Intro to Electromagnetic Radiation

POS Checklist:

- describe, qualitatively, how all accelerating charges produce EMR.
- compare and contrast the constituents of the electromagnetic spectrum on the basis of frequency and wavelength.
- explain the propagation of EMR in terms of perpendicular electric and magnetic fields that are varying with time and travelling away from their source at the speed of light.

- ☐ explain, qualitatively, various methods of measuring the speed of EMR.
- ☐ calculate the speed of EMR, given data from a Michelson-type experiment.

"So, what's new in the world of Physics?"

"Nothing. There hasn't been many major discoveries since the 1930's..."

So, let's look at what was happening back in the "good old days" of Physics...

Awesome Timeline of Physics

1687

Newton's Laws

1775

Americian Revolution

1785

Coulomb's Law

1789

French Revolution

1820

Orsted discovers current produces magnetic fields

1838

Faraday Invents $\vec{B}$ and $\vec{E}$ fields

1867

Canada is born

After Faraday had came up with the idea of electric and magnetic fields, the world was ripe for another big discovery!

Review:

- "A moving charge (current) produces a magnetic field".

- "A moving magnetic field produces a current".

Maxwell built further upon these ideas...

JamesClerk Maxwell (1831-1879)

- Maxwell wrote four elegant, simple equations which were released in 1864.

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i + \frac{1}{c^2} \frac{\partial}{\partial t} \int \vec{E} \cdot d\vec{A}$$

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

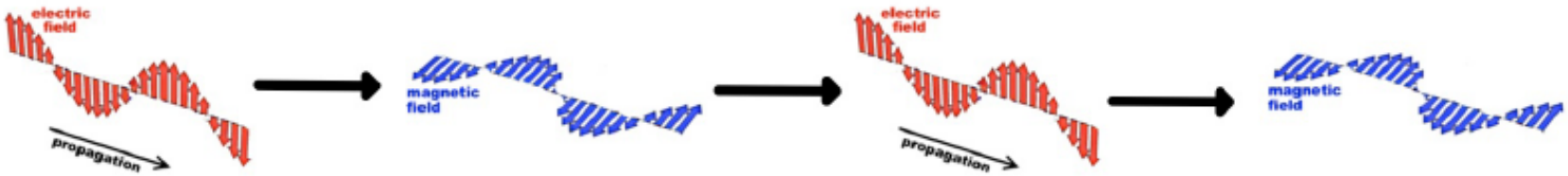
$$\oint \vec{B} \cdot d\vec{A} = 0$$

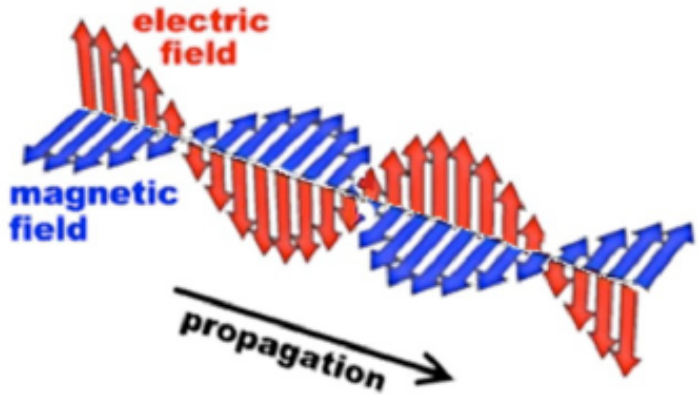
$$\oint \vec{E} \cdot d\vec{A} = \frac{q}{\varepsilon_0}$$

- These equations tied together much of what we have learned thus far in electromagnetism.

Maxwell theorized that just as a current could make a magnetic field and visa versa, an electric field produces a magnetic field, and visa versa.

The only catch was the object producing the field had to be accelerating in order to produce the field.





