Unit - 03

Optics, Optical Instruments and optical fibers

Refraction:— When light passes from one medium, Say air to another, say glass, a part is reflected back into the first medium and the rest passes into the second medium when it passes into the second medium, its direction of travel is changed it either bends towards the normal or away from the normal. This phenomenon is known as refraction as shown in fig.

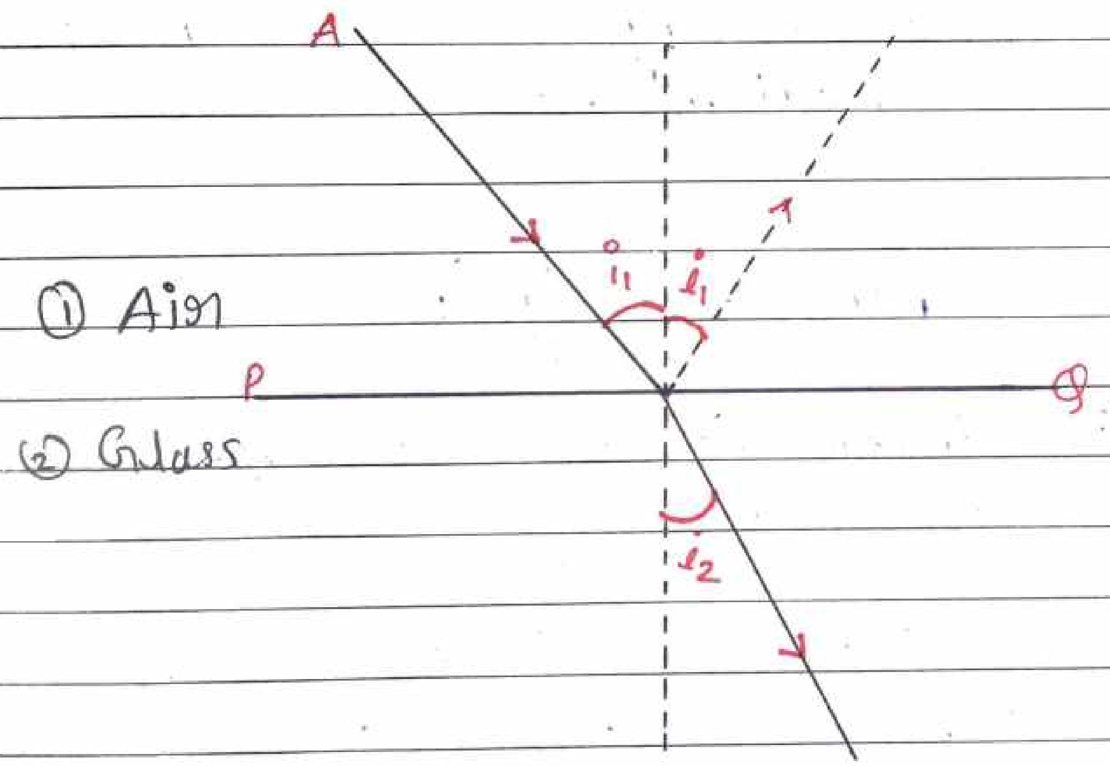

fig.

Law of Refraction:— The two laws of refraction are as follows:

(1) The incident ray, the refracted Ray and normal all lie in the same plane

(2) for two particular media the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant i.e.

$$\frac{\sin i_1}{\sin r_1} = \text{Constant}$$

$$(i_2 = r_1)$$

This is known as Snell's law.

<u>Refractive Index</u> :- The constant ratio $\frac{\sin i_1}{\sin r_1}$ is called refractive index for light passing from the first to the second medium. It is denoted by μ.

Thus,

$$_1\mu_2 = \frac{\sin i_1}{\sin i_2}$$

Refractive index is of two types which are as follows:

(1) Absolute Refractive index :- If medium 1 is a vacuum (or air) we refer $_1\mu_2$ as the absolute refrative index of medium 2 and denote it by μ_2 or simply μ.

