LIGHT
Part 1

Introduction

Light is a form of energy which travels as electromagnetic waves. The branch of physics that deals with the properties and applications of light is called optics. Two types of optics are ray optics and wave optics.

Sources of Light:

1. Natural sources of light
2. Artificial sources of light

- Incandescent Sources (Example: Candle, incandescent lamp)
- Gas Discharge Sources (Example: Neon lamp, Sodium lamp)

Properties of light:

1. Light is a form of energy.
2. Light always travels along a straight line. (Rectilinear propagation of light)-pin hole camera
3. Light does not need any medium for its propagation. It can even travel through vacuum.
4. The speed of light in vacuum or air is, $c = 3 \times 10^8\ ms^{-1}$.
5. Since, light is in the form of waves, it is characterized by a wavelength (λ) and a frequency (v), which are related by the following equation: $c = v\lambda$ (c - velocity of light).
6. Different coloured light has different wavelength and frequency.
7. Among the visible light, violet light has the lowest wavelength and red light has the highest wavelength.
8. When light is incident on the interface between two media, it is partly reflected and partly refracted.

Interaction of light with matter:

Transparent Material - allow light to pass through completely (ex: Eye glasses, clear drinking glass)

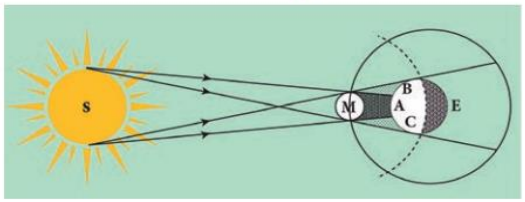
Translucent Material - allow light to pass through partially (ex: a rough window glass)

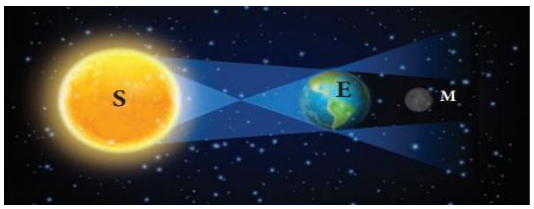
Opaque Material - not able to allow light to pass through (ex: Wall, thick card board, stone, etc.)

Shadows:

Light travels in a straight line and cannot bent according to object that is why we see shadow. Shadow appears in opposite side of light source. It is caused by opaque objects.

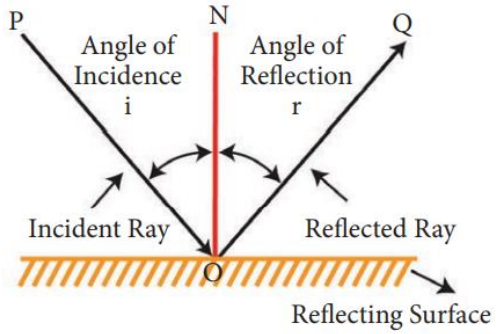
Solar eclipse





Reflection of Light:

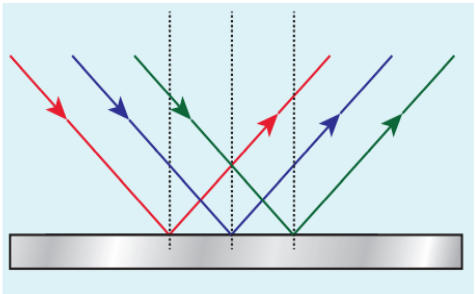
The bouncing back of light into the same medium when it encounters a reflecting surface is called reflection of light.



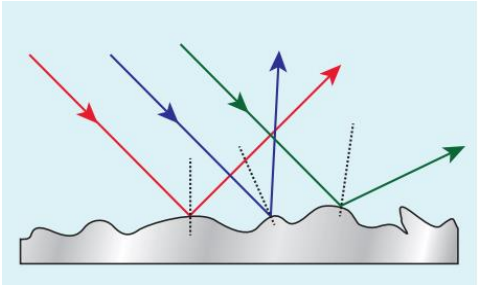
According to law of reflection,

a. The incident ray, reflected ray and normal to the reflecting surface all are coplanar (ie. lie in the same plane).

b. The angle of incidence (i) is equal to the angle of reflection (r). $\angle i = \angle r$.