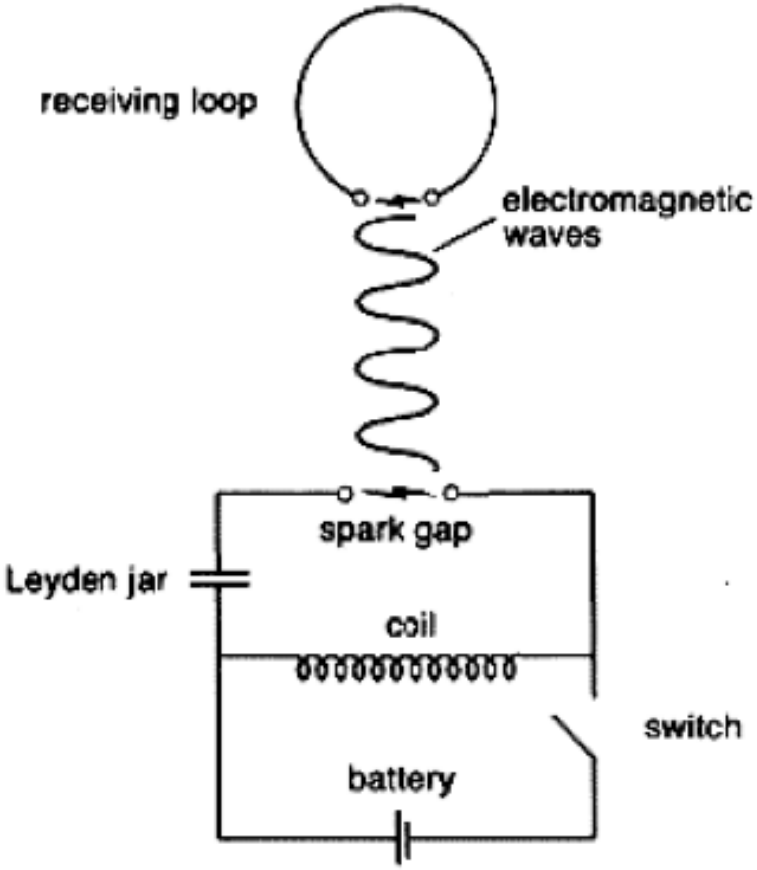
The resulting combination is called an electromagnetic field (or electromagnetic radiation, EMR).

Animation

Heinrich Hertz

- **Designed an experiment that verified Maxwell's prediction**
- **A spark (an accelerating charge) is produced by the induction coil.**
- **This is a changing electric field which will create a changing magnetic field….in other words an electromagnetic wave. It is detected by the loop receiver.**

Set Up


receiving loop
electromagnetic
waves
spark gap
Leyden jar
coil
switch
battery

Properties of EMR Waves

- any charged accelerated object (like an electron) also produces an EM wave.

- The propagation of the wave is in the same direction as the acceleration of the particle.

- EMR waves travel at the speed of light (as we will see, light is EMR)
- EMR waves don't need a medium to propagate through (they can go through empty space)

- **The electric field is always perpendicular to the magnetic field.**
- **Both are perpendicular to the direction of propagation (movement) of the wave.**
- **Follows the equation**

$$\vec{v} = f\lambda$$

The Universal Wave Equation

Where:

v = velocity (m/s)

f = frequency (s^{-1} or Hz)

λ = wavelength (lambda) (m)

Frequency

Frequency (f) is related to period (T) by the eqn:

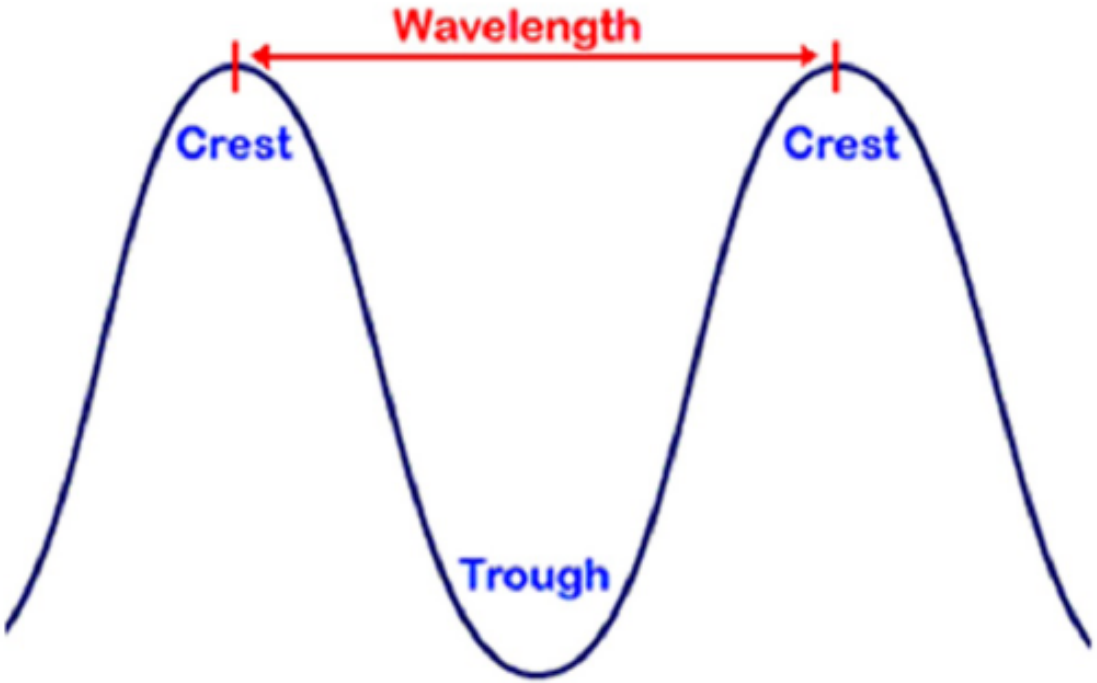
$$f = \frac{1}{T}$$

- Period is the time it takes to make one cycle of a movement (a circle, a back and forth movement, etc.)

- Frequency is the number of cycles that occur in one second (the unit of f is s^{-1} or a Hz).

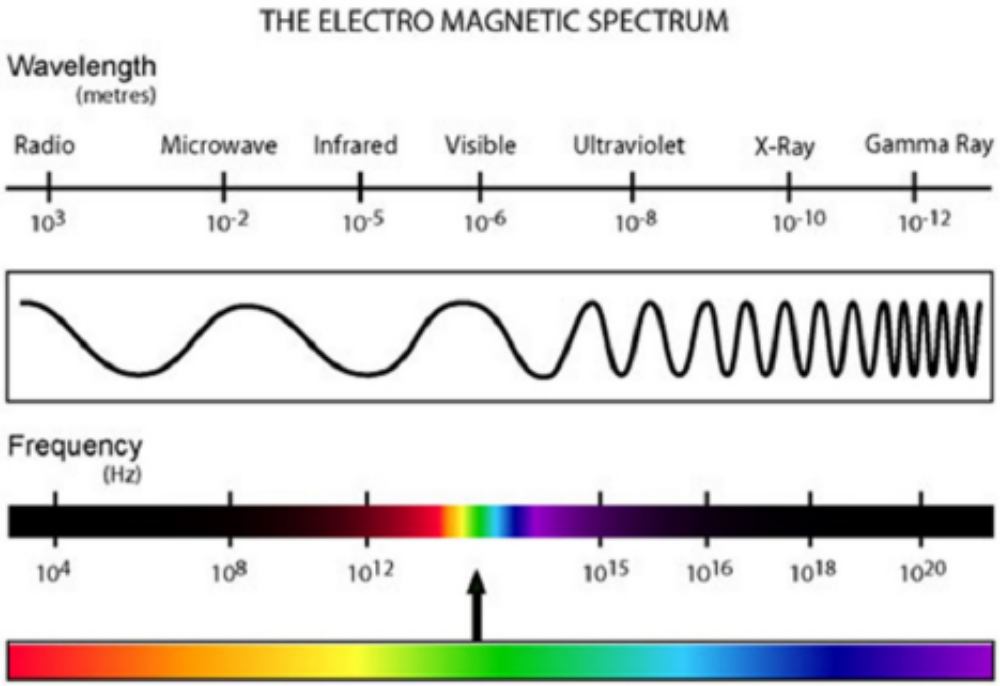
Wavelength

✦**Literally, the length (in m) between consecutive peaks or troughs in a wave.**



