4. Wave motion and its Applications

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★ Difference between mechanical waves and non mechanical waves.

Mechanical waves	Non mechanical waves
- Waves required an elastic medium for wave propagation is known as mechanical waves.	- Waves do not need a medium for propogation is known as non mechanical waves.
- Particles of elastic medium take part in the propogation of waves.	- Electric and magnetic vectors take part in propogation of waves.
- Ex. waves in string, sound waves in air and glass, water waves.	- Ex. Electromagnetic waves, light, x-ray.

★ Difference between Transverse wave and longitudinal wave.

Transverse Wave	Longitudinal wave
- The particles of the medium vibrate in the direction perpendicular to the direction of propogation of the wave.	- The particle of the medium vibrate in the direction parallel to the direction of propogation of the wave.
- The wave travels in the form of	- The wave travels in the form of compression

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crest and troughs.	and rarefactions.
- The wave is possible in solid media only.	- The wave is possible in liquids and gases.
- The waves can be polarised.	- The waves can not be polarised.
- light wave, rope wave, water wave	- Sound waves.

★ Relation between Frequency and Periodic Time.

Ans. $f = \frac{1}{T}$

where, f = frequency
T = time

★ Relation between velocity, wavelength and Frequency.

Ans.

Velocity of sound wave = Distance travelled by wave / Periodic time

$\therefore v = \frac{\lambda}{T}$

$\therefore v = \left(\frac{1}{T}\right)\lambda$

$\therefore v = f\lambda \quad \left[\because f = \frac{1}{T}\right]$

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☆ Properties of Sound Waves.

Ans. Sound waves are longitudinal waves.

- A medium is required for sound wave propogation.
- Sound cannot propagate in a vacuum.
- When a sound wave travels from one medium to another its frequency remains constant, but the velocity changes.
- Sound waves can also be absorbed, reflected, refracted, etc. by the surface.

☆ Properties of Light Wave.

Ans. A light ray travels in a straight line.

- The speed of light in a vacuum is 3×10^{8} m/s.
- The speed of light varies in different mediums.
- Light travels in a transperent medium and ~~its~~ meets the surface of another polished opaque medium, the light is reflected back in the same medium.
- When a ray of light is passing through rarer medium to denser medium, the refracted ray bend towards the normal.
- When a ray of white light is passing through the prism it splits up into its constituent colours.

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Wave Equation:-

During the wave propagation, particles of a medium vibrate simple harmonically and have different values of displacements resulting in different positions at different times.

The wave equation is given by / in the following form:

$$Y = A \sin(\omega t + \Psi)$$
$$\therefore Y = A \sin(\omega t \pm kx) \quad [\because \Psi = kx]$$

Y = Displacement of a particle at time t
A = Amplitude
ω = Angular Velocity

→ $\omega = 2\pi f = \frac{2\pi}{T}$

where f = frequency
λ = wavelength

k = wave vector
x = ± Direction of wave propagation
t = Time.

Principle of Superposition of Waves.

Ans. When two waves superpose on each other, the intensity of the resulting wave at any point in the medium is equal to the vector sum of the intensities of the two

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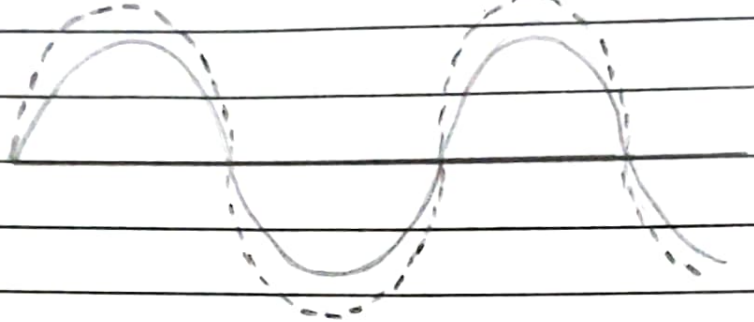
independent waves at the same point.



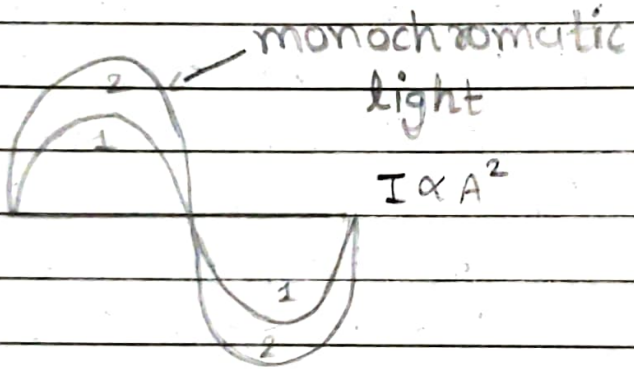
Superposition of waves

☆ Interference of light.

