General Properties of Waves

Oscillation of a Particle:

Centre/Undisturbed Position: position of the particle if it were not moving or did not have energy OR the position about which a particle oscillates.

Amplitude: maximum displacement from the center point.

Net Displacement: displacement from the center point.

Oscillation: to-and-fro motion about a center position with zero net displacement.

Speed of the Particle: max at the center & always 0 at end points.

Time Period, T: time taken to complete exactly 1 oscillation.

Frequency, F: the no. of oscillations completed in exactly 1 second $1/t = F$

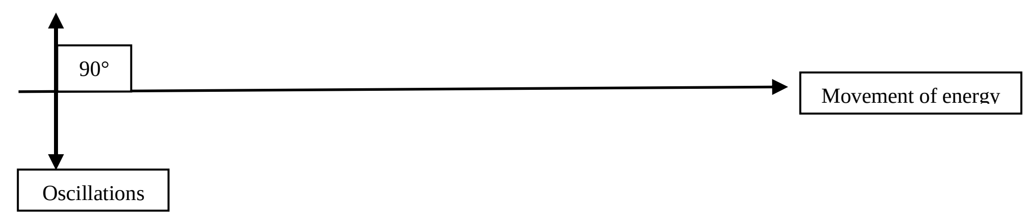
SI Unit: Hertz, Hz

Wave Motion:

- Transfer of energy through a medium.
- Particles of the medium oscillate.
- Medium has no net movement/displacement.

Transverse Wave:

A wave in which the medium oscillates perpendicular to movement of energy.



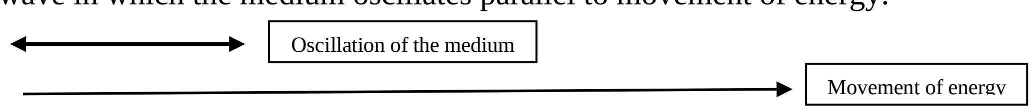
Examples of transverse waves:

- All waves without the word ‘sound’ in its name.
- Earthquake waves (seismic S-waves)

Crests and Troughs: move in the same direction and at the same speed as the energy.

Longitudinal Wave:

A wave in which the medium oscillates parallel to movement of energy.



Examples of Longitudinal waves:

- Any waves with the word ‘sound’ in its name, (sound, ultra-sound)
- Earthquake waves (seismic P-waves)

Compression: a point on the longitudinal wave where the medium is compressed.

Rarefaction: a point on the longitudinal wave where the medium is stretched.

Source is the cause, particles are the effect.

Energy: Source, Direction, Speed:

Source Motion: source oscillates causing particles to oscillate. Source and particles have the same amplitude, time period and frequency.

Representing transverse waves:

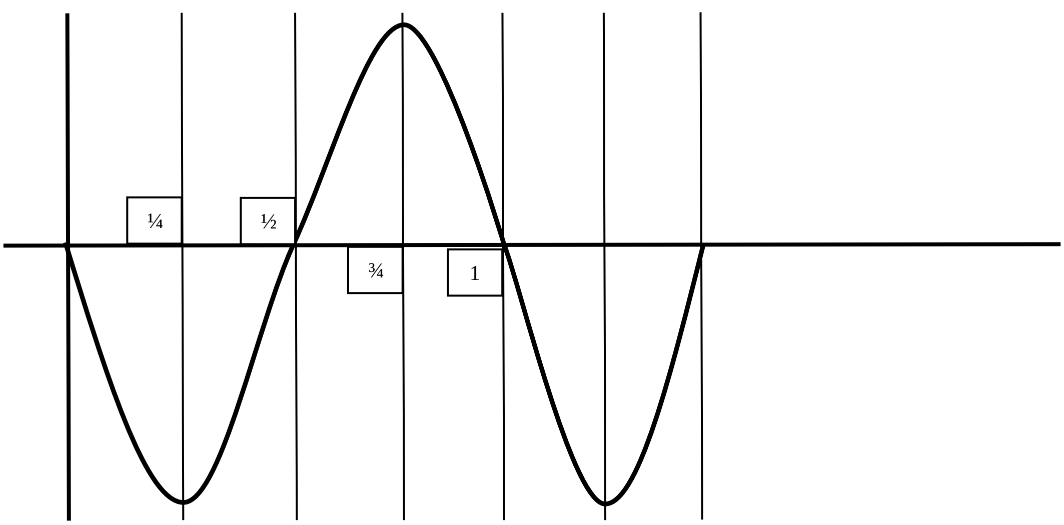
Making an arrow on the source: arrow on the source should be marked in the center. Same as the arrow on the particles.

Representing longitudinal waves:

Making an arrow on the source: arrow on the source should be marked in the center. Same as the arrow on the particles.

Wavelength, λ (Lambda): wavelength is the distance λ travelled by the wave in 1 time (T) period.

SI Unit: Meters, m



To Measure Frequency:

1. Start stop watch & stop after 10 s.
2. Count no. of waves passing through a reference point in 10 s.
3. Frequency = no. of waves/time taken.

4. f is measured in Hz.

Source Frequency: the no. of oscillations made per unit time or in 1 s.

Frequency of a Wave: the no. of waves that pass a given point per unit time or in 1 s.

Formula for Speed of a Wave:

$S = D/T$

$v = \lambda/T$ v is used to represent the velocity of a wave.

$v = f \, . \, \lambda$

Graphs of a Wave:

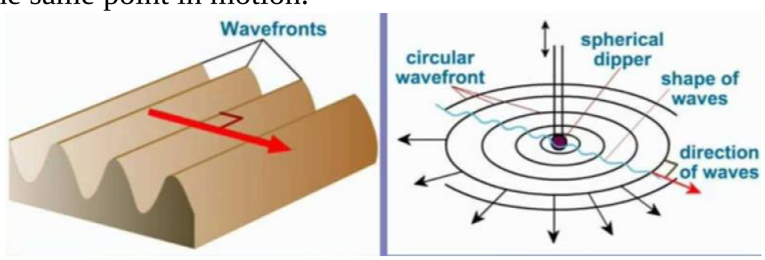
Amplitude versus Distance Graph: same point to same point gives you wavelength, λ. Distance from the center gives you amplitude.