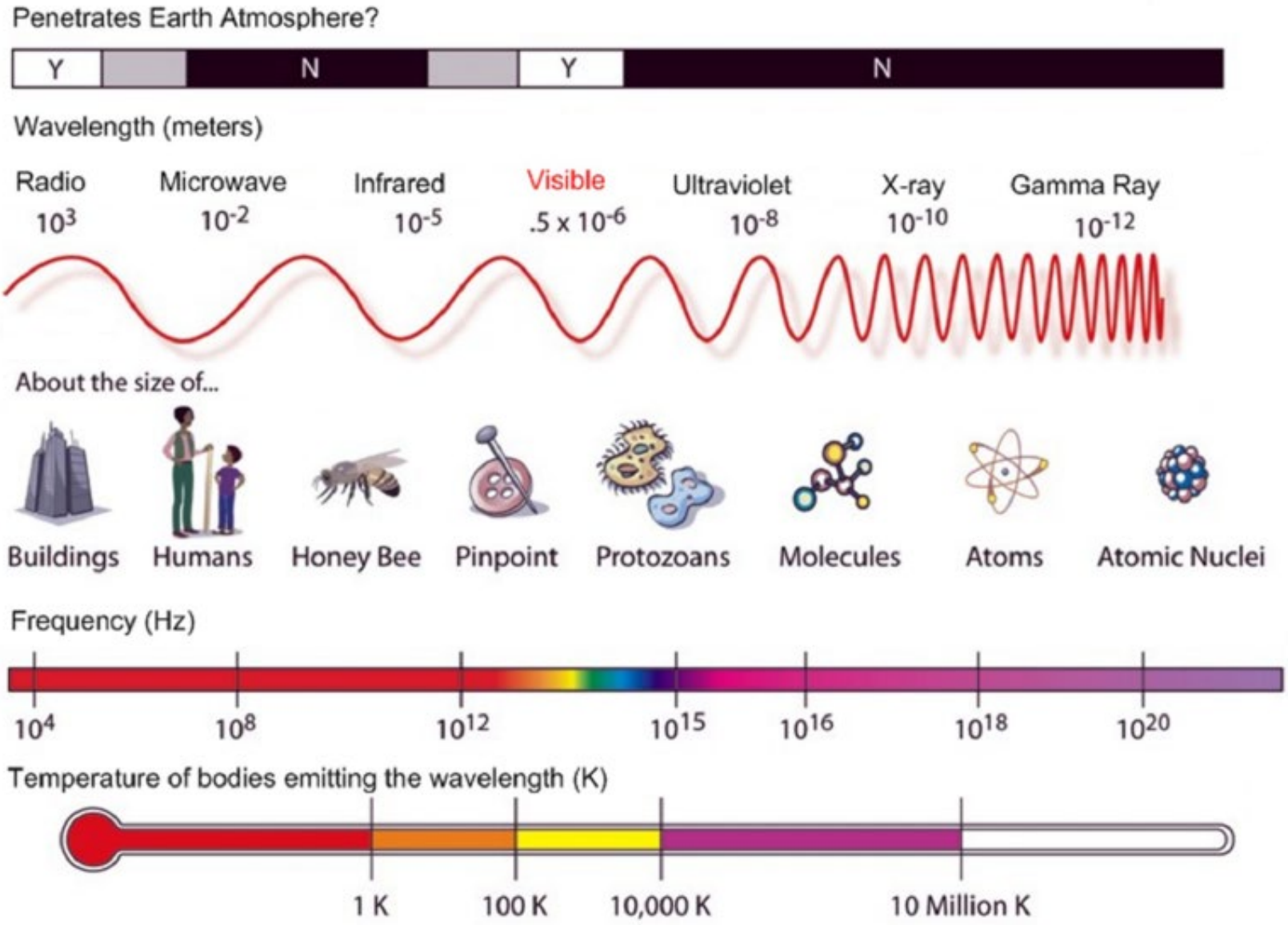
EM Spectrum

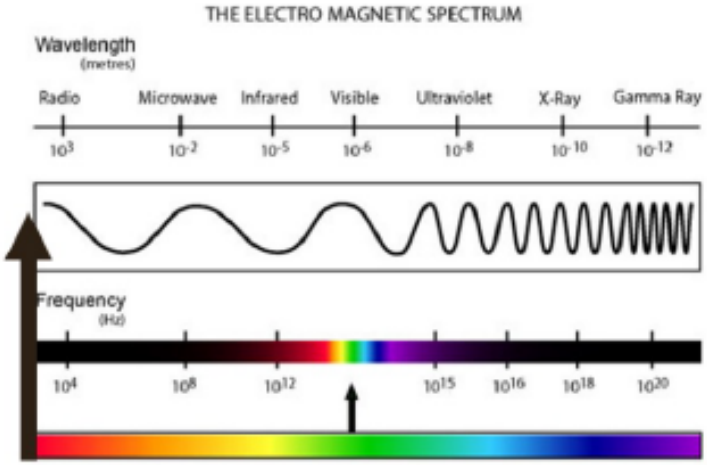
- **You may know some parts of the EM spectrum…let's review:**



Descriptions can be found on page 638 of your Pearson textbook.

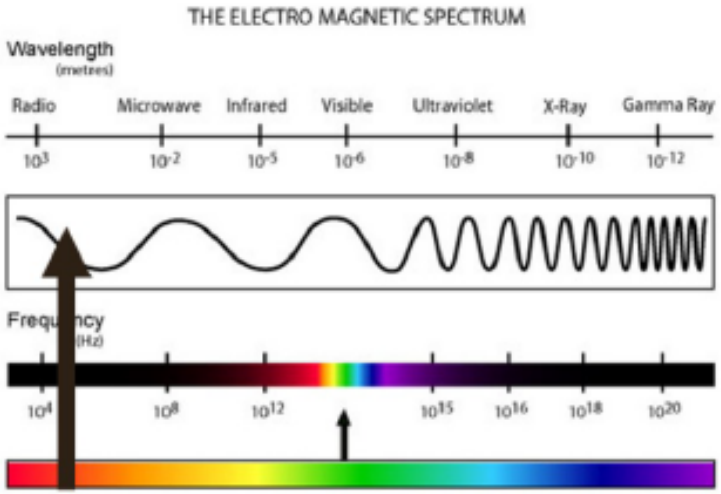
