EMR Spectrum and Its Properties

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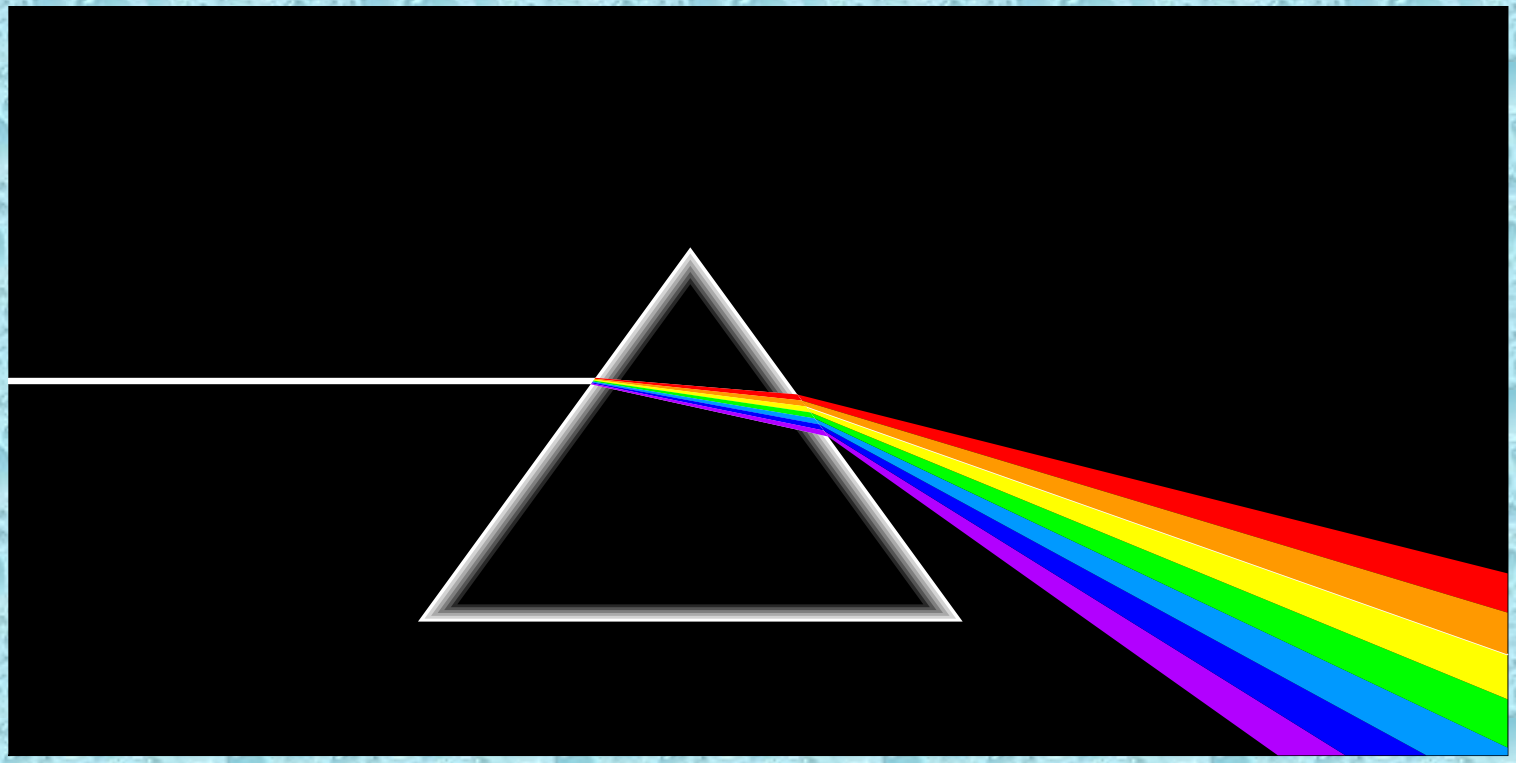
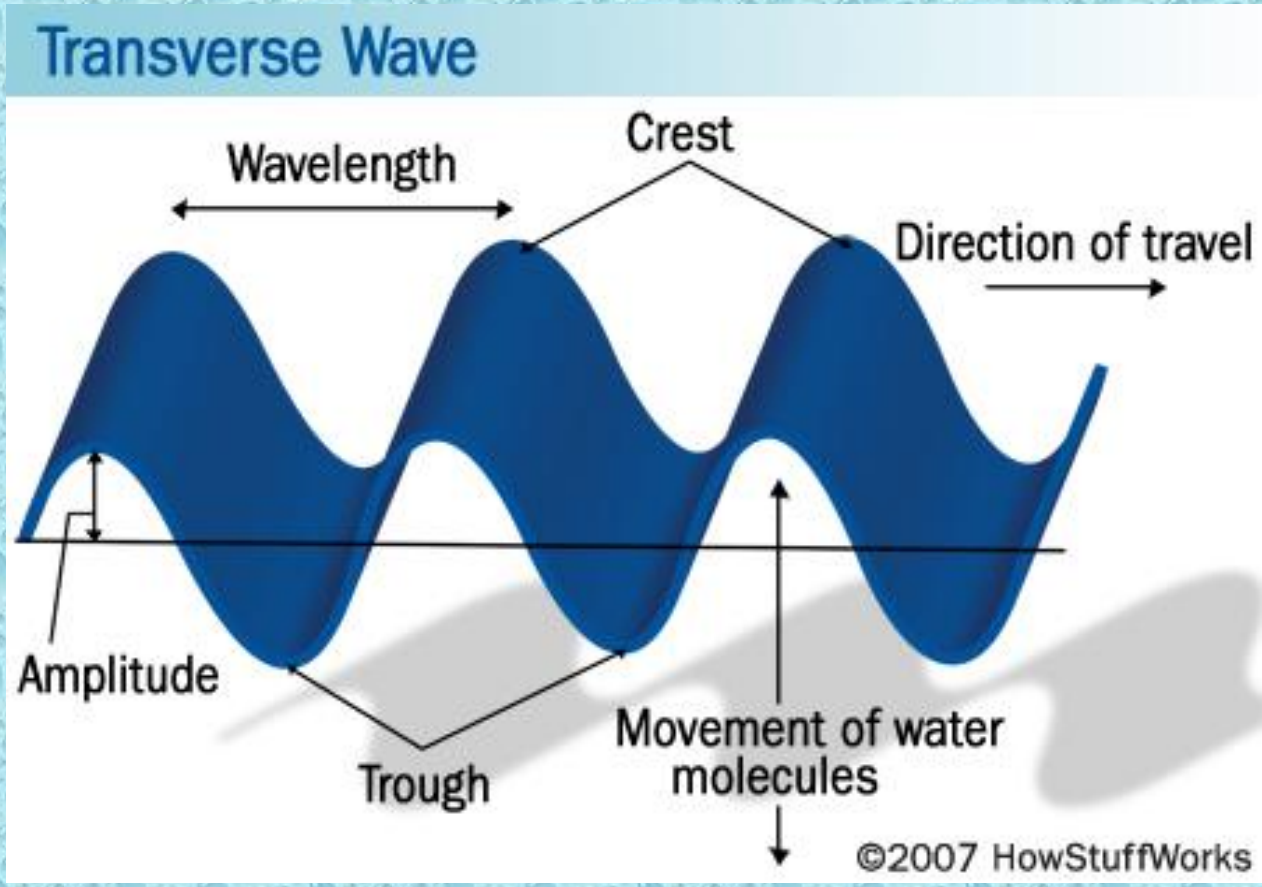
Electromagnetic Waves & the Electromagnetic Spectrum

