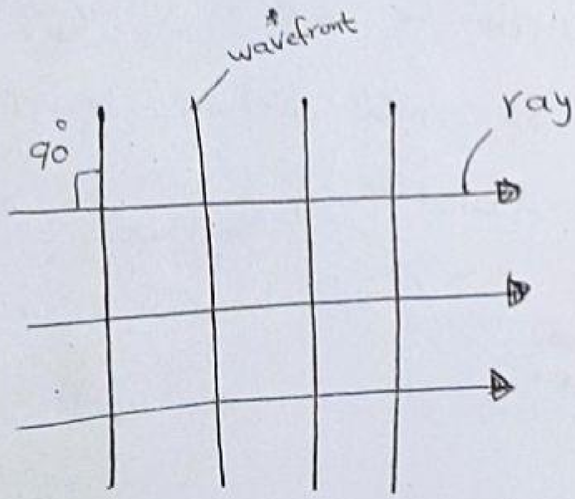
Geometrical Optics : البصريات الهندسية

As the wavelength of the light is much smaller than the physical dimensions of the optical system, we have idealized domain of geometrical optics.

Huygen's principle : مبدأ هايكنز

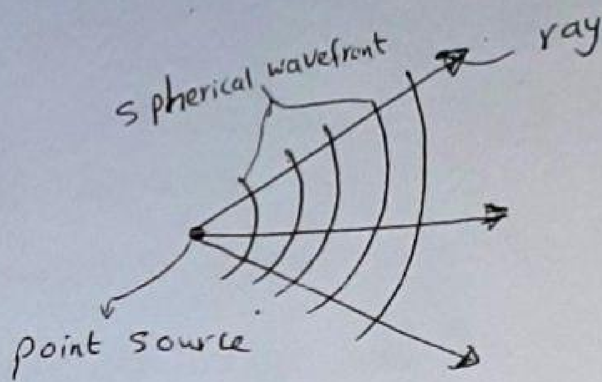
Every point on agiven wavefront may be regarded as the source of a new disturbance, called secondary wavelets.

Wavefronts : The surfaces joining all points of equall phase are known as wavefront.



plane wave front

for point Source we have spherical wavefront



in both cases the energy transfered perpendicular to wavefront

Fermat's principle of least time: مبدأ فيرمات لأدنى زمن

A ray of light in passing from one point to another through a set of media by any number of reflection and refraction selects a path for which the time is either a minimum or a maximum. let ds be small distance travelled by light between two points A and B in a medium of refractive index n as in Fig.(1).

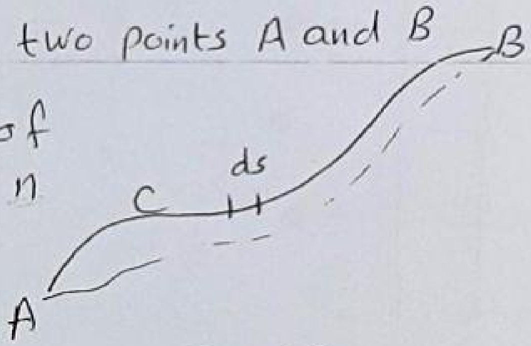


Fig.(1)

let v be the velocity of light in that medium

$$\int_A^B \frac{ds}{v} = \text{maximum or minimum}$$

$$\int_A^B \frac{n\,ds}{c} = \text{maximum or minimum}$$

$n = \frac{c}{u}$, c being the velocity of light in vacuum.

If the path ACB represents the actual path, then the time taken in traversing the path ACB will be an extremum in comparsion to any nearby path ABC. since the shortest distance between two points is along straight line, light rays in a homogeneous are straight line.

Reflection: الانعكاس

① The ~~reflected~~ incident ray, the normal to the surface of the incidence, and the reflected ray, lie in same plane.

② The angle between the incident ray and normal is equal to the angle between the reflected ray and the normal.