Amplitude versus Time Graph: same point to same point gives you time period, T. Distance from the center gives you amplitude.

Movement of a Wave: the wave doesn't move like snake but rather it just slides forwards.

Wave-front: lines joining points that are the same point in motion.

- Wave-front represents crests.
- Halfway point b/w 2 wave-fronts represents a trough.
- Distance b/w adjacent wave-front is equal to the wavelength.



Only Changes when source frequency changes. Does not change when medium changes

$v = f \, . \, \lambda$

V changes if speed changes.

- If v increases, λ increases (wave-fronts move apart)
- If v decreases, λ decreases (wave-fronts come closer)

Only Changes when medium changes.

When does speed (v) change & how?		
	V More	**V Less**
Water Wave	Deep	Shallow

Light	Vacuum → Air → Water → Glass	
Sound	Solid → Liquid → Gas (No sound in a vacuum)	
String/Rope	Taut (More tension)	Lose (Less tension)

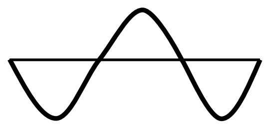
Representing a Wave:

Vacuum is unaffected by:

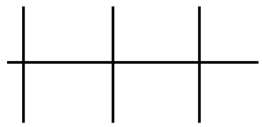
- Electric Field
- Magnetic Field
- Gravitational Field

L … . . … . . …

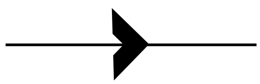
T



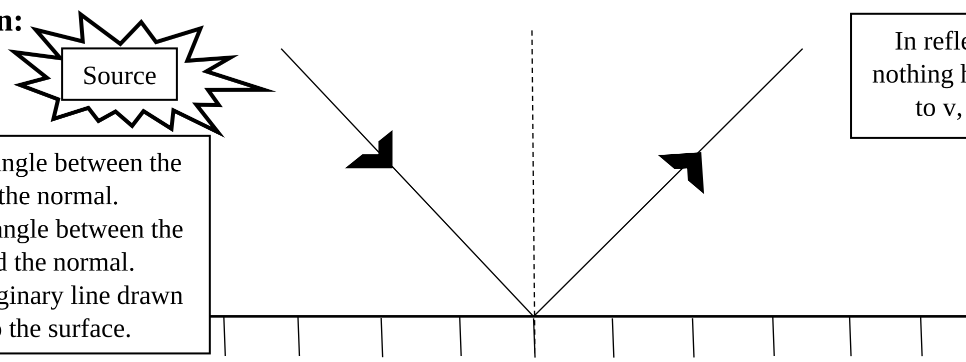
Wave-fronts



Arrows



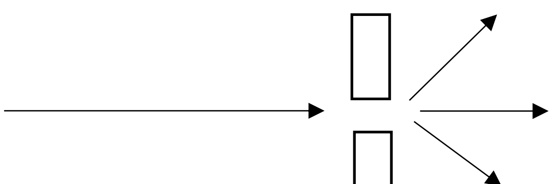
Reflection:



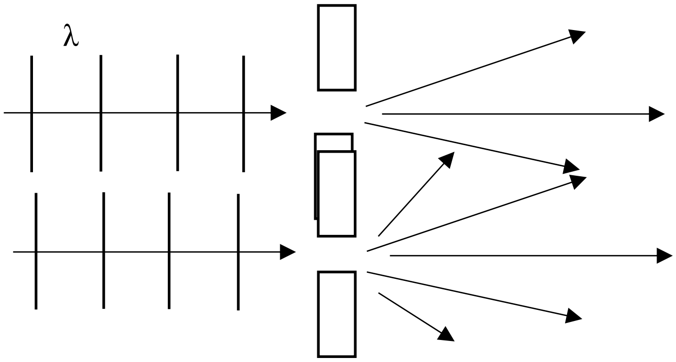
In reflection nothing happens to v, f, x

<u>Angle of i:</u> the angle between the incident ay and the normal.
<u>Angle of r:</u> the angle between the reflected ray and the normal.
<u>Normal:</u> an imaginary line drawn perpendicular to the surface.

Diffraction: it is the spread of a wave when the wave passes through an opening (aperture) or around an obstacle. It is the 1st observable when the wavelength is the same order (power of 10) as the size of the opening (aperture).



In diffraction no change to v, f, λ. This angle is dependent on the comparison between the size of the opening (aperture) & the wavelength.



The smaller the opening (aperture) relative to the wavelength, the greater the diffraction.

$v = f \cdot \lambda$

$f \; 1/\propto \lambda$

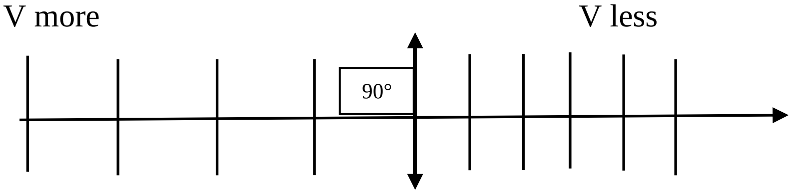
More Wavelength, Less Frequency. Less Wavelength, More Frequency

<u>Degree of Diffraction:</u>

- Diffraction depends upon the relative size of the wavelength λ and the size of the opening (aperture) size of the obstacle.
- Diffraction is the 1st noticeable when the gap size is equal (same order; power of 10) to the wavelength.

Refraction: it is the bending of a wave due to the speed change as a wave crosses from 1 medium to another. Bends towards the normal, the speed decreases, bends away from the normal the speed increases.