Now, Snell's law is

$$\mu \sin i = \text{Constant}$$

for two media $\mu_1 \sin i_1 = \mu_2 \sin i_2$

or $$\frac{\mu_2}{\mu_1} = \frac{\sin i_1}{\sin i_2} = {}_1\mu_2$$

(II) **Relative Refractive index:—** The refractive index of one medium relative to another by taking the ratio of the speeds of light in the corresponding media, Hence relative refractive index of glass relative to air is given by.

$$ {}_a\mu_g = \frac{\text{Speed of light in air}}{\text{Speed of light glass}}$$

Thus we can say that $i_1 > i_2$ if $\mu_2 > \mu_1$.. i.e., if a ray of light passes from a rarer to a denser medium it bends towards normal and vice-versa.

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prove that of multiple medium $_w\mu_g = \frac{_a\mu_g}{_a\mu_w}$

Or

Explane the refraction of light through different medium.

Suppose, there are different mediums say medium-1, medium-2, medium-3, and medium-4, A ray AB of light is incident on the boundary of the medium-1 and medium-2, then it is refracted from the medium-2 to medium-3 and finally emerges out in the medium-4 along a direction DE as shown in fig.

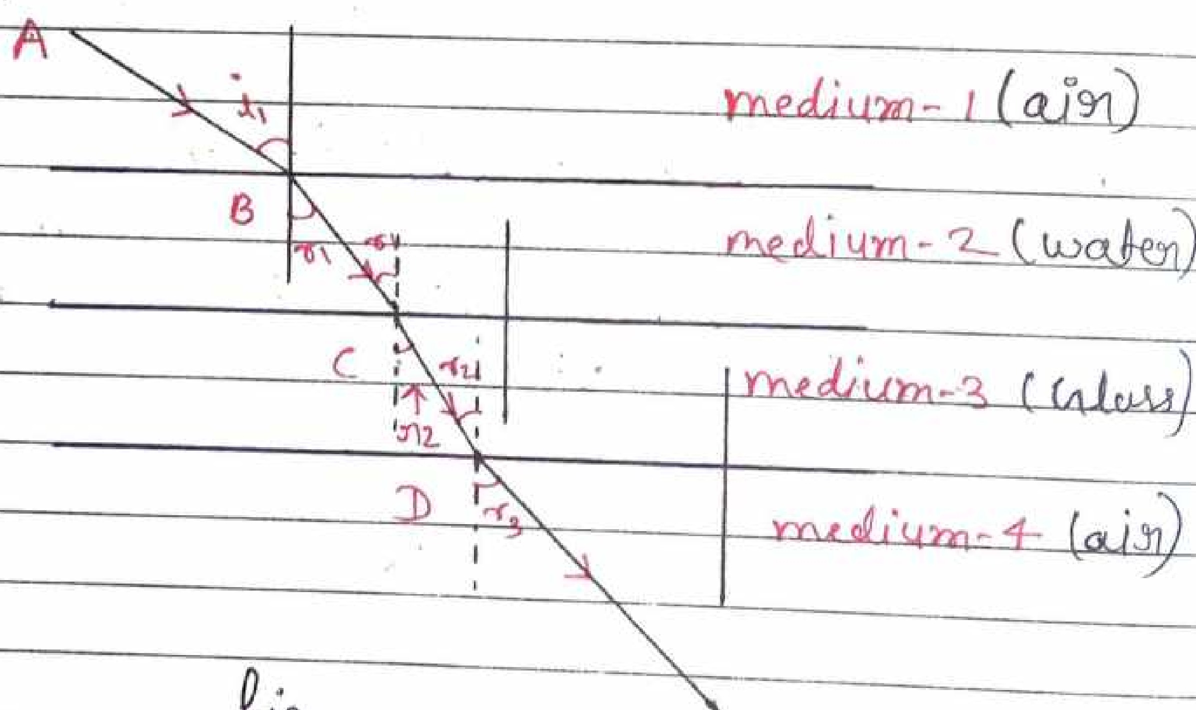

fig....

