Light

Light is a form of energy which is propagated as electromagnetic waves. In the spectrum of electromagnetic waves it lies between ultra-violet and infra-red region and has wavelength between 3900 A° to 7800 A°.

1. Electromagnetic waves are transverse, hence light is transverse wave.

2. Wave nature of light explains rectilinear propagation, reflection, refraction, interference, diffraction and polarisation of light.

3. The phenomena like photo electric effect, compton effect are not explained on the basis of wave nature of light. These phenomena are explained on the basis of quantum theory of light as proposed by Einstein.

4. In quantum theory, light is regarded as a packet or bundle of energy called photon. Photon is associated with it an energy E where $E = hv$.

5. Clearly light behaves as wave and particle both. Thus light has dual nature.

6. Speed of light was first measured by Roemer. (1678 AD).

7. Speed of light is maximum in vacuum and air (3 x 108 m/s)

Refractive index : R.I. of a medium is defined as the ratio of speed of light in vacuume to the speed of light in the medium.

$\mu = c/v$ = Speed of light in vacuum / Speed of light in the medium

----> Speed of light is different in different media. Velocity of light is large in a medium which has small refractive index.

Speed of light in different mediums

----> Light takes 8 minute 19 second (499 second) to reach from sun to earth.

----> The light reflected from moon takes 1.28 second to reach earth.

Luminous bodies : Those object which emit light by themselves are called luminous bodies.

e.g.—sun, stars, electric bulb etc.

Non-luminous bodies : Those objects which do not emit light by themselves but are visible by the light falling on them emitted by self luminous bodies are called non-luminous bodies.

A material can be classified as :

(i) Transparent : The substances which allow most of the incident light to pass through them are called transparent, e.g. glass, water.

(ii) Translucent : The substances which allow a part of incident light to pass through them are called translucent bodies e.g. oiled paper.

(iii) Opaque : The substances which do not allow the incident light to pass through them are called opaque bodies, e.g., mirror, metal, wood etc.

Reflection of light : Light moving in one medium when falls at the surface of another medium, part of light returns back to the same medium. This phenomenon of returning back of light in the first medium at the interface of two media is known as reflection of light.

Laws of reflection

(i) The incident ray, reflected ray and normal to the reflecting surface at the incident point all lie in the same plane.

(ii) The angle of reflection is equal to the angle of incidence.

Reflection from plane mirror

(i) The image is virtual, laterally inverted.

(ii) The size of image is equal to that of object.

(iii) The distance of image from the mirror is equal to distance of object from the mirror.

(iv) If an object moves towards (or away from) a plane mirror with speed v, relative to the object the image moves towards (or away) with a speed 2v.

(v) If a plane mirror is rotated by an angle 0, keeping the incident ray fixed, the reflected ray is rotated by an angle 20.

(vi) To see his full image in a plane mirror, a person requires a mirror of at least half of his height.

(vii) If two plane mirrors are inclined to each other at an angle 0 the number of images (n) of a point object formed are determined as follows:

(a) if 360/? is even integer, then n = 360/? -1

(b) If 360/? is odd integer,

then n = 360/? -1 for the objects is symmetrically placed. and \

n = 360/? for the objects is not symmetrically placed.

(c) If 360/? is a fraction then n is equal to integral parts.

Reflection from spherical mirror

Spherical mirror are of two types (i) Concave mirror and (ii) Convex mirror

Note: Image formed by a convex mirror is always virtual, erect and diminished.

Uses of Concave mirror:

(i) As a shaving glass.

(ii) As a reflector for the head lights of a vehicle, search light.

(iii) In opthalmoscope to examine eye, ear, nose by doctors.

(iv) In solar cookers.

Uses of Convex mirror:

(i) As a rear view mirror in vehicle because it provides the maximum rear field of view and image formed is always erect.

(ii) In sodium reflector lamp.