V more V less



Medium Changed

Speed Changed

λ to Change

Point where the wavelength hits

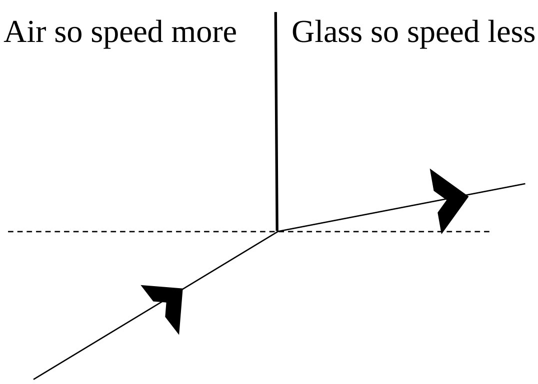
When the wave arrives at i = 0° to the boundary, it doesn't bend, but goes straight through.

IF SPEED IS DECREASED, WAVELENGTH IS DECREASED.

IF SPEED IS INCREASED, WAVELENGTH IS INCREASED.

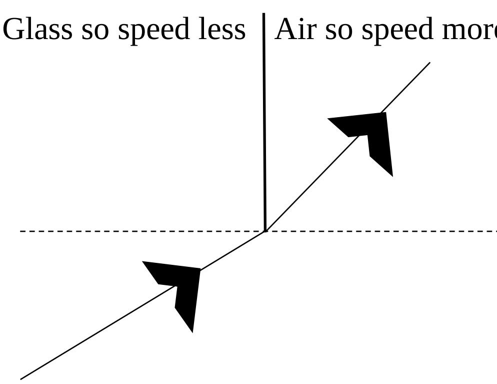
M1 M2

Air so speed more | Glass so speed less



M1 M2

Glass so speed less | Air so speed more



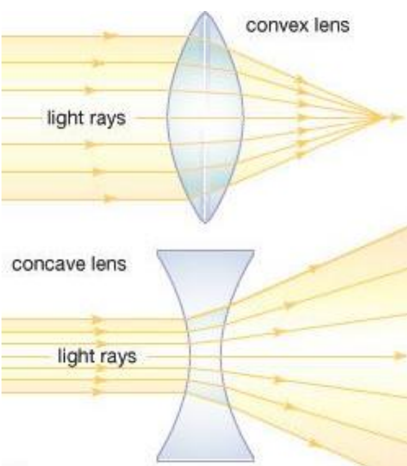
Refractive Index (n): It is the ratio of speed of light in a vacuum to the speed of light in the medium. It is the ration of Sine of the angle° of incidence to the Sine of the angle° of refraction.

- Denser the medium, the greater the refractive index.
- n = sin (i)/sin (r) refraction <u>not</u> reflection

Critical Angle° (c): Angle° of incidence in the denser medium for which the (refracted ray is parallel // to the surface or Angle° of refraction of 90°.)

- Critical Angle° is always in the denser medium.
- n = 1/sin (c)

<u>Refraction due to thin lenses:</u> a lens is a piece of plastic, glass or biological tissue that is transparent and causes light to bend due to refraction.



Representing Light Waves: Beam of light is made of multiple rays.

Parallel Beam:

Converging Beam Coming Together:

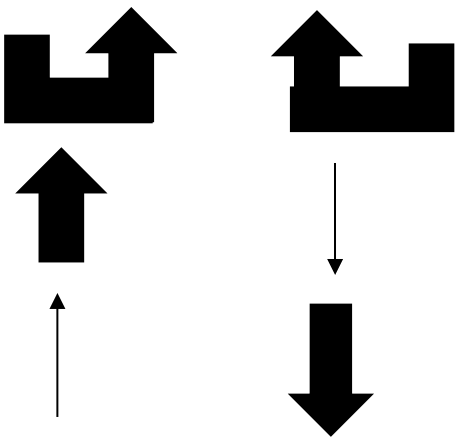
- Width of parallel beam remains the same.
- Width of diverging beam decreases.
- Width of converging beam increases.

Vision and image formation:

- The ability to see is called vision.
- The light rays from the object enter the eye and are refracted by the lens.
- The image of the object is formed where the rays courage.

Image Characteristic:

Object | Image



Upright,
Laterally inverted (left & right swapped)
Same size as the object.

Inverted
Diminished

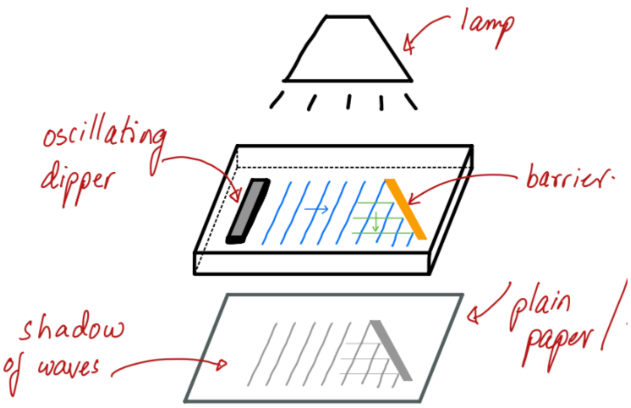
Inverted
Magnified

Reflection in a Mirror: Image in the mirror is as far behind the mirror as the object in front.

