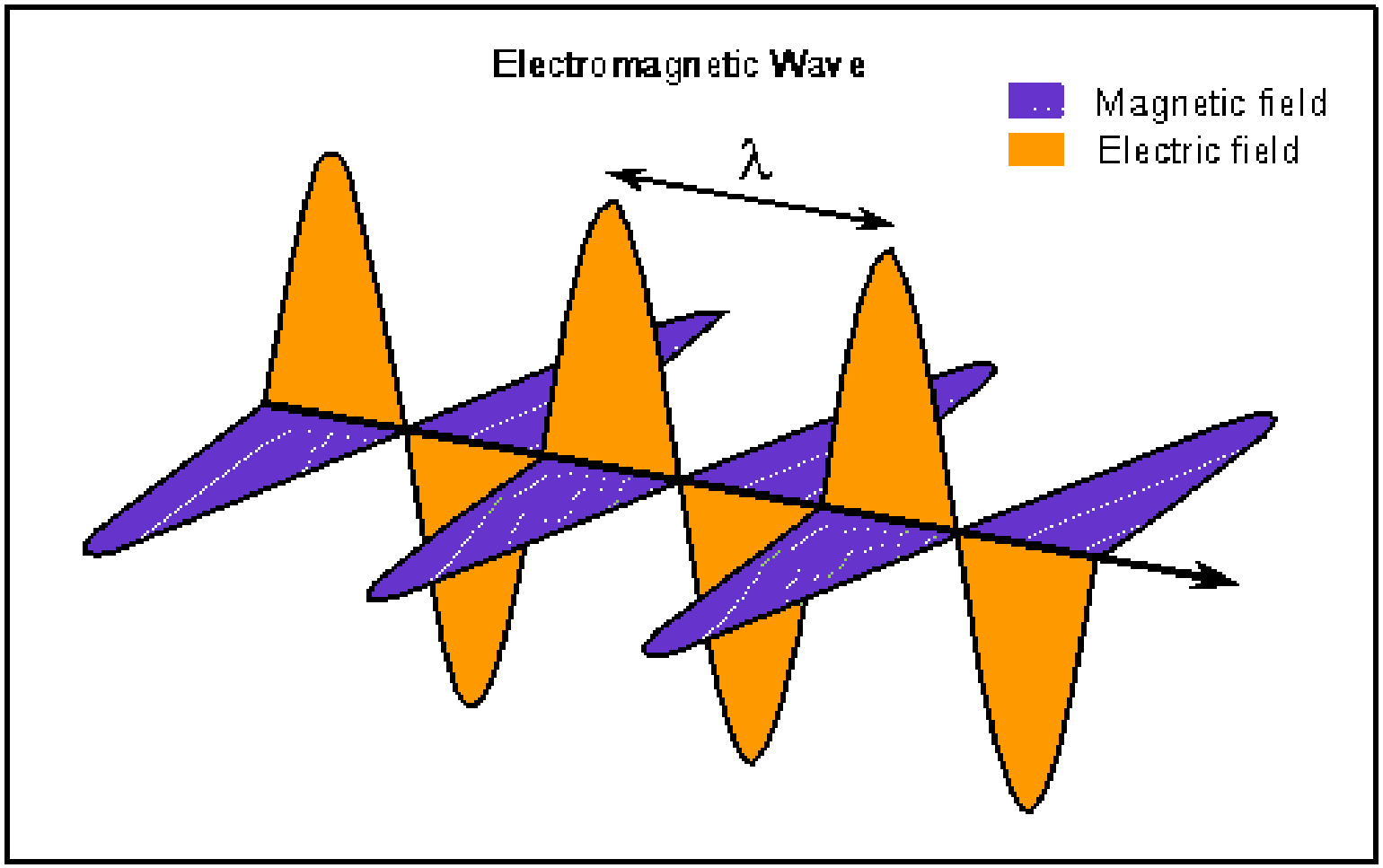
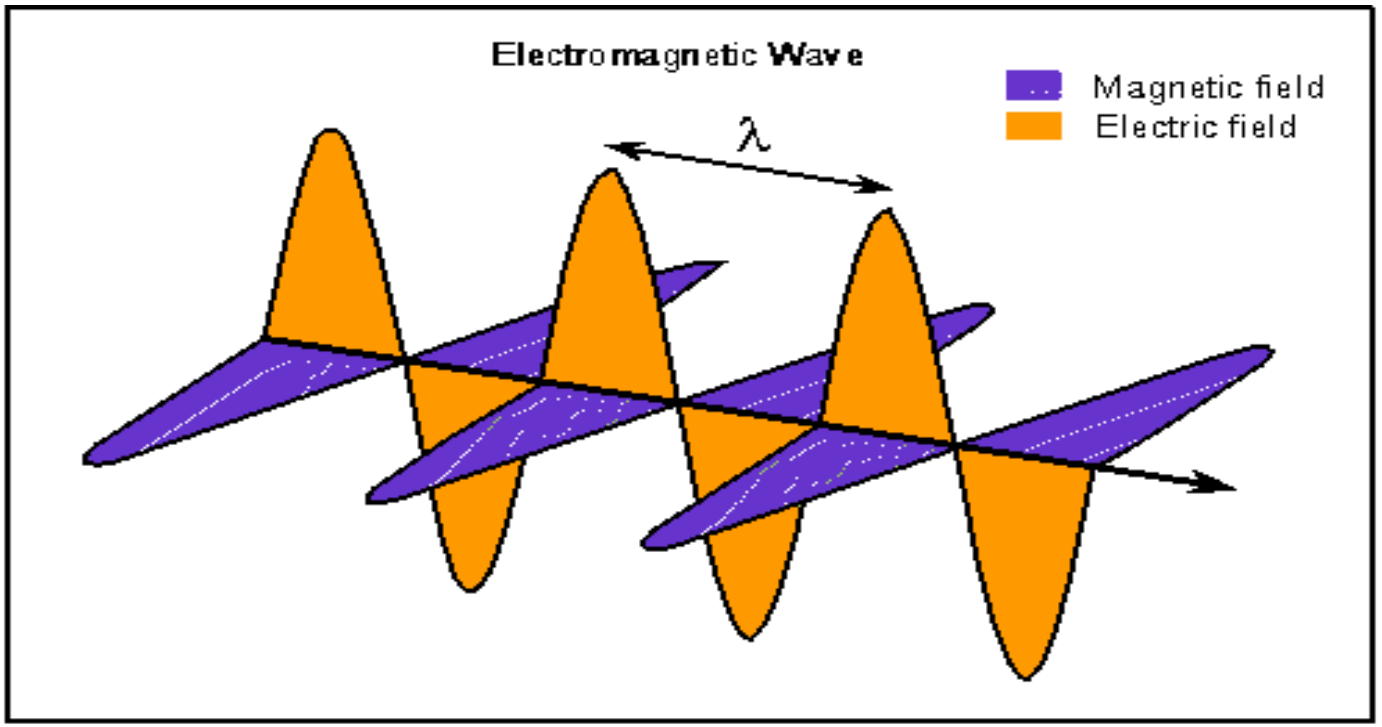


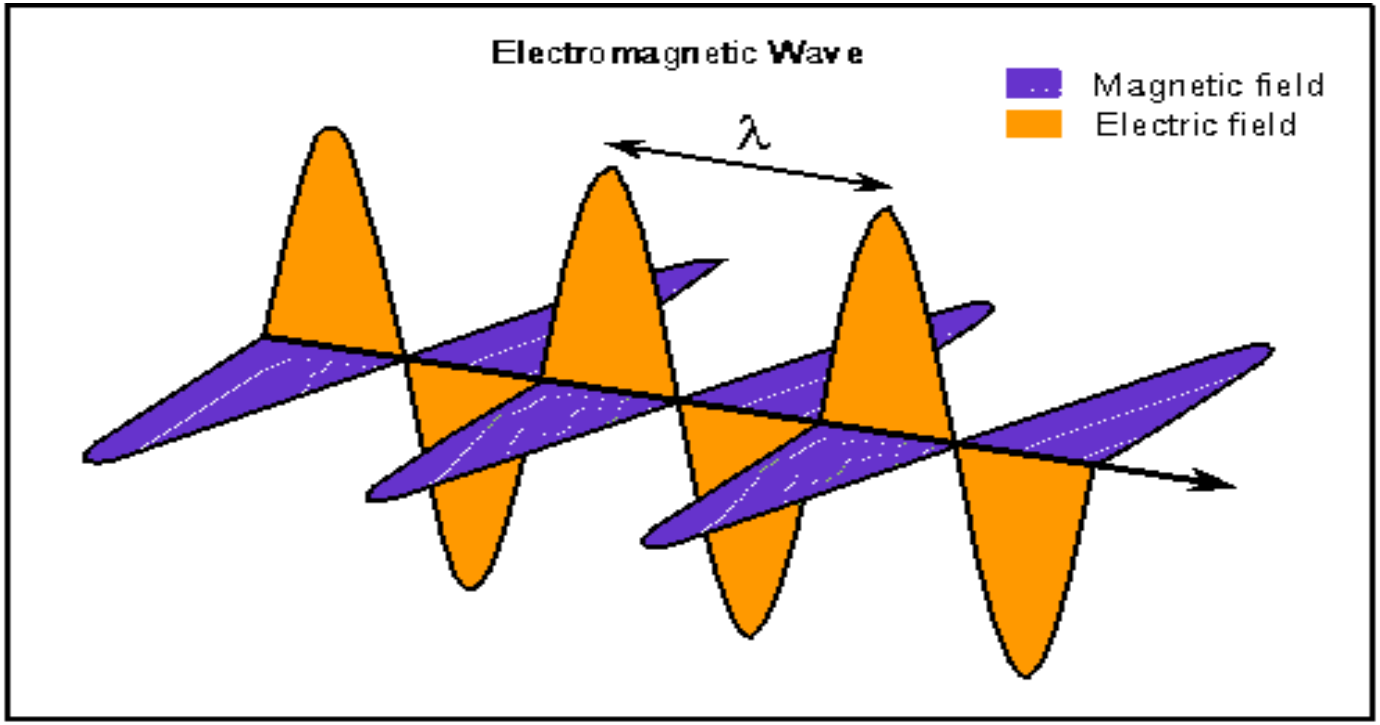
Making Electromagnetic Waves

- When an electric charge vibrates, the electric field around it changes creating a changing magnetic field.