10hrs.

The phenomenom of interference is produced when two waves of monochromatic light is incident on a point.

- As a result amplitude is produced which is different from the original amplitude. The intensity of light is proportional to the square of amplitude of the wave. As a result, the intensity of light is changed due to interference.



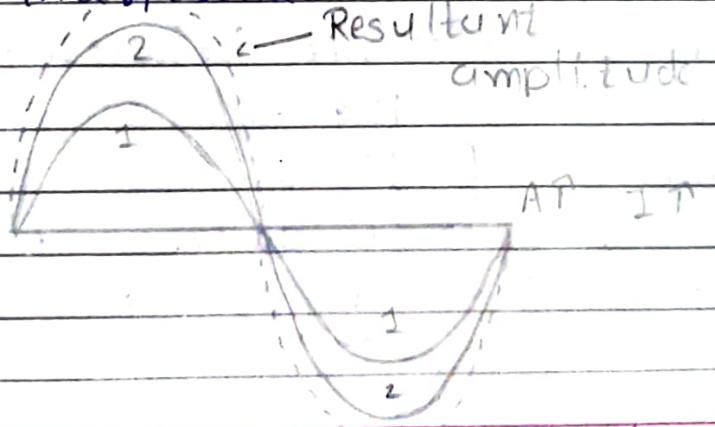
$I \propto A^2$

Interference of light

→ There are two types of interference:

1. Constructive Interference:-

When a crest of one wave is incident on crest of another wave at a point and a trough of one wave is incident on a trough of another wave at a point, the amplitude of the resultant wave increases. As a result intensity of light increases at a given incident point. This type of interference is called constructive interference.



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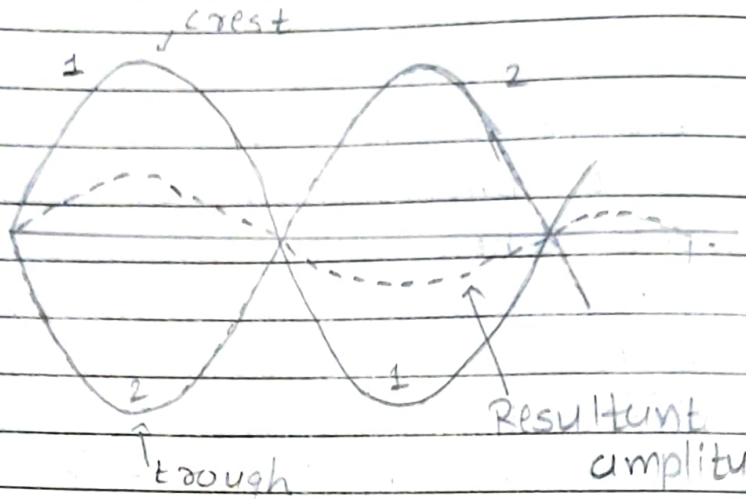
2. Destructive Interference:-



When a crest of one wave is incident on a trough of another wave at the point of incident, the amplitude of the resultant wave decreases. As a result intensity of light decreases. This type of interference is destructive interference.

★ Conditions for Interference

Both sources of light must have the wavelength, the same amplitude and emit continuous waves at the same time.

- The two sources of light should be coherent.
- The two sources of light should be very close to each other.
- The phase difference between the waves generated from the two sources must be zero
- Both sources of light should be narrow, otherwise, a wide source of light behaves as a set of many smaller sources.

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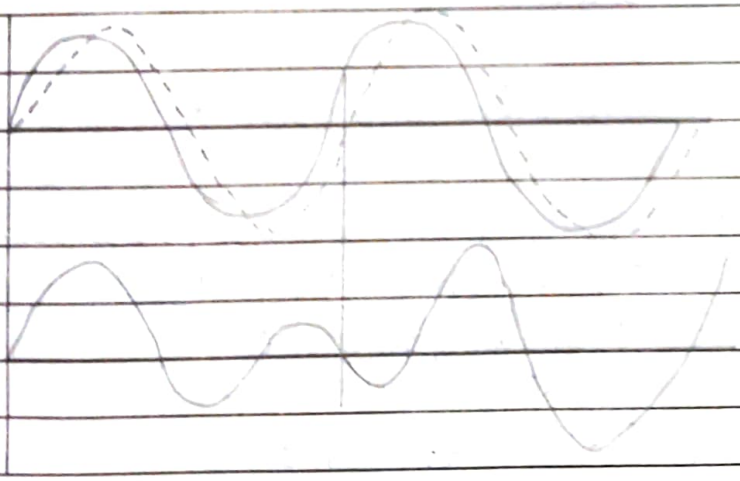
★ Beat and Beat formation :-

Ans. **Beat :-**

Due to interference of sound waves, the amplitude and intensity of the resulting sound wave increase and decrease at regular intervals at that point, which is called beats.