Ripple Tank: A water-tank with a glass bottom used to observe wave behavior

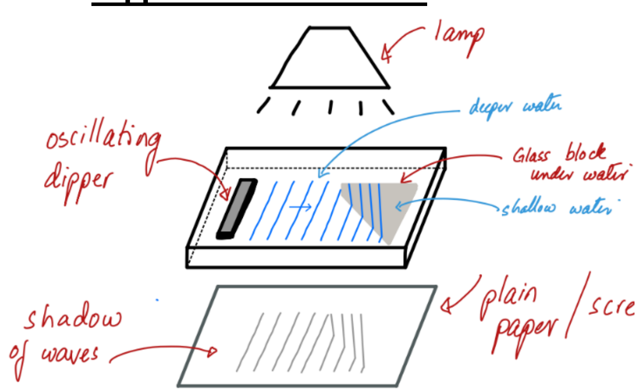
- Oscillating dipper
- Lamp above it
- Plain paper or screen below it to see the reflection of the waves

<u>Ripple Tank Reflection:</u>



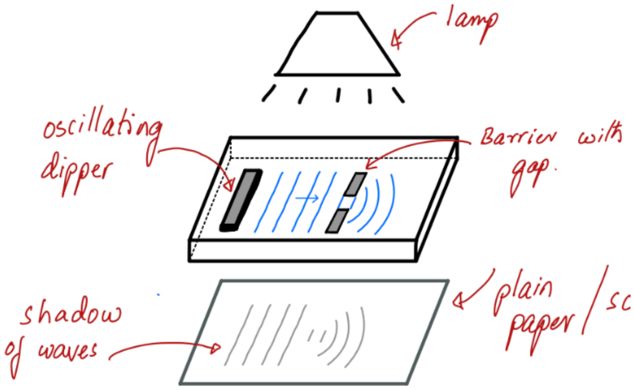
1. Place barrier as shown
2. Turn on dipper & lamp
3. Ripples travel to the barrier and reflect
4. Place screen below the ripple tank to observe reflection

<u>Ripple Tank Refraction:</u>

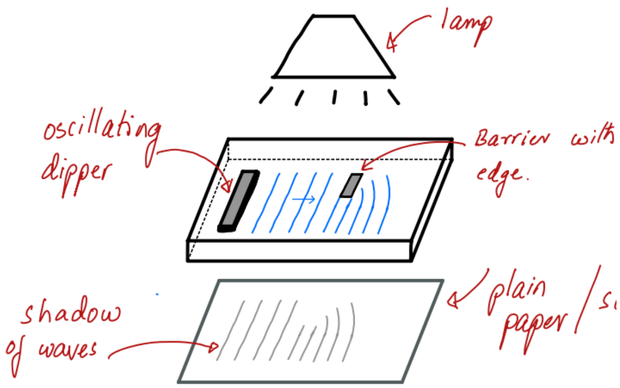


1. Place glass block as shown
2. Turn on dipper & lamp
3. Ripples travel to the glass block boundary and refract in shallow water
4. Place screen below the ripple tank to observe refraction

Ripple Tank Diffraction:



1. Place barrier with gap as shown
2. Turn on dipper & lamp
3. Ripples travel to the gap, pass through it and diffract.
4. Place screen below the ripple tank to observe diffraction



1. Place obstacle as shown
2. Turn on dipper & lamp
3. Ripples travel to the obstacle and diffract at the edge
4. Place screen below the ripple tank to observe diffraction

Magnifying Glass:

- **Lens Used:** converging/convex lens

Q. How is the convex lens used as a magnifying glass? [2]

Ans. Convex Lens is used as a magnifying glass, because the lens is brought close to the object so the object is between the focal point and the optical center (within the focal length)

Q. How is a virtual image formed? [2]

Ans. Virtual Image is formed as the diverging rays are extended backward to meet the lens. Rays appear to be coming from the image.

Real Image: an image in which the rays converge. It can be projected onto a screen (E.g. Camera, photographic magnifier, projector)

Virtual Image: an image in which the rays have to be extended behind the lens/mirror to converge. It cannot be projected onto a screen. (E.g. Mirror image, magnifying glass, image from a diverging/concave lens)

Focal Point: point on the principal axis where the parallel rays converge (convex lens)

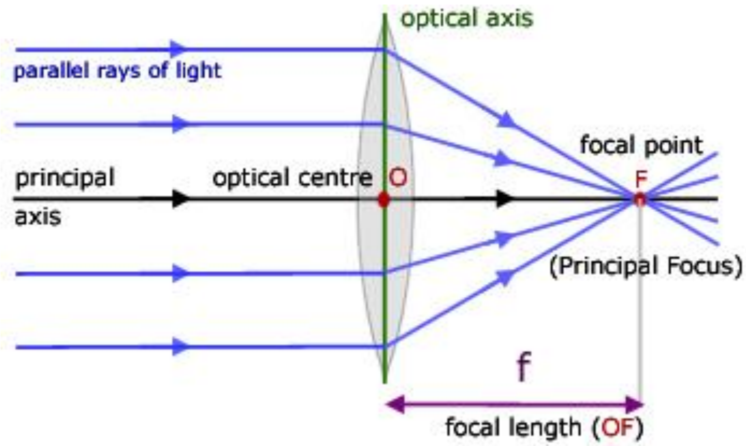
Focal Length: is the distance between the optical center & the focal point.

Optical Center: is the point that lies on the principal axis through which the rays of light pass without any deflection.

Linear Magnification: is the size of the image per size of the object.

- $\frac{\text{Size of image}}{\text{Size of the object}}$

Width of a Beam: draw a parallel beam, 1 inch wide refracting through the lens.



Q. How far away from the optical center does the width of the beam become greater than 1 inch? [2]

Ans. Beyond 2F

Dispersion of Light: is the separation of white light into its constituent colors. It is caused by the change in speed of each wavelength by a different amount

Color Range from:

Red Orange Yellow Green Blue Indigo Violet

ROYGBIV

Or

VIBGYOR

Each color has a unique frequency & wavelength

λ = 400nm

Violet Indigo Blue Green Yellow Orange Red

F ———————————— f

λ ———————————— λ

Q. Write the following colors in ascending order with the highest frequency.

1. **Indigo**
2. **Blue**
3. **Violet**
4. **Green**
5. **Orange**
6. **Red**
7. **Yellow**

Ans. 6 5 7 4 2 1 3

Refraction of Different “Colors” (i.e frequency)

