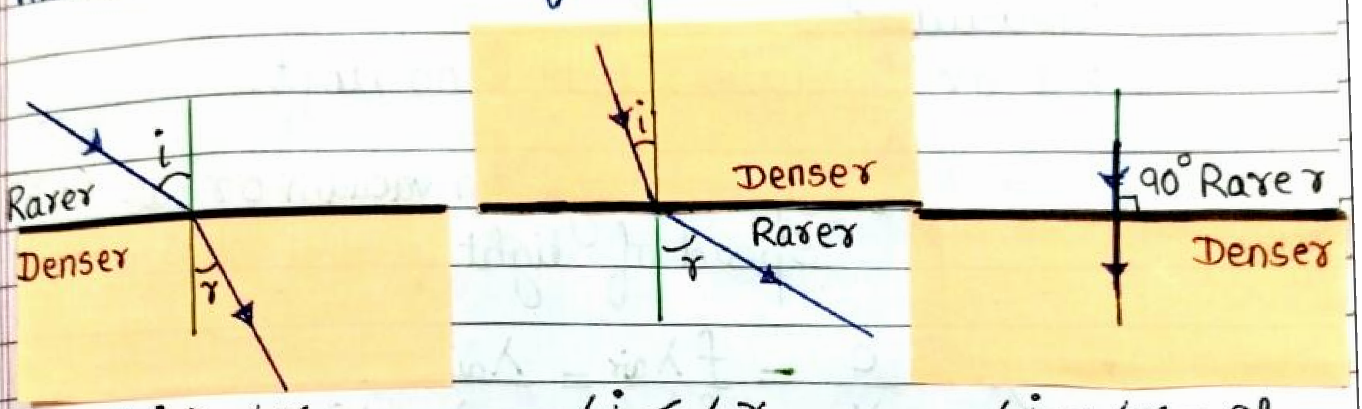
REFRACTION OF LIGHT AT PLANE SURFACE

REFRACTION OF LIGHT – The change in the direction of the path of light, when it passes from one transparent medium to another transparent medium is called refraction.



$\angle i > \angle r$ $\angle i < \angle r$ $\angle i = \angle r = 0°$

Refracted beam has change in speed (v), wavelength (λ), direction but frequency (ν) remains constant.

LAWS OF REFRACTION –

1) The incident ray, the refracted ray and the normal at the point of incidence all lie in same plane.

2) The ratio of sine of angle of incidence (i) to the sine of angle of refraction (r) is constant for given pair of media

$$\frac{\sin i}{\sin r} = \text{constant} = {}_1\mu_2$$

(R.I. of second medium wrt first medium)

This is also known as Snell's law.

Date
Page

REFRACTIVE INDEX -

The refractive index of second medium with respect to the first medium is defined as the ratio of sine of angle of incidence in first medium to the sine of angle of refraction in the second medium.

R.I. or absolute R.I. has no unit.

$$\mu = \frac{\text{Speed of light in vacuum or air (c)}}{\text{Speed of light in that medium (V)}}$$

$$\mu = \frac{c}{V} = \frac{f\lambda_{air}}{f\lambda_{medium}} = \frac{\lambda_{air}}{\lambda_{medium}}$$

Relative Refractive index - It is the ratio of speed of light in one medium to the speed of light in second medium.

$$_1\mu_2 \text{ or } n_{21} = \frac{V_1}{V_2} = \frac{\mu_2}{\mu_1}$$

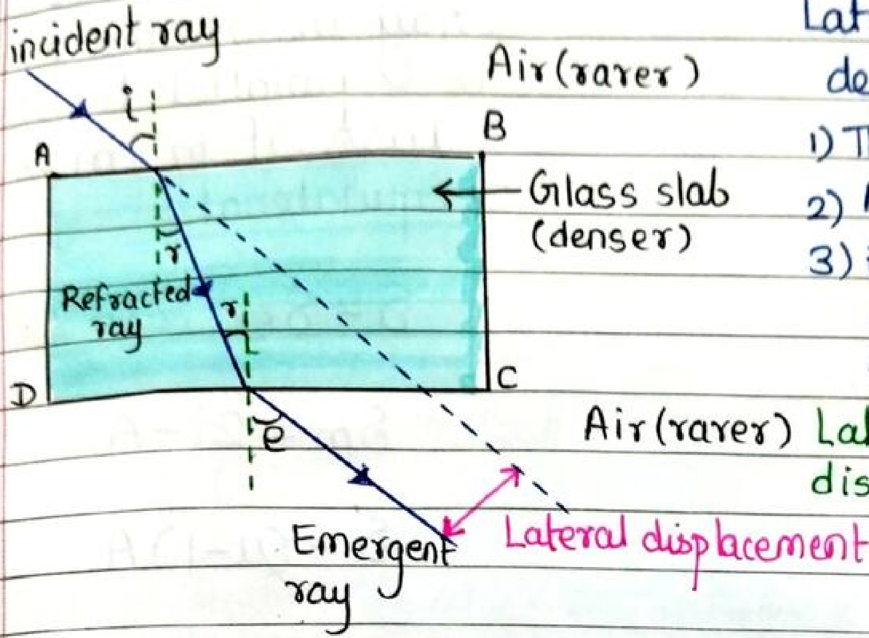
NOTE -

$$_1\mu_2 = \frac{1}{_2\mu_1}$$

Factors affecting refractive index of a medium -

1) Nature of medium (optical density)
2) Temperature of medium (temp↑ V↑ μ↓)
3) Colour or wavelength of light ($\mu_V > \mu_R$)