The Electromagnetic Spectrum





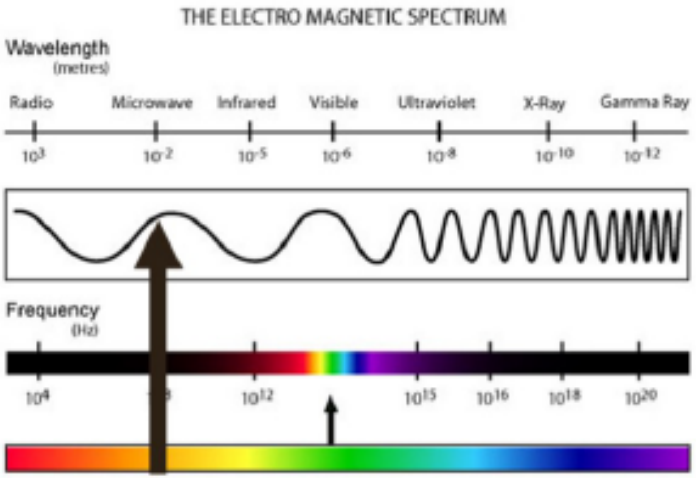
Low freq. AC

- **Produced by household appliances (vacuums, CD player, etc)**
- **Can interfere with cordless phones radios, guitar amplifiers.**
- **About 100 Mm in λ**