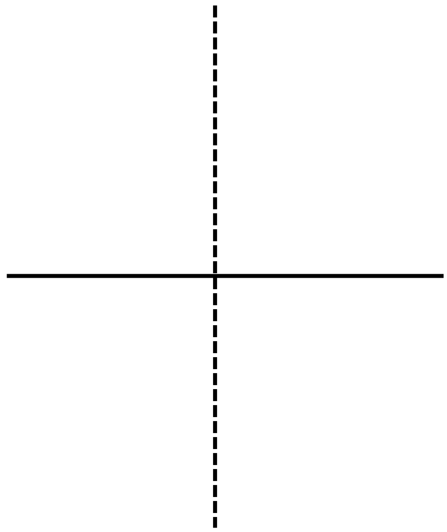
- In a vacuum all colors of light travel at the same speed, (even though they have unique frequencies & λ)
  $C = 3 \times 10^8$ m/s
- But in an optically denser medium, the speed of light is slightly different for each color.
  ↳ A transparent material that allows light to pass through, but is denser than a vacuum. E.g. Air, Water, Plastic, Glass
- When light enters/leaves an optically denser medium it refracts. The amount of refraction depends on the color of light.

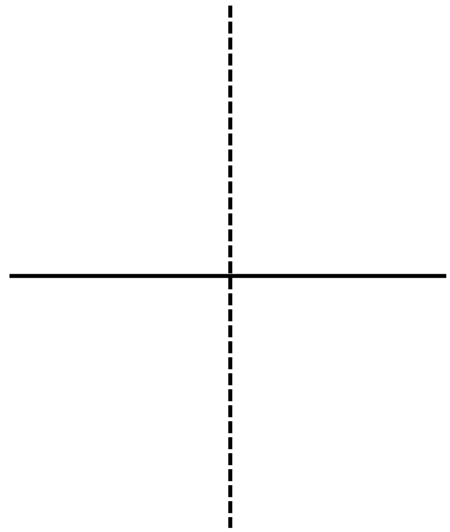
	Frequency	**Wavelength λ**	**Speed in Medium**	**Refraction or Refractive Index**	**Critical Angle°**
R	Lowest	Longest	Fastest	Least	Most
O	Lower	Longer	Faster	Lesser	More
Y	Low	Long	Fast	Less	Much
G	Neutral	Neutral	Medium	Medium	Medium
B	High	Small	Slow	Much	Less
I	Higher	Smaller	Slower	More	Lesser
V	Highest	Smallest	Slowest	Most	Least

Refraction (Refractive Index) $\propto f$

Speed in Medium $\propto 1/f$

Q. Sketch the following Graphs.





Speed of Blue is less. Blue slows down more so its wavelength decreases more wavefronts.

Speed of Red is more. Red slows down less so its wavelength increases less wavefronts.

Q. Two Differences in the diagrams?

1. Blue refracts more.
2. Wave-fronts are close together.

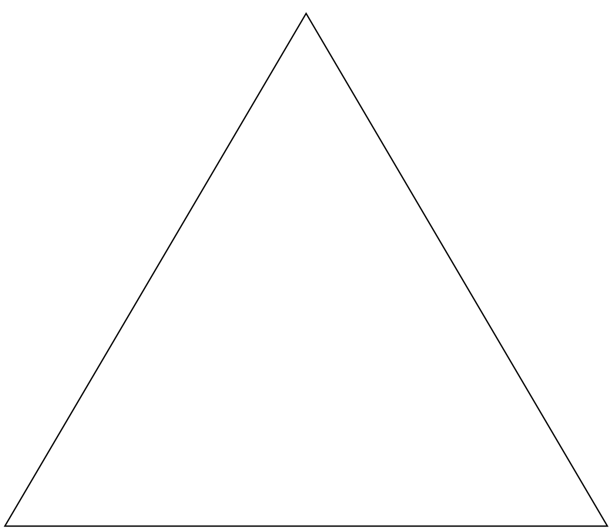
Q. Red and Blue light enter the glass at the same angle of incidence.

a) **Which color will have the greater change in speed?** ______
b) **Which color will have the greater change in wavelength?** ______
c) **Which color will have the closest wave-front?** ______

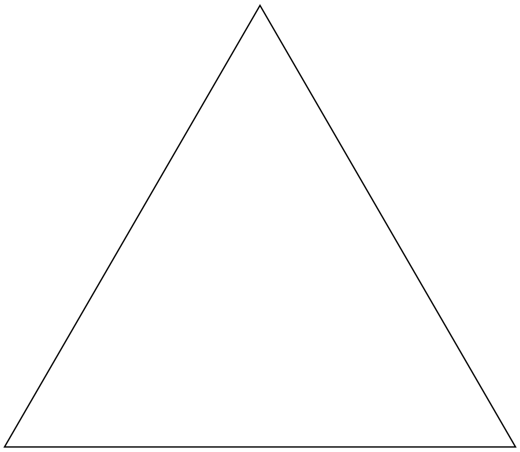
Q. VIBGYOR

i. **Draw the path of Red & Blue light.**

Blue & Red light allows the glass prism at the same point with the same angle° of incidence.