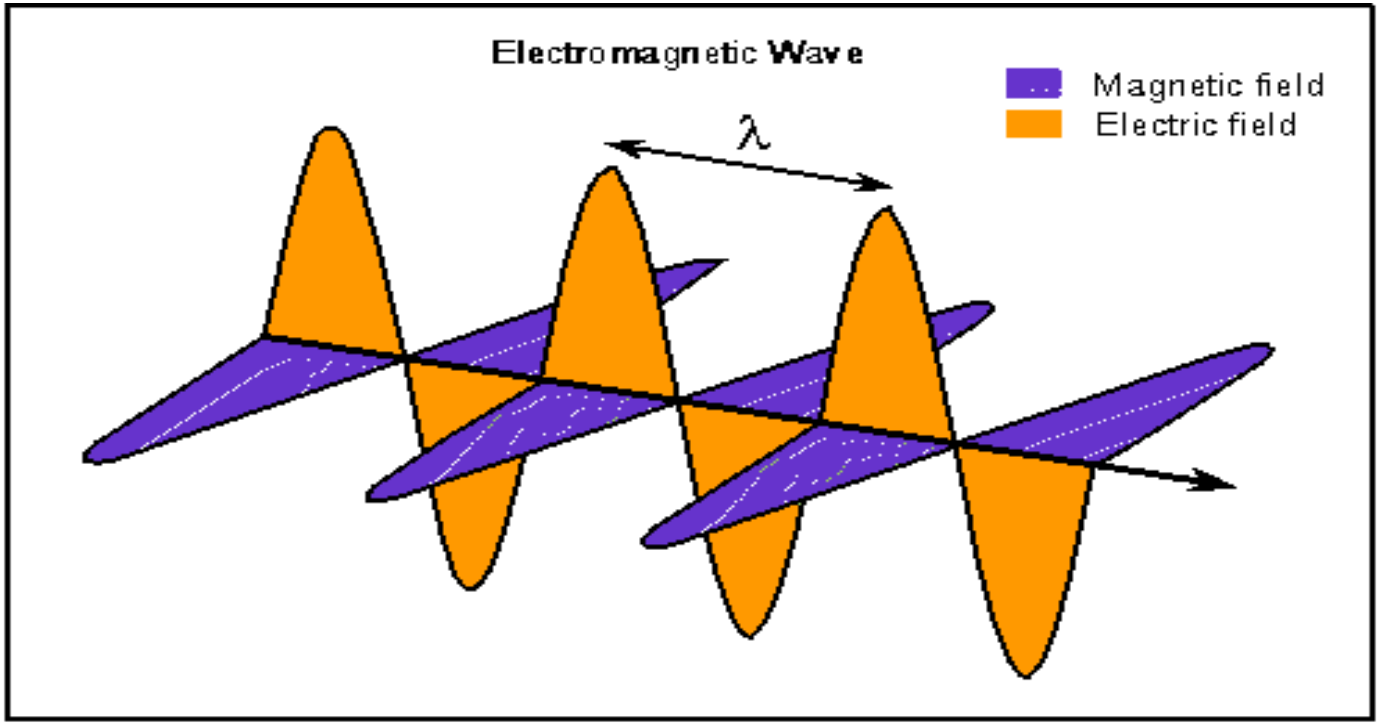
Making Electromagnetic Waves

- The magnetic and electric fields create each other again and again.



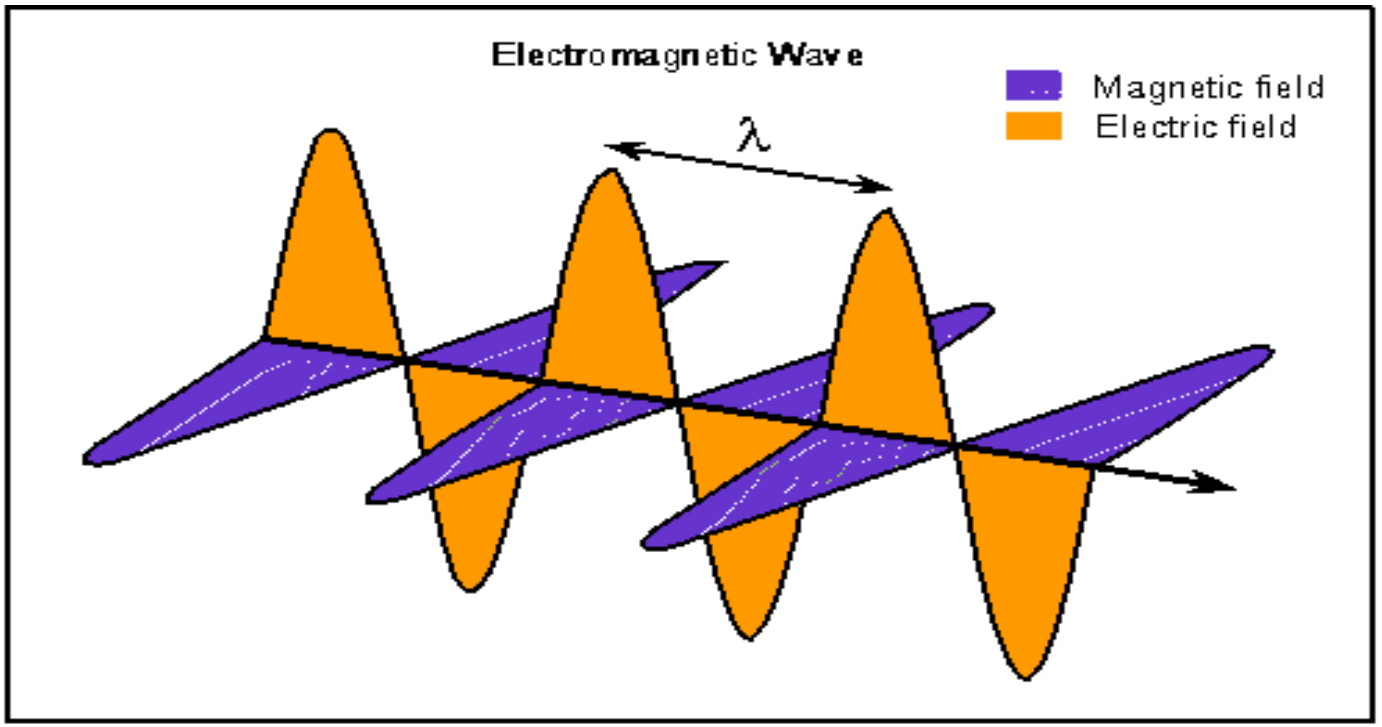
Making Electromagnetic Waves

- An EM wave travels in all directions. The figure only shows a wave traveling in one direction.



Making Electromagnetic Waves

- The electric and magnetic fields vibrate at right angles to the direction the wave travels so it is a transverse wave.



Properties of EM Waves

- All matter contains charged particles that are always moving; therefore, all objects emit EM waves.

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- All matter contains charged particles that are always moving; therefore, all objects emit EM waves.
- The wavelengths become shorter as the temperature of the material increases.
- EM waves carry *radiant energy.*

What is the speed of EM waves?

- All EM waves travel 300,000 km/sec in space. (speed of light- nature's limit!)

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- All EM waves travel 300,000 km/sec in space. (speed of light- nature's limit!)
- EM waves usually travel slowest in solids and fastest in gases.

Material	Speed (km/s)
Vacuum	300,000
Air	<300,000
Water	226,000
Glass	200,000
Diamond	124,000

What is the wavelength & frequency of an EM wave?

- Wavelength= distance from crest to crest.

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What is the wavelength & frequency of an EM wave?

- Wavelength= distance from crest to crest.
- Frequency= number of wavelengths that pass a given point in 1 s.
- As frequency increases, wavelength becomes smaller.

Can a wave be a particle?

- In 1887, Heinrich Hertz discovered that shining light on a metal caused electrons to be ejected.