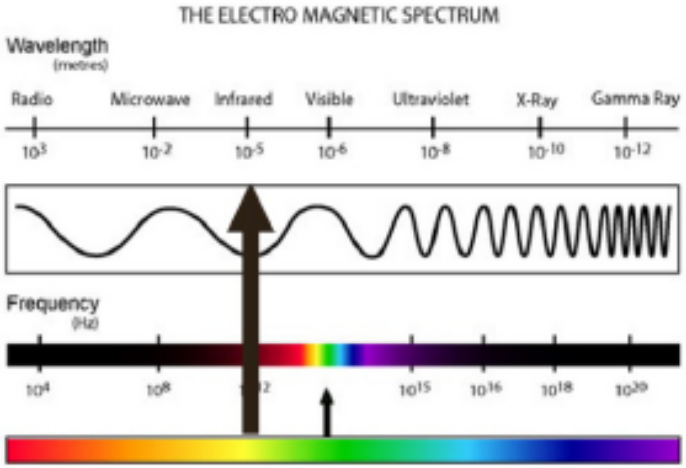
AM/FM TV/Radar

- Used most often in technology because they are easy to create .
- Used in Cell phones, cordless or wireless everything, TV, radio...etc
- 100 km - 10 m
- Produced by electric oscillator circuits



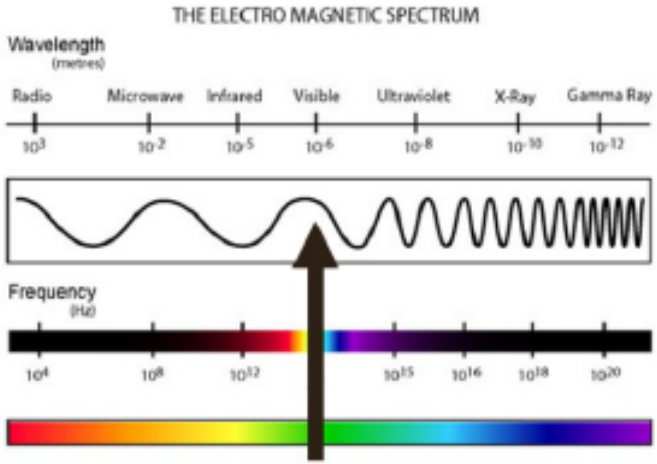
Microwaves

- Used to cook food, communication.
- About 1m - 1 cm
- Produced by electron tubes.