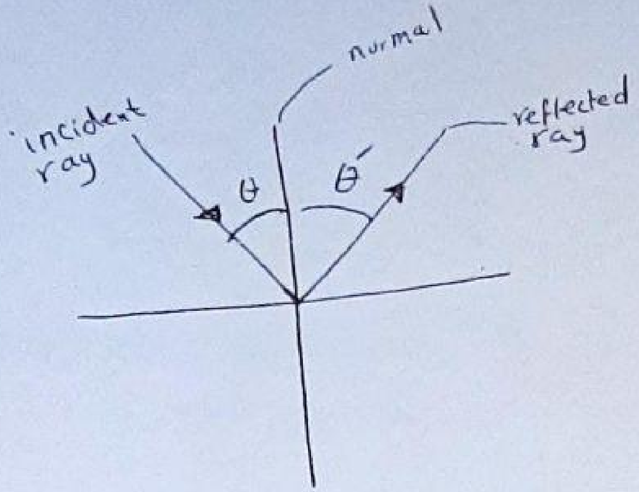


Fig.(2).

let alight ray from p reflected at point O of mirror MM' to another point Q

θ angle of incidence and θ' is angle of reflection.

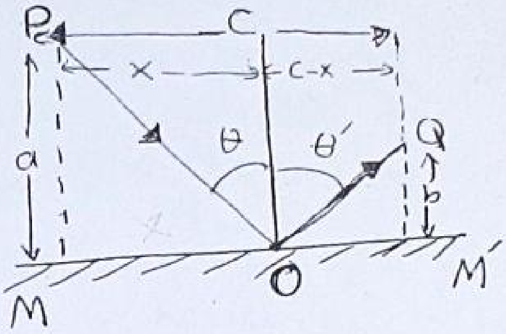


Fig.(3)

let a and b be the lengths of the perpindiculars drawn from points p and Q on the mirror MM'.

Let $MM' = C$ and $MO = x$, $OM' = (C-x)$

The optical path between p and Q is given

$$L = POQ = PO + OQ$$

$$L = \sqrt{a^2 + x^2} + \sqrt{b^2 + (c-x)^2}$$

According to Fermat's principle, O will have position such that the optical path L (or the time of travel) is a minimum or maximum

$$\frac{dL}{dx} = 0$$

$$L = (a^2 + x^2)^{\frac{1}{2}} + [(b^2 + (c-x)^2]^{\frac{1}{2}}$$

$$\frac{dL}{dx} = \frac{1}{\cancel{2}}(a^2 + x^2)^{-\frac{1}{2}}(\cancel{2}x) + \frac{1}{\cancel{2}}[(b^2 + (c-x)^2]^{-\frac{1}{2}}\cancel{2}((c-x)(-1) = 0$$

$$= \frac{x}{\sqrt{a^2 + x^2}} - \frac{c-x}{\sqrt{[b^2 + (c-x)^2]}}$$

From Fig. (3) we have $\dfrac{x}{\sqrt{a^2+x^2}} = \dfrac{MO}{PO} = \sin\theta$

and $\dfrac{c-x}{\sqrt{[b^2+(c-x)^2]}} = \dfrac{OM'}{OQ} = \sin\theta'$

$$\therefore \boxed{\sin\theta = \sin\theta' \quad \text{or} \quad \theta = \theta'}$$

This is law of reflection

Refraction : الانكسار

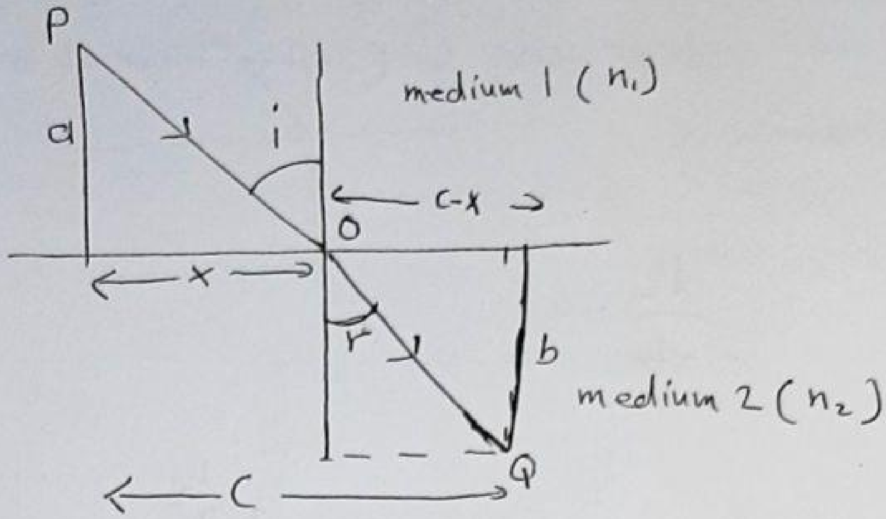


Fig. (4)