Let, the all four mediums, air, water, glass and again air let velocity of light ray in these medium are V_a, V_w, and V_g, refractive index of water with respect to air $_a\mu_w$, refractive index of glass with respect to water $_w\mu_g$ and

Refractive index of air with respect to water is $_w\mu_a$. At point B, light Ray passes from air to water then,

At point B,

$$_a\mu_w = \frac{V_a}{V_w} \quad \text{-----(1)}$$

At point C,

$$_w\mu_g = \frac{V_w}{V_g} \quad \text{-----(2)}$$

At point D,

$$_g\mu_a = \frac{V_g}{V_a} \quad \text{-----(3)}$$

Now multiplying, all three equations we get,

$$_a\mu_w \times {_w\mu_g} \times {_g\mu_a} = \frac{V_a}{V_w} \times \frac{V_w}{V_g} \times \frac{V_g}{V_a}$$

$$_a\mu_w \times {_w\mu_g} \times {_g\mu_a} = 1$$

or $$_a\mu_w \times {_w\mu_g} = \frac{1}{_g\mu_a}$$

or $$_a\mu_w \times {_w\mu_g} = {_a\mu_g} \quad \left(\because {_a\mu_g} = \frac{1}{_g\mu_a}\right)$$

or $$\boxed{_w\mu_g = \frac{_a\mu_g}{_a\mu_w}}$$

Hence proved.

Refraction through prism

A prism has two plane surfaces AB and AC inclined to each as shown in fig. ∠A is called the angle of prism or refractive angle.

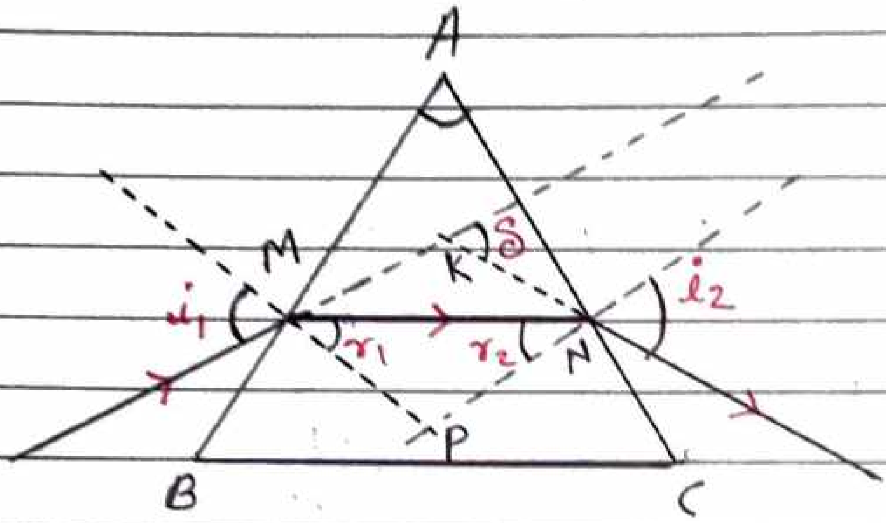

fig :- Refraction Through prism.

The importance of the prism really depends on the fact that angle of deviation suffered by light at the first refracting surface, say AB is not cancelled out by the deviation at the second surface AC, but is added to it, this is the reason that it can be used in a spectrometer, an instrument for analysing light into its component colours.

In quadrilateral AMPN

$$\angle AMP + \angle ANP = 180° \quad \text{---} \quad (1)$$

$$\angle A + \angle MPN = 180° \quad \text{---} \quad (2)$$

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In triangle MNP,

$$r_1 + r_2 + \angle MPN = 180^\circ \quad ----(3)$$

from eqn (2) and (3), we have

$$\boxed{r_1 + r_2 = A} \qquad (\because \angle A = A)$$

Deviation Angle (δ) of prism:- Deviation δ means angle between incident ray and emergent ray.

In reflection,

$$\delta = 180 - 2i = 180 - 2r$$

In refraction,

$$\delta = |i - r|$$

In prism,
A ray of light gets refracted twice one at M and other at N. At M its deviation is $i_1 - r_1$ and at N it is $i_2 - r_2$. these two deviations are added, so, the net deviation is,

$$\delta = (i_1 - r_1) + (i_2 - r_2)$$
$$= (i_1 + i_2) - (r_1 + r_2)$$
$$= (i_1 + i_2) - A$$

