Properties of Waves, including Light and Sound

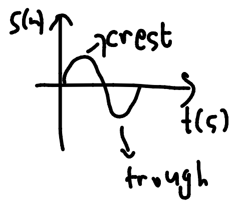
Sunday, October 25, 2020 8:39 PM

3.1:
General Wave Properties

Definitions:
1) Waves transfer energy without transferring matter. These is through periodic oscillations.
2) Wavefronts are the peaks of transverse waves and compressions of longitudinal waves. They lie on the surface and are perpendicular to the wave's direction or velocity.
3) Wave speed refers to the distance travelled by a wave per unit time (m/s)
4) Frequency refers to the number of oscillations per unit time(Hz)
5) Wavelength is the distance between two consecutive crests or troughs(m)
6) Amplitude refers to the maximum displacement from equilibrium(m)

$v = f \times \lambda$

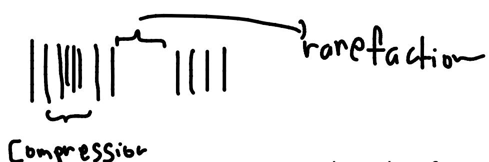
Types of waves:
1) Transverse: Waves with oscillations that are perpendicular to direction of propagation of energy



Eg:- Light; water waves

Wavelength is from crest to crest, **not crest to trough**

2) Longitudinal: Waves with oscillations that are parallel to the propagation of energy



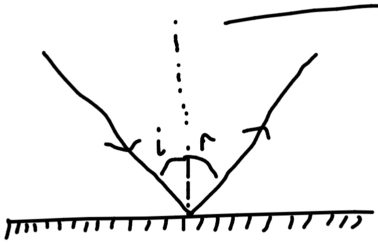
Wavelength is from compression to compression, **not compression to rarefaction**

Compression is a region where its molecules are closest together (high pressure and density) whereas rarefaction is a region where its molecules are furthest apart.

3.2:
Light
Reflection at a plane surface:
Reflection occurs when the wave meets a boundary, object or a change in medium, and is at least partially diverted backwards.

According to Law of Reflection, angle of incidence is equal to angle of reflection is surface is even.

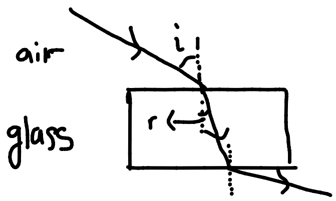
normal is ⊥ to surface



$\angle i = \angle r$

$\boxed{f \text{ and } \lambda = \text{constant}}$

Refraction: Refraction occurs when a wave travels from one medium to another, experiencing a change in velocity. Wave must hit the medium at an angle less than its critical angle (discussed later)



$\angle i \neq \angle r$

An analogy to remember is that more often times than not, people are greedy. When we go from a less dense medium (in this case less 'rich') to a denser medium (rich), the wave bends inwards as it wants get closer to become richer. On the other hand, when travelling from glass to air, it bends away as it wants to travel furthest from being not rich.

$$n(\text{refractive index}) = \frac{\sin i}{\sin r} = \frac{\sin r}{\sin i}$$ → If light is leaving the Block

$$\frac{V_2}{V_1} = \frac{\sin r}{\sin i} = \frac{C_2}{C_1} = \frac{n_1}{n_2}$$

C is the speed of light. Since light travels faster/slower depending the medium, C has different values.

f is constant

Since $T = \frac{1}{f}$, T is constant

V and λ changes

Total Internal Reflection: Occurs when a wave travels from an optically denser medium to a less dense medium and reflects at an angle greater than the critical angle

Critical angle is the incident angle at which the angle of reflection is 90 degrees.