ii. **Draw the path of Red & Blue light.**

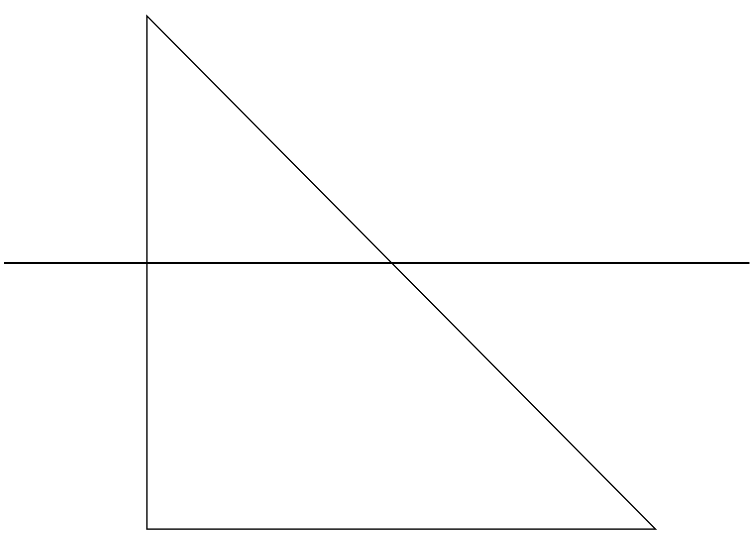


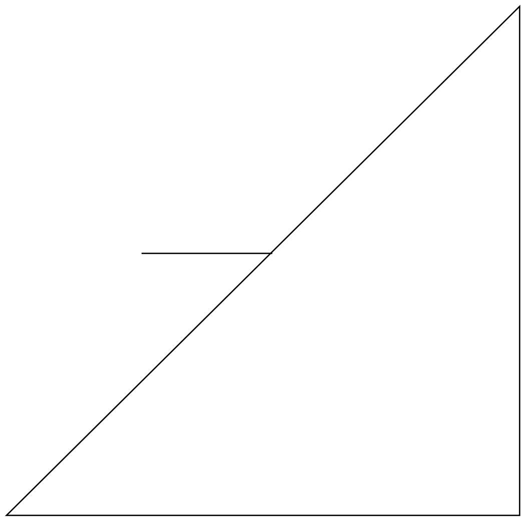
White Light:

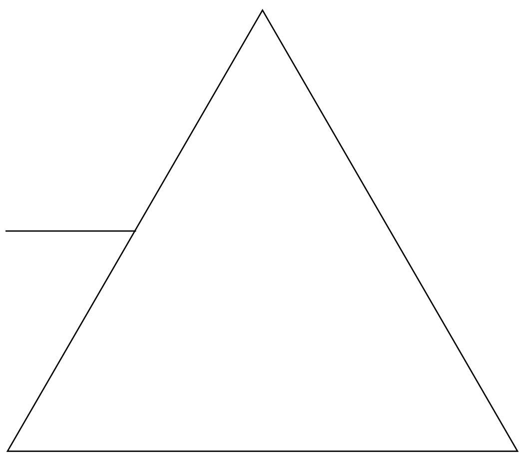
V + I + B + G + Y + O +R = White

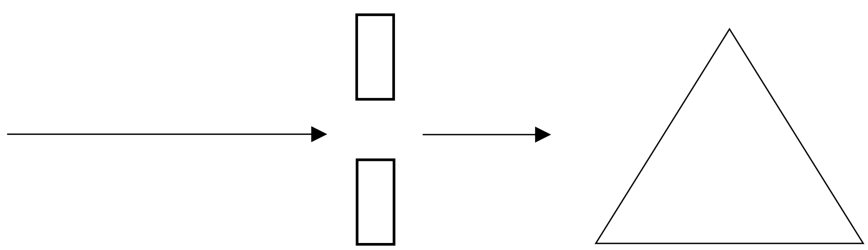
<u>Separation of White Light into a constituent spectrum:</u>

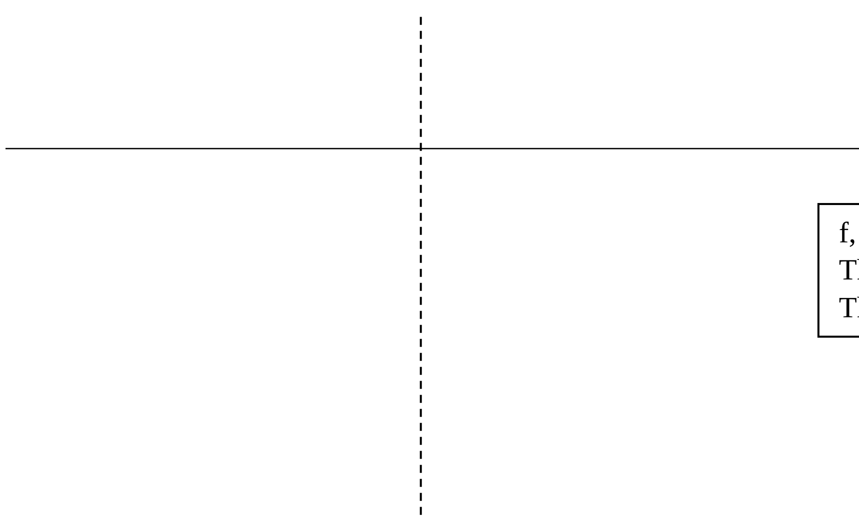
So the light doesn't refract so no spectrum











f, c
The critical angle° is the smallest in violet.
The critical angle° is the largest in red.

Angle° of incidence is greater than the critical angle°, total internal reflection.

$i > c$ Total internal reflection

$i < c$ Refraction

As the torch moves the Angle° of incidence is increased, the spectrum seen on the other side of the glass black gradually, shifts from refraction to total internal reflection. The critical angle° for violet is exceeded first, & that for real is exceeded last.

Sound: sand waves are longitudinal waves that have a frequency between 20 Hz - 20,000 Hz. They require a physical medium.

Ultrasound; a sound wave with a frequency greater the 20,000 Hz.

Infrasound: A sound wave with a frequency less than 20 Hz.