Thus $\delta = (i_1 + i_2) - A \quad ----- (4)$

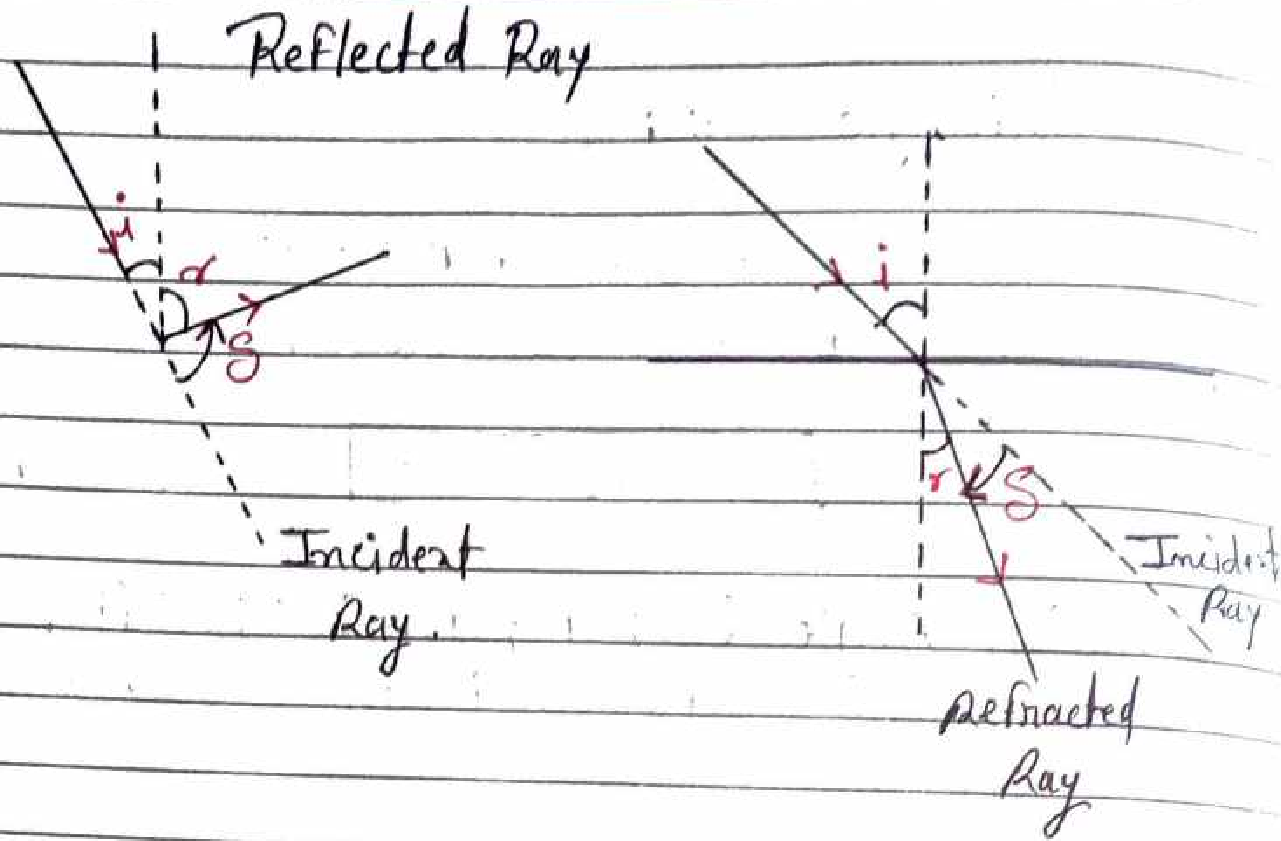

fig :- Deviation angle of prism

If A and i_1 are small, the expression for the deviation in this case is basically used for developing the lens theory. Consider a ray falling almost normally in air on a prism of small angle A. So that angle i_1 is small. Now $\left(\mu = \frac{\sin i_1}{\sin r_1}\right)$, therefore, r_1 will also be small, Hence, Sine of a small angle is nearly equal to the angle in radian, we have,

$$i_1 = \mu r_1$$

Also, $A = r_1 + r_2$ and so if A and r_1 are small r_2 and i_2 will also be small. from, $\mu = \frac{\sin i_2}{\sin r_2}$ we can say,

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$$i_2 = \mu r_2$$

Substituting these values in eqn (iv) we have

$$\delta = (\mu r_1 + \mu r_2) - A$$
$$= \mu (r_1 + r_2) - A$$
$$= \mu A - A$$
$$\boxed{\delta = (\mu - 1) A}$$

This expression shows that for a given angle A all rays entering a small angle prism at small angle of incidence suffer the same deviation.

prove that

$$\mu = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

or

Derive an expression for refractive index of prism.

from fig it is found that the angle of deviation δ varies with the angle of incidence i_1 of the ray incident on the first refracting surface of the prism.