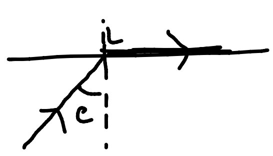
$$\sin C = \frac{n_2}{n_1}$$

$$C = \sin^{-1}\frac{n_2}{n_1}$$

Since max value of sin = 1

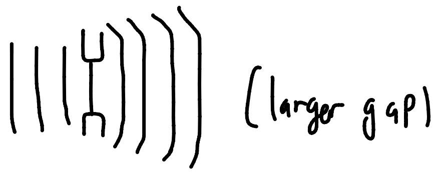
If $\frac{n_2}{n_1} > 1$, there is no critical angle

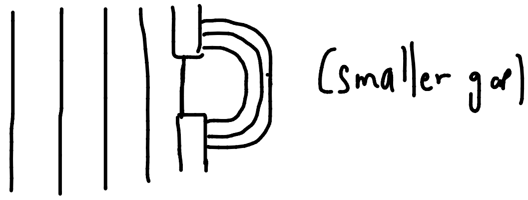
Concept of total internal reflection is used in optical fibers and endoscopy.



Diffraction: Occurs when a wave meets a whole in a wall that is of comparable size to its wavelength. Wave will bend. If hole is much larger than wavelength of much smaller, diffraction is minimal or even non existent.

Diffraction explains why no one every tries to hear a conversation through a keyhole as since wavelength of sound is way greater than keyhole, it cannot bend through the hole and hence, no sound is audible.

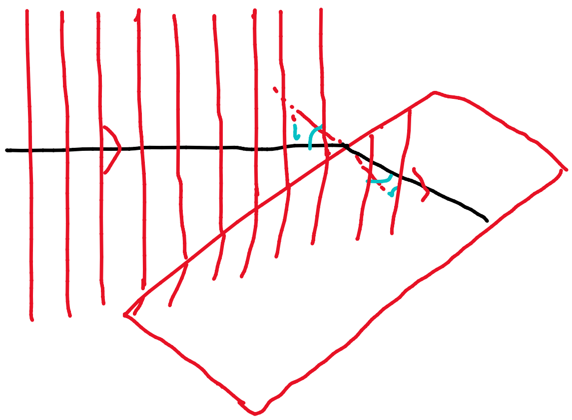




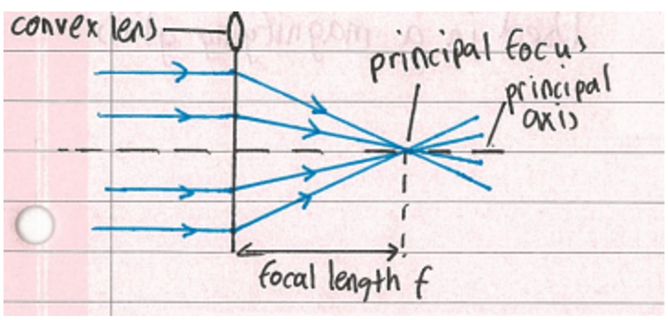
All 3 components remains constant.

Refraction due to a change of speed and depth

1) As water reaches a shallower area, it slows down and bends
2) Speed decreases, wavelength decreases but frequency remains constant

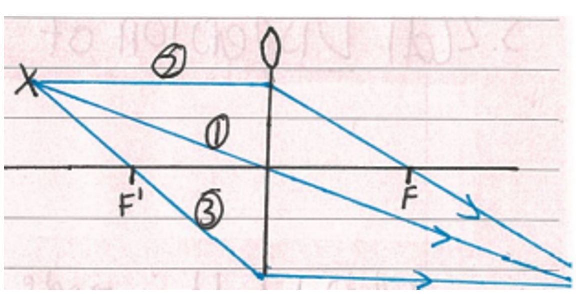


When parallel lights pass though a thin convex converging lens, they are focused to a point called the principal focus.