→ **Beat formation :-**

Consider two waves having equal amplitudes, nearly equal wavelengths and slightly different frequencies, travelling in the same medium in the same direction, superpose on eachother to form the interference at the point of superposition and beats are formed.



★ Stationary Waves :-

When two waves of the same amplitude and the same wavelength, moving in opposite directions superpose on each

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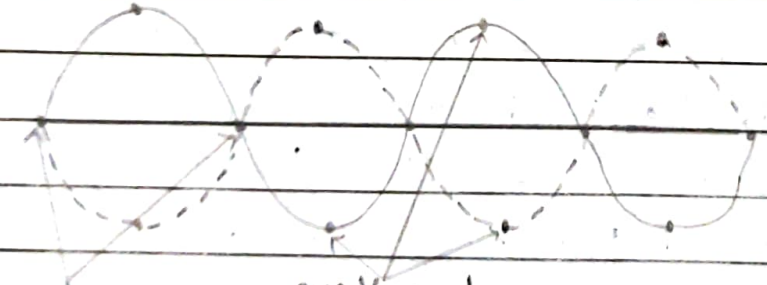
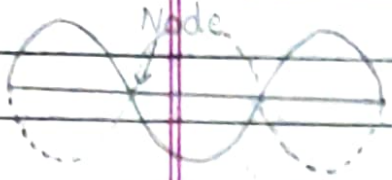
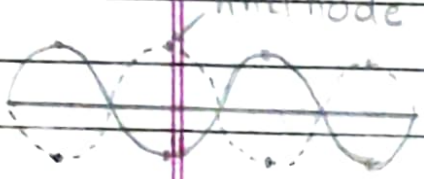
other, the resultant wave is called stationary (standing) waves.



Stationary Waves



Nodes: A point with a minimum amplitude in a stationary wave is called a node.



Anti Nodes: The point with maximum amplitude in a positive or negative direction in a stationary wave is called an anti-node.

★ Ultrasonic Waves:-

The sound waves having frequencies more than 20,000 Hz are known as ultrasonic waves.

→ Properties of ultrasonic waves:

- They are nothing but acustical waves with frequency higher than 20 kHz.
- They are highly energetic.
- They are longitudinal waves.
- Wavelength of ultrasonic waves is small.
- We cannot hear these waves.
- Some animals, mosquitoes, insects and birds can hear these waves.
- When they travel in medium, they produce heating effect.

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→ Applications of ultrasonic waves:

↔ Engineering applications:
- Soldering - Metals have been soldered or brazed by subjecting them to ultrasonic vibrations.
- Drilling - ultrasonic have also been used for drilling or metal cutting purpose.
- Crystalization - Crystalization rate is affected by ultrasonic waves.
- Utensils, clothes etc. that have to be cleaned are subjected to ultrasonic waves.
- Depth sounding - Echo sounding principle can be used to find out the depth of sea or the depth of water below a ship.
- certain chemical reaction are accelerated by ultrasonic waves.

→ Medical applications:
- Disease treatment - Ultrasonic therapy has been used to treat diseases like bursitis, abscesses or lumbago etc.
- Locating abnormal growth - To detect abnormal growth in brain, ultrasonic waves are made incident on the cerebral ventricles.
- Surgical use - Surgical use of ultrasonic wave includes the selective cutting of the tissues during an operation.
- Dental cutting - Ultrasonic wave have been very useful for dental cutting almost painless.

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Production of Ultrasonic Waves:-

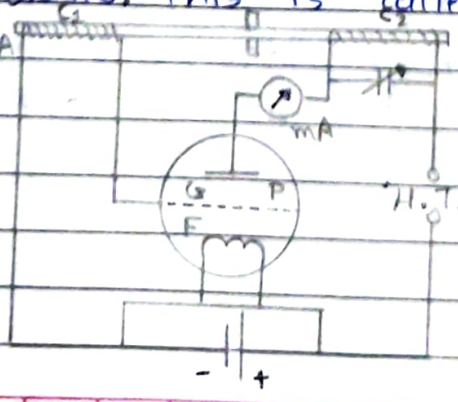
There are two methods to produce ultrasonic waves.