Infrared

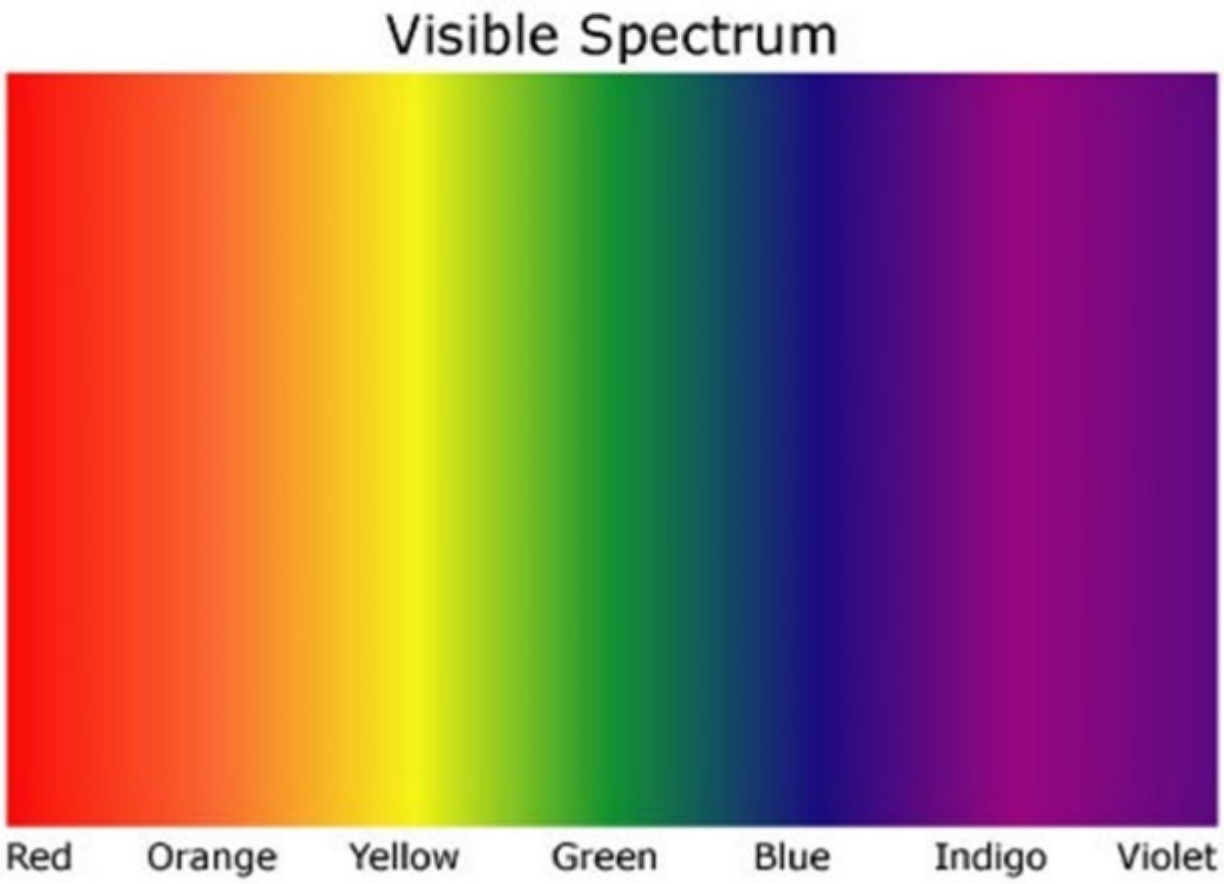
- Used in infrared heaters (in feedlots, to keep fries warm at McDonalds)
- Infrared goggles can be used to see in the dark.
- 1 cm - 1 micrometre (10^{-6})
- Produced by the motion of particles in an object (heat)

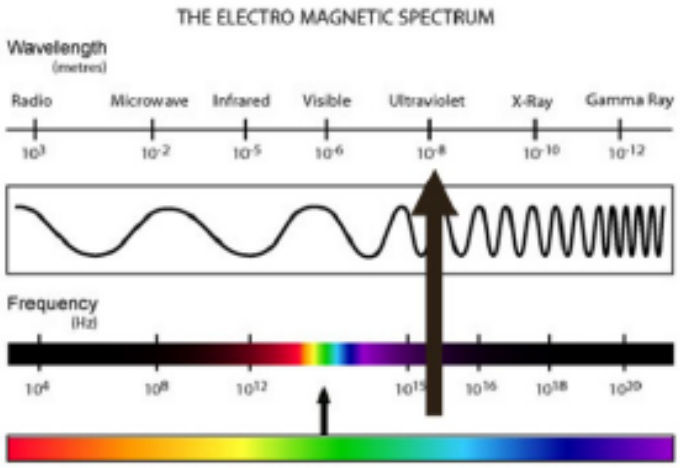


Visible

- **Red has highest wavelength, lowest freq.**
- **Violet has the lowest wavelength, highest freq.**
- **Remember ROY G BIV**
- **About 1000 nm in λ**
- **Produced by hot objects where valance electrons jump down in energy levels.**