The optical path between P and Q is given by

$$L = n_1 PO + n_2 OQ$$

$$= n_1\sqrt{a^2+x^2} + n_2\sqrt{b^2+(c-x)^2}$$

Fermat's principle requires that L be a minimum or a maximum

so $\frac{dL}{dx} = 0$

$$\frac{dL}{dx} = n_1 \frac{\cancel{2}x}{\cancel{2}}(a^2+x^2)^{-\frac{1}{2}} + n_2 \frac{1}{\cancel{2}}\left[b^2+(c-x)^2\right]^{-\frac{1}{2}} \cancel{2}(c-x)(-1) = 0$$

$$= \frac{n_1 x}{\sqrt{a^2+x^2}} - \frac{n_2 (c-x)}{\sqrt{[b^2+(c-x)^2]}}$$

$$n_1 \frac{x}{\sqrt{a^2+x^2}} = n_2 \frac{(c-x)}{\sqrt{[b^2+(c-x)^2]}}$$

$$\sin i = \frac{MO}{PO} = \frac{x}{\sqrt{a^2+x^2}}$$

$$\sin r = \frac{OM'}{OQ} = \frac{c-x}{\sqrt{[b^2+(c-x)^2]}}$$

So we get $\boxed{n_1 \sin i = n_2 \sin r}$ Snell's law of refraction.

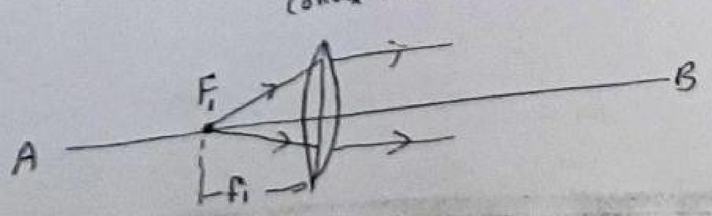
قانون سنيل

Convex lens :. A transparent refracting medium bounded by two spherical surfaces.

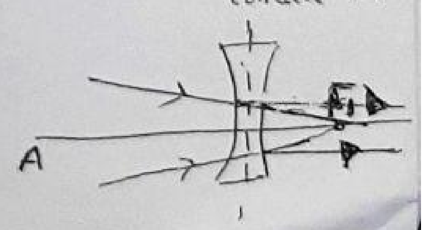
The line joining the center of two surfaces is called principal axis.

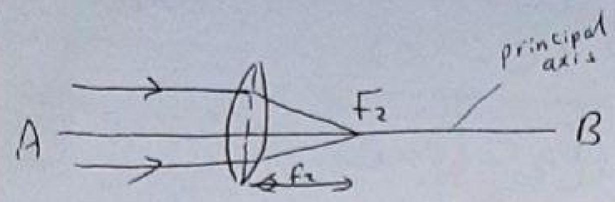
principal focus and Focal planes : البؤرة الأساسية والمستويات البؤرية

Convex lens

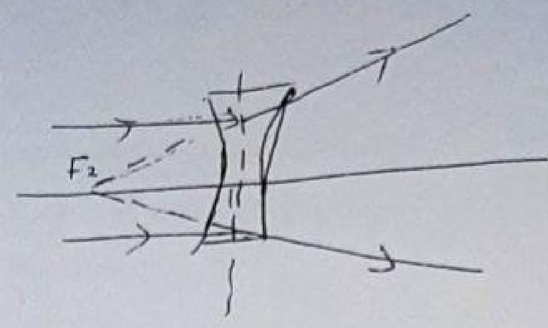


Concave lens





Convex lens



concave lens

$r_1 = (+)$, $r_2 (-1)$

$r_1 = (-)$, $r_2 (+)$

First principal Focus (F_1): It is that point on the principal axis of the lens, the rays starting from which (convex lens) or appear to converge at which (concave) become parallel to principal axis after refraction from the lens. The plane passing through F_1 and $\perp$ to the principal axis is called first focal plane.