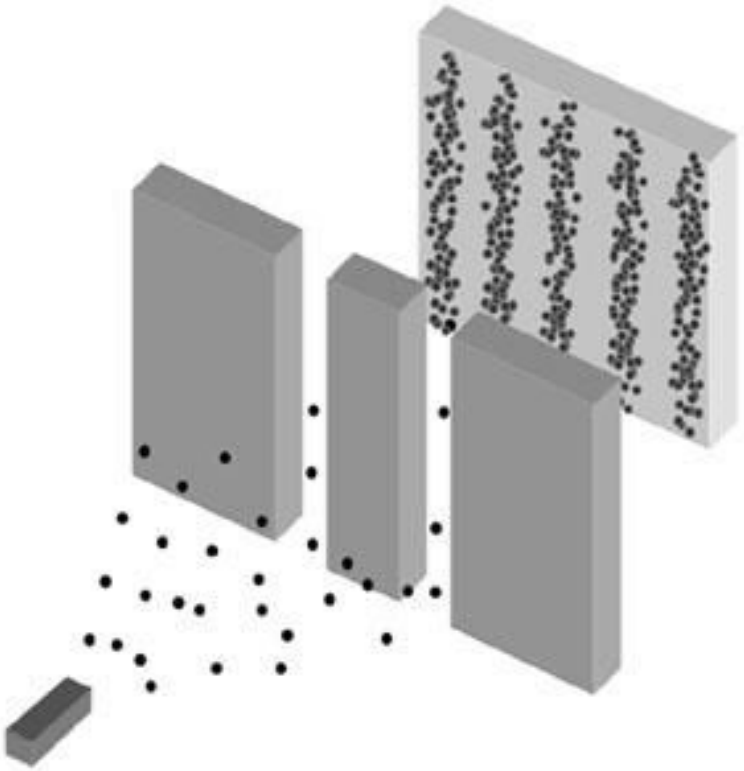
Can a wave be a particle?

- In 1887, Heinrich Hertz discovered that shining light on a metal caused electrons to be ejected.
- Whether or not electrons were ejected depended upon ***frequency*** not the amplitude of the light! Remember energy depends on amplitude.

Can a wave be a particle?

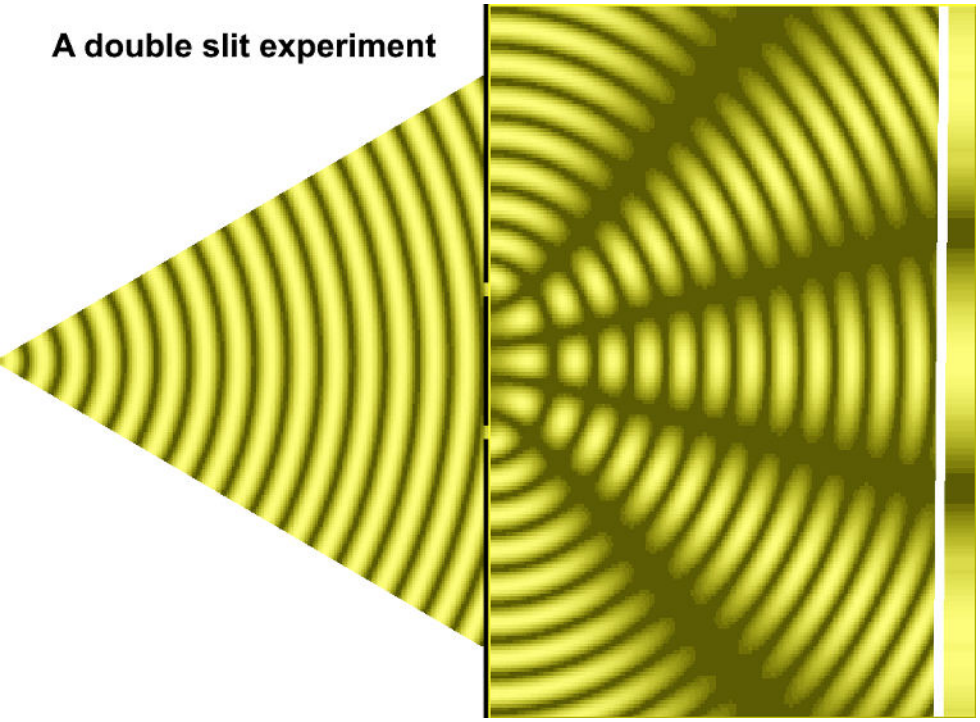
- Years later, Albert Einstein explained Hertz's discovery: EM waves can behave as a particle called a ***photon*** whose energy depends on the frequency of the waves.

Can a particle be a wave?



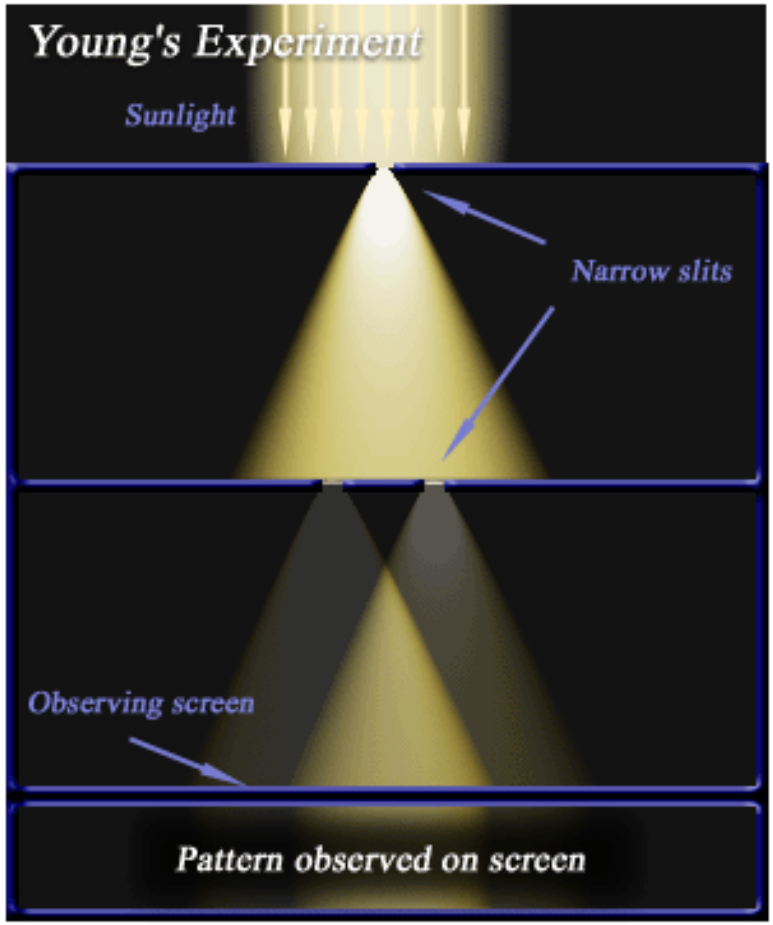
- Electrons fired at two slits actually form an interference pattern similar to patterns made by waves

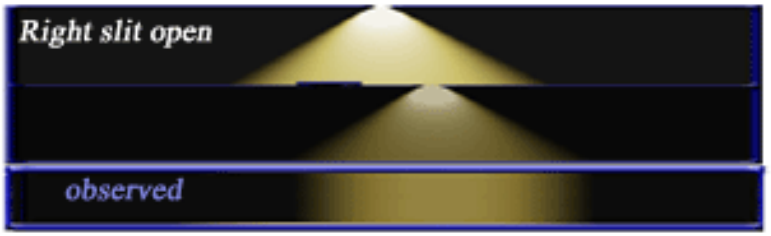
Can a particle be a wave?

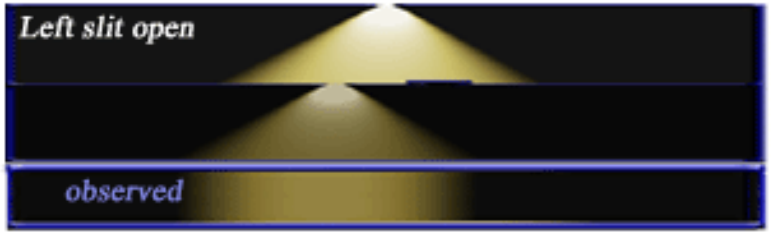


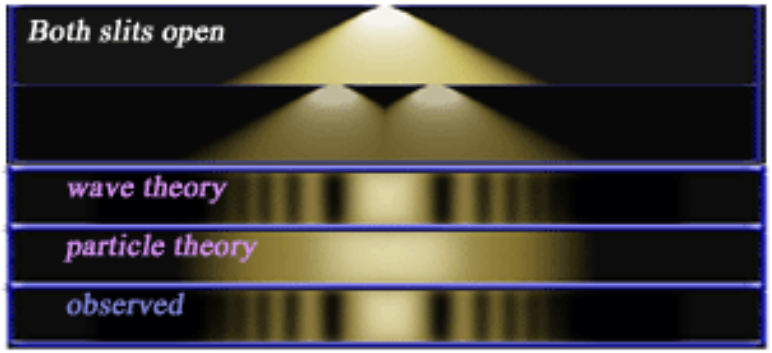
- Electrons fired at two slits actually form an interference pattern similar to patterns made by waves

What did Young's experiment show?