To draw a ray diagram, they are certain rules to follow:

1) Draw a ray from object through optical center
2) Draw a ray parallel to principal axis and then through principal focus
3) Draw a ray from object to principal focus and then parallel to principal axis



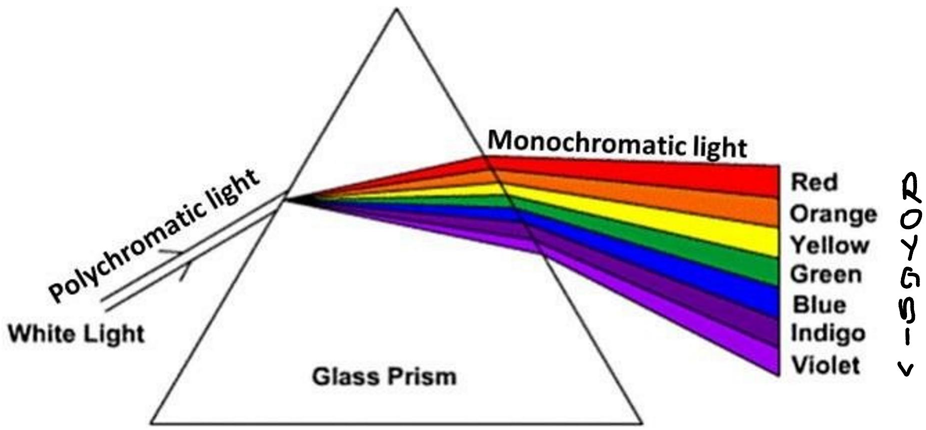
Where lines intersect is where image will form

Formation of real image occurs when object is at one side and image forms in the other side.

If the image is flipped, it is called inverted. If it is larger than object, it is magnified and diminished is vice versa.

Virtual images cannot be projected on a screen (magnifying glass) and real images can(camera and projectors).

Dispersion of Light:



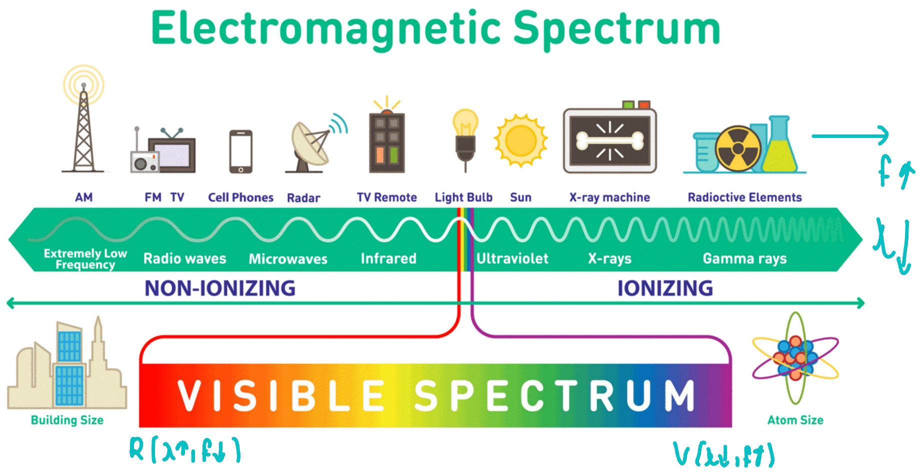
https://www.researchgate.net/figure/Dispersion-of-light-by-the-glass-prism_fig1_337443690

White light is composed of different colors with a range of frequencies. The individuals colors are called monochromatic. As seen from the diagram above, red is first whereas violet is the last. **This tells us valuable information such as the fact that red has the lowest frequency and hence travels the fastest in glass. On the other hand, violet has the highest frequency and hence travels the slowest. This also explains why red refracts the least and violet the most.**

This explains real life scenarios. The reason **why our traffic lights compose of colors on the top of the spectrum is due to this reason.** Since they have lower frequency, their wavelength is longer and hence can be seen afar.

3.3:
Electromagnetic Spectrum

The electromagnetic spectrum consists of different electromagnetic waves. Electromagnetic waves can travel in vacuum at a speed of $3x10^8$ m/s. They travel roughly at the same speed in air. This type of waves carry both electric and magnetic waves.



https://www.defendershield.com/safe-levels-electromagnetic-radiation/

The diagram above consists of information that will be discussed further in future chapters. However, it is crucial to know the arrangement of these waves.