Second principal Focus (F_2): IS that point on the principal axis at which the rays parallel to principal axis converge (convex lens) or appear to diverge (concave lens) after refraction from the lens.

اصطلاح الإشارة

Sign convention:

قياس

All distances are measured from the center of the lens. The distance from center to a real object or image is counted as postive, and the distance of a virtual object or image is negative.

معدود إيجابي

$m = -\frac{v}{u}$ بعد الصورة / بعد الجسم

Magnification of Image:

تكبير

The ratio of the length of the image to the length of the object is called magnification.

Example: An object, 2 cm in height, is placed $\perp$ to the axis of a lens of focal length 15 cm and at distance of 40 cm from the center. Find the position, size and character of image, if the lens is convex, and if the lens is concave.

جسم ارتفاع عمودي خط محوري في العدسة مركز بعد الموضع حجم صفات محدبة مقعرة

a- Convex lens

$v = \_\_\_ ?$

$u = 40$ cm

$f = 15$ cm

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

$v = 24$ cm since v is positive the image is real.

And on the opposite side of the lens, therefore inverted.

$$\text{magnification} = -\frac{v}{u} = \frac{24}{40} = \frac{-3}{5}$$

$$\text{height} = 2 \times \frac{3}{5} = 1.2 \text{ cm}$$

b). concave lens

∴ اذا كانت العدسة مقعرة البعد البؤري $f =-$ سالبة

$u = 40$ cm

$v = \_\_$?

$f = -15$ cm

$M = -\frac{v}{u}$

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

$$\frac{1}{v} = -\frac{1}{40} - \frac{1}{15}$$

$$v = -10.9 \text{ cm}$$

$$\text{Magnification} = -\frac{-v}{u} = \frac{120}{11 \times 40} = +\frac{3}{11}$$

Since v is negative the image is virtual (خيالي) and on the same side of the lens as the object, it is therefore erect (معتدلة)

$$\text{height} = 2 \times \frac{3}{11} = 0.54 \text{ cm}.$$

Example:

A beam is incident on the plane polished surface of quartz, making an angle of 31.25° with the normal. This beam Contains (مكونة) light of two wavelengths, 404.7 and 508.6 nm. The indices are 1.4697 and 1.4619 respectively. what is the $\boxed{\text{angle}}$ (زاوية) between the $\boxed{\text{two}}$ refracted rays?

$$n_1 \sin i = n_2 \sin r$$

$$1 \times \sin 31.25^\circ = 1.4697 \sin r$$

$$r = \sin^{-1}\left(\frac{1}{1.4697} \sin 31.25^\circ\right) = 20.6761^\circ$$

For $\lambda = 508.6$ nm

$$r' = \sin^{-1}\left(\frac{1}{1.4619} \sin 31.25^\circ\right) = 20.7915^\circ$$

$$\Delta r = 20.7915^\circ - 20.6761^\circ = 0.1154^\circ \times 60$$

$$\Delta r = 6.9 \text{ min of arc.}$$

$f = \frac{r}{2}$

Example: A Convex mirror (مرآة محدبة) has a radius of curvature of 22 cm, if an object is located 14 cm (u) in front (امام) of the mirror.

Find (بعد الصورة)

(1) The image distance (2) what is magnification (تكبير) in this case

1. $f = -\frac{r}{2} = -\frac{22}{2} = -11$

$\frac{1}{f} = \frac{1}{u} + \frac{1}{\cancel{v}}$

$= \frac{1}{+14} + \frac{1}{\cancel{v}} = \frac{2}{-22cm}$

$v = -6.2$ cm (virtual)

Magnification $= -\frac{v}{\cancel{u}} = -\frac{-6.2}{+14} = +0.44$

m is positive, the image must have the same orientation as the object

Example 6. Find the focal length of مقعرة concave lens has radii of curvature 42cm and is made of glass with $n = 1.65$.