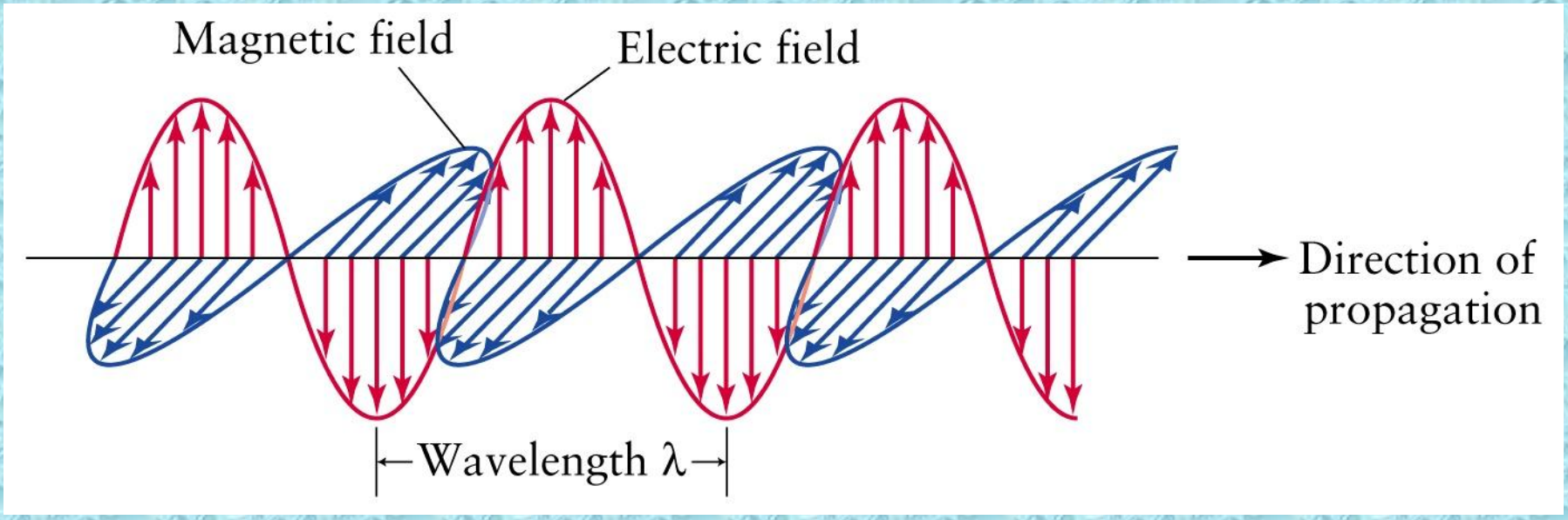


Electromagnetic Waves

- **Transverse waves without a medium!**
- (They can travel through **empty space**)

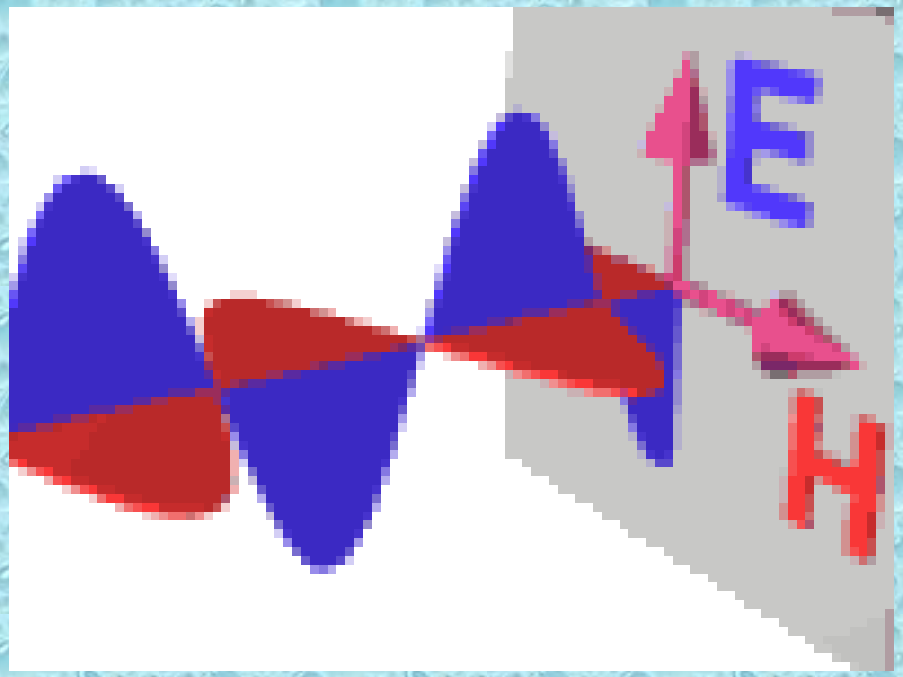


- They travel as **vibrations in electrical and magnetic fields.**
  - Have some magnetic and some electrical properties to them.



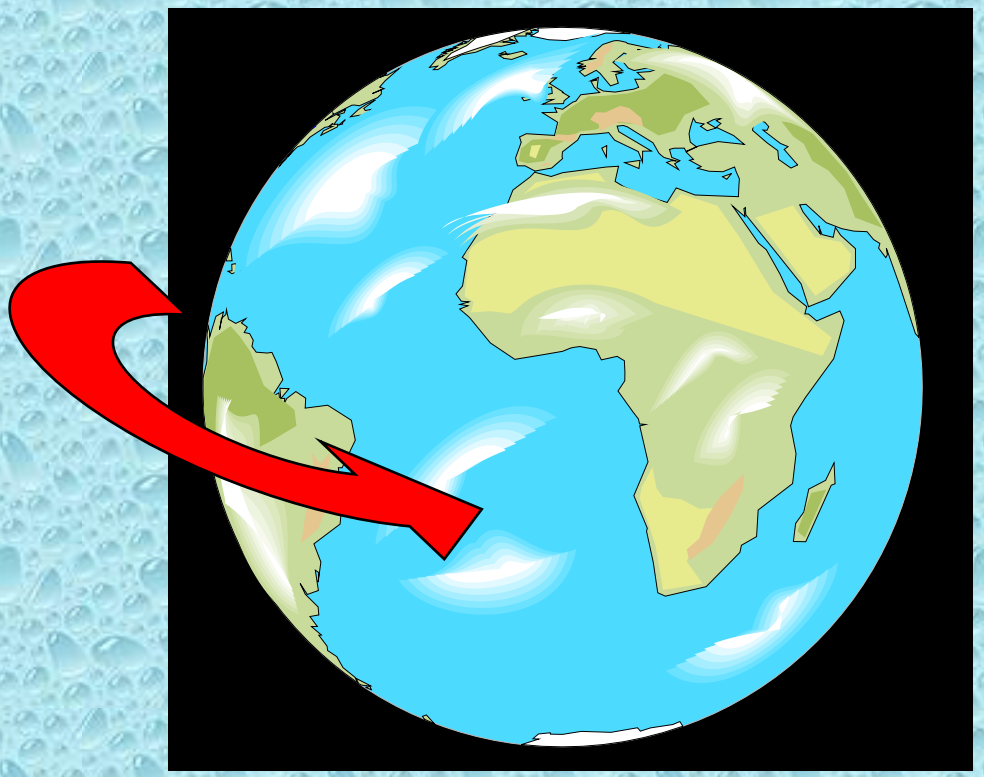
- When an electric field changes, so does the magnetic field. The changing magnetic field causes the electric field to change. When one field vibrates—so does the other.

- **RESULT-**An **electromagnetic wave.**

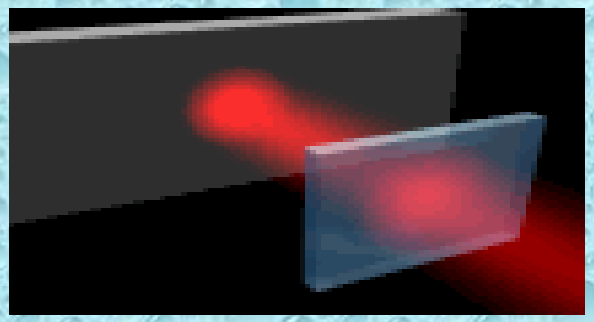


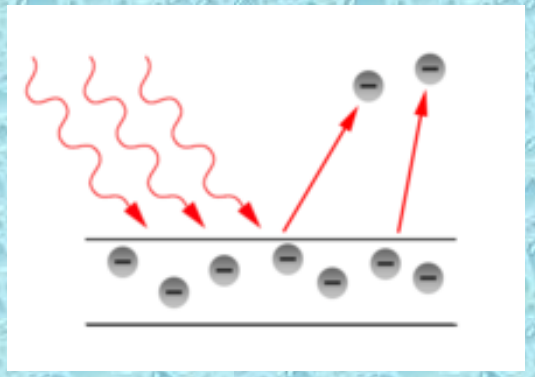
- Electromagnetic waves travel VERY FAST – around 300,000 kilometres per second (the speed of light).

At this speed they can go around the world 8 times in one second.