Regular reflection



Irregular reflection

Periscope:

It is an instrument used for viewing bodies or ships, which are over and around another body or a submarine. It is based on the principle of the law of reflection of light.

Angle of deviation due to reflection:

The angle between the incident and deviated light ray is called angle of deviation of the light ray(d).

$$d = 180 - 2i$$

Multiple Reflections: (Kaleidoscope)

Lateral inversion:

Lateral inversion means sidewise inversion. It is the apparent inversion of left and right that occurs in a plane mirror

Image formation in plane mirror:

The image distance inside the plane mirror is equal to the object distance in front of the plane mirror.

By geometry, the height of the mirror needed is only half of the height of the person. (h/2)

The number of images formed is equal to $(360° / \theta) - 1$

The mirror equation : $1/f = 1/v + 1/u$

Real and virtual images:

The images that are obtained on a screen are called 'real image' and that which cannot be obtained on a screen 'virtual image'.

Refraction of light:

When a ray of light travels from one transparent medium into another obliquely, the path of the light undergoes deviation. This deviation of ray of light is called refraction. Refraction takes place due to the difference in the velocity of light in different media. The velocity of light is more in a rarer medium and less in a denser medium. Refraction of light obeys two laws of refraction.

Law of refraction is called Snell's law.

i. The incident ray, the refracted ray and the normal at the point of intersection, all lie in the same plane.
ii. The ratio of the sine of the angle of incidence (i) to the sine of the angle of refraction (r) is equal to the refractive index of the medium, which is a constant

$$\sin i / \sin r = \mu_2/\mu_1$$

Angle of deviation due to refraction

$$d = i - r$$

On the other hand, if light travels from denser to rarer medium it deviates away from normal and if the light travels from rarer to denser medium it moves towards the normal.

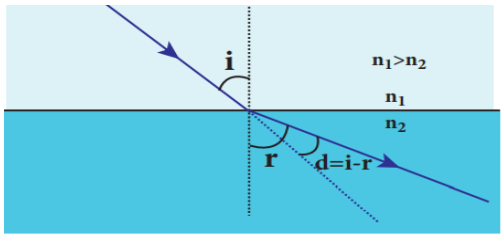


Figure 6.17 Angle of deviation due to refraction from denser to rarer medium

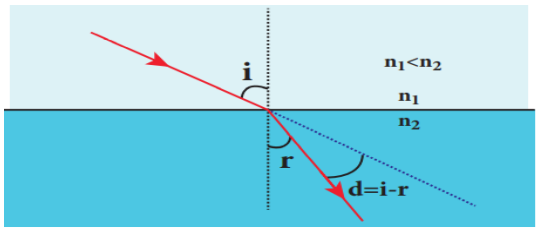


Figure 6.16 Angle of deviation due to refraction from rarer to denser medium

Atmospheric refraction:

Due to refraction of light through different layers of atmosphere which vary in refractive index, the path of light deviates continuously when it passes through atmosphere.

Critical angle and total internal reflection:

The angle of incidence in the denser medium for which the refracted ray graces the boundary is called critical angle (i_c). As angle of incidence i is gradually increased, r rapidly increases and at a certain stage it becomes 90° or gracing the boundary.

If the angle of incidence in the denser medium is increased beyond the critical angle, there is no refraction possible in to the rarer medium. The entire light is reflected back into the denser medium itself. This phenomenon is called total internal (Ex: Optical fibre, glittering of diamond and endoscope).