Electromagnetic Waves

How they are formed	Kind of wave	Sometimes behave as

Electromagnetic Waves

How they are formed

Waves made by vibrating electric charges that can travel through space where there is no matter

Kind of wave

Transverse with alternating electric and magnetic fields

Sometimes behave as

Waves or as

Particles (photons)

Electromagnetic Waves

Section 2 The Electromagnetic Spectrum

The whole range of EM wave…

- Frequencies is called the ***electromagnetic spectrum.***

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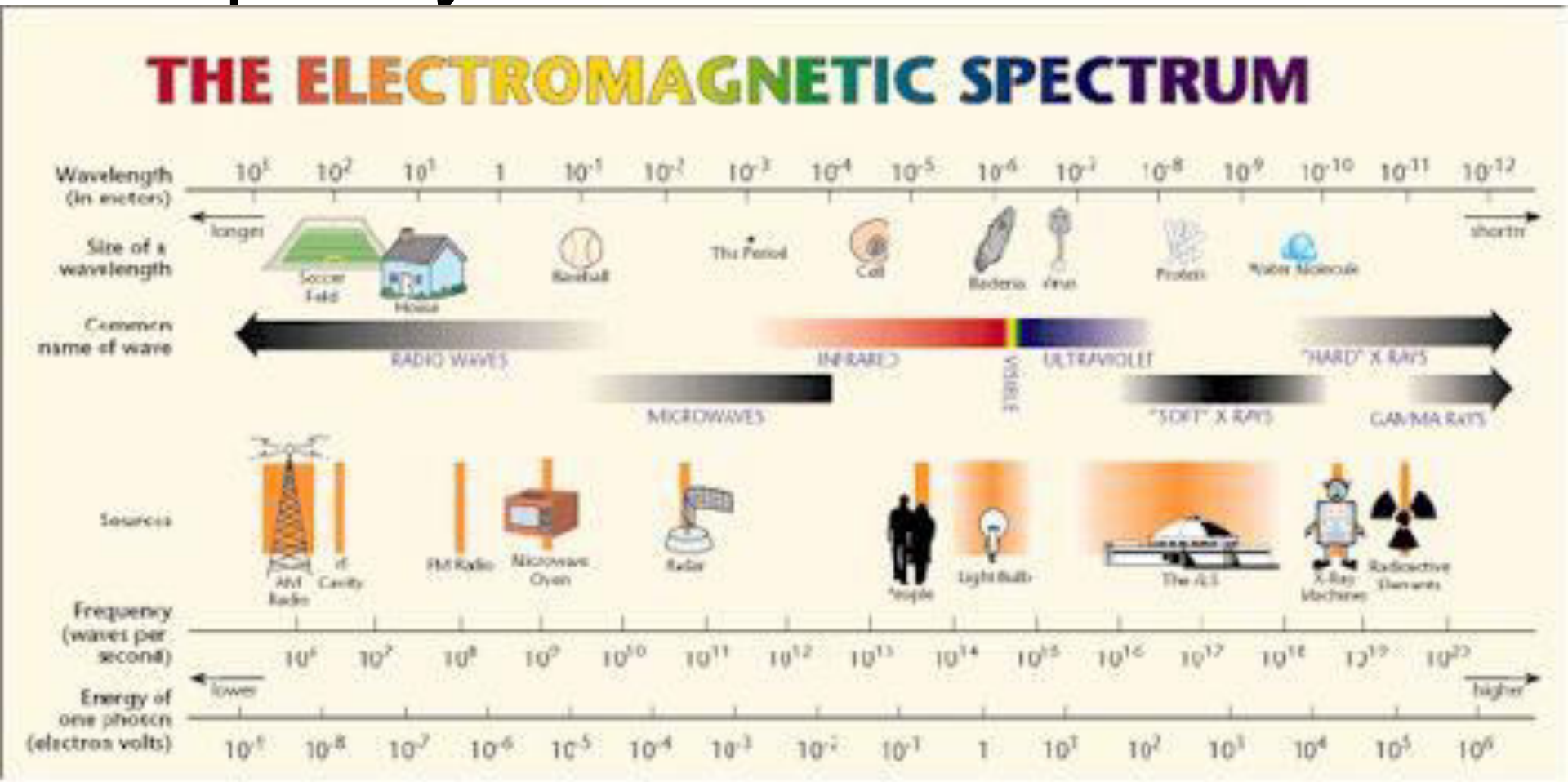
- Different parts interact with matter in different ways.

The whole range of EM wave…

- Frequencies is called the ***electromagnetic spectrum.***
- Different parts interact with matter in different ways.
- The ones humans can see are called visible light, a small part of the whole spectrum.

As wavelength decreases, frequency increases…



Devices detect other frequencies:

- Antennae of a radio detects radio waves.

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- Antennae of a radio detects radio waves.
- ***Radio waves*** are low frequency EM waves with wavelengths longer than 1mm.
- These waves must be turned into sound waves by a radio before you can hear them.

What are microwaves?

- ***Microwaves*** are radio waves with wavelengths less than 30 cm and higher frequency & shorter wavelength.

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- Cell phones and satellites use microwaves between 1 cm & 20 cm for communication.

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- ***Microwaves*** are radio waves with wavelengths less than 30 cm and higher frequency & shorter wavelength.
- Cell phones and satellites use microwaves between 1 cm & 20 cm for communication.
- In microwave ovens, a vibrating electric field causes water molecules to rotate billions of times per second causing friction, creating TE which heats the food.

How does radar work?

- **Ra**dio **D**etecting **A**nd **R**anging or radar is used to find position and speed of objects by bouncing radio waves off the object.

What is magnetic resonance imaging?

- MRI was developed in the 1980s to use radio waves to diagnose illnesses with a strong magnet and a radio wave emitter and a receiver. Protons in H atoms of the body act like magnets lining up with the field. This releases energy which the receiver detects and creates a map of the body's tissues.

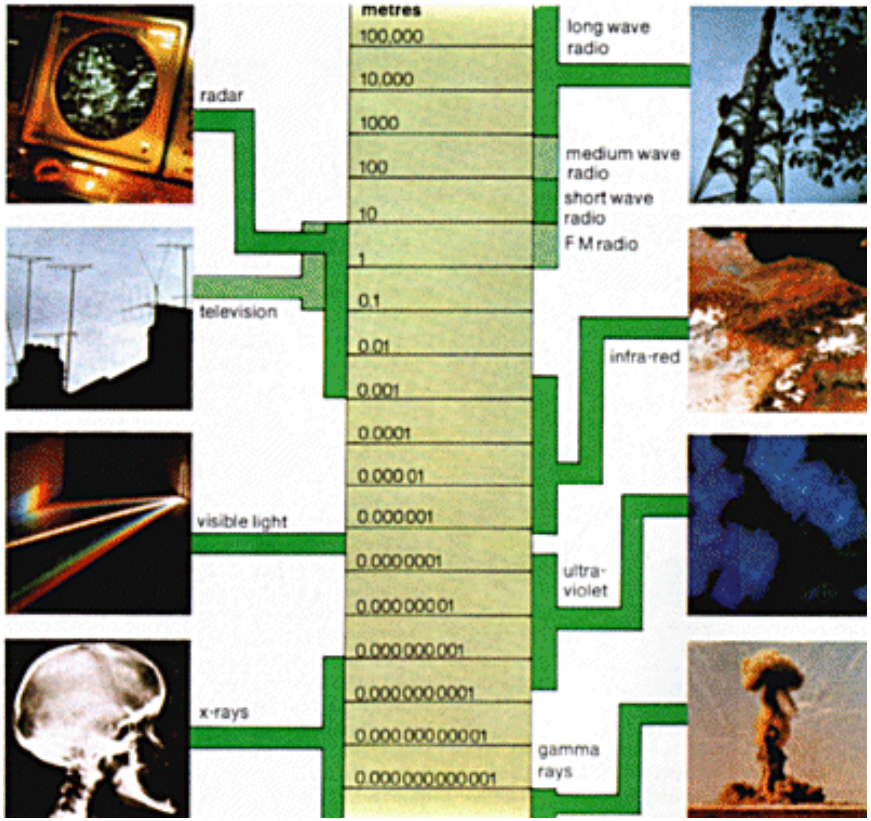
Infrared Waves

- EM with wavelengths between 1mm & 750 billionths of a meter.
- Used daily in remote controls, to read CD-ROMs
- Every objects gives off infrared waves; hotter objects give off more than cooler ones. Satellites can ID types of plants growing in a region with infrared detectors

Visible Light

- Range of EM humans can see from 750 billionths to 00 billionths of a meter.
- You see different wavelengths as colors.
  - Blue has shortest
  - Red is the longest
  - Light looks white if all colors are present