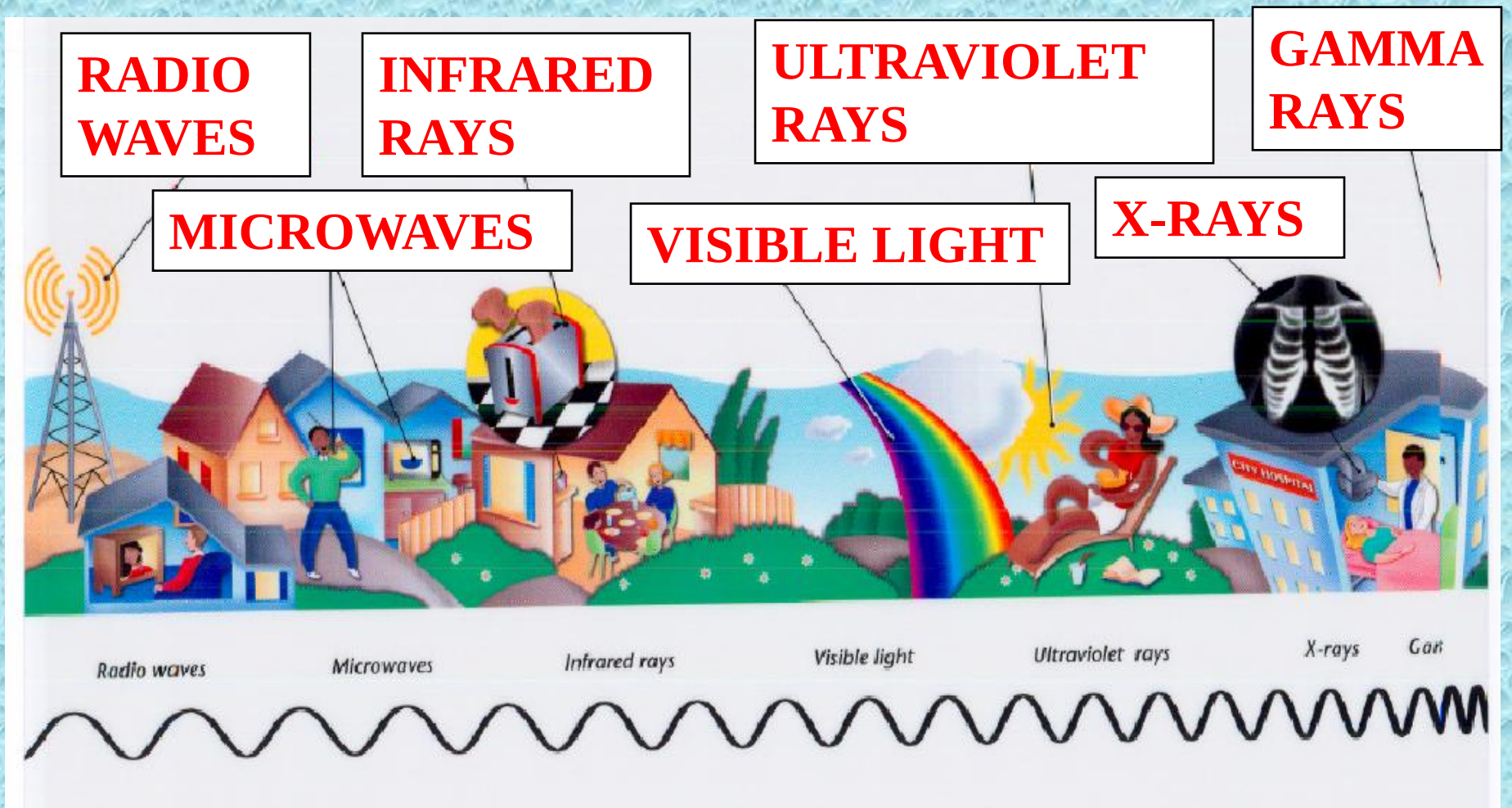


- **Waves or Particles?**
- Electromagnetic radiation has properties of waves but also can be thought of as a **stream of particles.**
  - Example: Light
    - Light as a wave: Light behaves as a transverse wave which we can filter using polarized lenses.
    - Light as particles (photons): When directed at a substance light can knock electrons off of a substance (Photoelectric effect)