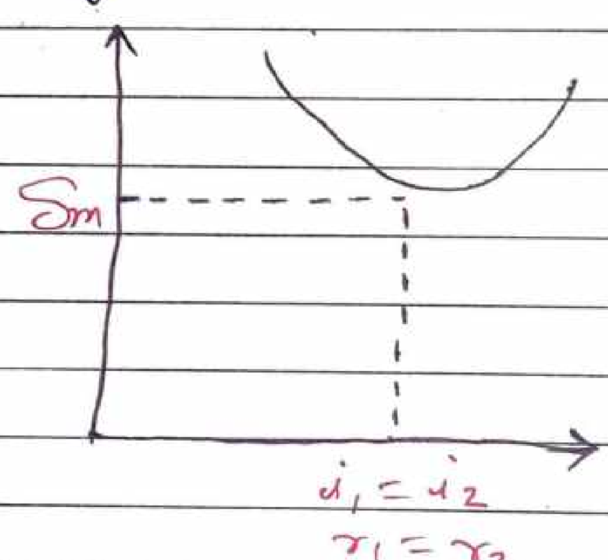
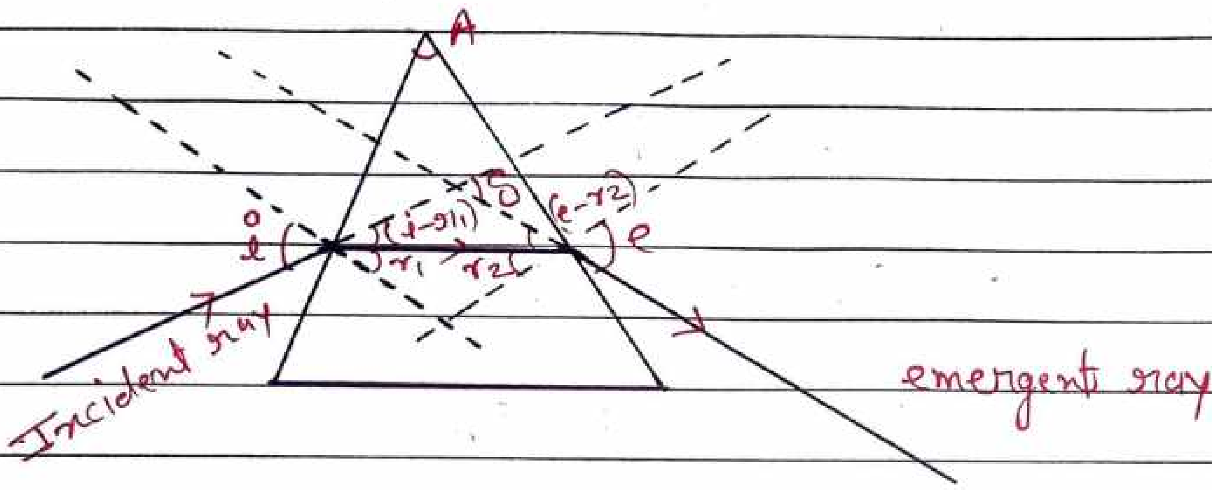


fig - 1

The variation is shown in fig and for one angle of incidence it has a minimum value δmin. At this value the ray passes symmetrically through the prism ie, the angle of emergence of the ray from the second face equals the angle of incidence of the ray on the first face



Deviation Angle,

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

in case of minimum deviation

Let, $i = e = i$

$r_1 = r_2 = r$

Minimum deviation Angle

$$\delta m = (i - r) + (i - r)$$

$$\delta m = 2i - 2r \quad \text{----- (1)}$$

We know that,

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

in case of minimum deviation

$r_1 = r_2 = r$ and $\angle A = A$

$$A = r + r$$

$$A = 2r$$

$$r = \frac{A}{2} \quad \text{----- (2)}$$

from eqn (1),

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$$\Rightarrow \delta m = 2i - 2 \times \frac{A}{2}$$

$$\Rightarrow \delta m = 2i - A$$

$$\Rightarrow A + \delta m = 2i$$

$$\Rightarrow i = \frac{A + \delta m}{2} \quad \text{----} \; (3)$$

$$\because \mu = \frac{\sin i}{\sin r} \quad \text{----} \; (4)$$

putting value of i and r,

$$\mu = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin \frac{A}{2}}$$