REFRACTION OF LIGHT THROUGH A GLASS SLAB -

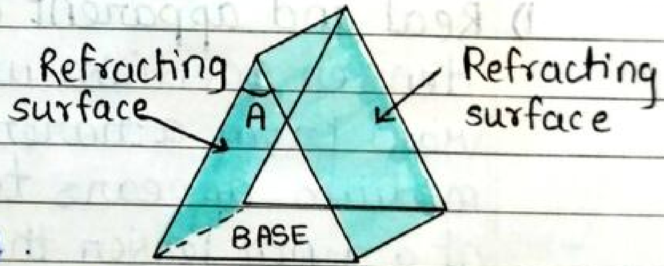


Lateral displacement depends upon -
1) Thickness of glass block
2) Angle of incidence
3) Refractive index of glass

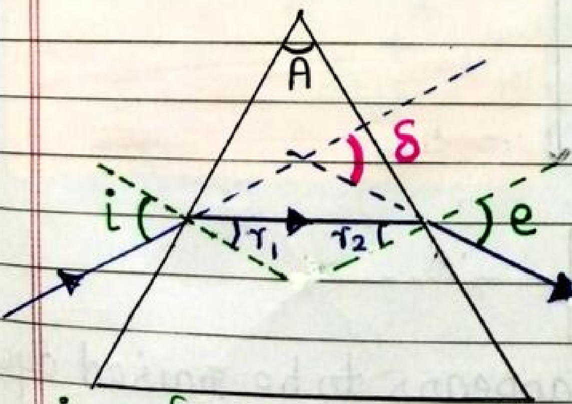
$$\text{Lateral displacement} = \frac{t\sin(i-r)}{\cos r}$$

REFRACTION OF LIGHT THROUGH PRISM -

Prism - It is a transparent medium bounded by five plane surfaces with a triangular cross section.



The different relation of ∠ in prism -



i) $\delta = (\angle i + \angle e) - (\angle r_1 + \angle r_2)$

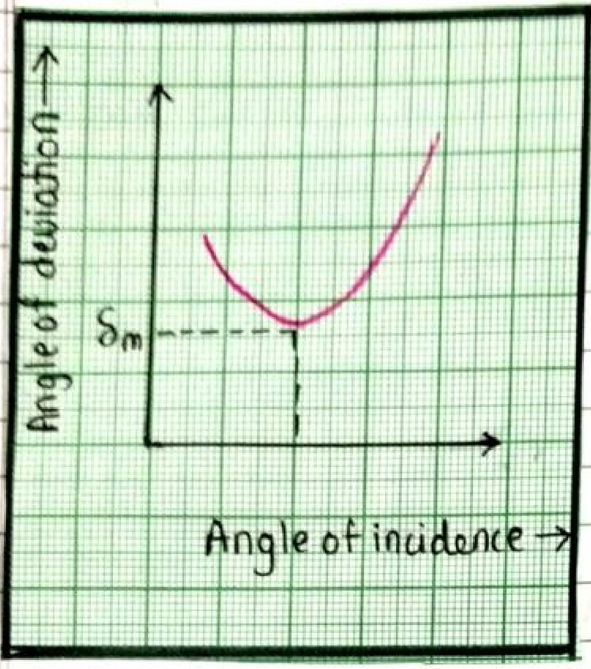
ii) $\angle i + \angle e = \angle A + \delta$

iii) $\angle r_1 + \angle r_2 = \angle A$

i - ∠ of incidence
e - ∠ of emergence
δ - ∠ of deviation
r_1, r_2 - ∠ of refraction

Factors affecting δ -
1) angle of incidence (∠i)
2) material of prism (μ)
3) angle of prism (∠A)
4) colour or wavelength of light (λ)

Relation b/w $\angle i$ & $\angle \delta$.



In the position of minimum deviation the refracted ray inside the prism is parallel to its base, if prism is equilateral.

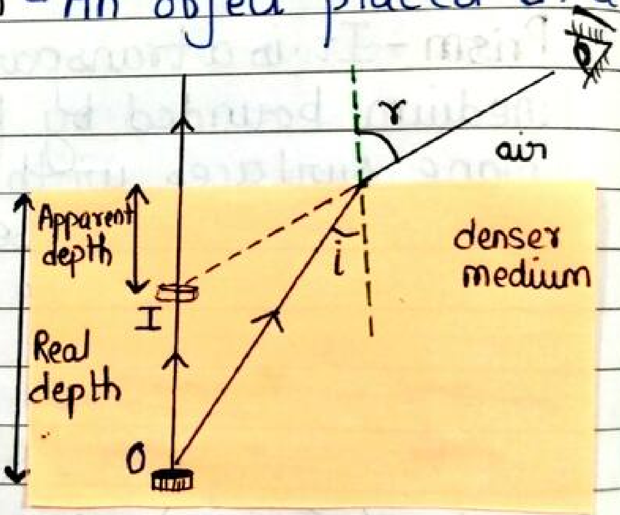
$$\delta = \delta_m \quad \angle i = \angle e$$

$$\delta_m = 2i - A$$

$$\delta = (\mu - 1)A$$

APPLICATIONS OF REFRACTION OF LIGHT

Real and apparent depth - An object placed in a denser medium when view from a rarer medium appears to be at a depth lesser than its real depth.