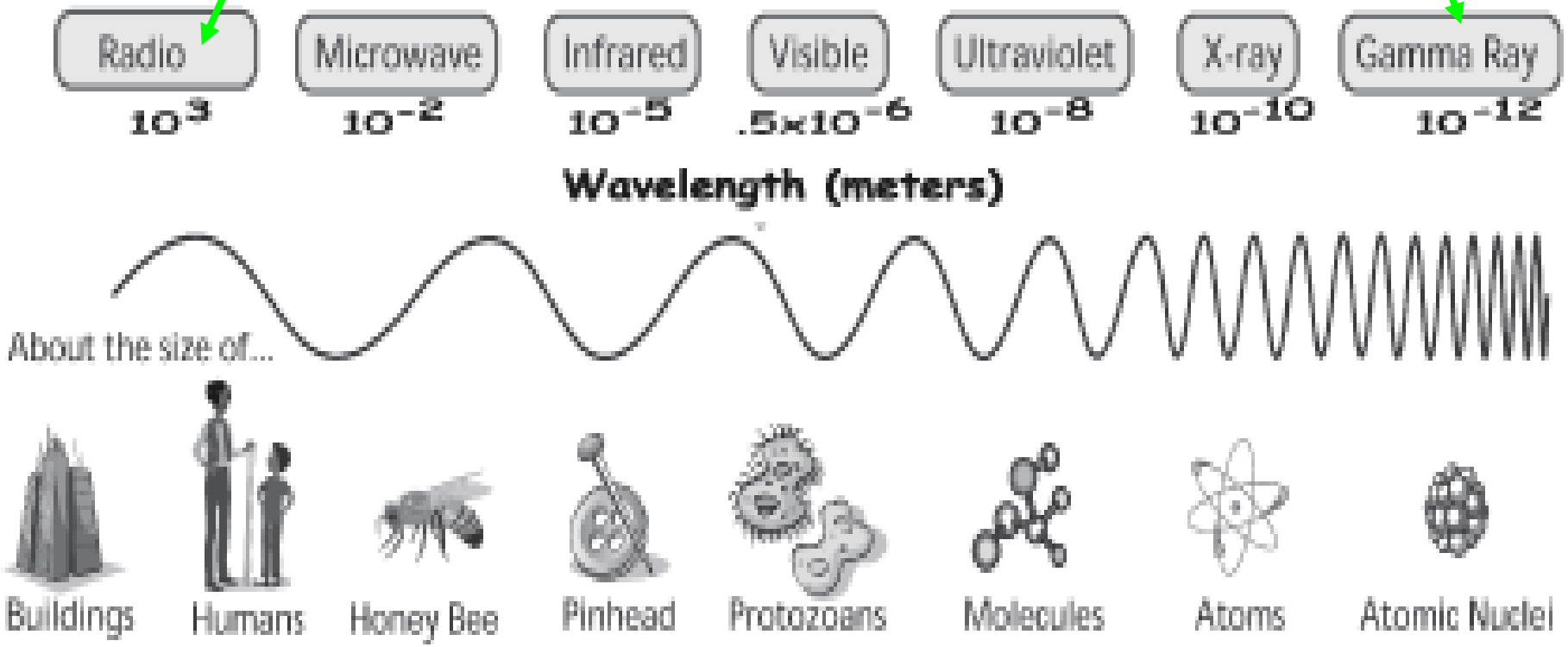




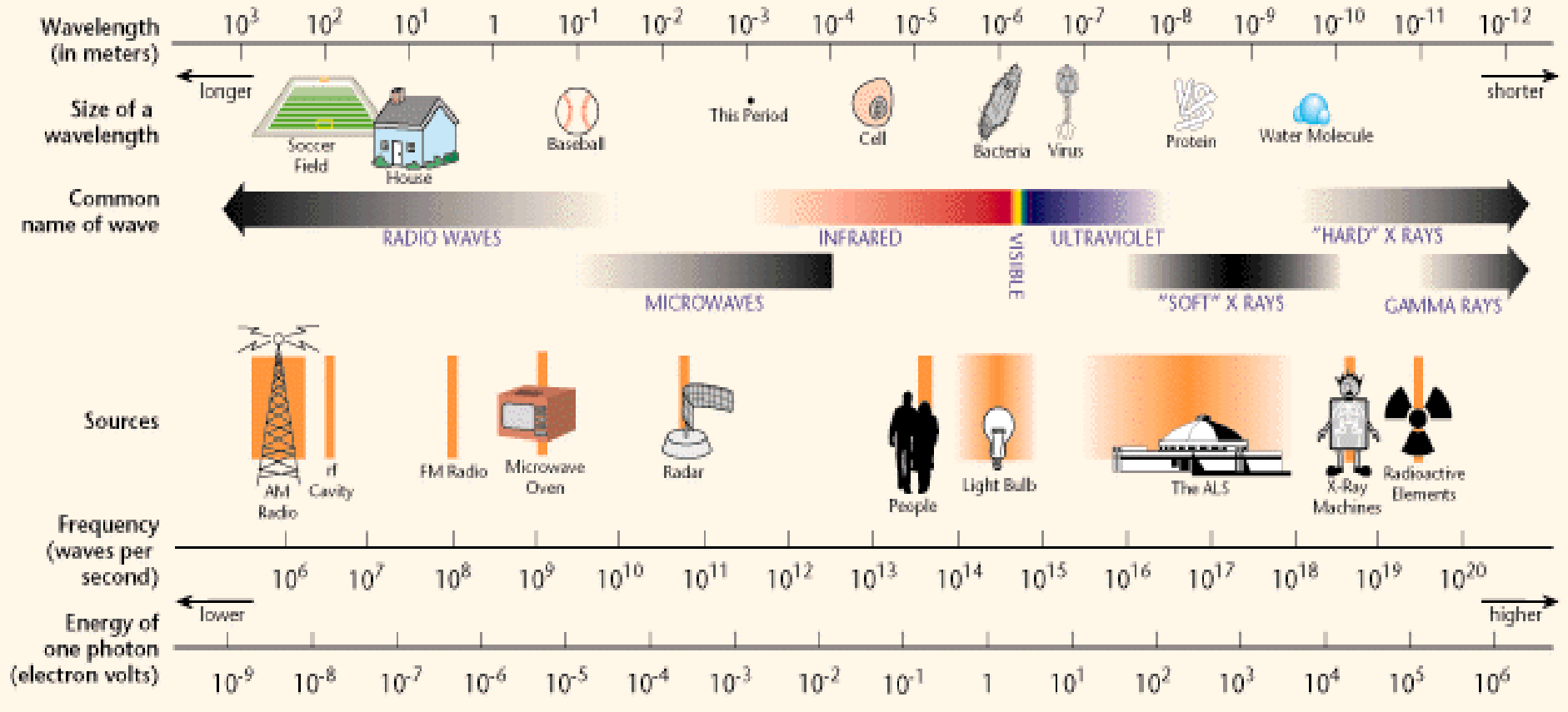
- **Electromagnetic Spectrum**—name for the range of electromagnetic waves when placed in order of increasing frequency



Notice the wavelength is long (Radio waves) and gets shorter (Gamma Rays)



THE ELECTROMAGNETIC SPECTRUM

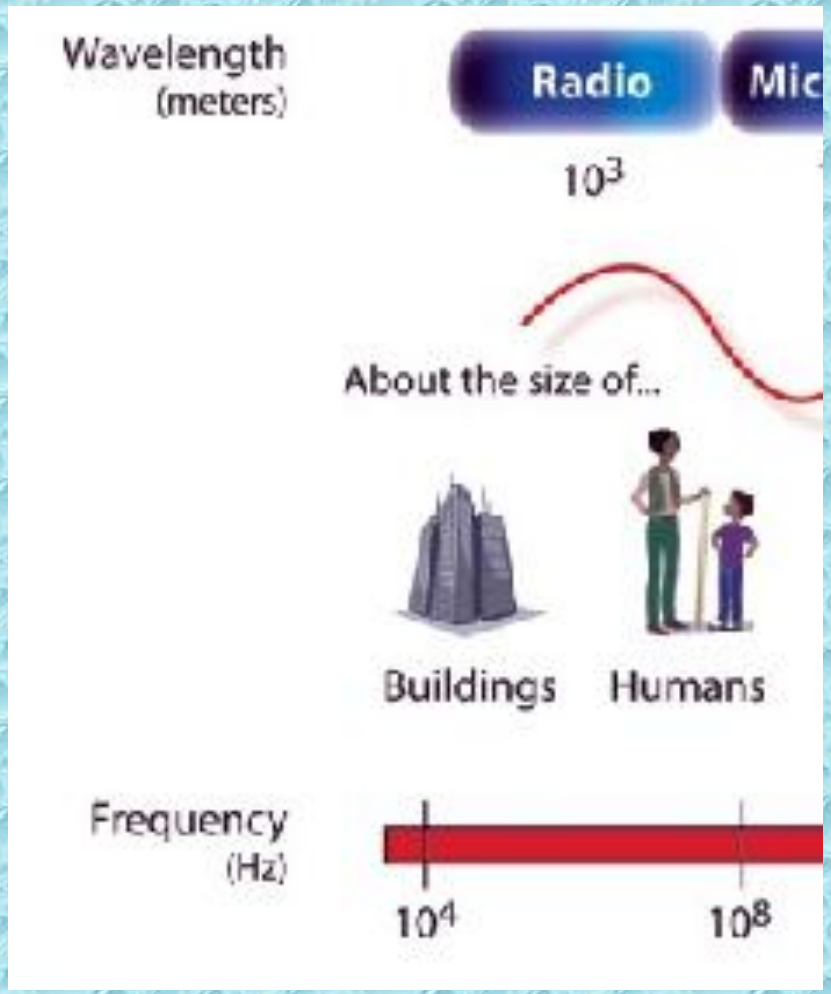


Spectrum of Electromagnetic Radiation

Region	Wavelength (Angstroms)	Wavelength (centimeters)	Frequency (Hz)	Energy (eV)
Radio	$> 10^{9}$	> 10	$< 3 \times 10^{9}$	$< 10^{-5}$
Microwave	$10^{9} - 10^{6}$	$10 - 0.01$	$3 \times 10^{9} - 3 \times 10^{12}$	$10^{-5} - 0.01$
Infrared	$10^{6} - 7000$	$0.01 - 7 \times 10^{-5}$	$3 \times 10^{12} - 4.3 \times 10^{14}$	$0.01 - 2$
Visible	$7000 - 4000$	$7 \times 10^{-5} - 4 \times 10^{-5}$	$4.3 \times 10^{14} - 7.5 \times 10^{14}$	$2 - 3$
Ultraviolet	$4000 - 10$	$4 \times 10^{-5} - 10^{-7}$	$7.5 \times 10^{14} - 3 \times 10^{17}$	$3 - 10^{3}$
X-Rays	$10 - 0.1$	$10^{-7} - 10^{-9}$	$3 \times 10^{17} - 3 \times 10^{19}$	$10^{3} - 10^{5}$
Gamma Rays	< 0.1	$< 10^{-9}$	$> 3 \times 10^{19}$	$> 10^{5}$

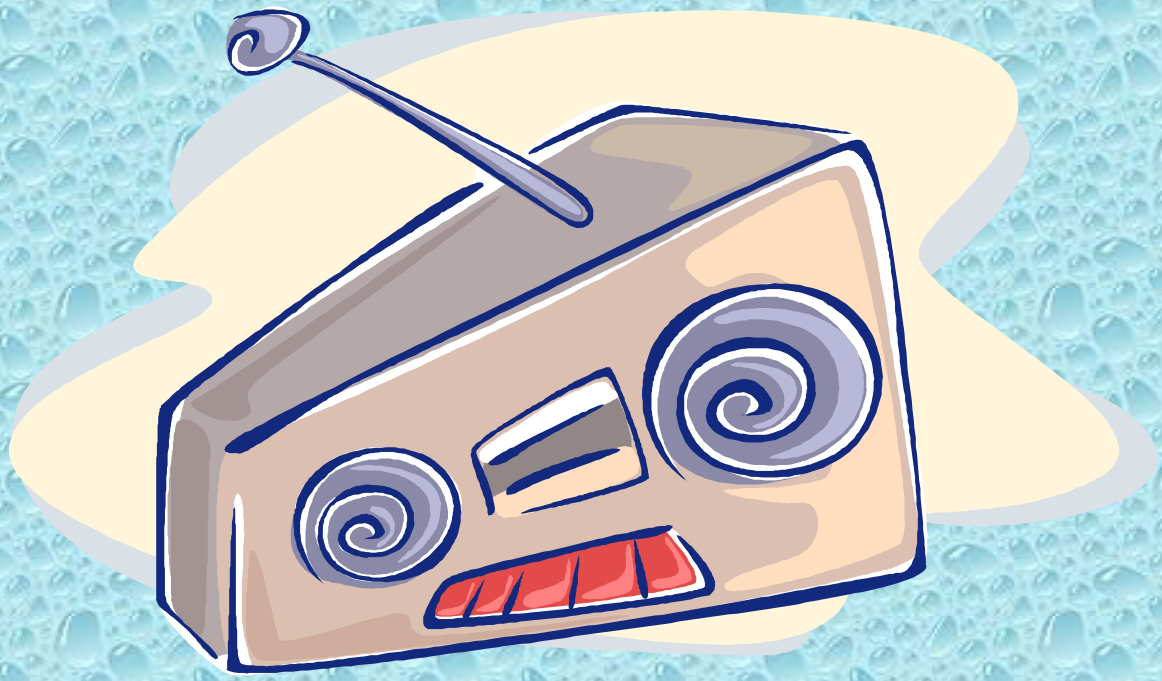
RADIO WAVES

- Have the **longest** wavelengths and **lowest** frequencies of all the electromagnetic waves.