1. Magnetostriction Effect
2. Piezoelectric Effect

(1) Magnetostriction Effect :-

When a strong electric field is applied parallel to the length of a ferromagnetic [Nickel(Ni)/Cobalt(Co)/Iron(Fe)] material rod, the length of the rod increases (changes). On removing the magnetic field, the rod gets its original length. This is called the magnetostriction effect. Thus, the magnetostriction effect is the dimensional change of a ferromagnetic object under a change in the magnetic field. Nickel shows more magnetostriction than other ferromagnetic materials.

When an alternating magnetic field is produced by Alternating Current and it is applied parallel to the length of the ferromagnetic rod, its dimensions changes frequently and produces Ultrasonic waves. This is called the magnetostriction effect.



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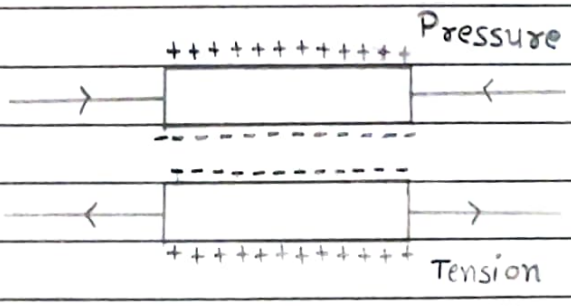
(2) Piezoelectriction Effect :

When pressure is applied to the opposite faces of a quartz crystal plate, whose faces are cut perpendicular to its optic axis, equal and opposite charges are developed on the faces subjected to pressure. If the crystal plate is subjected to tension instead of pressure, the signs of the charges are reversed. By subjecting the crystal plate to alternate compressions, tensions, an alternating potential difference is set up between its face.

- On the country if an alternating current applied between faces of the crystal plate expands and contracts periodically.
- This is known as piezo electric effect. The vibrations of the crystal plate produce high frequency longitudinal wave i.e. ultrasonic waves.
- Rochelle salt and zink blonde also possess similar properties.



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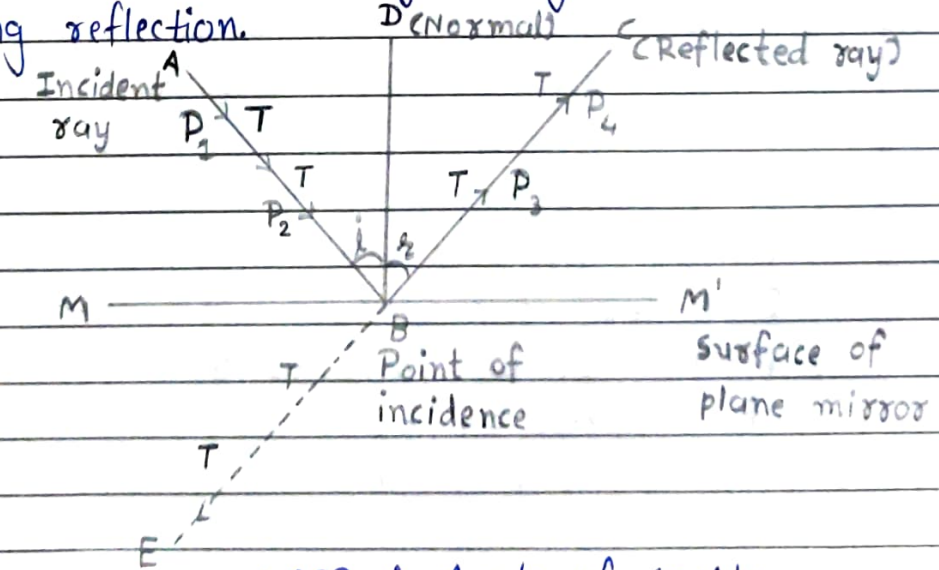
Uses of polarisation:-

Ans. Followings are the uses of polarisation:

- It is used in polarimetry.
- It is used in spectroscopy.
- It is used in spectrography.
- It is used in three dimension pictures.
- It is used in spectacles (sunglass).
- It is used to reduce glare in motor car.

Laws of reflection:-

- The incident ray, normal and reflected ray, all lie in one plane.
- The angle of incidence is equal to angle reflection (r) i.e. $i = r$.
- Incident ray and reflected ray are opposite to normal.
- A normal incident ray of light retraces its path during reflection.