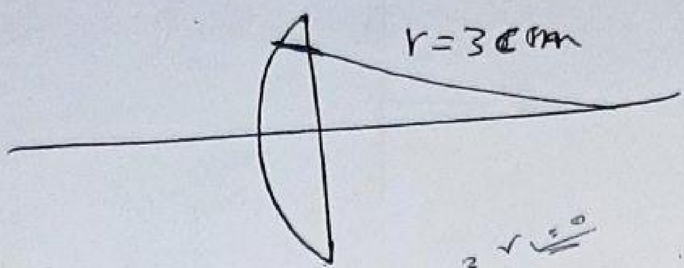
$\frac{1}{f} = (n-1)\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

$= (1.65-1)\left[\frac{1}{-42} - \frac{1}{42cm}\right]$

$f = -32$ cm (virtual focus)

(16)

Find the focal length of plano-$\boxed{\text{convex}}$ thin lens of radius 3 cm and refractive index $n = 1.5$.



$r_1 = 3$ $r_2 = -3$

$r_1 = 3\ cm$ $\quad r_2 = \infty$

$$\frac{1}{f} = (1.50 - 1)\left[\frac{1}{3} - \frac{1}{\infty}\right]$$

$f = +6\ cm$

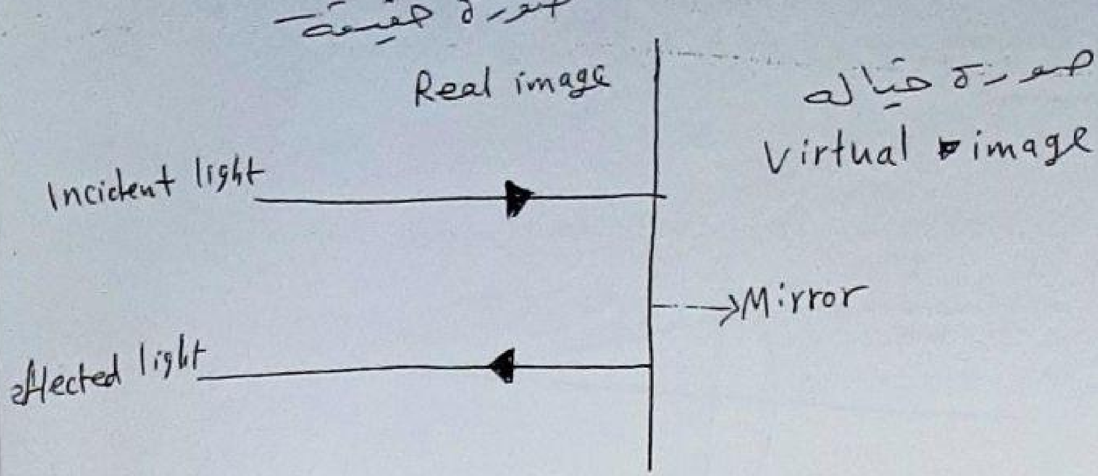
(2) if the plane surface faces the light