- Global Positioning Systems (GPS) measure the time it takes a radio wave to travel from several satellites to the receiver, determining the distance to each satellite.

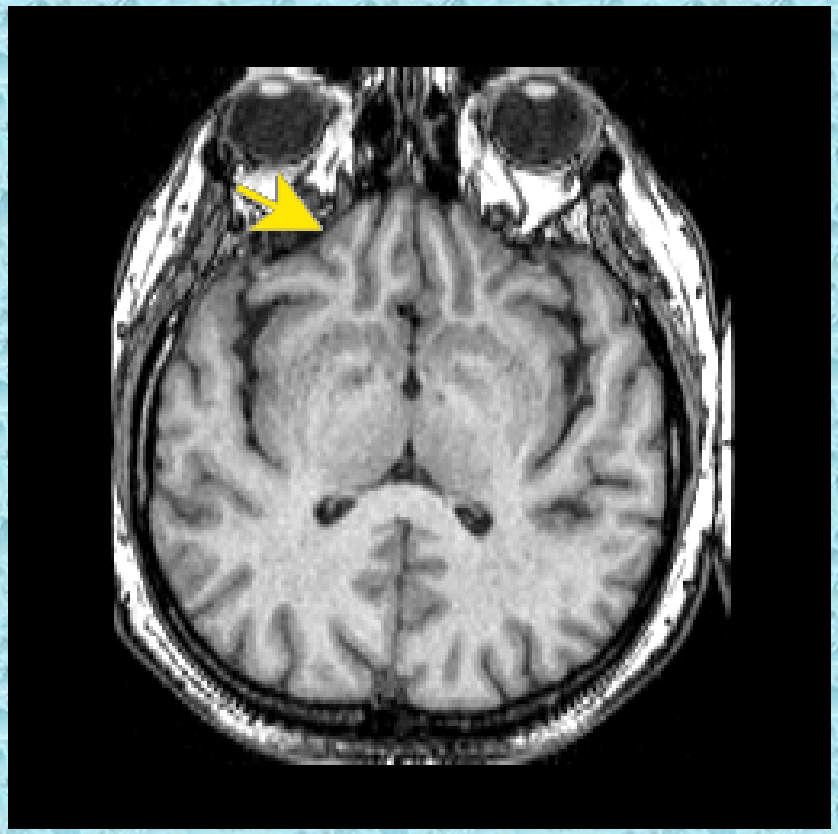
- A radio picks up radio waves through an antenna and converts it to **sound waves.**
  - Each radio station in an area broadcasts at a different frequency.
    - # on radio dial tells frequency.



MRI

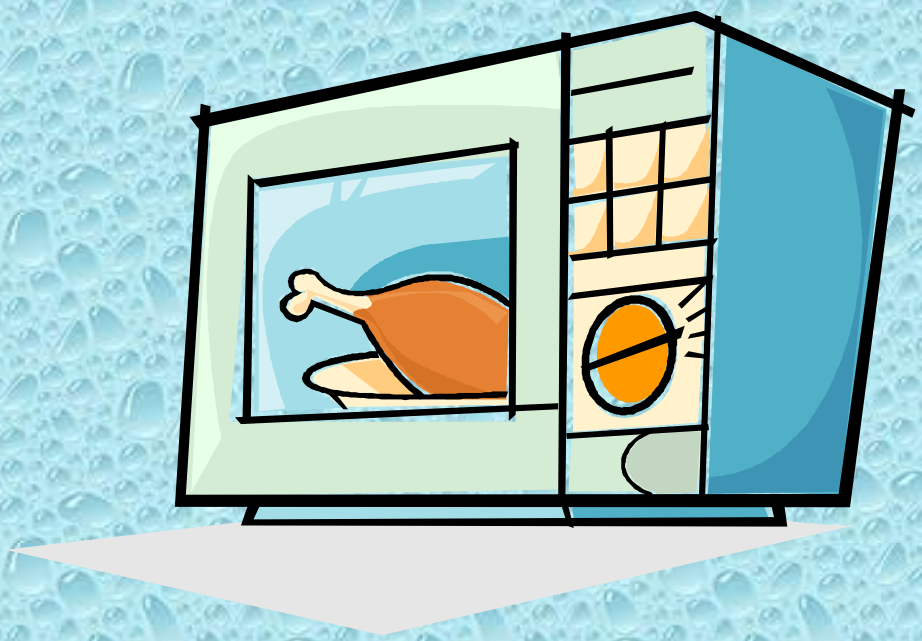
(MAGNETIC RESONACE IMAGING)

Uses Short wave radio waves with a magnet to create an image.



MICROWAVES

- Have the shortest wavelengths and the highest frequency of the **radio waves.**

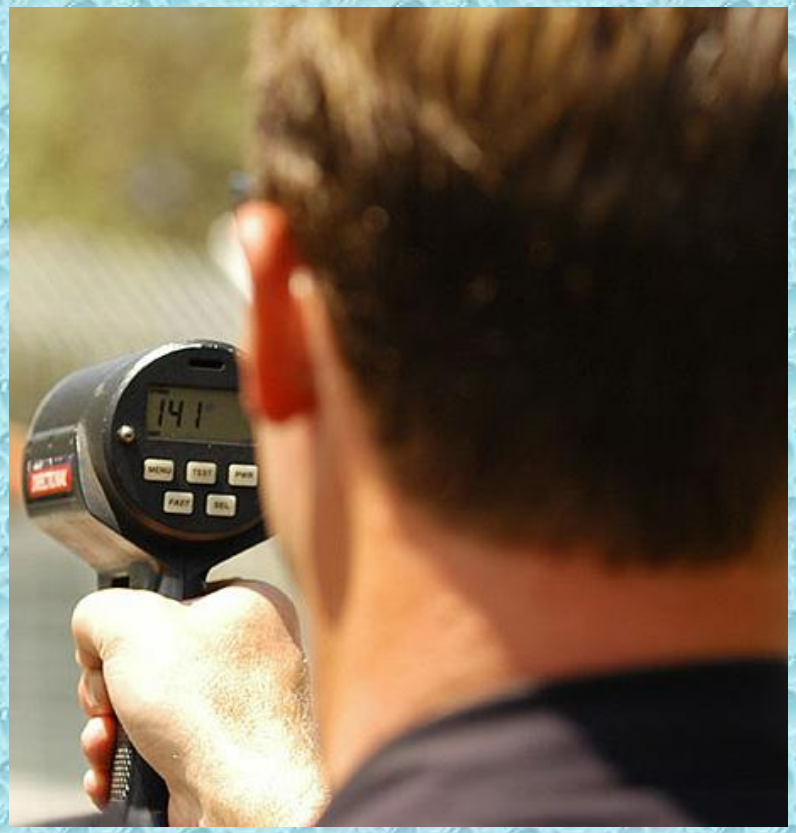


Used in microwave ovens.

- Waves transfer energy to the water in the food causing them to vibrate which in turn transfers energy in the form of heat to the food.

RADAR (Radio Detection and Ranging)

- Used to find the speed of an object by sending out radio waves and measuring the time it takes them to return.