A range of frequencies



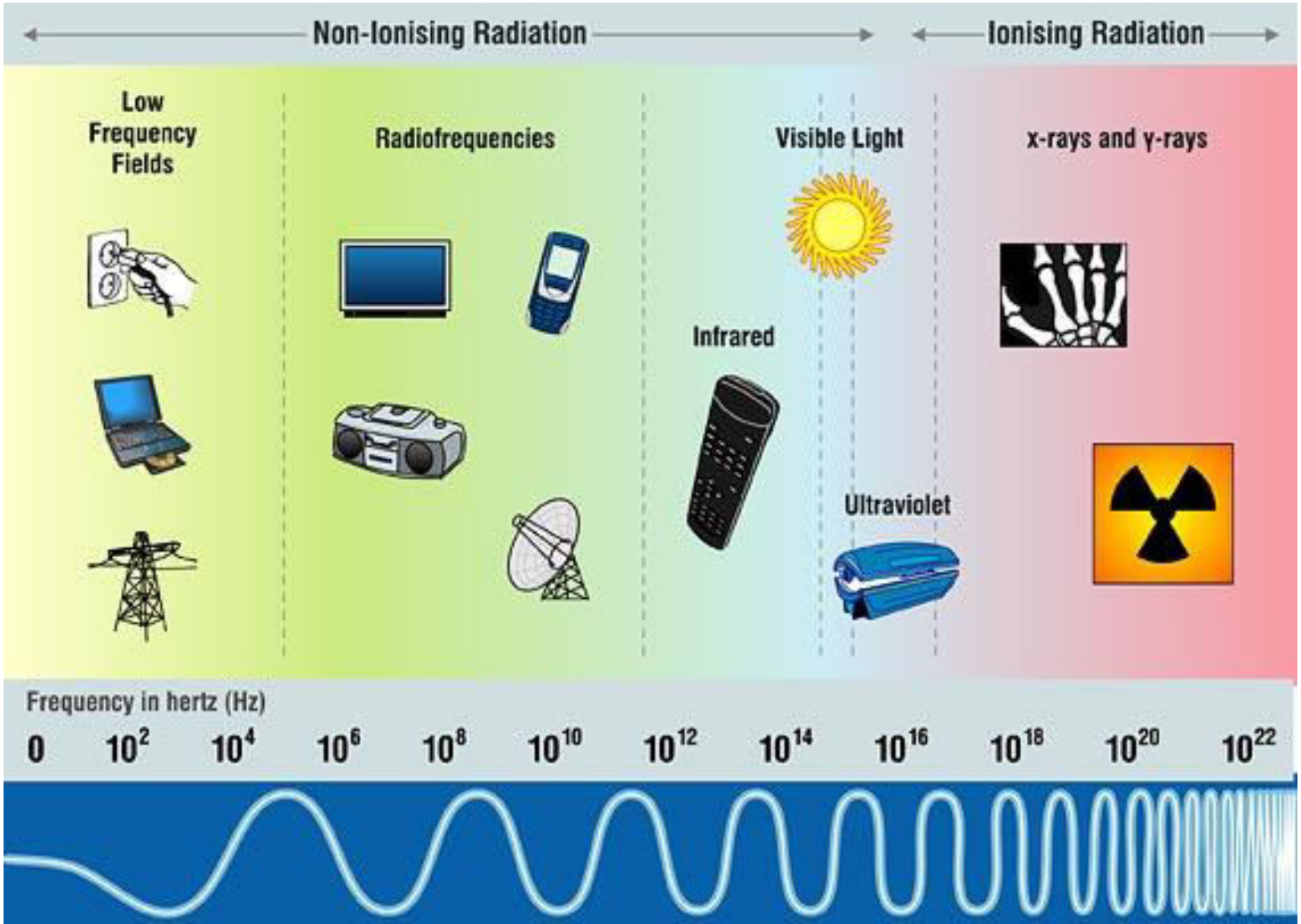
In order of increasing frequency and decreasing wavelength, the EM spectrum consists of: very long wave radio, used for communication with submarines; long, medium and short wave radio (used for AM broadcasting); FM radio, television and radar; infra-red (heat) radiation, which is recorded in the Earth photographs taken by survey satellites; visible light; ultraviolet light, which, while invisible, stimulates fluorescence in some materials; x rays & gamma rays used in medicine and released in radioactive decay

Ultraviolet Waves

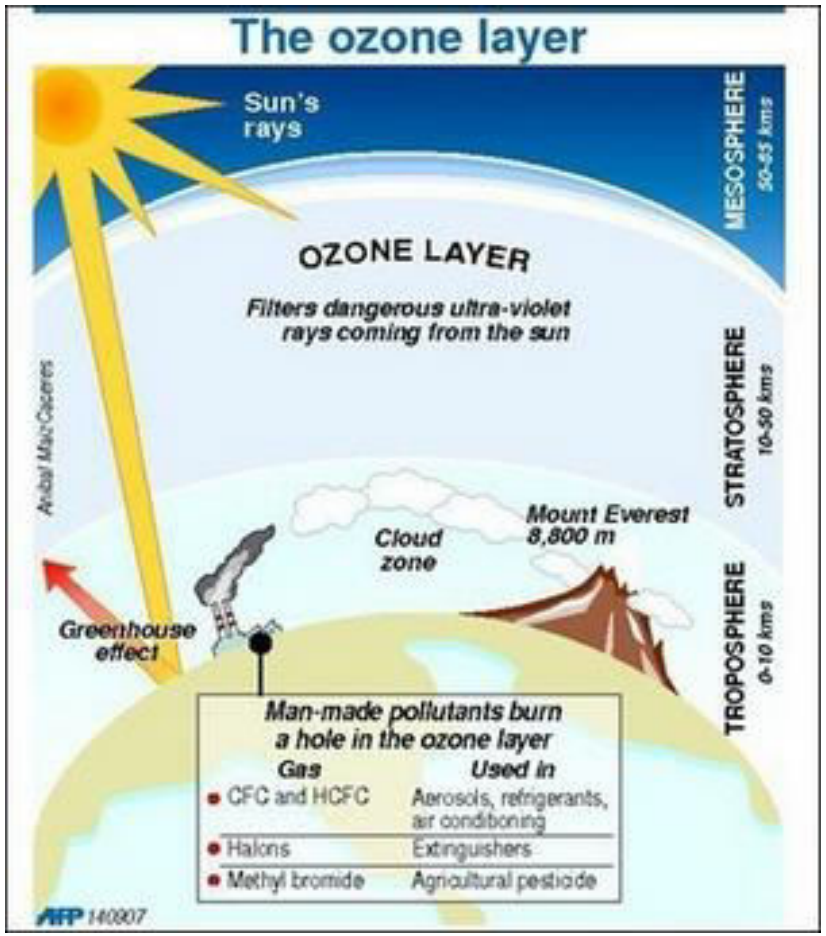
- EM waves with wavelengths from about 400 billionths to 10 billionths of a meter.
- Have enough energy to enter skin cells
  - Longer wavelengths – UVA
  - Shorter wavelengths – UVB rays
  - Both can cause skin cancer

Can UV radiation be useful?

- Helps body make vitamin D for healthy bones and teeth
- Used to sterilize medical supplies & equip
- Detectives use fluorescent powder (absorbs UV & glows) to find fingerprints


Non-Ionising Radiation
Ionising Radiation
Low Frequency Fields
Radiofrequencies
Visible Light
x-rays and γ-rays
Infrared
Ultraviolet
Frequency in hertz (Hz)
0
10^2
10^4
10^6
10^8
10^10
10^12
10^14
10^16
10^18
10^20
10^22

What is the ozone layer?



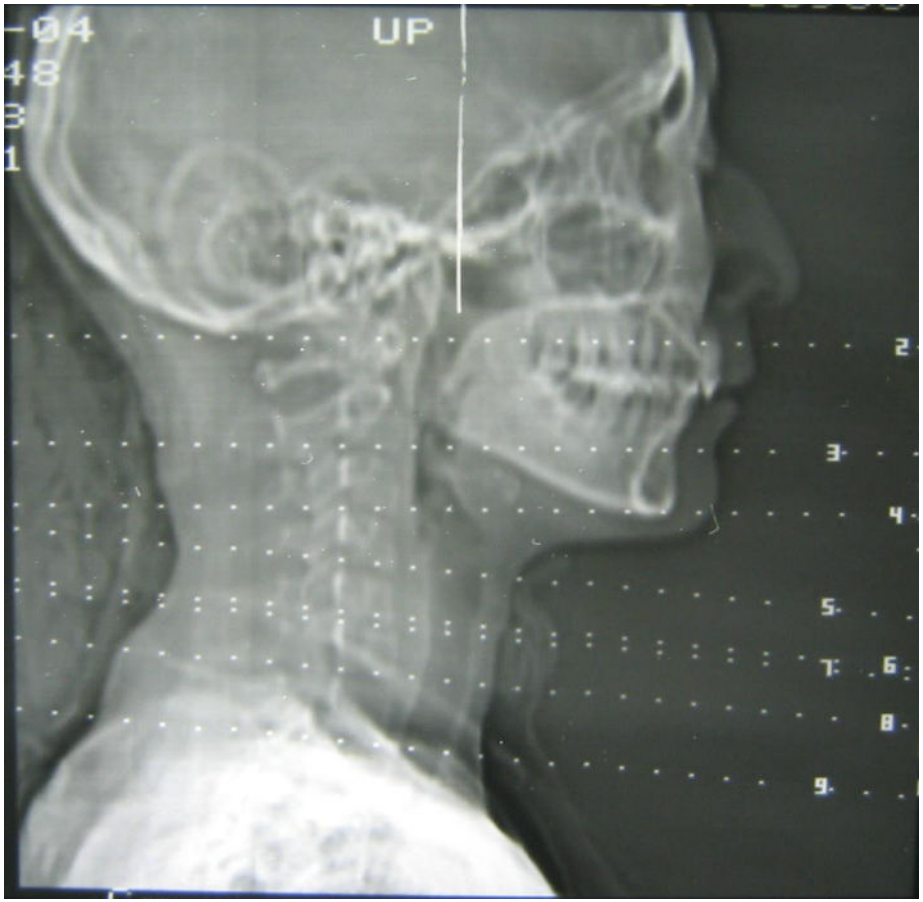
- 20-50 km above earth
- Molecule of 3 O atoms
- Absorbs Sun's harmful UV rays
- Ozone layer decreasing due to CFCs in AC, refrigerators, & cleaning fluids

What could happen to humans…

- And other life on Earth if the ozone layer is destroyed?