Shift OI = Real depth − Apparent depth

$$\text{Shift} = \text{real depth}\left[1 - \frac{1}{{}_a\mu_m}\right]$$

Shift by which the object appears to be raised depends

1) Refractive index of medium $\mu\uparrow$ shift $\uparrow$
2) Thickness of medium $\uparrow$ shift $\uparrow$
3) Wavelength (color) of light $\lambda\uparrow$ shift $\downarrow$ $\mu_V > \mu_R$

shift V > shift R

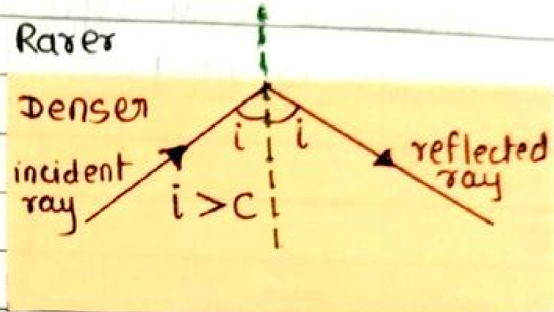
TOTAL INTERNAL REFLECTION -

When a ray of light travelling in a denser medium is incident at the surface of rarer medium at the angle of incidence greater than critical angle for the given pair of media, the ray is totally reflected back into the denser medium.

Conditions for TIR -

1) Light must travel from denser to rarer medium.

2) $\angle i > C$

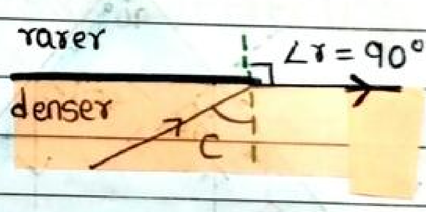


Critical Angle - The angle of incidence in denser medium for which the angle of refraction in rarer medium is 90°. It is denoted by C.

Factors affecting C -

1) Color of light $\lambda \uparrow \; C \uparrow$

2) Temperature temp $\uparrow$ $C \uparrow$



Relation between Critical Angle and Refractive index -

R.I. of rarer medium wrt denser medium $= {}_d\mu_r = \dfrac{\sin i}{\sin r}$

if $\angle i = \angle C$, $\angle r = 90°$ ${}_d\mu_r = \dfrac{\sin C}{\sin 90°}$ ${}_d\mu_r = \sin C$

$${}_r\mu_d = \frac{1}{\sin C}$$

(R.I. of denser medium wrt rarer medium)

For glass ${}_a\mu_g = \dfrac{3}{2}$

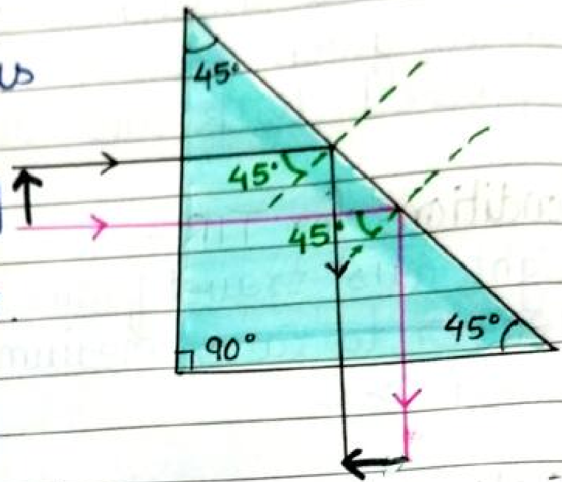
$$\sin C = \frac{1}{{}_a\mu_g} = \frac{2}{3}$$

$$C = \sin^{-1}\left[\frac{2}{3}\right] = 42°$$

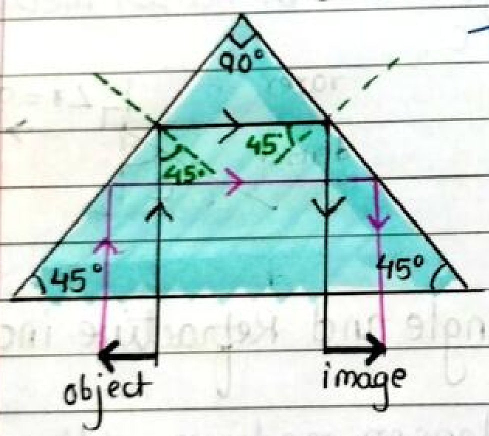
Total internal reflection in a prism -

a) To deviate light through 90°

This action of prism is used in periscope, where a total reflecting prism is preferred over a plane mirror.



b) To deviate light through 180°

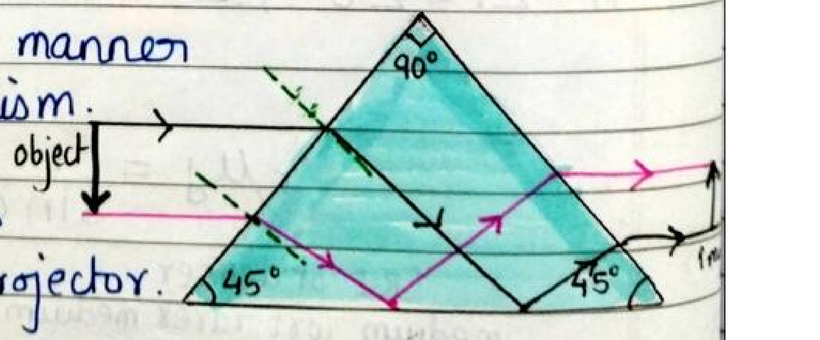


This action is used in binocular and camera to invert the image without the loss of intensity.