$\angle ABD = i$ = Angle of incidence
$\angle CBD = r$ = Angle of reflection

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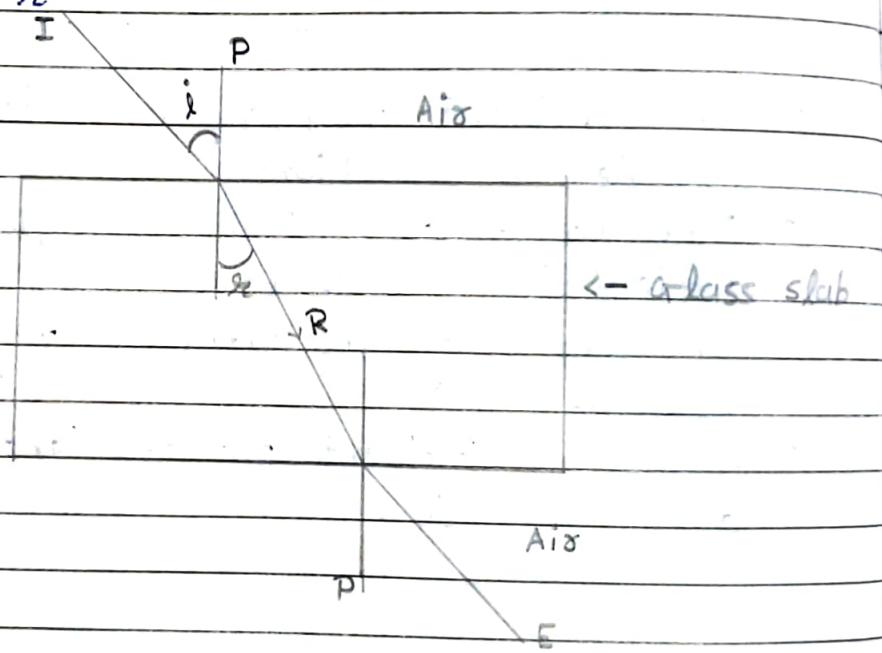
Laws of Refraction:-

- Incident ray, normal and the refracted ray are in the same plane.
- Incident ray and refracted ray are in different media.
- Ratio of sine of angle of incidence to sine of the angle of refraction is constant for the given two media. It is termed as refractive Index (μ).

$\therefore \mu = \frac{\sin i}{\sin r}$ - snell's law



I - Incident ray
R - Refracted ray
E - Emergent ray
P - Normal to glass surface
∠i - Incident angle
∠r - Refracted angle

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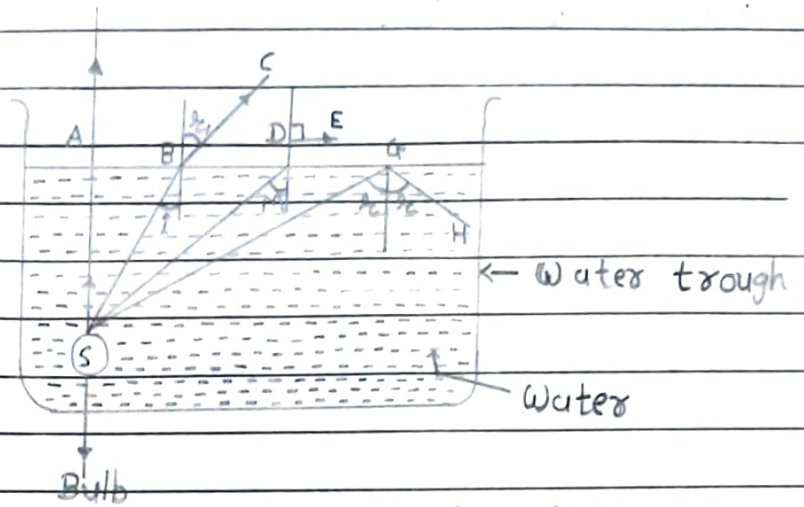
Total Internal Reflection of Light:-



Consider the case of a light sources placed in a medium of higher refractive index say water and emitting light rays in all directions as shown in figure. We know that when a ray of light passes from an optically denser to a rarer medium, the refracted ray is bent away from the normal i.e. the angle of refraction is greater than the angle of incidence. First of all we consider a ray SB striking the interface at an angle i it is refracted at an angle r_1, Obviously $< r_1 > < i$, As the angle of incident increase the angle of refraction also increases till for a particular angle of incidence the refracted ray emerges along the surface of separation. This particular angle is known as critical angle.

Now next we consider the ray SD which is incident on critical angle and hence it is refracted along the boundry of seperation. If now any ray say SG is incident at an angle greater than critical angle $< M$, no refraction occurs and

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the incident ray is reflected in the same medium, i.e. water. This phenomenon is called as total internal reflection.

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Definitions:-

1. Periodic Time (T):-

~~It is~~ The time required to complete one vibration is known as periodic time.

or

The time required for one complete oscillation is called periodic time.

