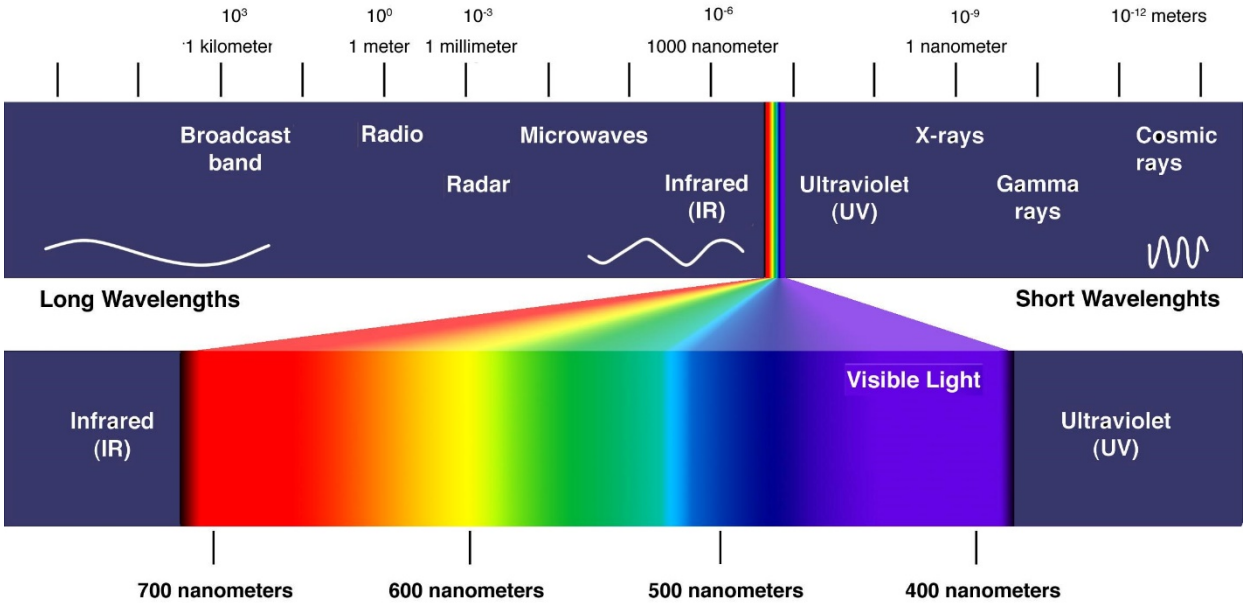
Physical Science – Q2T4 – Electromagnetic Waves