Refraction of light : When a ray of light propagating in a medium enters the other medium, it deviates from its path. This phenomenon of change in the direction of propagation of light at the boundary when it passes from one medium to other medium is called refraction of light.
When a ray of light enters from rarer medium to denser medium (as from water to glass) it deviates towards the normal drawn on the boundary of two media at the incident point. Similarly in passing from denser to rarer medium, a ray deviates

away from the normal. If light is incident normally on the boundary i.e. parallel to normal, it enters the second medium undeviated.

Laws of refraction

(i) Incident ray, refracted ray and normal drawn at incident point always lie in the same plane.

(ii) Snell's law : For a given colour of light, the ratio of sine of angle of incidence to the sine of angle of refraction is a constant,

i.e. sin i/sin r = $_1\mu_2$ (constant)

This constant $_1\mu_2$ is called refractive index of second medium with respect to the first medium.

1. Absolute refractive index of a medium is defined as the ratio of speed of light in free space (vacuum) to that in the given medium.

2. i.e. absolute refractive index (μ) = Speed of light in vacuum/Speed of light in the medium.

3. The refractive index of a medium is different for different colours. The refractive index of a medium decreases with the increase in wavelength of light. Hence refractive index of a medium is maximum for violet colour of light and minimum for red colour of light.

4. The refractive index of a medium decreases with the increase in temperature. But this variation is very small.

5. When a ray of light enters from one medium to other medium, its frequency and phase donot change but wavelength and velocity change.

Some illustrations of Refraction

(i) Bending of a linear object when it is partially dipped in a liquid inclined to the surface of the liquid.

(ii) Twinkling of stars.

(iii) Oval shape of sun in the morning and evening.

(iv) An object in a denser medium when seen from a rarer medium appears to be at a smaller distance.

This is way (a) A fish in a pond when viewed from air appears to be at a smaller depth them actual depth (b) A coin at the base of a vessel filled with water appears raised.

Critical angle : In case of propagation of light from denser to rarer medium through a plane boundary, critical angle is the angle of incidence for which angle of refraction is 90°.

Total Internal Reflection : If light is propagating from denser medium towards the rarer medium and angle of incidence is more than critical angle, then the light incident on the boundary is reflected back in the denser medium, obeying the laws of reflection. This phenomenon is called total internal reflection as total light energy is reflected, no part is absorbed or transmitted.

For total internal reflection,

(i) Light must be propagating from denser to rarer medium.

(ii) Angle of incidence must exceeds the critical angle.

illustrations of total internal reflection

(i) Sparkling of diamond

(ii) Mirage and looming.

(iii) Shining of air bubble in water.

(iv) Increase in duration of sun's visibility-The sun becomes visible even before sun rise and remains visible even after sunset due to total internal reflection of light.

(v) Shining of a smoked ball or a metal ball on which lamp soot is deposited when dipped in water.

(vi) Optical Fibre : Optical fibre consists of thousands of strands of a very fine quality glass or quartz (of refractive index 1.7), each strand coated with a layer of material of lower refractive index (1.5). In it, light is propagated along the axis of fibre through multiple total internal reflection, even though the fibre is curved, without loss of energy.

Applications :

(i) For transmitting optical signals and the two dimensional pictures.

(ii) For transmitting electrical signals by first converting them to light.

(iii) For visualising the internal sites of the body by doctors in endoscopy.

Refraction of Light Through Lens

1. Lens is a section of transparent refractive material of two surfaces of definite geometrical shape of which one surface must be spherical. Lens is generally of two types : (i) Convex lens (ii) Concave lens.

2. When a lens is thicker at the middle than at the edges, it is called a convex lens or a converging lens. When the lens is thicker at the edges than in the middle, it is called as concave lens or diverging lens.

3. Some terms regarding a lens.

O - optical Centre

F - First Focus

C1C2 - Principal axis

F2 - Second Focus

Power of a lens

Power of a lens is its capacity to deviate a ray. It is measured as the reciprocal of the focal length in meters, i.e. P = 1/f SI Unit of power is dioptre (D).
Power of a convex lens is positive and that of a concave lens is negative.
If two lenses are placed in contact, then the power of combination is equal to the sum of powers of individual lenses.