Echo: a sound wave that refracts after a reflection (Both Sound, & ultrasound create an echo)

- Rarefaction: low pressure
- Compression: high pressure

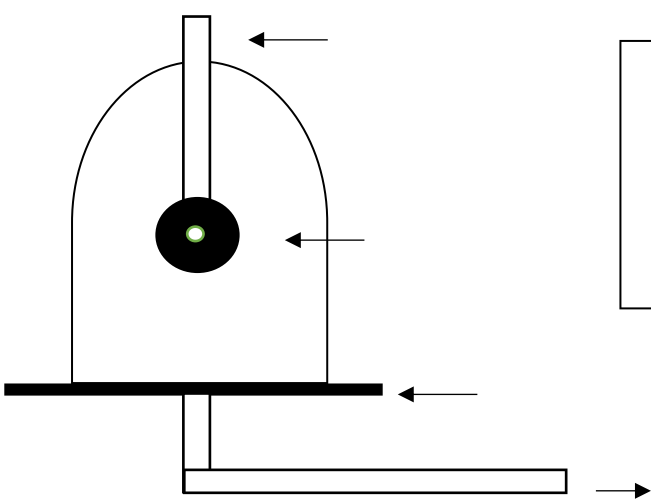
Production of sound by vibrating sources:

1. The source oscillates left & right
2. This causes the molecules adjacent to the source to oscillate in the same direction & with the same frequency & amplitude.
3. The molecules collide with the adjacent molecules & pass on the energy to their neighboring molecules.
4. This sets up a longitudinal sound wave consisting of compressions and rarefactions.

Sound in a Vacuum:

1. Sound requires a physical medium (solid, liquid, gas) to travel.
2. Vacuum does not have any physical medium hence sound cannot travel in a vacuum.

Experiment to demonstrate that sound does not travel in a vacuum:

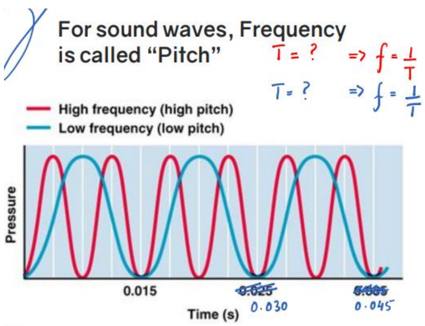


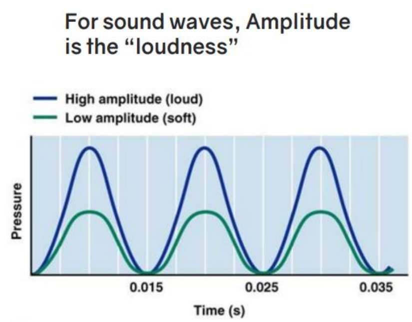
1. Set up the apparatus as shown.
2. Connect the terminal to a battery & observe the sound of the electronic buzzer.
3. Remove the air through the suction pump.
4. The sound will decrease, this confirms that a medium (air) is needed for propagation of sound.

- Some sound is still heard because sound energy travels from the electric buzzer to the bell jar through the physical connection.

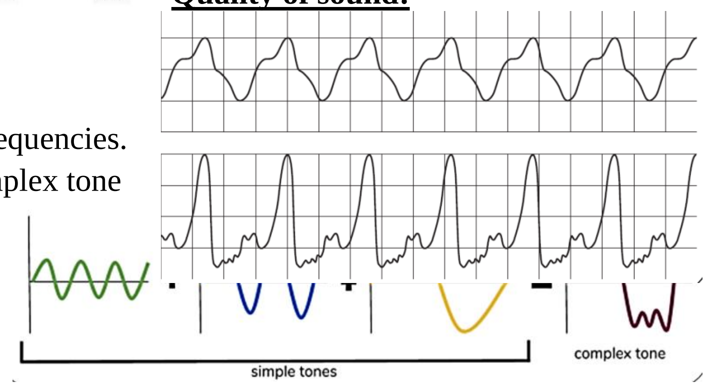
<u>For Sound Waves, Frequency is called Pitch:</u>

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





<u>Quality of sound:</u>



- "Tones" are a form of sound that have a single frequency.
- Most sounds we hear have a combination of frequencies.
- Two sources of sound producing the same complex tone will sound different to us; one will sound better than the other!
- "Timbre " is a perceived quality of sound

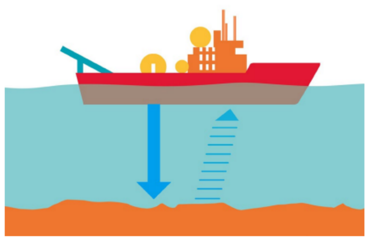
<u>Speed of sound in solids, liquids, gases:</u>

- Sound waves require a physical medium to travel.
- The denser the medium, the faster the speed. Speed in gases ~ x102, liquids ~ x103, solids `x104
- The speed of sound in air is approximately 330–350 ms-1
- If a star explodes in space, only the light (EM wave, can travel in a vacuum) will reach us and not the sound wave (requires a physical medium).

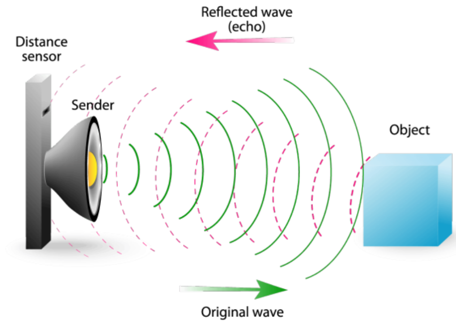
<u>Production of an echo using reflection of sound:</u>

- Sound waves moving away from the source will reflect if they are incident on a surface.
- Reflected sound wave is received back at the **source**.
- The velocity, frequency, and wavelength of the echo is always the same.
- The amplitude of the echo is always less than the initial sound wave because energy is lost during propagation and reflection.