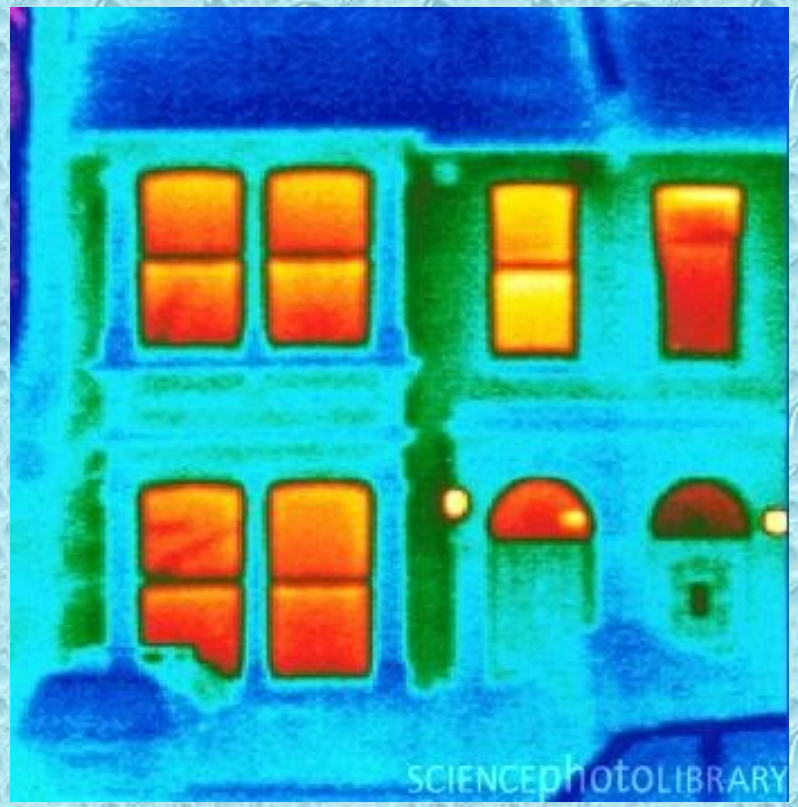


INFRARED RAYS

- **Infrared**= below red
- Shorter wavelength and higher frequency than microwaves.

- **You can feel the longest ones as warmth on your skin**

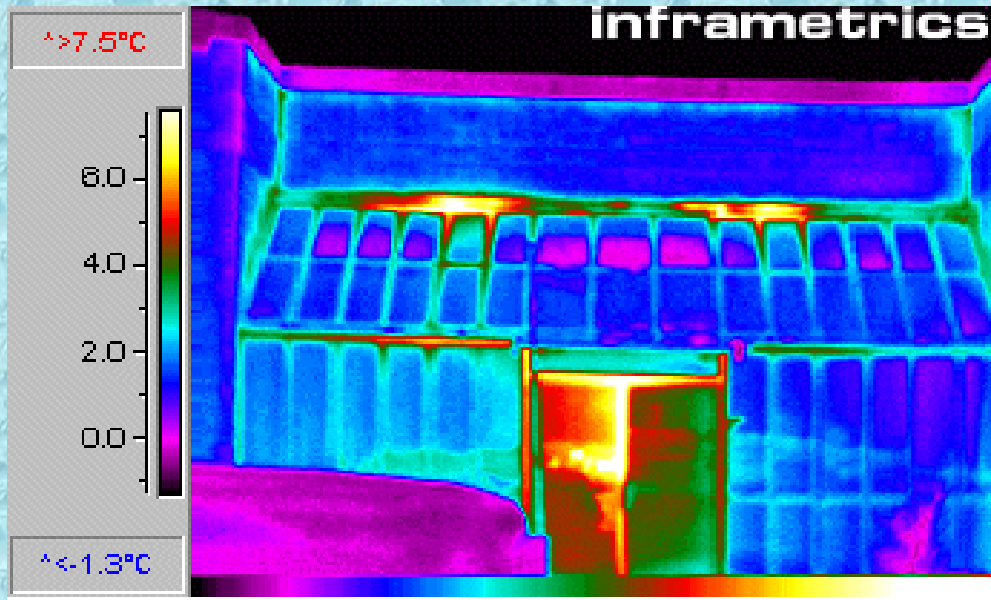
Warm objects give off more heat energy than cool objects.

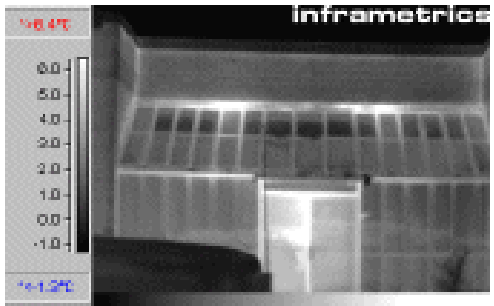


Thermogram—a picture that shows regions of different temperatures in the body. Temperatures are calculated by the amount of infrared radiation given off.

- Therefore people give off infrared rays.

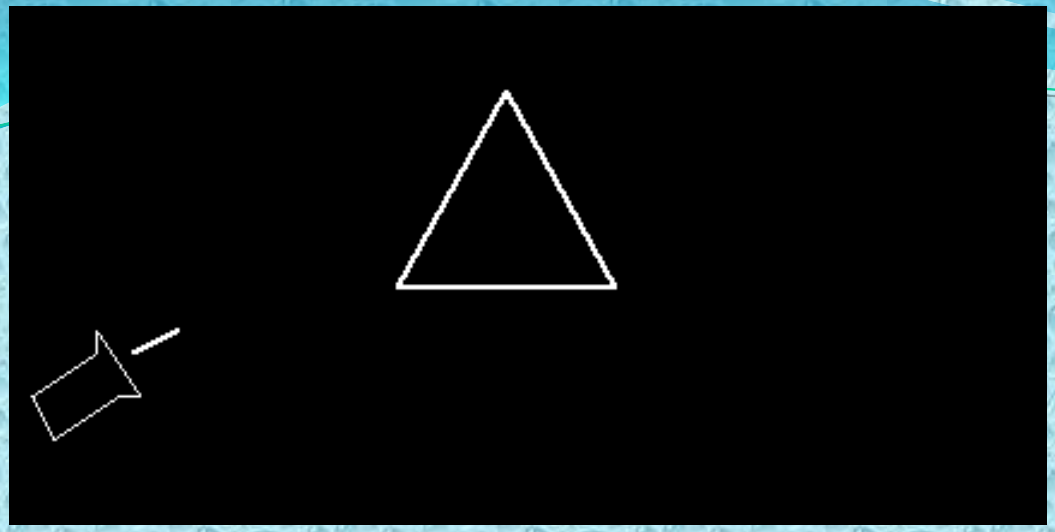
- Heat lamps give off infrared waves.

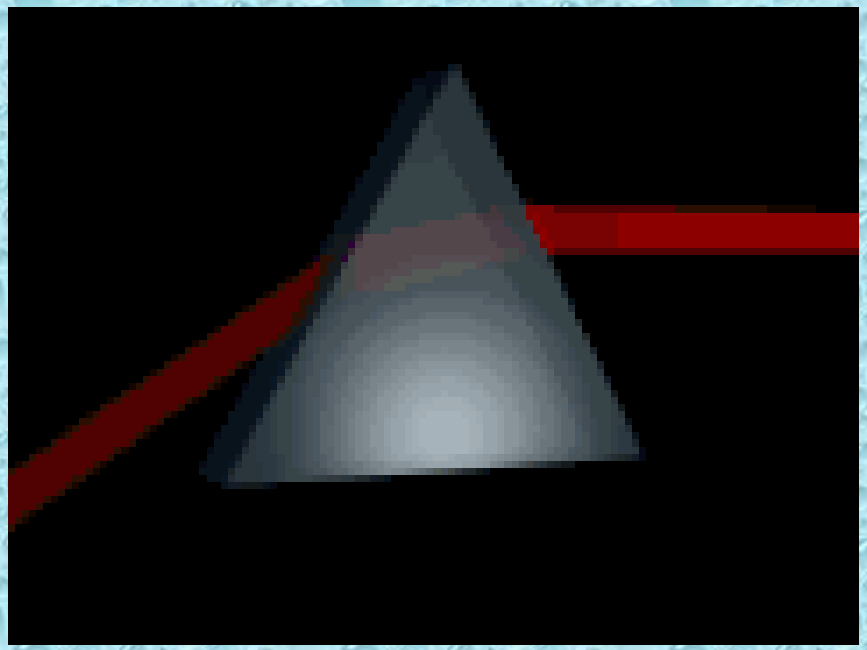




VISIBLE LIGHT

- Shorter wavelength and higher frequency than infrared rays.
- Electromagnetic waves we **<u>can see.</u>**
- **<u>Longest wavelength= red light</u>**
- **<u>Shortest wavelength= violet (purple) light</u>**