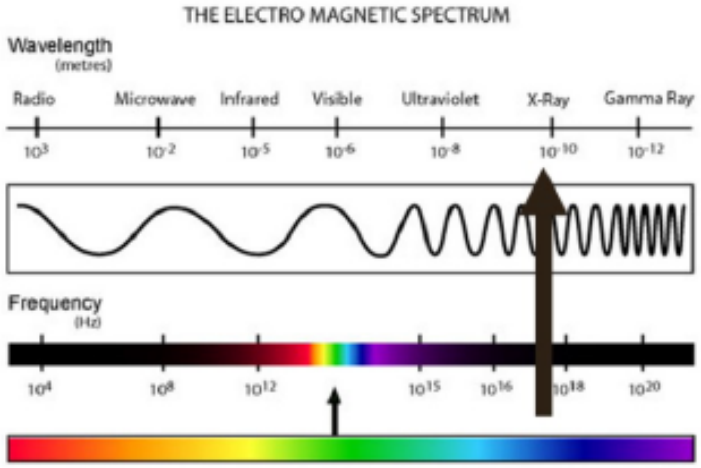
The Visible Spectrum





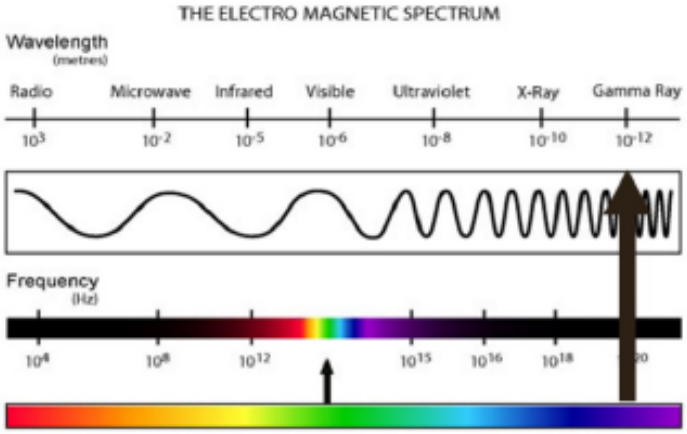
Ultraviolet

- **UV radiation produces tanned look in skin and creates vitamin D in the body.**
- **Also causes skin cancer.**
- **About 100 nm - 10 nm**
- **Produced by valence electrons jumping down in energy levels.**



X-Rays

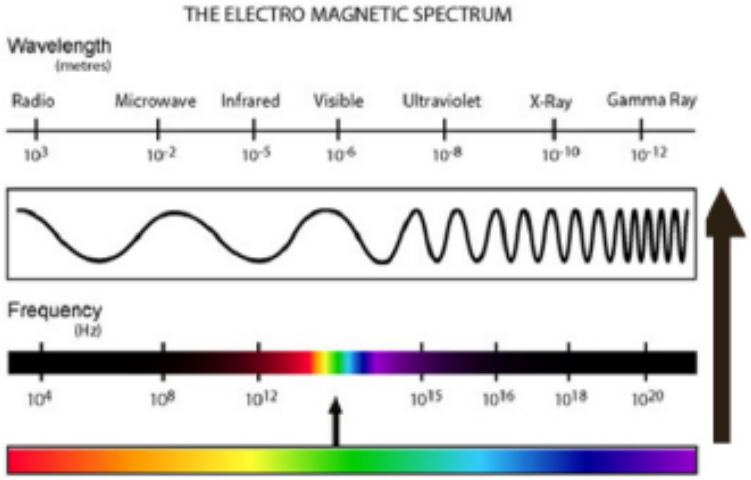
- **Because of their lower wavelength, they can penetrate less dense materials (like flesh), but not more dense materials (like bone)**
- **About 10 nm - 1Å**
- **Produced by sudden deceleration of electrons.**



Gamma Rays

- Used in Radiation therapy to treat cancer patients.
- Are formed in nuclear reactions

- About 1Å - 1×10^{-5} Å
- Produced by nuclear decay.



Cosmic Rays

- Very dangerous to living things.
- Created when high energy particles hit the earth's atmosphere.
- About 1 x 10^{-5} Å and smaller.