c) To erect the inverted image without deviation -

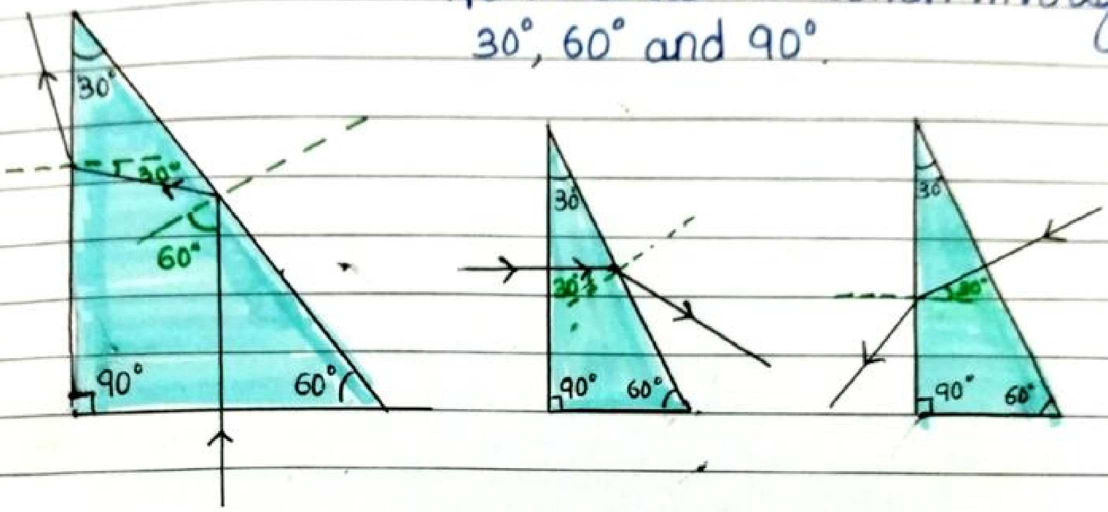
A prism used in this manner is called erecting prism.

This action of prism is used in a slide projector.



Prism of angle (30°, 60° and 90°)
It can be used to deviate a light ray through an angle less than 60° by TIR.

No internal reflection through 30°, 60° and 90°.



SOME CONSEQUENCE OF TOTAL INTERNAL REFLECTION -

1) On hot sunny day, a driver may see a pool of water (or wet road) in front of him at some distance. (MIRAGE)
2) A crack in glass vessel often shines like mirror.
3) A piece of diamond sparkles when viewed from certain directions.
4) An optical fibre is used to transmit a light signal over a long distance without much loss of energy.

FORMULA SHEET

1) $_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{V_1}{V_2}$

$\mu = \frac{c}{v}$

$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$

2) Lateral displacement $= \frac{t \sin(i-r)}{\cos r}$

3) R.I. of prism $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

$\delta_{min} = 2i - A$

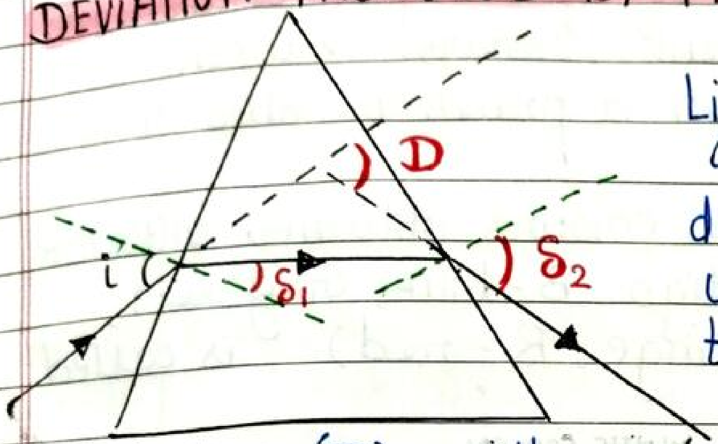
$\delta = (\mu - 1)A$

4) Shift = real depth $\left[1 - \frac{1}{{}_a\mu_m}\right]$

5) $\mu = \frac{1}{\sin C}$

SPECTRUM

DEVIATION PRODUCED BY TRIANGULAR PRISM -



Light ray while passing through a prism gets deviated two time while passing through the two refracting surface. The total deviation (D) with respect to incident ray is given as –

$$D = \delta_1 + \delta_2$$

depends on

① $\angle i$ at first surface ② Angle of prism (A) ③ R.I. of prism (color of light)

Dependence of angle of deviation on colour of light (λ) -

For different colours of light the R.I. of a given transparent medium is different.

$$\lambda \uparrow \quad \mu \downarrow$$

$$\lambda_{red} > \lambda_{violet} \quad \therefore \mu_{violet} > \mu_{red}$$

As a result prism deviate violet light most and red light least.