Change in the power of a lens : If a lens is dipped in a liquid, its focal length and power both change. This change depends upon the refractive indices of lens and the liquid. If a lens of refractive index μ is dipped in a liquid of refractive index μ', then the following three situations are possible

(i) μ > μ' i.e. lens is dipped in a liquid of smaller fractive index like a lens of glass (μ = 1.5) is dipped in water (μ' = 1.33), then the focal length of the lens increases and the power of the lens decreases.

(ii) μ = μ' i.e. lens is dipped in a liquid of equal refractive index then the focal length of the lens becomes infinite i.e. its power becomes zero. The lens and the liquid behave as a single medium.

(iii) $\mu < \mu'$ i.e. lens is dipped in a liquid of higher refractive index the focal length increases i.e. power decreases as well as the nature of the lens also changes i.e. convex lens behaves as concave lens and vice-versa. For example, an air bubble trapped in water or glass appears as convex but behaves as concave lens. Similarly a convex lens of glass ($\mu = 1.5$) when dipped in carbon disulphide ($\mu' = 1.68$), it behaves as a concave lens.

Between lens and F on the same sideBetween lens and F on the same side

Dispersion of Light : When a ray of white light (or a composite light) is passed through a prism, it gets splitted into its constituent colours. This phenomenon is called dispersion of light. The coloured pattern obtained on a screen after dispersion of light is called spectrum.

1. **T**he dispersion of light is due to different deviation suffered by different colours of light. The deviation is maximum for violet colour and minimum for red colour of light. The different colours appeared in the spectrum are on the following order, violet, indigo, blue, green, yellow, orange and red. (VIBGYOR)

2. The dispersion of light is due to different velocities of light of different colorus in a medium. As a result, the refractive index of a medium is different for different colours of light.

3. The velocity of light in a medium is maximum for that colour for which refractive index is minimum. Clearly, the velocity of violet colour of light is minimum in a medium and retroactive index of that medium is maximum for violet colour. Similarly, the velocity of light in a medium is maximum for red colour and refractive index of that medium is minimum for red colour.

Rainbow : Rainbow is the coloured display in the form of an arc of a circle hanging in the sky observed during or after a little drizzle appearing on the opposite side of sun. Rainbow is formed due to dispersion of sun light by the suspended water droplets.

Rainbow is of two types : (i) Primary rainbow (ii) Secondary rainbow

----> Primary rainbow is formed due to two refractions and one total internal reflection of light falling on the raindrops. In the primary rainbow, the red colour is on the convex side and violet on the concave side. Primary rainbow has an angular width of 2° at an average angle of elevation of 41°.

----> Secondary rainbow is formed due to two refractions and two internal reflections of light falling on rain drops. The order of colour on the secondary rainbow is in the reverse order and has an angular width of 3.5° at an average elevation of 52.75°. Secondary rainbow is less intense than primary rainbow.

Theory of Colours : Colour is the sensation perceived by the rods in the eye due to light.

Primary Colours : The spectral colours blue, green and red are called primary colours because all the colours can be produced by mixing these in proper proportion.
Blue + Red + Green = White

Secondary Colours : The colour produced by mixing any two primary colours is called a secondary colour. There are three secondary colours yellow, magenta and cyan as

Green + Red = Yellow
Red + Blue = Magenta
Blue + Green = Cyan

When the three secondary colours are mixed, white colour is produced

Yellow + Magenta + Cyan = White

Complementary Colours : Any two colours when added produce white light, are said to be complementary colours. Clearly a secondary colour and the remaining primary colour are complementary colours. Red and cyan, blue and yellow and green and magenta are complementary of each other.

----> The different colours and their mixtures are shown by the colour triangle.

----> In coloured television, the three primary colours are used.
Colour of bodies : The colour of a body is the colour of light which it reflects or transmits. An object is white, if it reflects all the components of white light and it is black if it absorbs all the light incident over it. This is why a red rose appears red when viewed in white or red light but appears black when viewed in blue or green light.
How a body will appear in light of different colour can be understood by the following table

Scattering of light : When light waves fall on small bodies such as dust particles, water particles in suspension, suspended particles in colloidal solution, they are thrown out in all directions. This phenomenon is called scattering of light.