X Rays and Gamma Rays

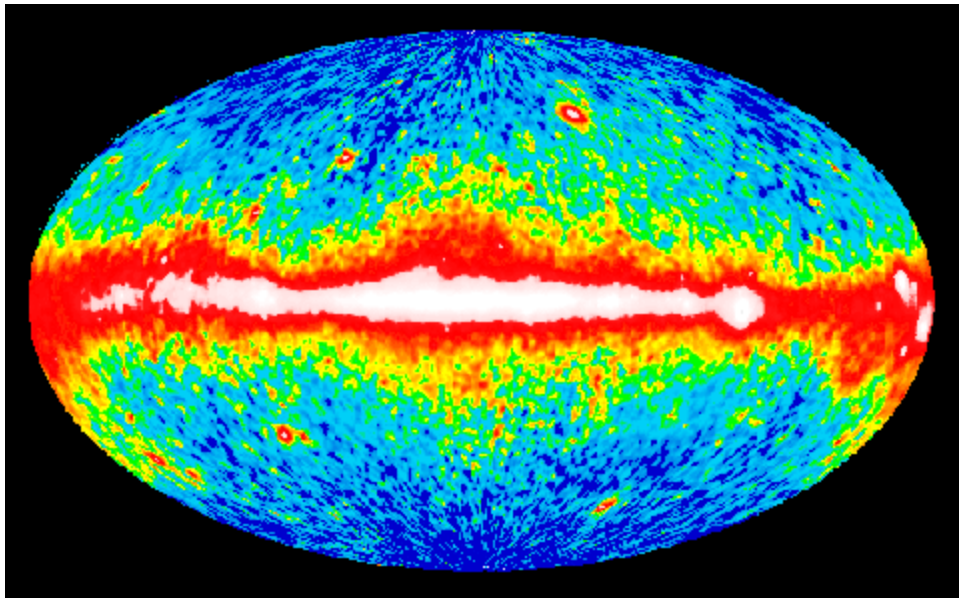
- EM waves with shortest wavelength & highest frequency
- High Energy- go through skin & muscle
- High level exposure causes cancer



X Rays and Gamma Rays

- EM with wavelengths shorter than 10 trillionths of a meter.
- Highest energy, can travel through several centimeters of lead.
- Both can be used in radiation therapy to kill diseased cells.

- The composite image shows the all sky gamma ray background.

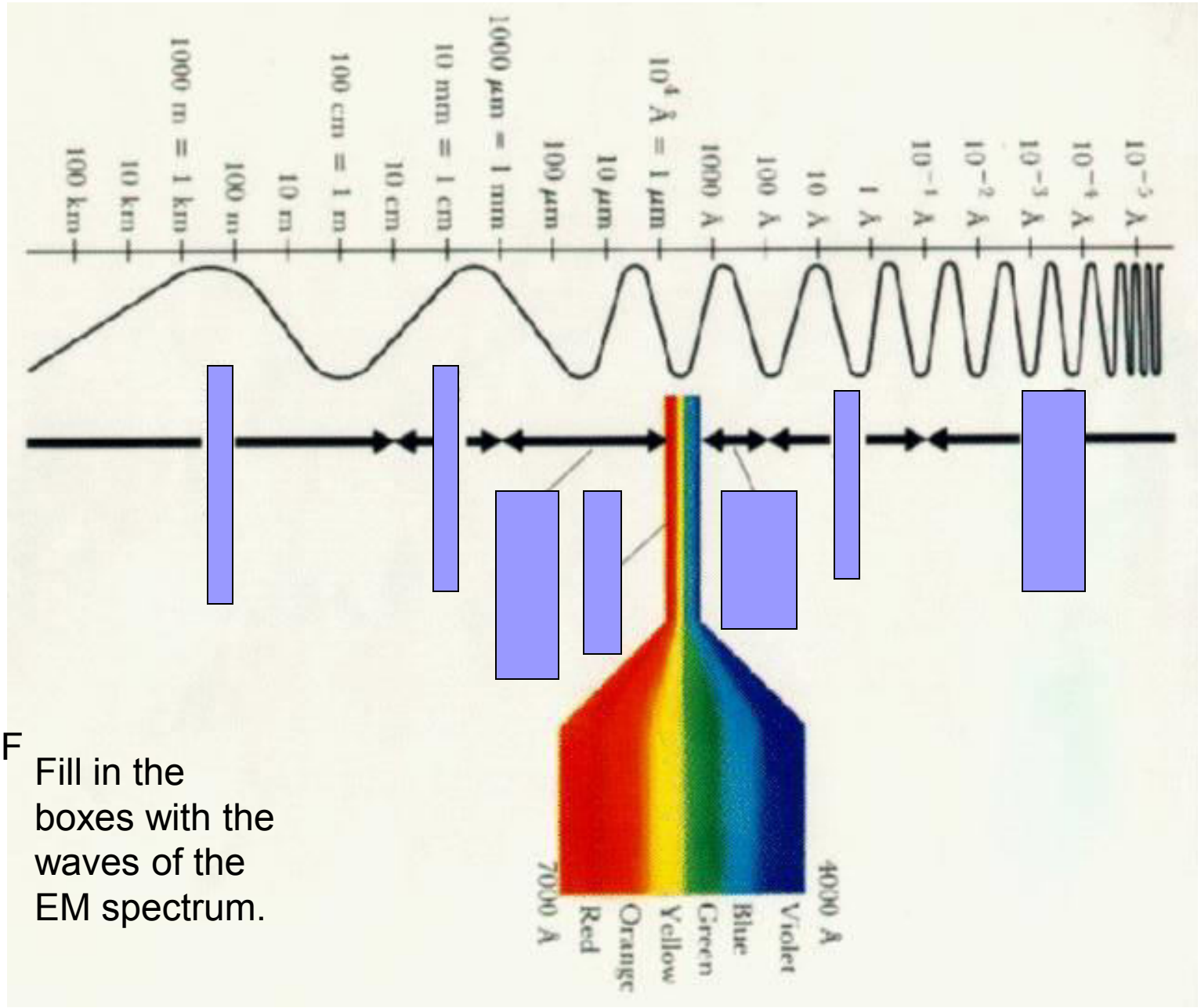


Identify which statement is not true:

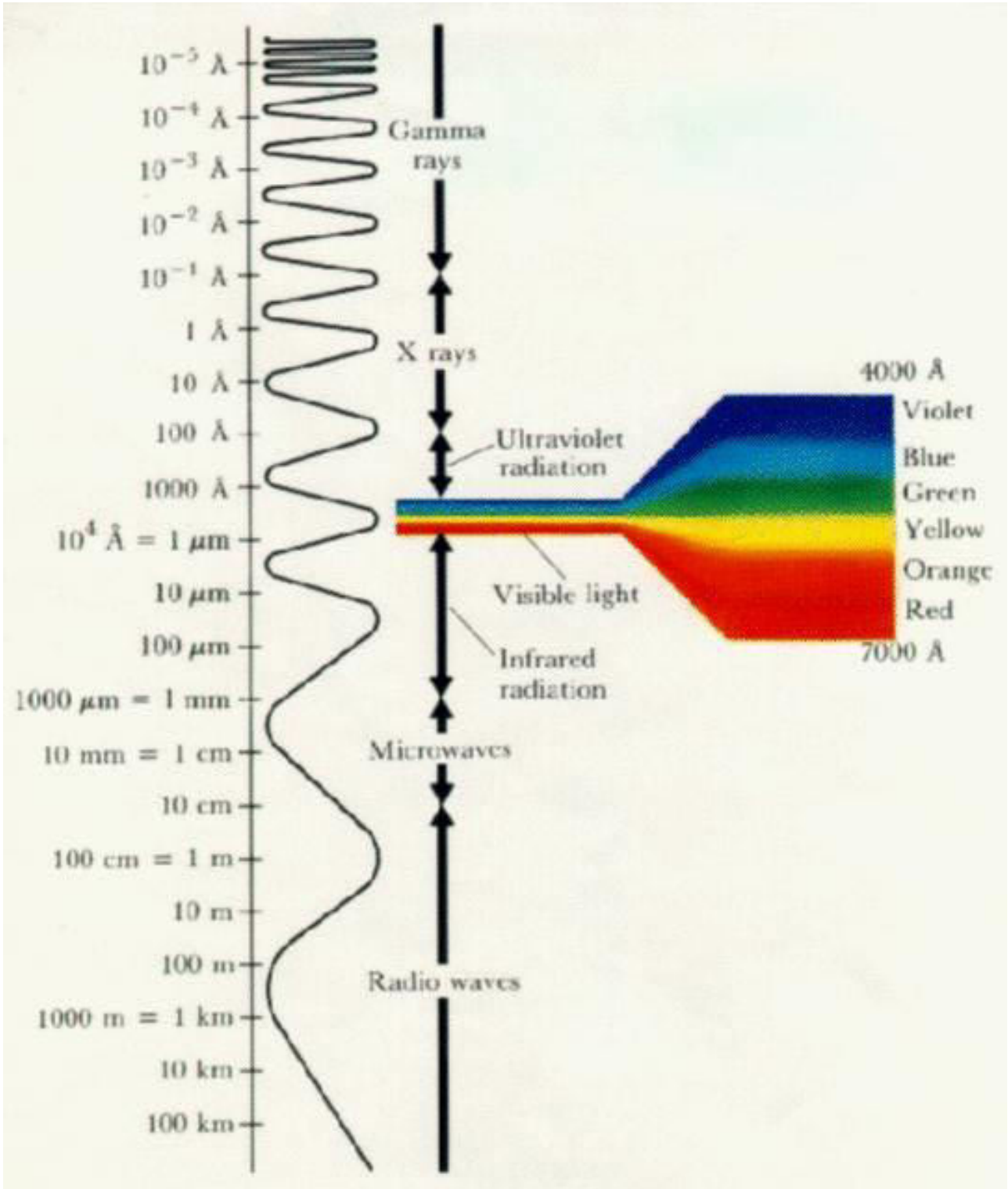
- A. Gamma rays are low frequency waves.
- B. X rays are high-energy waves.
- C. Gamma rays are used to treat diseases.

