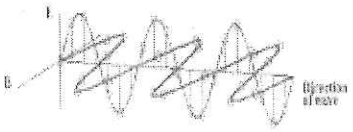
Skill 5: EM Waves

- **Electromagnetic (EM Wave)–** produced by the acceleration (oscillation) of a charged particle. EM waves are able to travel through a vacuum. (A VACUUM IS A SPACE WITHOUT MATTER. OUTER SPACE IS A VACUUM)



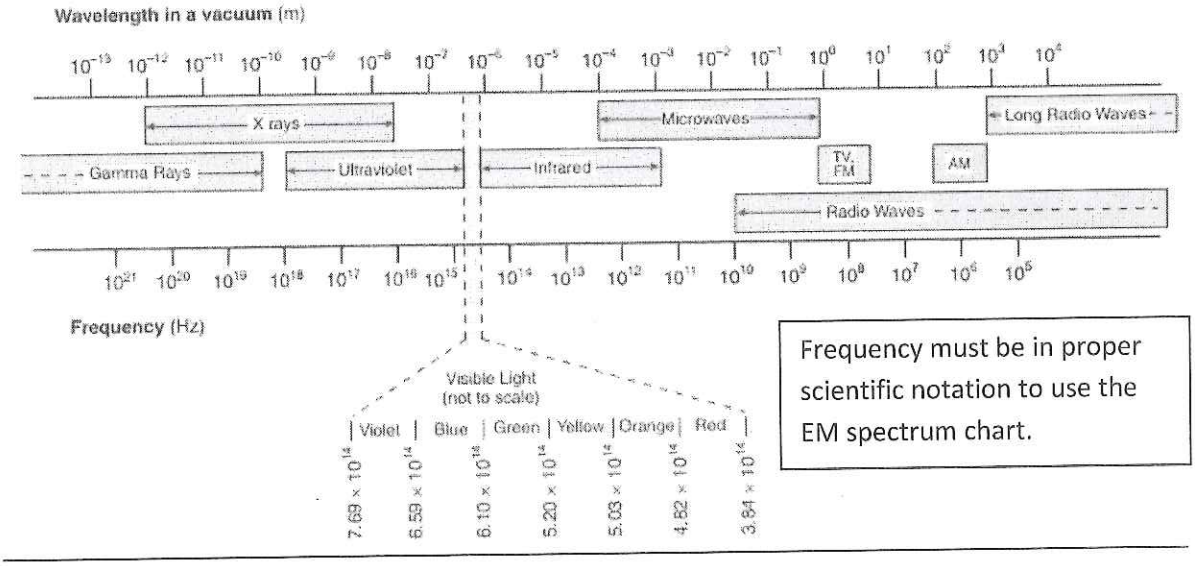
A moving charge has an electric field and also creates a perpendicular magnetic field. This in turn creates an electric field and .....

- Ex: Visible light, radio waves, microwaves, gamma rays, X-rays etc. Categories of EM waves are listed on the EM spectrum.

-They are different due to the frequency of the charge that created the wave

EM SPECTRUM CHART FROM REFERENCE TABLE: VALUES GIVEN FOR A VACUUM, THEREFORE THE SPEED OF EVERY WAVE ON THIS CHART IS 3×10^8 m/s **. If you know wavelength and speed you can find frequency.**

$f = v/\lambda$



Frequency must be in proper scientific notation to use the EM spectrum chart.

- All EM waves move at the same speed in a vacuum. This speed is known as "c" or "the speed of light" which is equal to 3×10^8 m/s

- When an EM wave enters a medium the speed of the wave will depend on the index of refraction "n" of the medium. The speed in the new medium can be calculated using the equation $n = c/v$ which means $v = c/n$

  Index of refraction and speed of EM wave in a medium have an inverse relationship.

- The frequency of an EM does not change if it enters a new medium– frequency comes from the source charge
- Energy of an EM wave is related to the frequency of the wave. (EM waves DO NOT encounter friction so they do not lose amplitude). The greater the frequency the greater the energy of an EM wave. If comparing two waves of the same frequency only then is amplitude considered an indication of energy.
- Amplitude of an EM wave is related to brightness of light.
- EM Waves are photons. They behave as both particles and waves.

- The Frequency of a wave is used to determine the category of EM wave for any wave not in a vacuum or for the specific color of visible light.

new material means new "n" → since "f" is constant "v" must change and "λ" must change with "v" direct

$V = c/n$ inverse (inverse) $V = f\lambda$ direct

Practice:

19. A wave traveling through a vacuum has a wavelength of 100 nm. What type of wave is this?

To use EM spectrum convert to "m" (meters) and put in proper scientific notation

$100nm = 100 \times 10^{-9}m = 1 \times 10^{-7}m$ (low end of 10^{-7} is UV high end of 10^{-7} is visible) so UV

20. A wave traveling through a vacuum has a wavelength of 4.70×10^{-8}m. What type of wave is this?

$V = 3 \times 10^8 m/s$ $\lambda = 4.7 \times 10^{-8}m$ $f = \frac{3 \times 10^8 m/s}{4.7 \times 10^{-8}m} = 6.38 \times 10^{15} Hz$ so UV or X Ray

correct λ 10^{-8} m

you can also find frequency 3×10^{15} Hz

21. A wave has a wavelength of 50×10^{-6}m. What type of wave is this?

$50 \times 10^{-6}m = 5 \times 10^{-5}m$ = Infrared

22. An electromagnetic wave with a wavelength of 5×10^{-9} m is traveling through outer space. (vacuum)

a. What is the speed of this wave? $3 \times 10^8 m/s$

b. Determine the frequency of this wave

$f = V/\lambda = \frac{3 \times 10^8 m/s}{5 \times 10^{-9}m} = 6 \times 10^{16} Hz$

c. In what part of the electromagnetic spectrum is this wave found? X-Ray or UV

23. An electromagnetic wave with a frequency of 6.2×10^{14} Hz is passing through unknown substance that has an index of refraction of 2.4

a. In what part of the electromagnetic spectrum is this wave found? Visible Light → Blue

b. Determine the speed of the wave in this medium.