$r_1 = \infty$ and $r_2 = -3\ cm$

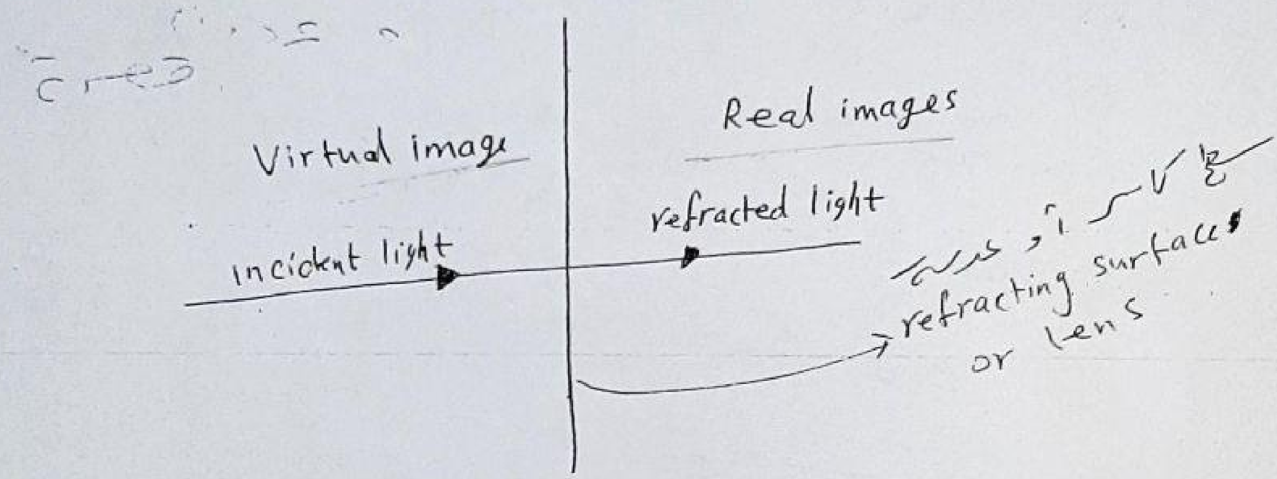
$$\frac{1}{f} = (1.5 - 1)\left[\frac{1}{\infty} - \frac{1}{-3}\right]$$

$f = +6\ cm$

* اذا اكض r تعوض سالب
* اذا احدب r تعوض موجب



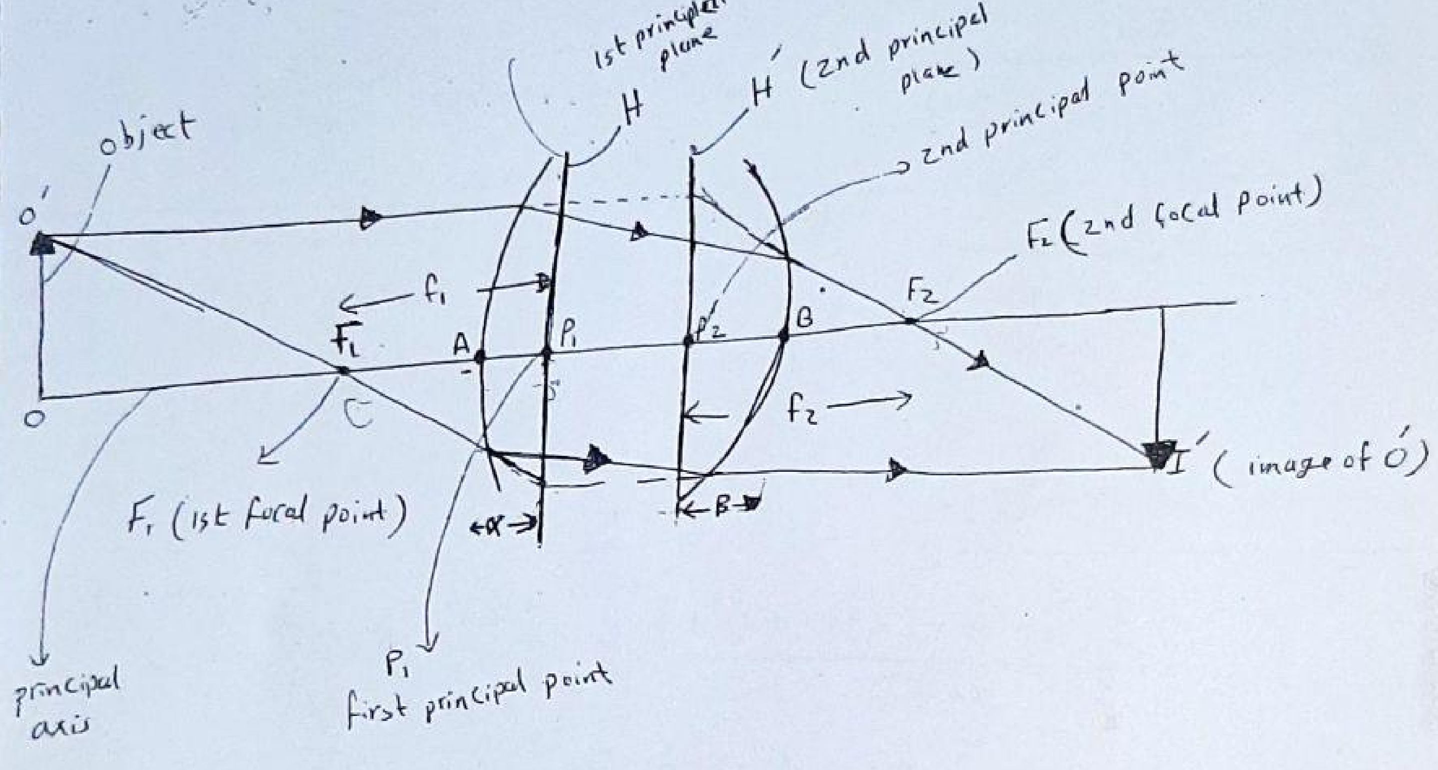
Real images are formed on the same side as the incident light for mirrors