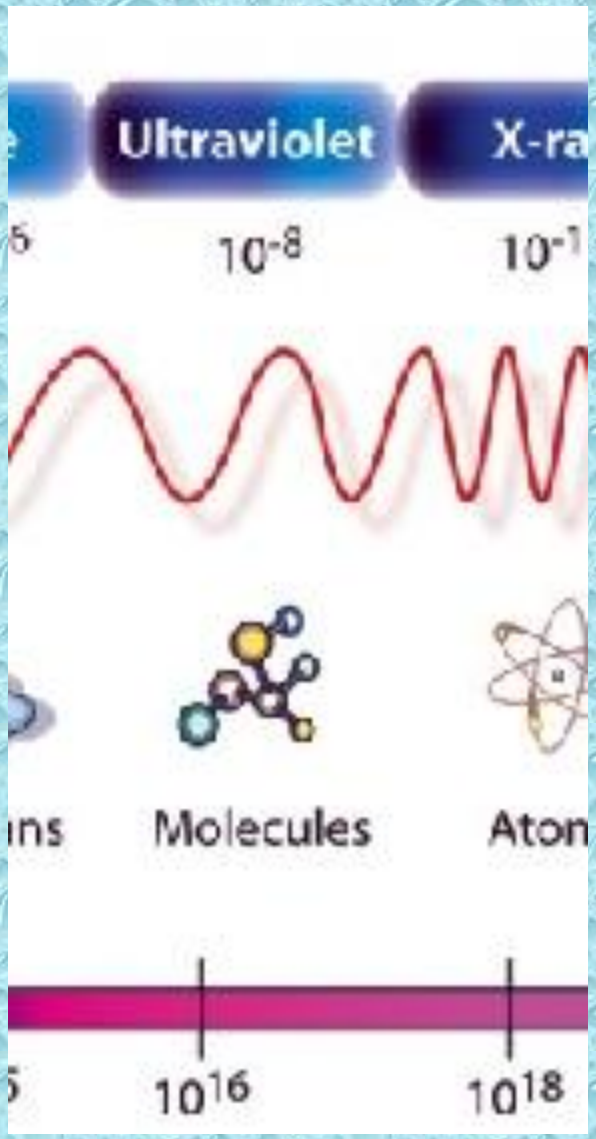




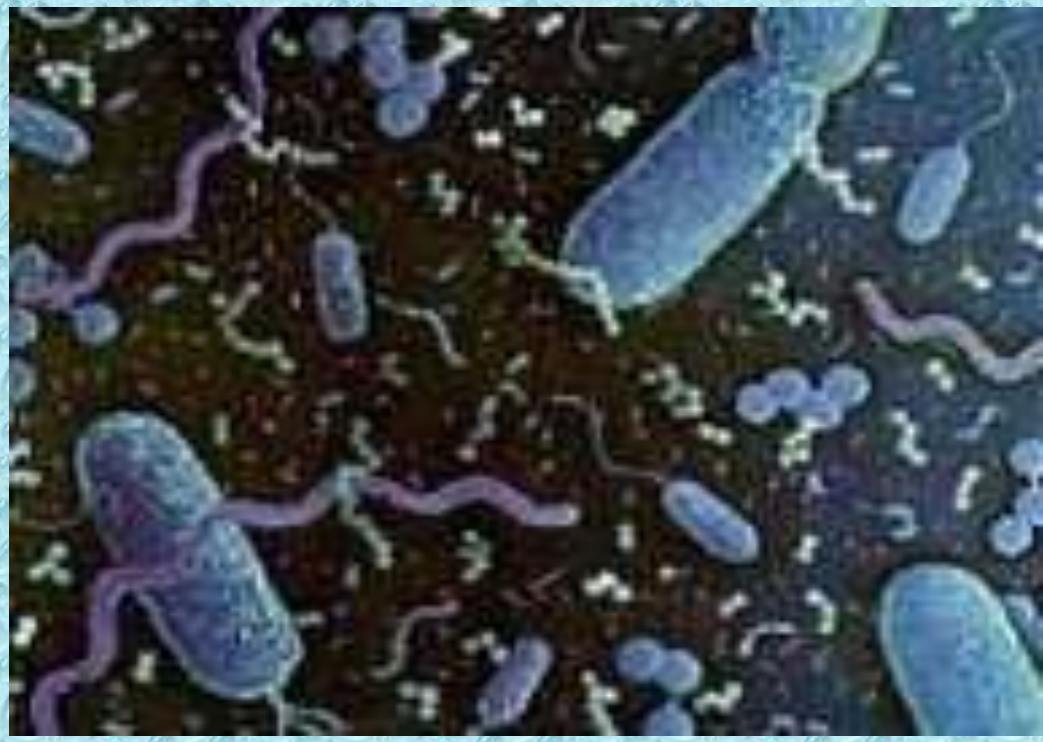
When light enters a new medium it bends (refracts). Each wavelength bends a different amount allowing white light to separate into it's various colors **ROYGBIV.**

ULTRAVIOLET RAYS

- Shorter wavelength and higher frequency than visible light
  - Carry **more energy** than visible light



- Used to **kill bacteria.** (Sterilization of equipment)

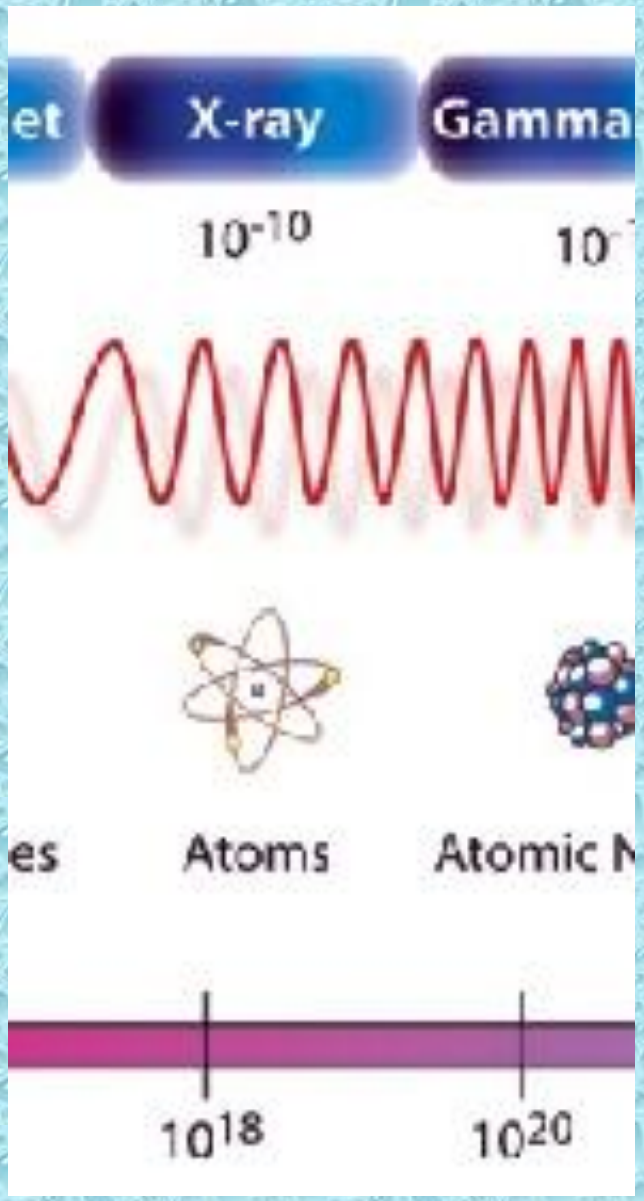


- Too much can cause skin cancer.
- Use sun block to protect against (UV rays)

- Causes your skin to produce **vitamin D** (good for teeth and bones)

X- RAYS

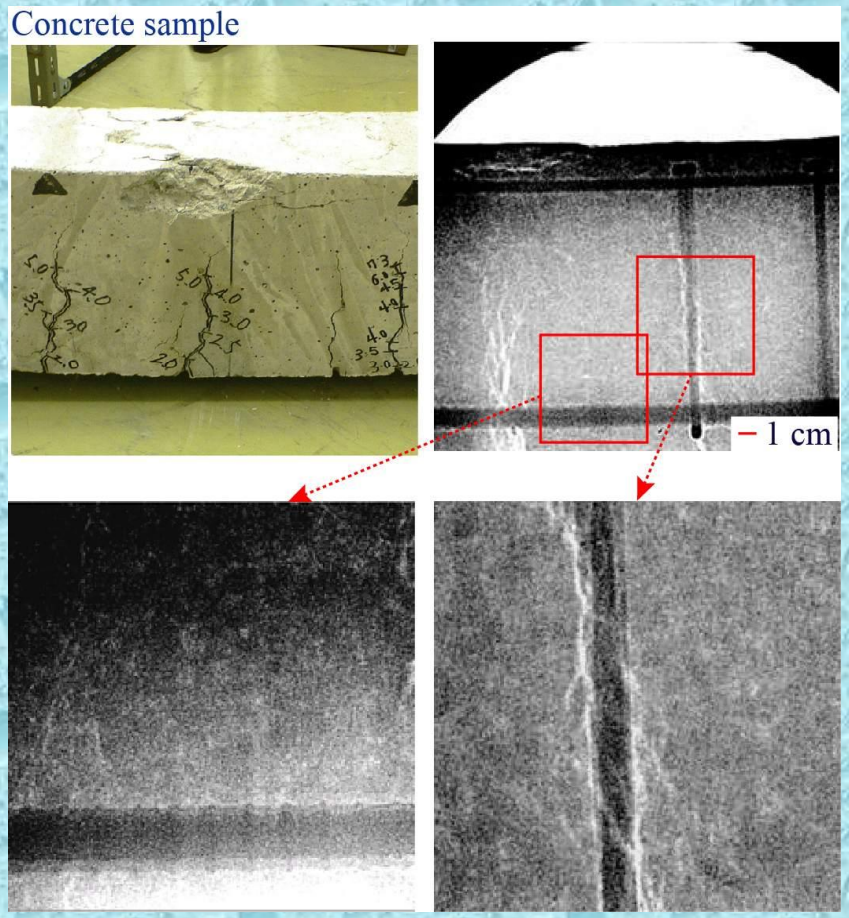
- Shorter wavelength and higher frequency than UV-rays
- Carry a great amount of energy
  - Can penetrate most matter.