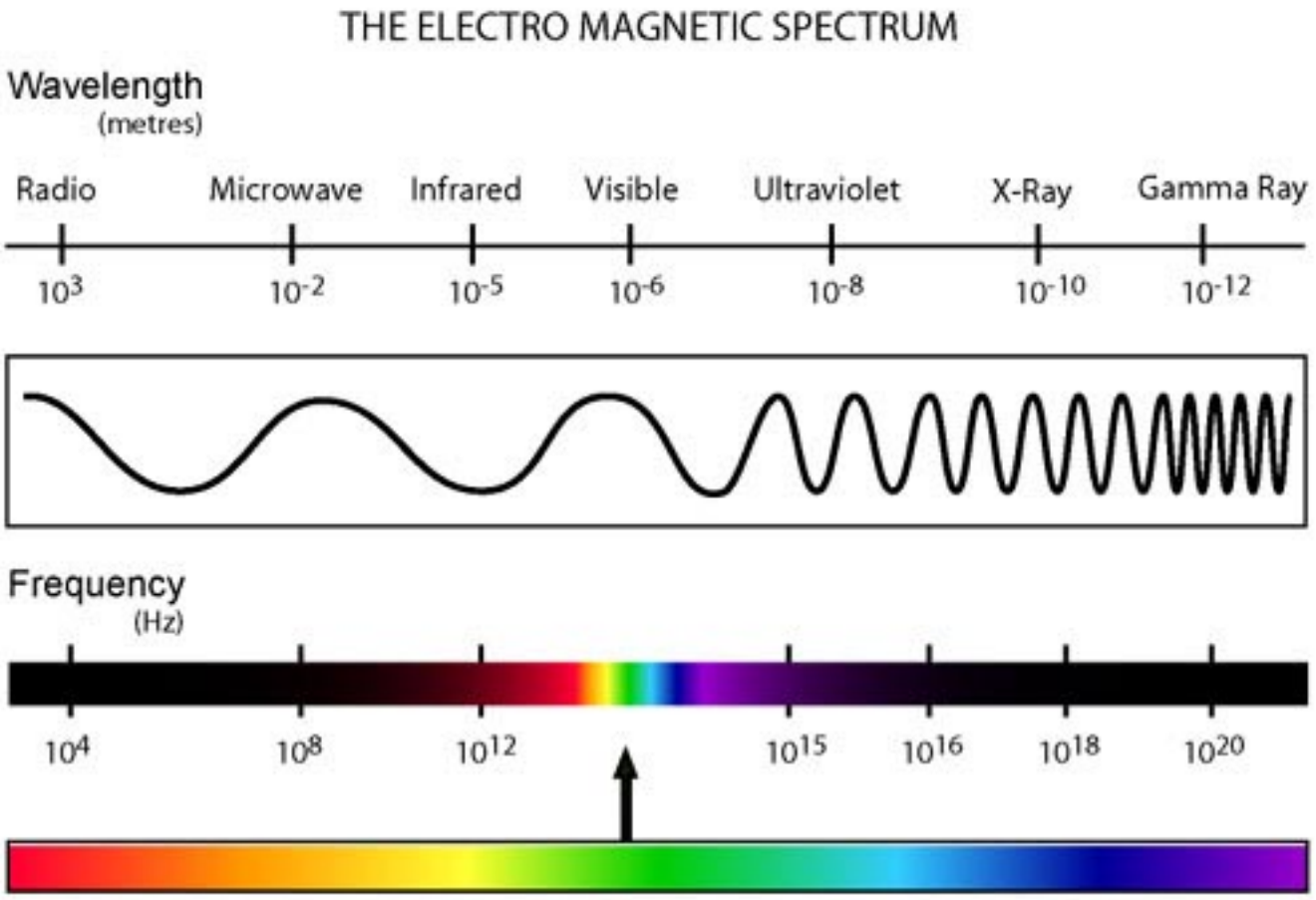
- Electromagnetic waves do not require a medium and can travel through empty space (a vacuum).
- The speed of all electromagnetic waves through a vacuum is 299792458 m/s. The "speed of light" refers to the speed through a vacuum and is designated by the **lower case** letter 'c'.
- When electromagnetic waves pass through a medium, their speed is lower than through a vacuum.
- The frequency of the wave does not change. The wavelength is shorter in a medium in which it moves more slowly.
- The bending (refraction) of electromagnetic waves is a result of the change in wavelength.
- Because the speed of light is a constant, it is easy to determine the frequency from the wavelength (in a vacuum) and the wavelength (in a vacuum) from the frequency.

- $\boxed{v = f\lambda}$, therefore: $\boxed{c = f\lambda}$ and from that: $\boxed{f = \frac{c}{\lambda}}$ and $\boxed{\lambda = \frac{c}{f}}$.
- Electromagnetic waves do not have amplitude.
- The energy content of an electromagnetic wave is directly proportional to its frequency.
- Electromagnetic waves are generally classified according to wavelength (in a vacuum)



- One of the lowest energy (frequency) EM waves that concern humans is electrical power. When electrical energy moves through wires, EM waves of the same frequency are generated around the wire. The frequency of the American power system is 60 Hz which generates EM waves with a length of 5.00×10^6 m. Power frequencies vary around the world. Europe uses a frequency of 50 Hz whose wavelength is 6.00×10^6 m.
- Most countries use either 50 Hz or 60 Hz.