Scattering of light is maximum in case of violet colour and minimum in case of red colour of light.

1. Blue colour of sky is due to scattering of light.

2. The brilliant red colour of rising and setting sun is due to scattering of light. Interference of light : When two light waves of exactly the same frequency and a constant phase difference travel in same direction and superimpose then the resultant intensity in the region of superposition is different from the sum of intensity of individual waves. This modification in the intensity of light in the region of superposition is called interference of light. Interference is of two types

(i) Constructive interference (ii) Destructive interference

Constructive interference : At some points, where the two waves meet is same phase, resultant intensity is maximum. Such interference is called constructive interference.

Destructive interference : At some points, where the two waves meet in opposite phase, resultant intensity is minimum. Such interference is called destructive interference.

Diffraction of light : When light waves fall on a small sized obstacle or a small aperture whose dimension is comparable to the wavelength of light, then there is a departure from the rectilinear propagation and light energy flavours out into the region of geometrical shadow. The spreading of light energy beyond the limit prescribed by rectilinear propagation of light is called diffraction of light. In other words, diffraction is the process by which a beam of light or other systems of wave is spread out as a result of passing through a narrow opening or across an edge.

Polarisation of light : Polarisation is the only phenomenon which proves that light is a transverse wave. Light is an electromagnetic wave in which electric and magnetic field vectors vibrate perpendicular to each other and also perpendicular to the direction of propagation. In ordinary light, the vibrations of elecltric field vector are in every plane perpendicular to the direction of propagation of wave. Polarisation is the phenomenon of restricting the vibrations of a light in a particular direction in a plane perpendicular to the direction of propagation of wave.

The visible effect of light is only due to electric field vector.

Human Eye

----> Least distance of distinct vision is 25 cm.

Defects of human eye and the remedies :

1.Myopia or short sightedness : A person suffering from myopia can see the near objects clearly while far objects are not clear.

Causes :

(i) Elongation of eye ball along the axis.

(ii) Shortening of focal length of eye lens.

(iii) Over stretching of ciliary muscles beyond the elastic limit.

Remedy : Diverging lens is used.

2.Hyperopia or hypermetropia or longsightedness : A person suffering from hypermetropia can see the distant objects clearly but not the near objects.

Causes :

(i) Shortening of eye ball along the axis.

(ii) Increase in the focal length of eye lens.

(iii) Stiffening of ciliary muscles.

Remedy : A converging lens is sued.

3.Presbyopia : This defect is generally found in elderly person. Due to stiffening of ciliary muscles, eye looses much of its accommodating power. As a result distanct as well as nearby objects can not be seen. For its remedy two separate lens or a bifocal lens is used.

4.Astigmatism : This defect arises due to difference in the radius of curvature of cornea in the different planes. As a result rays from an object in one plane are brought to focus by eye in another plane. For its remedy cylindrical lens is used.

----> There are two kinds of vision cells in the retina. They are called rods and cones on account of their peculiar shape. Rods decides the intensity of light where as cones distinguish colour of light.
Simple microscope : This is simply a convex lens of small focal length. The object to be enlarged is placed within the focus of lens.

Magnifying power of a simple microscope is given as
M = 1 + D/f where D = 25 cm, f = focal length of lens.

Compound microscope : It consists of two convex lenses coaxially fitted in a hollow tube. The lens facing the object is called objective and the lens towards the eye is called eye piece.

1. The aperture of objective is smaller than that of eye piece.

2. Both the lenses are of smaller focal lengths. This increases the magnifying power of instrument.

Telescope

Telescopes are used to view distant objects which are not visible to naked eye. Telescope can be divided as astronomical telescope, terrestrial telescope and Galilean telescope.

1. Astronomical telescope consists of two convex lenses placed coaxially in a hollow tube. The lens facing the object is called objective and the lens towards the eye is called eye piece.

2. The objective has large aperture so that the rays from the object can be easily collected.

3. The focal length of objective is larger than that of eye piece.