The two conditions for total internal reflection are,

a) light must travel from denser to rarer medium,
b) angle of incidence in the denser medium must be greater than critical angle (i>ic)

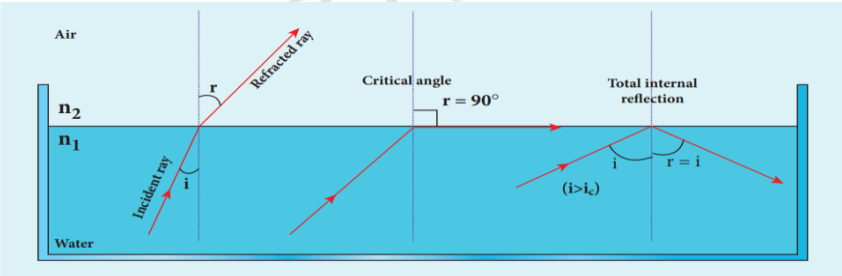


Figure 6.21 Critical angle and total internal reflection

Mirage and looming:

For of the shaky nature of the layers of air, the observer feels as if the object is getting reflected by a pool of water or wet surface beneath the object. This phenomenon is called mirage.

In the cold regions like glaciers and frozen lakes and seas, the reverse effect of mirage will happen. Hence, an inverted image is formed little above the surface. This phenomenon is called looming.

Refraction of a composite light dispersion of light:

When a beam of white light or composite light is refracted through any transparent media such as glass or water, it is split into its component colours. This phenomenon is called as 'dispersion of light'.

Prism:

A prism is an object made up of a transparent material, like glass or plastic that has at least two flat surfaces that from an acute angle (less than 90O degrees).

Newton Disc:

Using this disc, one can explain that white is a combination of VIBGYOR

The band of colours is termed as spectrum. This spectrum consists of following colours: Violet, Indigo, Blue, Green, Yellow, Orange, and Red represented by acronym "VIBGYOR".

Angle of refraction is the smallest for red and the highest for violet.

INTERFERENCE: (Dazzling colours on soap bubble)

The phenomenon of addition or superposition of two light waves which produces increase in intensity at some points and decrease in intensity at some other points is called interference of light.

DIFFRACTION:

Diffraction is bending of waves around sharp edges into the geometrically shadowed region.

Refractive Index:

Refractive index is a ratio of two similar quantities (speed) and so, it has no unit.

The smallest value of refractive index is for vacuum, which is 1. For any other medium refractive index is greater than 1. Refractive index is also called as optical density of the medium. Higher the refractive index of a medium, greater is its optical density and speed of light through the medium is lesser and vice versa.

μ = Speed of light in air (c)/ Speed of light in the medium (v)

Refractive index of different media	
Media	**Refractive Index**
Vacuum	1.00
Air	1.0003
Carbon dioxide gas	1.0005
Ice	1.31
Pure water	1.33

Ethyl alcohol	1.36
Quartz	1.46
Vegetable oil	1.47
Olive oil	1.48
Acrylic	1.49
Table salt	1.51
Glass	1.52
Sapphire	1.77
Zircon	1.92
Qubic zirconia	2.16
Diamond	2.42
Gallium phosphide	3.50

Optical Fiber:

Optical fibres consists of inner part called core and outer part called cladding (or) sleeving. Signal in the form of light is made to incident inside the core-cladding boundary at an angle greater than the critical angle. Hence, it undergoes repeated total internal reflections along the length of the fibre without undergoing any refraction.

Acceptance angle ia = $\sin^{-1} \sqrt{(n_1^2 - n_2^2)}$

Optical path:

Optical path of a medium is defined as the distance d' light travels in vacuum in the same time it travels a distance d in the medium. [v= d/t or t= d/v]

$d' = nd$

As n is always greater than 1, the optical path d' of the medium is always greater than d.

Scattering of light:

When sunlight enters the Earth's atmosphere, the atoms and molecules of different gases present in the atmosphere refract the light in all possible directions. This is called as 'Scattering of light'.

Visible light is a spectrum of number of waves with different wavelength range from 400nm to 700nm (1nm = 10^{-9} metre) each wave has a definite wavelength represents a particular color.

Rayleigh scattering:

The scattering of sunlight by the atoms or molecules of the gases in the earth's atmosphere is known as Rayleigh scattering.

Amount of scattering 'S' $\propto 1/ \lambda 4$

Violet colour which has the shortest wavelength gets much scattered during day time. The next scattered colour is blue. As our eyes are more sensitive to blue colour than violet colour the sky appears blue during day time.

Raman scattering:

Raman Scattering is defined as "The interaction of light ray with the particles of pure liquids or transparent solids, which leads to a change in wavelength or frequency."