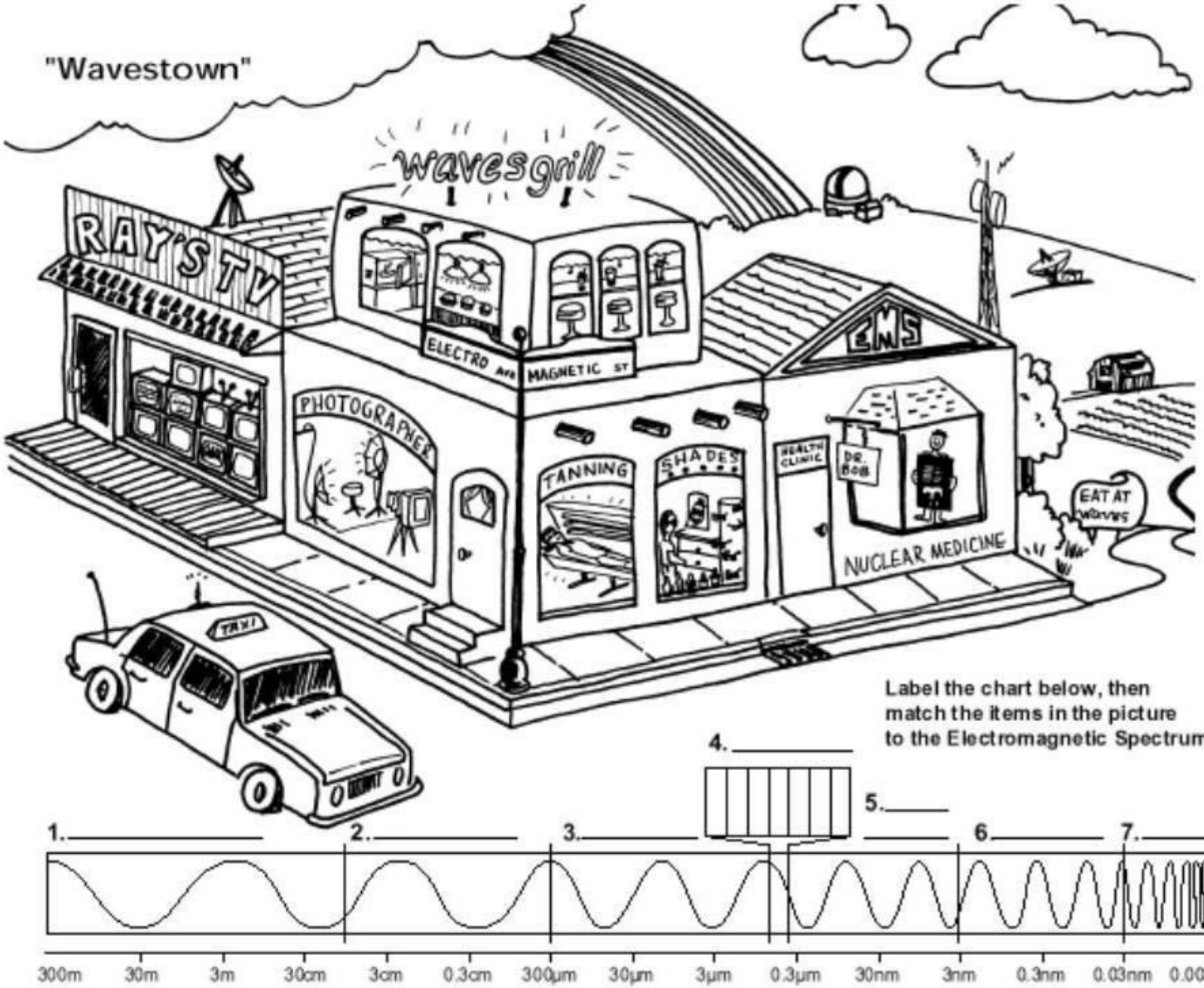
Why do you think MRIs cause ...

- Less harm than X rays?



F Fill in the boxes with the waves of the EM spectrum.


10^{-5} Å
10^{-4} Å
10^{-3} Å
10^{-2} Å
10^{-1} Å
1 Å
10 Å
100 Å
1000 Å
10^4 Å = 1 μm
10 μm
100 μm
1000 μm = 1 mm
10 mm = 1 cm
10 cm
100 cm = 1 m
10 m
100 m
1000 m = 1 km
10 km
100 km
Gamma rays
X rays
Ultraviolet radiation
Visible light
Infrared radiation
Microwaves
Radio waves
4000 Å
Violet
Blue
Green
Yellow
Orange
Red
7000 Å

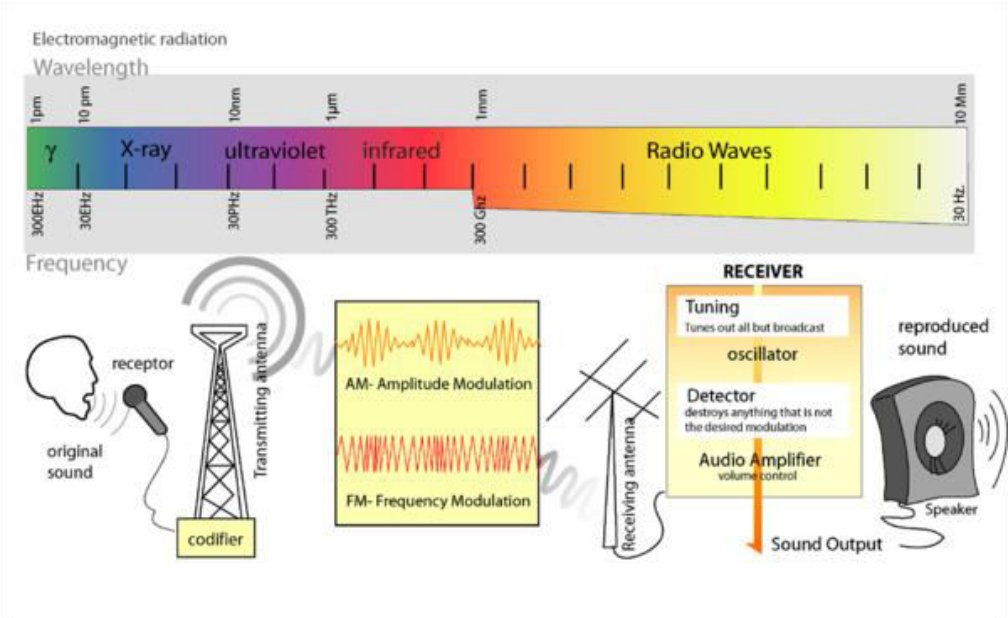

"Wavestown"
RAY'S TV
wavesgrill
ELECTRO MAGNETIC ST
PHOTOGRAPHER
TANNING
SHADES
HEALTH CLINIC
DR. BOB
EMS
EAT AT
NUCLEAR MEDICINE
TAXI
Label the chart below, then match the items in the picture to the Electromagnetic Spectrum.
4.
5.
1.
2.
3.
6.
7.
300m
30m
3m
30cm
3cm
0.3cm
300μm
30μm
3μm
0.3μm
30nm
3nm
0.3nm
0.03nm
0.003nm

Electromagnetic Waves

Chp. 12 Section 3 Radio Communication

Radio Transmission

- Radio stations change sound to EM waves & then your radio receiver changes the EM waves back to sound waves again.



How does a radio receive different stations?

- Each station broadcasts at a certain frequency which you tune in by choosing their frequency.
- ***Carrier wave***- the frequency of the EM wave that a station uses
- Microphones convert sound waves to a changing electric current or electronic signal containing the words & music.