$$\delta_{violet} > \delta_{red}$$

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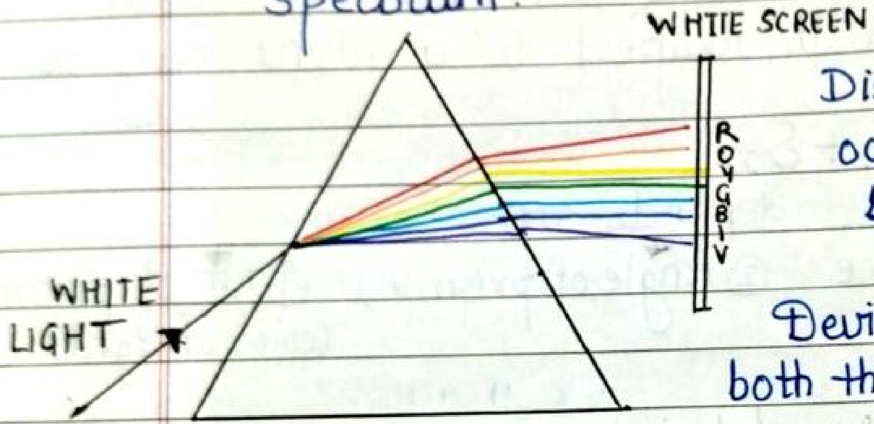
Dispersion of white light by glass prism-

The phenomenon of splitting of white light into its constituent colours when it passes through a prism is called dispersion.

This band of seven colours obtained VIBGYOR, (V = violet, I = indigo, B = blue, G = green, Y = yellow, O = orange, R = red) is called spectrum.



Dispersion of white light occurs at the first surface of prism.

Deviation of light occurs at both the surfaces of prism.

The prism does not produce colours but it only splits the various colours present in the light incident on it.

Wavelength and frequency of different colours of white light

Colour	Wavelength range (Å)	Frequency range (10^{14} Hz)
Violet	4000 – 4460	7.5 – 6.73
Indigo	4460 – 4640	6.73 – 6.47
Blue	4640 – 5000	6.47 – 6.01
Green	5000 – 5780	6.01 – 5.19
Yellow	5780 – 5920	5.19 – 5.07
Orange	5920 – 6200	5.07 – 4.84
Red	6200 – 8000	4.84 – 3.75

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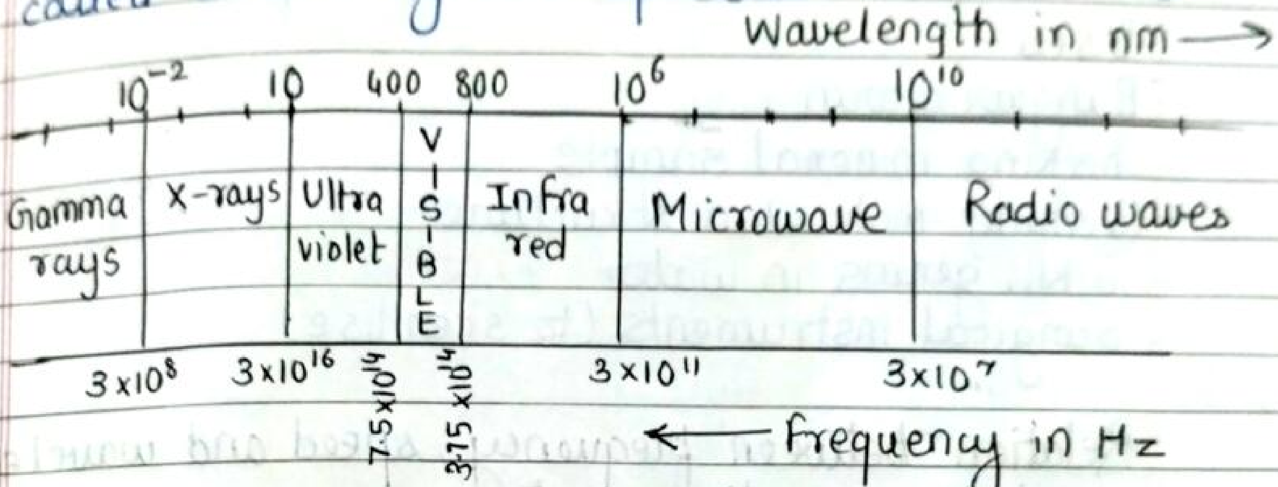
ELECTROMAGNETIC SPECTRUM AND ITS BROAD CLASSIFICATION-

The orderly distribution of electromagnetic radiations according to their wavelength or frequency is called electromagnetic spectrum.



1) Electromagnetic wave do not require material medium for their propagation.
2) They travel with same speed in vacuum. ($c = 3\times10^{8}$ m/s)
3) Exhibit property of reflection and refraction.
4) They do not deflect by electric and magnetic fields.
5) These are transverse waves.

Properties and uses of different rays-

INFRARED WAVES -

- Heat waves, i.e. produced from heat radiating bodies and molecules.
- High penetration power - frequency → 3×10^{11} Hz to 4×10^{14} Hz

Uses -

- Physical therapy
- Satellite for army purpose
- Weather forecasting
- Producing dehydrated fruits
- Solar water heat, solar cells and cooker.

ULTRAVIOLET RAYS –

- Produced by special lamps and very hot bodies.
- Sun is important source of UV rays.
- frequency 10^{14} to 10^{16} Hz

Uses –

- Burglar alarm
- Checking mineral sample
- To study molecular structure
- To kill germs in water
- Surgical instruments (to sterilise)

Relation between frequency, speed and wavelength of electromagnetic spectrum –

$$\text{Frequency } (\nu) = \frac{\text{Speed of EM wave } (v)}{\text{Wavelength } (\lambda)}$$

SCATTERING OF LIGHT –

Scattering is the process of absorption and then re-emission of light energy.

The air molecules of size smaller than the wavelength of incident light absorb the energy of incident light and then re-emit it without change in its wavelength.