Ray
McDonald
Is
Very
Ugly
Xcept
Gary

f↑
λ↓

↑ ↓
$V = f \times \lambda$
constant

If you realize, the first letters of this mnemonic are the first letter of the waves itself. The order here is crucial. As seen from the diagram, the top of the spectrum, **frequency is the lowest and increases as you go down. We can also hence deduce that wavelength will decrease down the spectrum as velocity is constant for all electromagnetic waves.**

If you notice, there is a region called visible spectrum. This is the colors produced when white light is dispersed. The spectrum agrees with the above said discussion where red light has the longest wavelength and lowest frequency. This is due to the fact that red is above violet in the overall electromagnetic spectrum and we know that as we go down the spectrum, the wavelength decreases and frequency increases.

It is important to understand that ionizing waves should be avoided as much as possible as in the long term, exposure can lead to cancer. This is especially true for gamma and x rays. Ways to reduce exposure when handling these waves is to wear protective clothing and goggles. Lead can be used as the material.

3.4:
Sound

Sound is a type of longitudinal wave. This means that it requires a medium to travel. Its direction of propagation of energy is parallel to its oscillations.

Sound is produced when objects vibrate. When object vibrates, the air molecules also vibrate to form a series of **compressions and rarefactions.** These 2 components have already been discussed above.

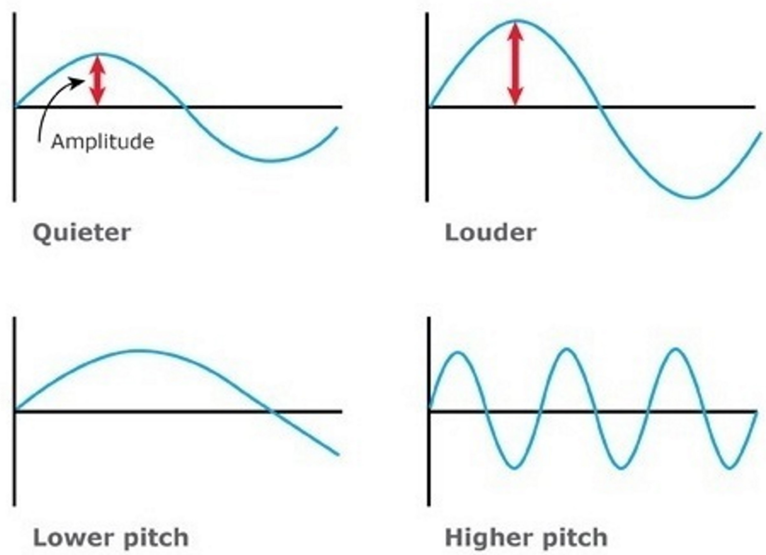
The human ear is able to hear sound ranging from 20Hz to 20000Hz. This is why sounds produced by whales and bats are inaudible as they are ultrasound (higher than 20kHz).

When sound waves hits an object, it can be reflected back to form an echo. This is the basis behind ultrasound imaging and sonar technology.

For understanding only (beyond syllabus): If you are curious about how that works, think about the properties of sound. We know that sound travels 343m/s in air, 1500m/s in water and 5000m/s in solids(generalized speed). Henceforth, when aircrafts emit sound waves and they receive a reflection, they can calculate the distance between the object with respect to the time period that has elapsed.

On the other hand, ultrasound imaging is a bit more complicated. A special gel is spread evenly across the surface of the body. High-frequency sound waves is projected onto the 'gelled' surface with a probe. The probe will then receive reflections. A computer than processes these reflections to form an image. By no means is the image produced colored. Instead, it displays varying intensities. The same concept is used where distance is calculated with respect to speed and time.

With that being said, it is also important to understand that the amplitude of a sound wave determines its loudness and its frequency determines its pitch. The greater the amplitude, the louder the sound. The greater the frequency, the greater its pitch.



https://www.sciencelearn.org.nz/resources/573-measuring-sound