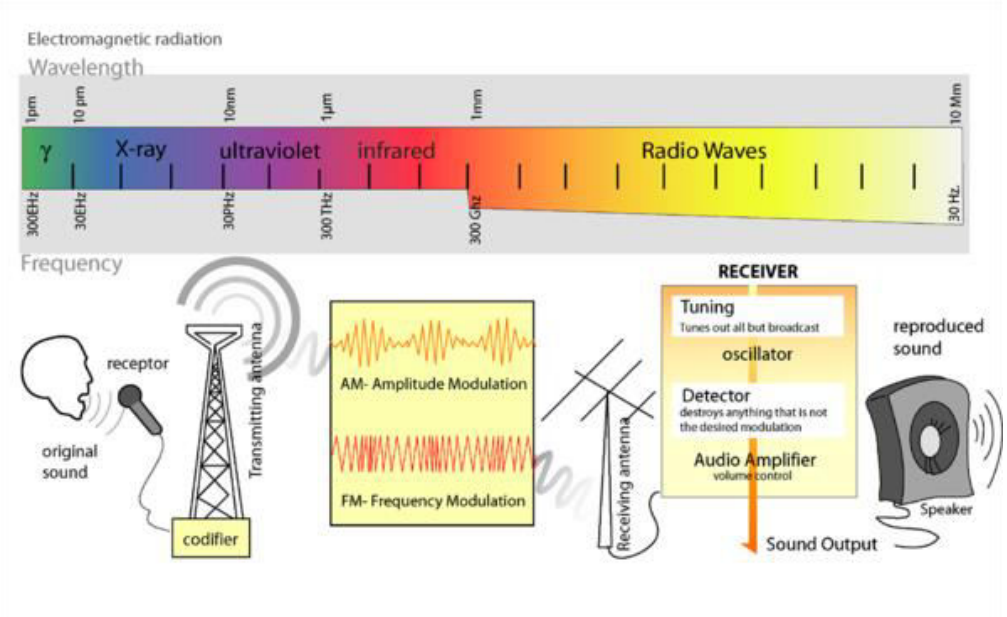
How does a radio receive different stations?

- Microphones convert sound waves to a changing electric current or electronic signal containing the words & music.
- The modified carrier wave vibrates electrons in the station's antennae creating a radio wave that travels out in all directions at the speed of light to your radio antennae.

How does a radio receive different stations?

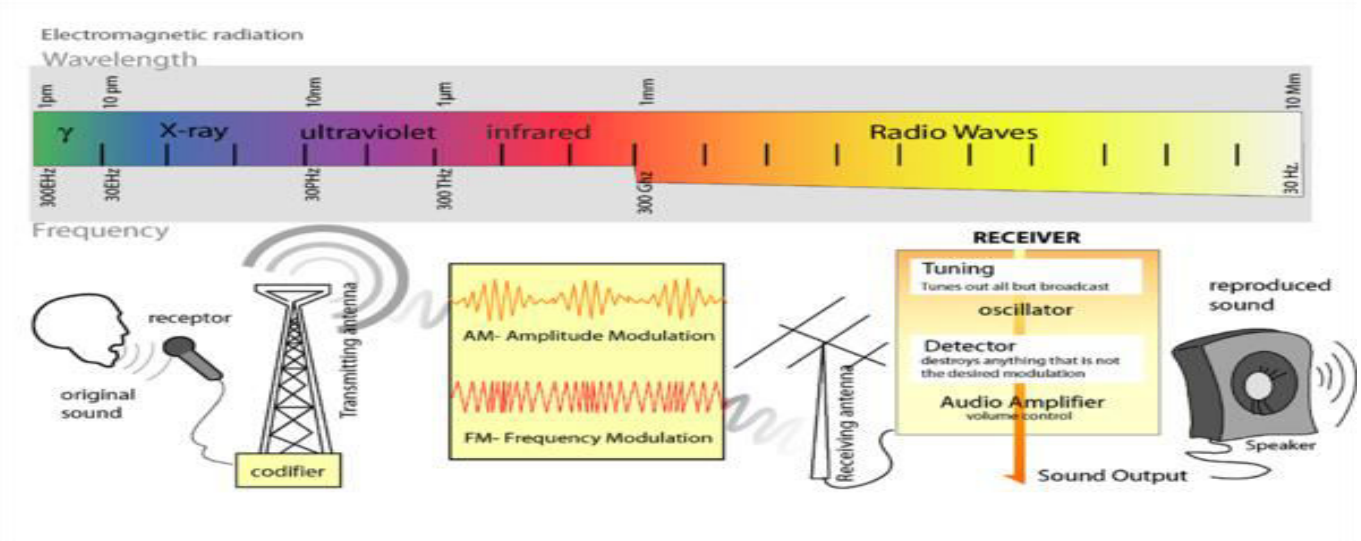
- The modified carrier wave vibrates electrons in the station's antennae creating a radio wave that travels out in all directions at the speed of light to your radio antennae.
- The vibrating electrons produce a changing electric current which your radio separates the carrier wave from the signal to make the speakers vibrate creating sound waves….

What is AM radio?



In AM amplitude changes but frequency does not. AM frequencies range from 540,000 Hz to 1,6000,000 Hz usually listed in kHz.

What is FM radio?



- In FM radio stations transmit broadcast information by changing the frequency of the carrier wave. The strength of FM waves is always the same and is in megahertz. Mega=million

Television

- Uses radio waves to send electronic signals in a carrier wave.
- Sound is sent by FM; color and brightness is sent at the same time by AM signals.

What is a cathode-ray tube?

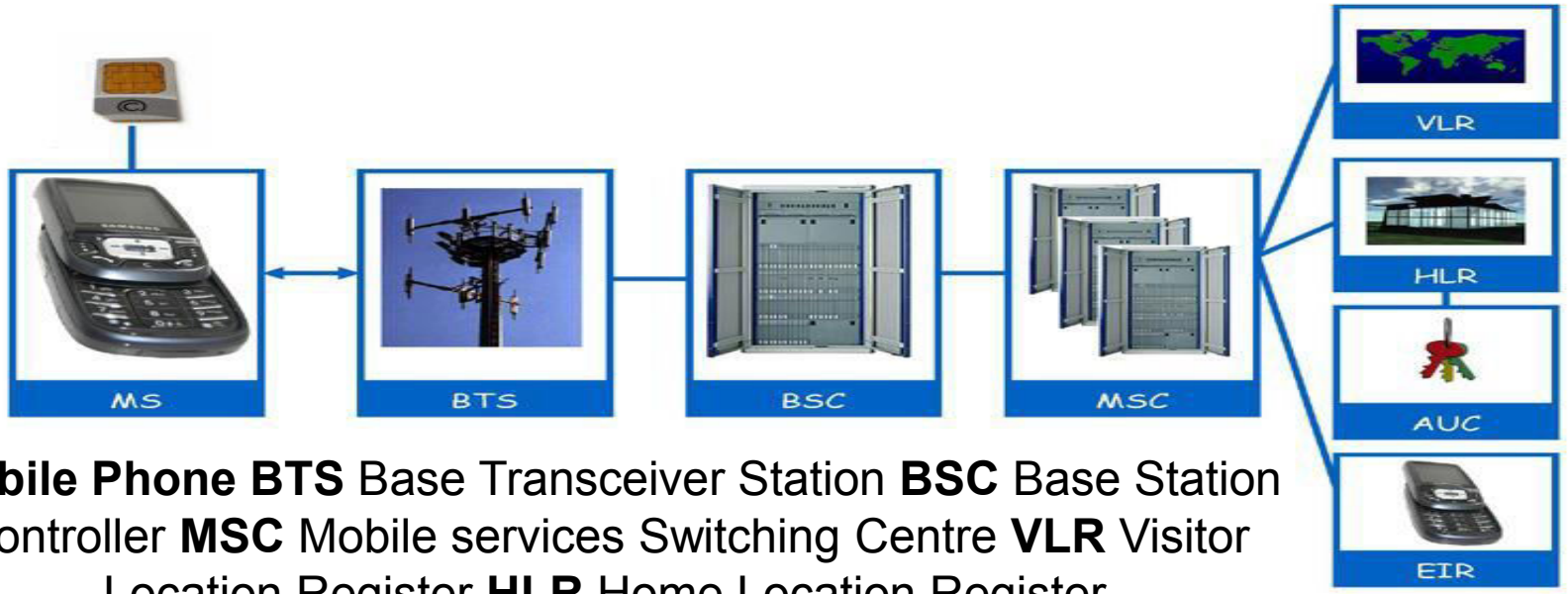
- Many TVs and computer monitors display images on a CRT, a sealed vacuum tube in which beams of electrons are produced.
- Color TV produces 3 electron beams inside the CRT which strike the inside of the screen that is covered with more than 100,000 rectangular spots.

What is a cathode-ray tube?

- There are 3 types of spots, red, green and blue. The electron beams move back and forth across the screen.
- The signal from the TV station controls how bright each spot is. Three spots together can form any color.
- You see a full color image on the TV.

Telephones

- Sound waves→ microphone→ electric signal→ radio waves→ transmitted to and from microwave tower → receiver→ electric signal → speaker→ sound wave



Mobile Phone BTS Base Transceiver Station **BSC** Base Station Controller **MSC** Mobile services Switching Centre **VLR** Visitor Location Register **HLR** Home Location Register

How do cordless phones work?

- Cell phones and cordless telephones are ***transceivers,*** device that transmits one signal & receives another radio signal from a base unit.
- You can talk and listen at the same time because the two signals are at different frequencies.

How do pagers work?

- A pager is a small radio receiver with a phone number. A caller leaves a message at a terminal with a call-back number.
- At the terminal, the message is turned into an electronic signal transmitted by radio waves.
- Newer pagers can send and receive messages.

Communications Satellites

- Thousands of satellites orbit Earth. A radio or TV station sends microwave signals to the satellite which amplifies the signal and sends it back to a different place on Earth. Satellite uses dif freq to send & receive.

Global Positioning System

- GPS is a system of 24 satellites, ground monitoring stations and portable receivers that determine your exact location on Earth. GPS receiver measures the time it takes for radio waves to travel from 4 different satellites to the receiver. The system is owned and operated by the US Dept of Defense, but the microwaves can be used by anyone.