The air molecules of size bigger than wavelength of incident light scatter the light of all wavelengths of white light to the same extent.

$$I \propto \frac{1}{\lambda^4}$$

I → Intensity of scattered light

λ → wavelength of light

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Blue colour of Sky –

The sky appears blue during the day because the particles in the atmosphere scatter shorter wavelengths of light particularly blue more then the longer wavelengths like red. This scattered blue light reaches our eyes.

FORMULA SHEET

- $\text{frequency} = \frac{\text{speed}}{\text{wavelength}}$
- $I \propto \frac{1}{\lambda^4}$
- $\lambda \uparrow \Rightarrow v \uparrow \Rightarrow \mu \downarrow \Rightarrow S \uparrow$

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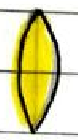
REFRACTION THROUGH A LENS

LENS - A lens is a transparent refracting medium bounded by either the two spherical surfaces or one surface spherical and other surface plane.

Types of lens

Convex (Converging lens)



Concave (Diverging lens)

Terms related to a lens -

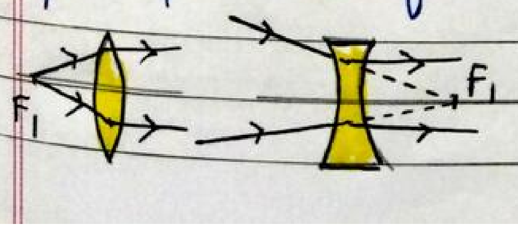
1) Centre of curvature - It is the centre of sphere whose part is a lens surface. It is denoted by C.
2) Radius of curvature - The radius of the sphere whose part is the lens surface.
3) Principal axis - Line joining the centre of curvature of the two surfaces of lens.
4) Optical centre - Point on the principal axis of lens such that a ray of light passing through this point emerges parallel to its direction of incidence.
5) Principal focus -

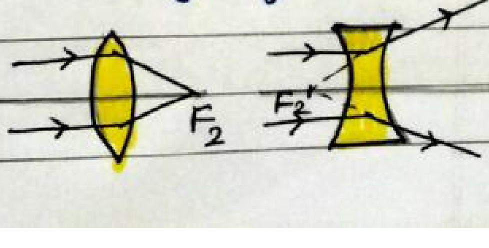
First principal focus

Point on principal axis of lens at which the rays starting from or directed to become parallel to principal axis after refraction.

Second principal focus

Point on principal axis at which the rays coming parallel to principal axis converge or appears to diverge from the lens.

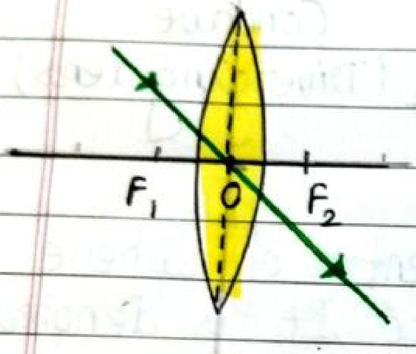




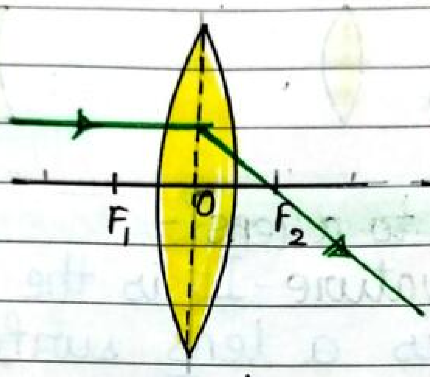
6) Focal length - The distance between focus and optical centre of lens.

7) Focal plane - The plane passing through the focus and perpendicular to the principal axis.