$V = c/n = \frac{3 \times 10^8 m/s}{2.4} = 1.25 \times 10^8 m/s$

c. Calculate the wavelength of this wave in this medium.

$V = f\lambda$ $\lambda = V/f = \frac{1.25 \times 10^8 m/s}{6.2 \times 10^{14} Hz} = 2 \times 10^{-7}m$

24. Bees have specially adapted eyes that can detect electromagnetic radiation outside of what humans refer to as 'visible light'. Some flowers that bees visit have colorations that are invisible to humans, and yet match this amazing evolutionary development in bees! Bees also use these specially adapted eyes to aid them in navigation when it is cloudy. This type of radiation has a somewhat higher frequency than that of visible light.

What part of the electromagnetic spectrum are these bee eyes able to see?
Ultraviolet

25. An electromagnetic wave traveling through a vacuum has a wavelength of 1.5×10^{-1} meter. What is the period of this electromagnetic wave?
(1) 5.0×10^{-10} s (2) 1.5×10^{-1} s (3) 4.5×10^{7} s (4) 2.0×10^{9} s

$V=\lambda f$ $f=1/T$ so $V=\lambda/T$ $T=\frac{\lambda}{V}=\frac{1.5\times10^{-1}m}{3\times10^{8}m/s}=5\times10^{-10}s$

26. The speed of a ray of light traveling through a substance having an absolute index of refraction of 1.1 is
(1) 1.1×10^{8} m/s (2) 2.7×10^{8} m/s (3) 3.0×10^{8} m/s (4) 3.3×10^{8} m/s $v=c/n$

27. A microwave and an x-ray are traveling in a vacuum. Compared to the wavelength of the microwave, the x-ray has a wavelength that is λ is shorter
(1) longer and a period that is shorter (2) longer and a period that is longer
(3) shorter and a period that is longer (4) shorter and a period that is shorter

$v=f\lambda$ $\lambda=v/f$ inverse $v=\lambda/T$ $\lambda=vT$ direct

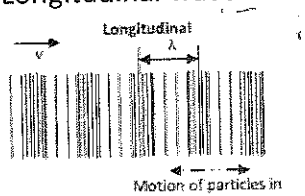
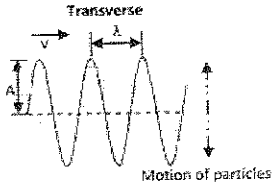
28. Which wavelength is in the infrared range of the electromagnetic spectrum?
(1) 100 nm $1\times10^{-7}m$ (2) 100 mm $1\times10^{-1}m$ (3) 100 m $1\times10^{2}m$ (4) 100 µm $1\times10^{-4}m$

29. To determine the type or category of a wave on the EM spectrum you can use either the wavelength or frequency if traveling in a Vacuum unless it is Visible light. If the wave is traveling through a substance you must solve for frequency, because it does not change when an EM wave enters a new medium.

Radio waves are categorized as EM because they can travel through the vacuum of space. The type of particle vibration for radio waves is transverse which means the particles move perpendicular to the motion of the wave. Visible light (such as Red, Orange..) is similar to a radio wave in type of wave and type of particle vibration but it has a greater energy, a smaller wavelength and a greater frequency. In a vacuum the speed of a radio wave and a visible light are the same (which is 3×10^{8} m/s).

Sound waves are categorized as mechanical because they cannot travel through a vacuum. The type of particle vibration for sound waves is longitudinal. Mechanical waves other than sound can also have transverse particle vibration. The speed of a sound wave in air at STP is 331 m/s. The speed of sound in air is less than water because the particles are less dense.

See IWP #121-188

	Sound Waves	Electromagnetic Waves
What do they do?	Transfer energy	Transfer energy
Where do they come from?	Vibration within a medium. (Sound is a pressure wave)	Vibration (acceleration) of a charged particle. The motion of the charged particle causes the electric field to oscillate. The oscillation of the electric field causes the oscillation of the magnetic field.  EM waves are photons that behave as particles and waves.
Types of Vibration	Longitudinal wave 	Transverse only 
Speed	Speed of sound at STP 3.31 x 10^2m/s	Speed of light (EM waves) in a vacuum 3.0 x 10^8 m/s
How speed changes with medium	Can only move (propagate) through a medium. Speed up with density. CANNOT propagate through a medium	Move at 3 x 10^8 m/s in a vacuum Speed in a medium is inversely related to index of refraction. v=c/n
Energy of a propagating wave is related to...	Amplitude	Frequency
To compare the energy of two different types of wave consider	Amplitude	Frequency
Amplitude is related to...	Loudness	Brightness
Increasing frequency is related to....	Increasing pitch	Increasing energy (See EM spectrum)
Wavelength is the distance	Between two compressions or two rarefactions	Between two crests or two troughs