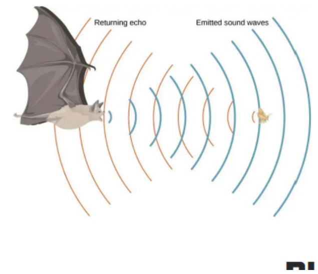
EXAMPLE 1

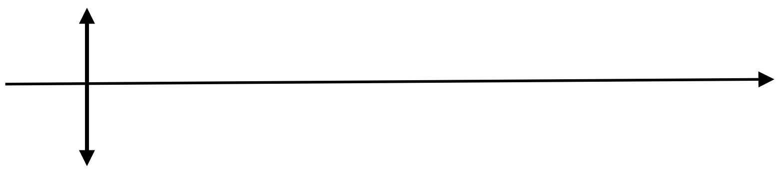


EXAMPLE 2



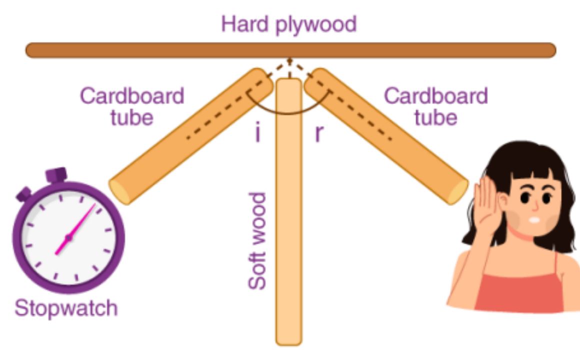
EXAMPLE 3





Experiment to show reflection of sound waves:

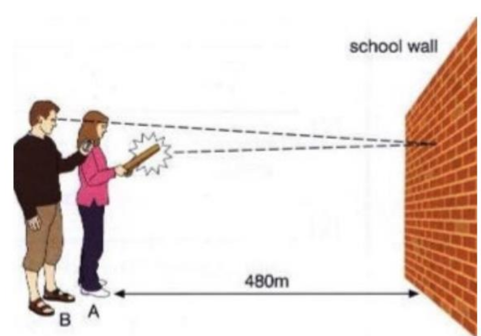
1. Set up the apparatus as shown.
2. Sound waves pass from the clock, into the air and down the cardboard tube.
3. They are reflected at the surface of the hard plywood.
4. If the other cardboard tube is positioned correctly, the sound can be heard by listening at the end of tube B
5. It is found that the angle of incidence, i, is equal to the angle of reflection, r.



- The softwood barrier stops the sound waves from travelling directly from the watch to the ear.
- The hard plywood is needed to ensure a strong echo (least energy loss).

Experiment to determine speed of sound in air:

1. Measure the distance to the wall.
2. One person bangs the two objects together while the other starts a stopwatch simultaneously.
3. The stopwatch is stopped when an echo is heard. The time displayed on the stopwatch is noted.
4. Repeat the experiment two more times and take the average of the recorded time.
5. Calculate the speed of sound using the formula:
   Speed = (2 x distance) / average time



- Experiment is repeated and average value taken to reduce error associated with human reaction time.

Ultrasound and Its Uses:

Range of audible frequencies:

- Normal hearing range: $20Hz - 20{,}000Hz$
- Ultrasound: Greater than $20{,}000Hz$
- Infrasound: Less than $20Hz$

Transmission of ultrasound:

1. The molecules oscillate in the same direction and with the same frequency & amplitude as the source.
2. The molecules collide with their adjacent molecules and pass on the energy to their neighboring molecules.
3. This sets up a longitudinal ultrasound wave consisting of compressions and rarefactions

Use of Ultrasound in cleaning:

- Ultrasound is used in cleaning delicate objects.
  - ➔ The ultrasound energy (non-audible sound waves) is absorbed by any dirt on the surface.
  - ➔ As the dirt absorbs the energy is vibrates at the same high frequency as the wave causing it to break up and fall off.

Use of Ultrasound in pre-natal scanning:

- The transducer emits ultrasound waves that travel through the body and reflect at tissue boundaries.
- The reflected (echo) ultrasound waves are used by the transducer to create a live image.

EM Spectrum:

Radiation	Approximate Wavelength Range/m
Γ- rays	10^{-10} - 10^{-16} & shorter
X – rays	10^{-9} - 10^{-12} & shorter
Ultra - Violet	10^{-7} - 10^{-9}
Visible (ROYGBIV)	$(4 \times 10^{-7}) - (7 \times 10^{-7})$
Infra - Red	10^{-2} - 10^{-6}
Microwaves	10^{-3} - 10^{-1}
Radiowaves	10^{-1} - 10^{-4} & longer

Spectrum is a Range of Waves:

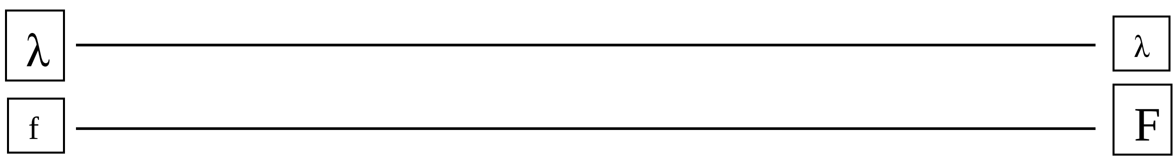
Energy in space is transformed by means of EM waves.

Fields carry energy from the sun to the earth. They are electric & magnetic.

Properties common to all EM Waves:

- All are transverse.

- All travel with the same speed in vacuum (3×10^8).
- All can travel in a vacuum.



Speed of EM Waves= 3×10^8 m/s

Earth → Satellite → Bounces to the other side

Uses of EM Waves:

Radio Waves: • For radio, television communication, astronomy.
Microwaves: • Heating food. • Cellphone, blue-tooth and satellite communication. How it works? Signals are sent from earth to the satellite. The satellite receives the signal, amplifies the signal (b/w energy is dissipated. The signal travels from earth to satellite) & retransferred to the receiver on the earth.
Infrared: • Intruder detection systems: Infrared IR beam is sent from the transmitter to the receiver. The intruder breaks the infrared beam causing the receiver to sound the alarm. • Electrical appliances, remote controllers. • Thermal imaging and Optical Fibers.
Visible Spectrum: • To see things/vision & photography.
UV Rays: • Sun-tan beds & sterilization. • Security marking, detecting counterfeit bank notes.
X-Rays: • Used in medical Imaging, security scanners, detecting cracks in metals.
Gamma Rays: • Cure Cancer, detecting cracks in metals, sterilizing food and medical equipment.

Harm is not only dependent on the frequency but also amplitude of the wave.