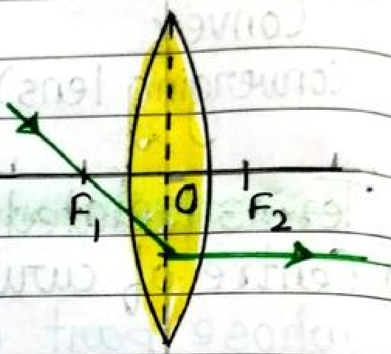
PRINCIPAL RAYS FOR RAY DIAGRAMS -



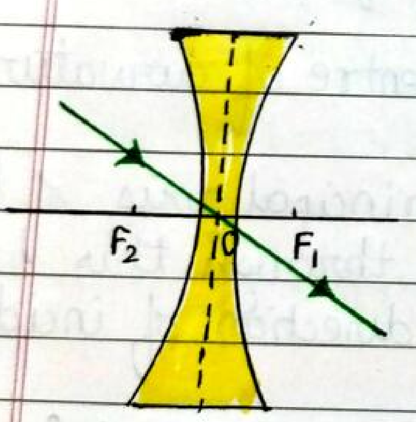
convex lens



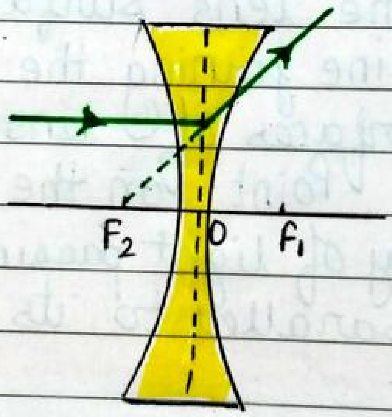
convex lens



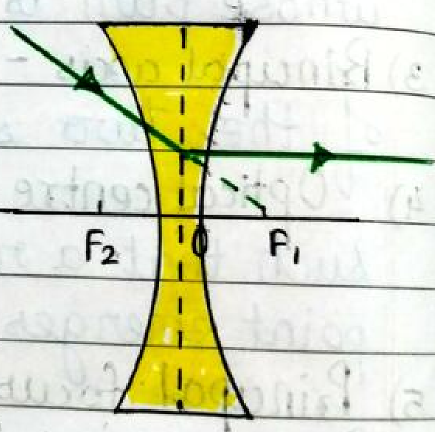
convex lens



concave lens



concave lens



concave lens

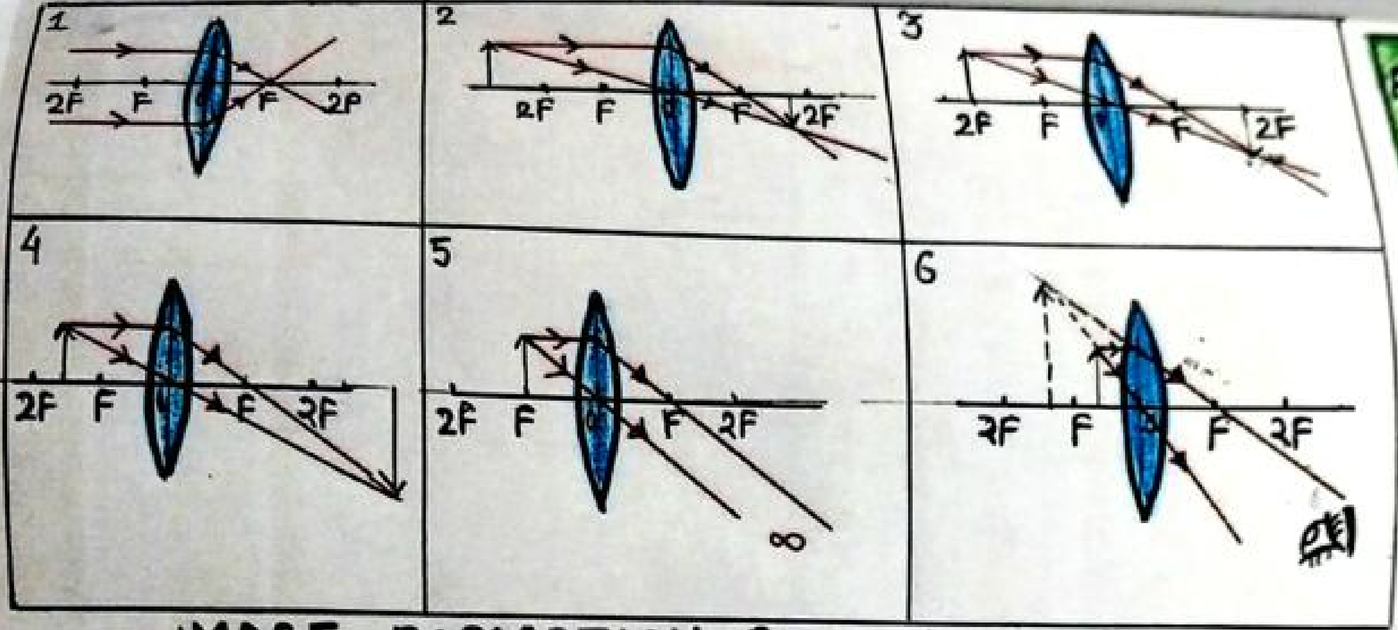
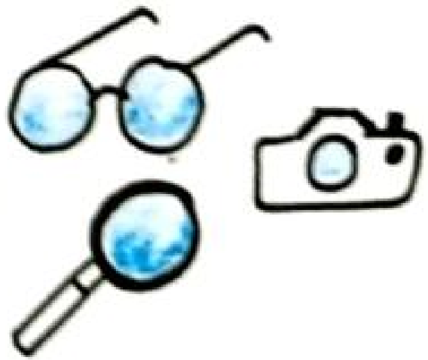


IMAGE FORMATION BY CONVEX LENS

S.No.	Position of object	Position of image	Size of image	Nature of image
1	At infinity	At F	Point sized	Real & inverted
2	Beyond 2F	Between F & 2F	Diminished	Real & inverted
3	At 2F	At 2F	Same size	Real & inverted
4	Between 2F & F	Beyond 2F	Enlarged	Real & inverted
5	At F	At infinity	Highly Enlarged	Real & inverted
6	Between F & O	On the same side of lens as the object	Enlarged	Virtual & erect