- Radio stations are listed by frequency such as 102.1 MHz (WIOQ). This station's broadcast has a wavelength (in a vacuum) of 2.94 m.
- Wireless phones and WIFI routers are also categorized by their frequencies.
- Students must always be aware of the fact that the use of frequency and wavelength are interchangeable.
- A band is a range of frequencies within the spectrum.



- Electromagnetic waves are best understood and described as waves when they are travelling from place to place.
- Electromagnetic waves behave most like particles when being emitted or absorbed. Electromagnetic particles are called photons.
- Radio frequencies are used for transmitting information and were classified before it was known that light and higher energy electromagnetic waves are on the same spectrum as radio waves.
- Long, short and micro waves refer to the relative lengths of the waves as compared to one another.
- Visible light, x–rays, gamma and cosmic rays all have wavelengths much smaller than the shortest of the radio waves.
- Microwaves are used for cell phone communication and for radar which detects objects by the reflection of microwaves. Sonar uses a similar process but the waves used are sound. Ultra–sound imaging also uses mechanical waves but in a range of frequencies that cannot be detected by the human ear.
- A microwave oven heats objects containing water by resonance with the water molecules. Metal containing objects spark and start fires through a different mechanism.
- The visible spectrum is a small band in the electromagnetic spectrum and is characterized by the fact that a ***hypothetical average*** human eye is sensitive to these photons.
- The human eye sends only four distinct kinds of visual information to the brain.
    - The “rods” send only brightness information to the brain and can produce black and white images in very dim lighting.
    - There are three kinds of signals sent to the brain by the “cones”. These are ***red, green*** and ***blue.***
    - The various intensities of the signals sent to the brain as red, green and blue are responsible for the brain’s interpretation of the entire rainbow of colors.

- Mirrors and lenses produce ***images.***
- Images allow us to see objects in places where they are not actually located and in sizes different from their own.
- ***Virtual*** images can be observed only by looking into the device that is producing the image.
- Virtual images are not reversed or inverted and can be larger, smaller or the same size as the object.
- ***Real*** images actually exist at a place and can be seen by putting a screen or another object at the location of the image.
- Real images are inverted and reversed and can be larger, smaller or the same size as the object.
- Real images can be seen only when focused onto a surface or screen of some kind.
- Plane (flat) mirrors produce virtual images that not reversed and are the same size as the object. The focal length of a plane mirror is infinite.
- There are two basic types of lenses although there are several variations.
    - One type of lens is the ***converging*** lens.
        - Converging lenses will focus sunlight at a point and are generally referred to as "magnifying glasses".
        - Converging lenses have **positive focal lengths** and can form ***real*** images of objects.
        - Converging lenses are thicker in the middle than they are at the edges.
        - Objects closer to a converging lens than its focus will form virtual images larger than the object.
        - Objects further from a converging lens than its focus will form real images on the side of the lens opposite the object.
    - The other type of lens is ***diverging***.
        - Diverging lenses will spread sunlight away from a point.
        - Diverging lenses have **negative focal lengths** and **cannot form real images** of real objects.
        - Diverging lenses are thinner in the middle than they are on the edges.
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- The equation used to describe the relationship among the positions of the object, the image and the foci is: $\boxed{\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}}$
  where d_o is the distance of the object from the lens; d_i is the distance of the image from the lens and f is the focal length of the lens.
- The magnification of a lens is the ratio of the image height (h_i) to the object height (h_o).
- The magnification is also equal to the ratio of image distance (d_i) to the object distance (d_o) with the addition of a negative sign to account for the location of the image relative to the object.
  $\boxed{M=\frac{h_i}{h_o}=-\frac{d_i}{d_o}}$
- A magnification greater than one means the image is larger than the object.
- A magnification less than one means the image is smaller than the object.
- In addition to the physical understanding of electromagnetic waves as having both wave and particle characteristics, it is often convenient to consider light as "rays" that travel in straight lines.
- We often draw ***ray diagrams*** to see how light travels through systems of lenses and mirrors.