- The unit of periodic time is second.

$$\text{Periodic time} = \frac{1}{\text{frequency}}$$

2. Frequency:-

The number of complete vibrations performed by the particle in one second is called frequency.

- The unit of frequency is vibration/second or herts (Hz).

$$\text{Frequency} = \frac{1}{\text{Periodic time}}$$

3. Wave Length:-

The distance between two consecutive particles having phase difference 2π radian or 180° is called the wavelength of that wave.

- It expressed in Angstrom (Å) unit.

$1 \text{ Å} = 10^{-10} \text{ m}$

$= 10^{-8} \text{ cm}$

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4. Amplitude:-

The maximum displacement made by a particle in any direction from its mean position during wave motion is called amplitude.

- The unit of amplitude is centimeter or milimeter.

5. Speed of Sound Waves:-

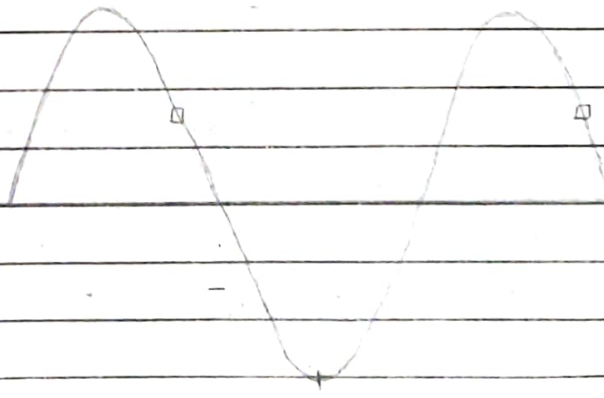
The distance that a wave travels per second is called the speed of waves.

- The unit of speed of sound waves is meter per second (m/s).

6. Phase:-

The phase is defined by stating the direction and displacement of motion at the given instant.

- The particals having an equal displacement in the same direction of motion are in the same phase.



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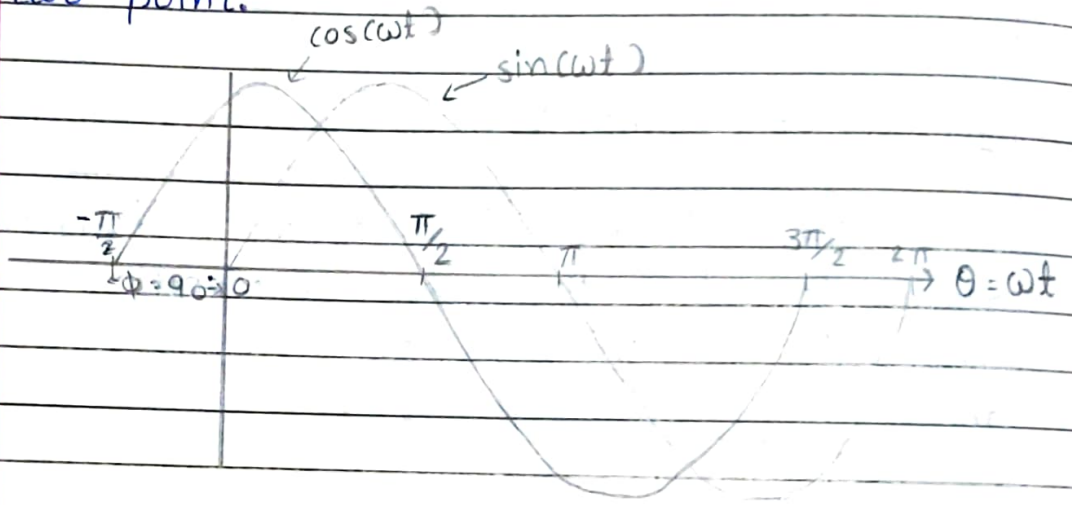
7. Phase Difference:-

If the maximum and minimum displacements of two waves are found together at the same point, relative to the same frequency and time is called phase difference between the two point.



8. Resonance:-

When a body is subjected to a periodic force whose frequency coincides with natural frequency of the body, the body begins to vibrate with very large amplitude. This phenomenom is called resonance.

9. Stationary Interference:-

If the intensity of light at a point where two/more waves superpose on eachother, does not change with time, the interference is known to be stationary Interference.

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10. Infrasonic sound:-

The sound that has a frequency less than 20 Hz is called infrasonic sound.