APPLICATIONS OF CONVEX LENS

- To correct Far-sightedness
- Magnifying glass
- Camera lens
- Projectors



APPLICATIONS OF CONCAVE LENS

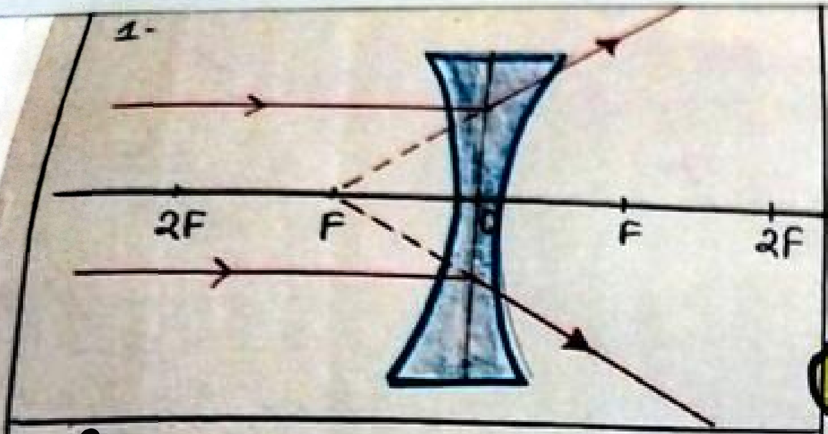
- door peepholes or spyholes

- To correct near sightedness

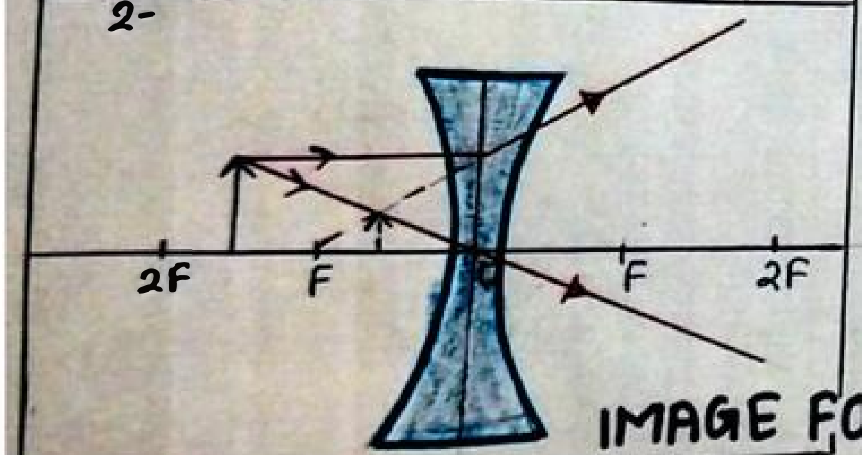
- Binoculars

IMAGE FORMATION : CONCAVE LENS

1-

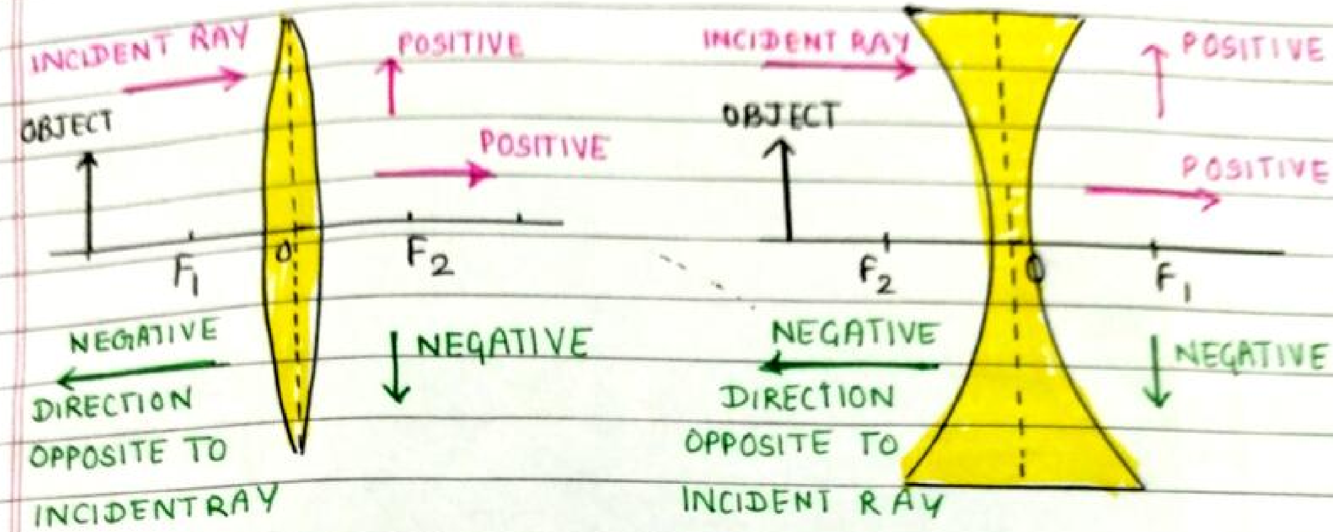


2-



S.No	Position of object	Position of image	Size of image	Nature of image
1	At infinity	At F, same side as the object	Diminished	Virtual & erect
2	Between lens & infinity	Between F & O, on same side as the object	Diminished	Virtual & erect

SIGN CONVENTION AND LENS FORMULA



$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

f → focal length
u → object distance
v → image distance

LINEAR MAGNIFICATION - The ratio of length of image to the length of object (both perpendicular to principal axis)

$$m = \frac{h_I}{h_o} = \frac{v}{u}$$

POWER OF A LENS - The deviation of the incident light rays produced by a lens on refraction through it, is a measure of its power.

$$\text{Power of lens} = \frac{1}{\text{focal length}}$$

It is measured in dioptre (D).

FORMULA SHEET

① $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

② $m = \frac{h_I}{h_o} = \frac{v}{u}$

$m \Rightarrow + \Rightarrow$ virtual, erect image

$m \Rightarrow - \Rightarrow$ real, inverted image

$|m|$

- $|m| > 1$ enlarge image
- $|m| = 1$ same size
- $|m| < 1$ diminished image

③ $P = \frac{1}{f}$

$P \Rightarrow + \Rightarrow$ Convex lens

$P \Rightarrow - \Rightarrow$ Concave lens