Lesson 22: Electromagnetic Radiation

Electromagnetic radiation is a way that energy can be transferred.

- It is special in that it is made up of alternating, perpendicular electric and magnetic fields.
- These alternating fields essentially act as transverse waves traveling outwards from their source.
  - That's where the "radiation" part comes from... they ***radiate*** outwards in all directions.

EMR (as **electromagnetic radiation** is often referred to) travels at an incredibly high velocity of 3.00e8m/s.

- The form of EMR that most people easily recognize is visible light, so we often refer to this velocity simply as the speed of light.
- Always remember that this velocity refers to ***all*** forms of EMR, not just visible light.

Although all EMR has the same velocity, the different kinds all have their own distinct **sources**, **frequencies**, and **wavelengths**.

- The different sources all involve **accelerating charges** of some sort, which is the cause of the electric and magnetic fields.
  - The EMR can be detected either...
    - **Directly**, if it travels directly from the source to the observer.
      - e.g. looking at a fire.
    - **Indirectly**, ***reflected*** from a surface or ***transmitted*** through a substance.
      - e.g. visible light from a lamp is ***reflected*** off a page of a book to your eyes.
      - e.g. sunlight is ***transmitted*** through a window,

When we start to look at EMR, we often look at it as a **spectrum**.

- You are already used to looking at the spectrum of visible light, probably by remembering the order of the colors of the rainbow using ROY G BIV.
- Visible light is actually a very small part of the entire EMR spectrum.

EMR Spectrum

The EMR spectrum starts with very low frequencies, and goes up to higher and higher frequencies.

- This means that the wavelengths are getting smaller and smaller.
- This is based on the universal wave equation...

$$v = f\lambda$$

- Since we will always be referring to EMR for these situations, we can replace "v" with the symbol commonly used for the speed of light "c"

$$c = f\lambda$$

Did You Know?
You've already seen the symbol for the speed of light... everyone has! It's in the most famous physics formula of all time: $E = mc^2$

Low Frequency AC

Basically this was the first form of EMR that was created artificially, detected, and studied by Heinrich Hertz based on the work of James Clerk Maxwell (Lesson 24).

- This EMR is very weak and does not transfer much energy
- It is created by low frequency alternating current (AC) running through modern electrical devices.

    - This results in random **static**.
    - You might have noticed warning labels on electronics, especially things with electric motors, about its emissions interfering with radio signals.
        - The government has regulations about how strong the interference of any one electronic device can be.

Radio and Radar

Often it is assumed that radio waves can only be used for AM and FM radio, but this isn't true.

- These frequencies are used by cell phones, cordless phones, and TV signals.
    - Specific government regulations are in place to make sure that signals from different devices don't conflict with each other.
- This EMR is created by electrons vibrating in antennas.

On some radios you might notice that AM stations are shown as kHz, and FM stations as MHz. So a station like 630 CHED is 630 kHz = 630e3 Hz.

Microwaves

Yep, these are the ones you use to cook food.

- The frequency of microwaves made in microwave ovens matches the natural resonant frequency of water (about 2.4 GHz), which causes the food to heat up.
- The microwaves are created by vibrating electrons is special tubes.

They're called "*micro*waves" because as we've been working our way up to higher frequencies the wavelength has been going down.

- We're actually going to deal with wavelengths much smaller than this as we continue, but this is the name that was given to these waves.

Microwaves are also used to send signals over short distances without losing quality.

- This is possible because microwaves can be more carefully "aimed" at their destination.
- Microwaves are sometimes used to send signals like phone calls over distances too short for satellite signals, but too far for wired connections.

Infrared Radiation

If you feel heat from the sun, or while under a heater in the LRT station, you're feeling IR (infrared) radiation.

- IR happens as electrons in the outer part of atoms jiggle around a bit, making jumps in the outer energy levels.
- We can use devices like IR goggles to see an object in the dark by detecting the IR it is giving off.
- IR is also used in devices like remote controls.

Visible Light

This is the classic form of light that can be detected by human eyes.

- **Red**, **Orange**, **Yellow**, **Green**, **Blue**, **Indigo**, and **Violet**… **ROY G BIV**.
- Visible light happens when electrons make big jumps around energy levels in atoms.

- You need to remember that **red** is the lower frequency & big wavelength (**λ = 700nm**), **green** in the middle (**λ = 500nm**), and **violet** at high frequency & small wavelength (**λ = 350nm**).

Ultraviolet Radiation

UV (ultraviolet) is just past violet on the visible spectrum.

- It is created when electrons make even bigger jumps through energy levels.

UV causes tanning in human skin.

- Labels on suntan lotions refer to UVA, UVB, and UVC, the specific frequencies of UV that can have increasingly stronger effects on human tissue.
- The protection the lotion offers is against premature aging or even skin cancer.

You actually need some UV radiation to allow your body to make vitamin D.

- Babies born in the winter are given vitamin D drops to make sure that they are able to grow and develop normally during the shorter days.

X-Rays

X rays are able to pass through less dense materials (like flesh), but can't easily get through dense material (like bones and teeth).

- The x ray machines your doctor uses usually involve shooting electrons at very high speeds at metal plates.

X rays are safe in low doses, but prolonged exposure over a long time can damage cells.

- This is why a dentist steps out of the room when he takes an x-ray, otherwise he'd be exposed to x-rays hundreds of times a day for many years.
- It is also why airline pilots and flight attendants need to take a break from flying every so often.
  - When you're in a plane with less atmosphere above you, you are exposed to x-rays from space.

Gamma Rays

Gamma radiation is created during the radioactive decay of atoms

- This is the dangerous "radiation" you always hear about when talking about nuclear reactors and bombs.
- It is also used as radiation therapy for some types of cancer.

Cosmic Rays

These are the highest frequency, highest energy EMR waves on the EM spectrum.

- They are created when super high energy particles (mostly protons, alpha particles, and some electrons) traveling through space at super high speeds hit Earth's atmosphere.
- In high doses it can be very dangerous to living things, but the common low doses that naturally happen are not dangerous since the EMR can easily pass through matter.
- Of all the EMR types, cosmic rays are the least understood.
  - This is because the energies of the particles hitting the upper atmosphere are sometimes as high as 10^{20} eV. In comparison, even the Large Hadron Collider only gets particles up to about 10^{12} eV.