11. Audible sound:-

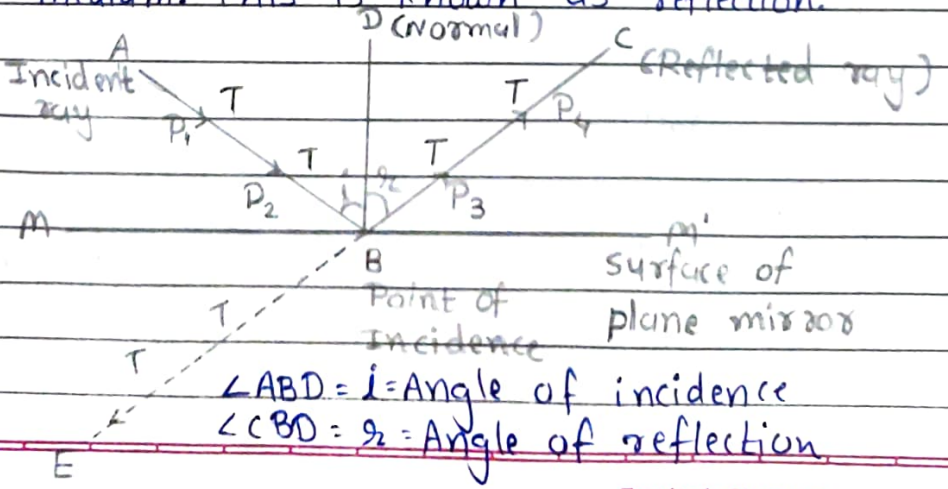
Sound with a frequency of 20 Hz to 20 kHz (20,000 Hz) induces sensations in the human ear. The range of this frequency is called the audible range.

12. Ultrasonic waves:-

The sound waves having frequencies more than 20,000 Hz are known as ultrasonic waves.

13. Reflection of light:-

Light travels in a transparent medium and meets the surface of another polished opaque medium, the light is reflected back in the same medium. This is known as reflection.



$\angle ABD = i$ = Angle of incidence
$\angle CBD = r_2$ = Angle of reflection

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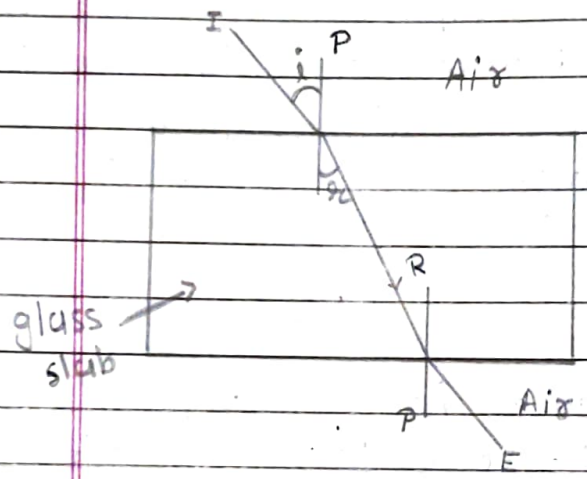
14. Refraction of light:-

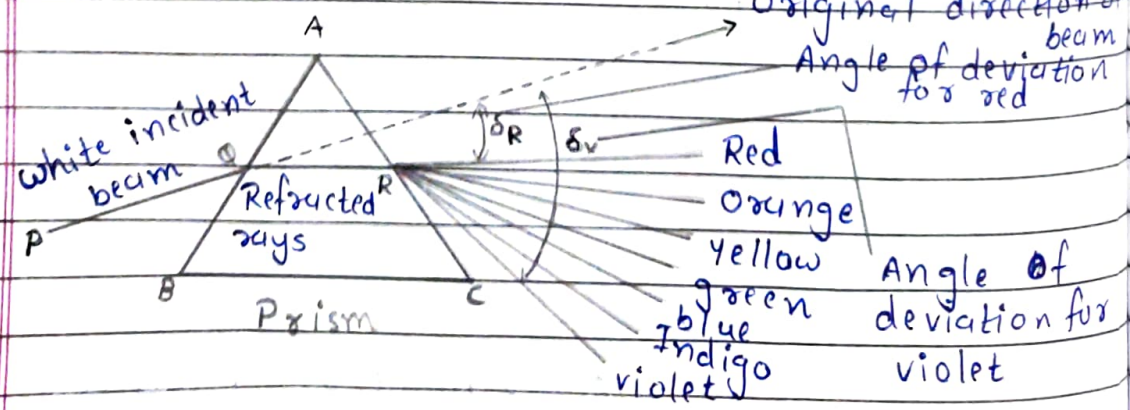
When a ray of light is travelling from one medium to another medium, it changes its direction of travelling at the contact surface of the two medium. This phenomena is called refraction.