Bones and teeth absorb x-rays. (The light part of an x-ray image indicates a place where the x-ray was absorbed)

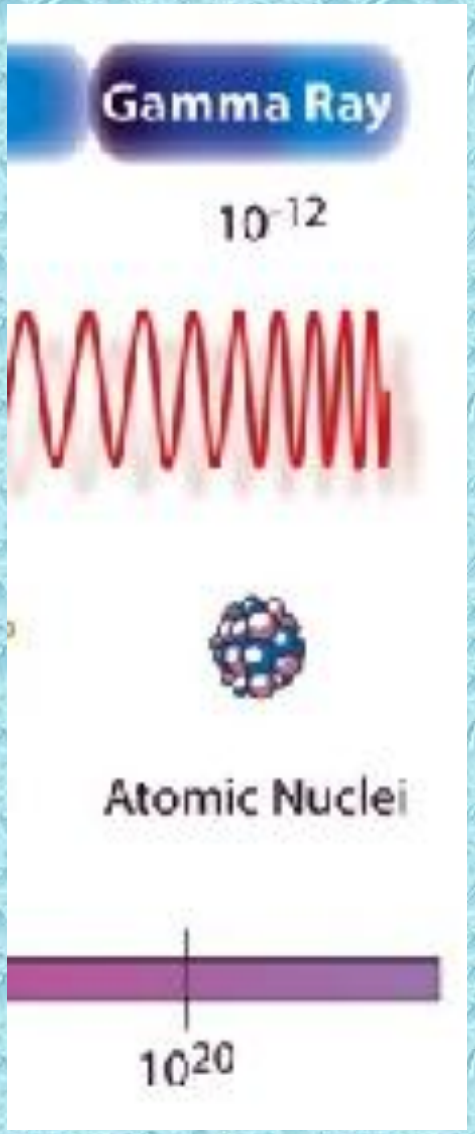
Too much exposure **can cause cancer** (lead vest at dentist protects organs from unnecessary exposure)

- Used by **engineers** to check for tiny cracks in structures.
  - The rays pass through the cracks and the cracks appear dark on film.



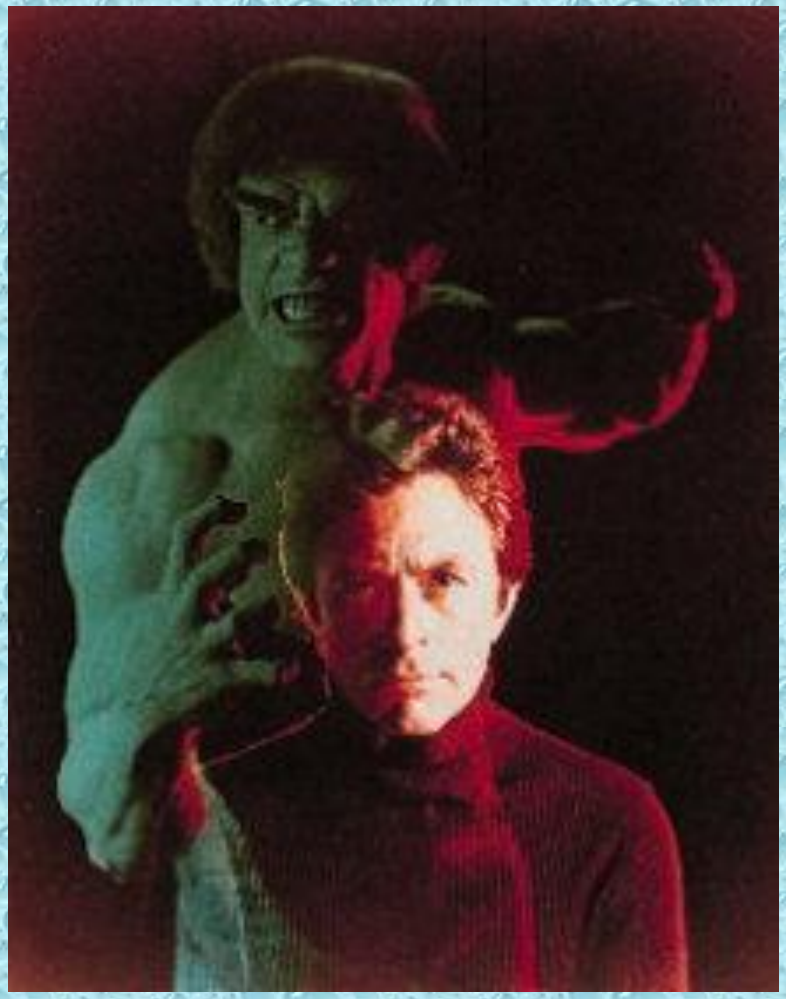
GAMMA RAYS

- Shorter wavelength and higher frequency than X-rays
- Carry the **greatest amount of energy** and penetrate the most.



- Used in **radiation treatment** to kill cancer cells.
- Can be very harmful if not used correctly.

- The Incredible Hulk was the victim of gamma radiation.



Exploding nuclear weapons emit gamma rays.

ACTIVE SENSORS

Laser Fluorosensors

Typical excitation wavelength 355nm

Emission measurements: 430-750nm

← Radar (SAR/SLAR) →

K X S L

Ka Ku C

Frequency (Hz)

10^{15} 10^{14} 10^{13} 10^{12} 10^{11} 10^{10} 10^{9}

100nm 1μm 10μm 100μm 1mm 1cm 10cm

Wavelength

UV imagers

Visible-NIR spectrometers

Typical wavelength range 400-1100 nanometers (nm)

Thermal IR sensors

Typical wavelength range 8-14 micron (μm)

Microwave Radiometers

One or more bands in the range 1-100 GigaHertz (GHz)

PASSIVE SENSORS

	What is measured?	Advantages	Disadvantages	Example of use in sea ice monitoring
Visible	Measures reflected radiation from the sun	Objects with a higher albedo reflect more, making them stand out	As it involves measuring reflected radiation from the sun, visible data can only be collected during the day time Clouds prevent a satellite from viewing the land below	Use in sea ice monitoring, as the ice has a higher albedo that the surrounding sea, making it easy to detect from remote sensing instruments
Infrared	The amount of heat emitted from an object at the earth's surface	Most objects with an average earth temperature emit energy in the infrared region	Clouds can prevent a satellite from viewing the land below	Easy to detect sea ice as its temperature is generally much colder that the surrounding ocean
Passive Microwave	Microwaves emitted by the earth's surface	Clouds do not reflect much microwave radiation, therefore microwaves can penetrate to the land below	Energy level is relatively low so little detail is seen	The ability to detect sea ice through clouds during day and night means all areas of ice can be covered every day
Active Microwave (also known as radar)	Microwaves emitted from satellite sensors which have reflected off the earth's surface and returned to the sensor	Clouds do not reflect much microwave radiation, therefore microwaves can penetrate to the land below	Images can be difficult to interpret	The ability to detect sea ice through clouds during day and night means all areas of ice can be covered every day

Brief SUMMARY

- A. **All electromagnetic waves** travel at the same speed. (300,000,000 meters/second) in a vacuum.
- B. They all have different **wavelengths** and different **frequencies.**
  - Long wavelength-→lowest frequency
  - Short wavelength→ highest frequency
  - The higher the frequency the **higher the energy.**
  - Optical sensors are used to measure ultraviolet, visible, and infrared wavelengths, and microwave sensors are used for the microwave portion of the EMS.

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Thank You !