Mie scattering:

Mie scattering takes place when the diameter of the scatterer is similar to or larger than the wavelength of the incident light. Mie scattering is responsible for the white appearance of the clouds.

Tyndall Scattering:

The scattering of light rays by the colloidal particles in the colloidal solution is called Tyndall Scattering or Tyndall Effect.

Apparent depth:

It is a common observation that the bottom of a tank filled with water appears raised

Previous Year Questions

1. Red light has a wavelength of 7000A^{o} In 'nm' it is,
   a. 7 nm b. 0.07nm c. 70nm **d. 700nm**
   சிவப்பு நிற ஒளியின் அலைநீளம் 7000A°. nm-ல் அதன் மதிப்பு
   a. 7 nm b. 0.07nm c. 70nm d. 700nm
   (Technical Assistant(Air Conditioning) Exam 2019)

2. A ray of light is incident normally on a glass surface of refractive index 1.5. the angle of refraction is
   a. 30^{o} b. sin^{-1}(0.666) **c. Zero** d. sin^{-1} (0.75)
   ஒளி விலகல் எண் 1.5 உடைய கண்ணாடி பரப்பின் மீது ஒளியானது குத்தாக விழும் போது ஒளிவிலகல் கோணம்
   a. 30^{o} b. sin^{-1}(0.666) c. சுழி d. sin^{-1} (0.75)
   (Technical Assistant(Air Conditioning) Exam 2019)

3. A rock containing the fluorescing calcite is illuminated by ultraviolet light. Then, the colour of the rock seems to be
   a. Violet b. Blue c. Green **d. Red**e. Answer not known
   ஒளி உமிழும் கால்சைட்டைக் கொண்ட ஒரு பாறை புறஊதா ஒளியால் ஒளிர்விக்கப்படுகிறது. அப்போது, பாறையின் நிறமாகத் தோன்றுவது
   a. ஊதா b. நீலம் c. பச்சை d. சிவப்பு e. விடை தெரியவில்லை
   (Group I Prelim Exam 03.01.21)

4. Raman effect is scattering by
a. Pure Solids **b. Pure Liquids** c. Pure Gases
d. Impure Gases e. Answer not known
இராமன் விளைவு எவ்வகை ஒளிச்சிதறல்
a. தூய்மையான திடப்பொருட்களில் நிகழும் ஒளிச்சிதறல்
b. தூய்மையான திரவங்களில் நிகழும் ஒளிச்சிதறல்
c. தூய்மையான வாயுக்களில் நிகழும் ஒளிச்சிதறல்
d. தூய்மையற்ற வாயுக்களில் நிகழும் ஒளிச்சிதறல்
e. விடை தெரியவில்லை

(Group I Prelim Exam 03.01.21)

5. Holography can be used in the formation of
a. three dimensional images b. two dimensional images
c. one dimensional images d. half dimensional images
ஹோலோகிராபி இதனை உருவாக்க பயன்படுகின்றது.
a. முப்பரிமான பிம்பங்கள் b.இரு பரிமான பிம்பங்கள்
c. ஒரு பரிமான பிம்பங்கள் d. அரை பரிமான பிம்பங்கள்

(Curator in Museum Exam 2019)

6. The speed of light is minimum when it pass through
a. vacuum b. air **c. glass** d. water
ஒளியின் வேகம் எவற்றின் வழியாக செல்லும்போது குறைவாக இருக்கும்?
a. வெற்றிடம் b. காற்று c. கண்ணாடிப் பட்டகம் d. நீர்

(Project Officer in Tamil Nadu General Service and Psychologist in Tamil Nadu Jail Service 2019)

7. The colour of light that travels through glass with minimum speed is
a. Violet b. Blue c. Red d. Green e. Answer not known
ஒளியில் எந்த, நிறம் கண்ணாடி வழியாக குறைந்த வேகத்தில் செல்லும்?
a. ஊதா b. நீலம் c. சிகப்பு d. பச்சை e. விடை தெரியவில்லை

(Agriculture & Horticulture Exam 18.04.21)