I = Incidence Ray
R = Refracted Ray
E = Emergent Ray
P = Normal to Glass surface
$\angle i$ = Incident Angle
$\angle r$ = Refracted Angle

15. Dispersion of light:-

When a ray of white light is passing through the prism it splits up into its constituent colours.



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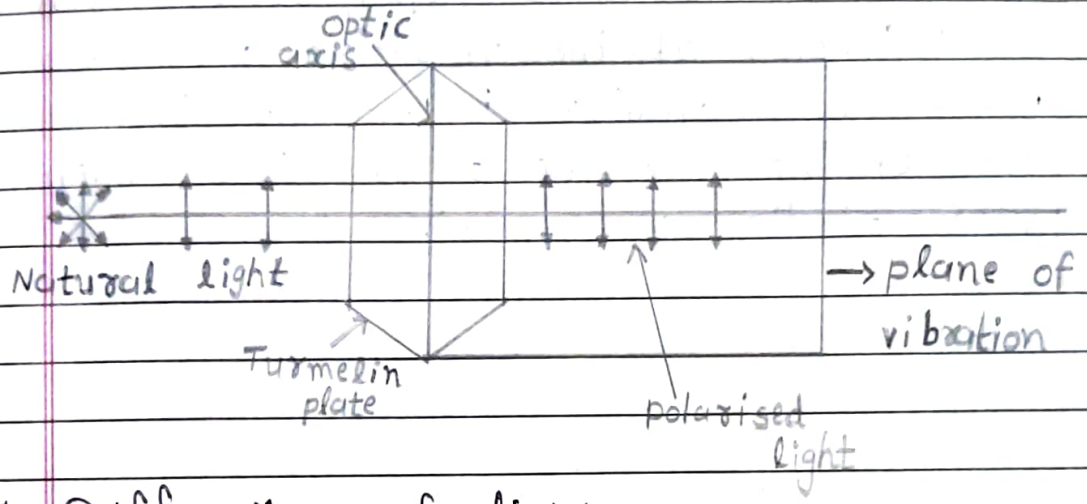
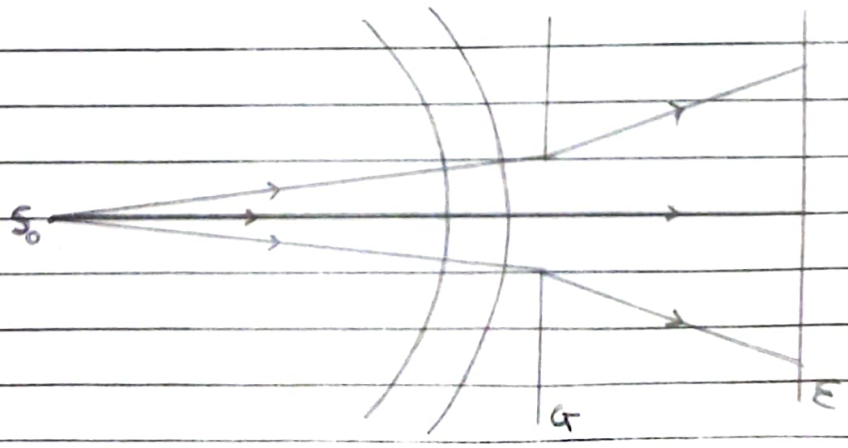
16. Polarisation of light:-

When a light wave is passing through crystal of turmaline, the only vibrations which are parallel to the optic axis of it can pass through it. This phenomenon is called polarisation.



17. Diffraction of light:-

When a wave is obstructed by an obstacle, the rays bend around the corner. This phenomenon is known as diffraction.



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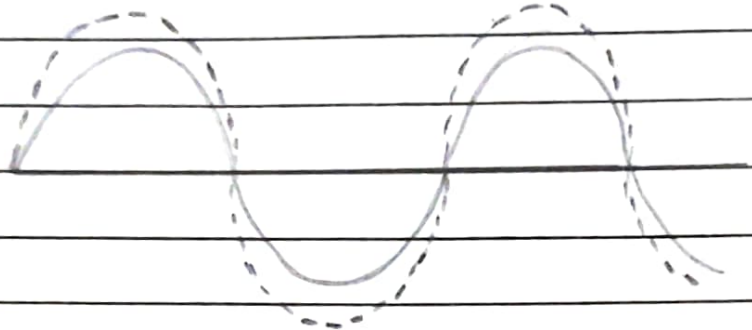
18. Echo:-

This repetition of sound due to reflection from an obstucal is called echo.

19. Superposition of waves:-

When two waves superpose on each other, the intensity of the resulting wave at any point in the medium is equal to the vector sum of the intensities of the two independent waves at the same point.



Superposition of waves