Real image are formed on opposite side for refracting surface and for lens.

A thick lens :. العدسة السميكة

If the distance between the poles (أقطاب) of two spherical refracting surfaces is not negligible (مهملة) in comparison (مقارنة) to the ~~rad~~ radii of curvature of the spherical surfaces, the combination of two spherical refracting surfaces is called a thick lens.



f_1 = distance of first focal point F_1 from the first principal ~~plane~~ point (P_1)

f_1 = first focal length البؤرة الأولية

f_2 = distance of second focal point F_2 from the second principal point

f_2 = second focal length البؤرة الثانوية

α = distance of first principal point P_1 from the vertex A of the first surfac

distance of second principal point P_2 from Vertex B of the second surface.

The formula for the focal length of a thick lens in terms of refractive index, thickness, and radii of curvature of two faces is given by:

$$f = \frac{\mp n r_1 r_2}{n(n-1)(r_1 - r_2) - (n-1)^2 t}$$

$$\alpha = \frac{t r_1}{n(r_1 - r_2) - t(n-1)}$$

$$\beta = \frac{t r_2}{n(r_1 - r_2) - t(n-1)}$$

Power of a thick lens:

$$P = \frac{1}{f} = \frac{-[n(n-1)(r_1 - r_2) - (n-1)^2 t]}{n r_1 r_2}$$

$$= \frac{n-1}{r_1} - \frac{n-1}{r_2} + \frac{(n-1)^2 t}{n r_1 r_2}$$

$$= P_1 + P_2 - \frac{t P_1 P_2}{n}$$

$P_1 = \frac{n-1}{r}$

Here, P_1 and P_2 are the powers of the two surfaces.

**

Example: 1

$r_1 \to (+)$ $r_2 \to (-)$

A thick double Convex lens has the radii of curvature of its surfaces as 20 cm and 30 cm. The refractive index is 1.6 and the thickness is 6 cm. Calculate the focal length and the positions of the principal planes.

$$f = \frac{-n r_1 r_2}{n(n-1)(r_1 - r_2) - (n-1)^2 t}$$

$$= \frac{-1.6 \times (20)(-30)}{1.6(1.6-1)[(20-(-30)] - (1.6-1)^2 \times 6}$$

$$= 20.94 \text{ cm}$$

$$\alpha = \frac{t r_1}{n(r_1 - r_2) - (n-1)t}$$

$$\alpha = \frac{6 \times 20}{1.6 \times [(20-(-30)] - (1.6-1) \times 6}$$

$$\alpha = 1.571 \text{ cm}$$

$$\beta = \frac{t r_2}{n(r_1 - r_2) - (n-1)t} = \frac{6 \times (-30)}{1.6(20-(-30)) - (1.6-1) \times 6}$$

$$\beta = -2.356 \text{ cm}$$

*

Xample : 2

Calculate the focal length of a lens in the form of a sphere of glass ($n = 1.5$) and radius $= 5$ cm. Indicate the positions of the focal and principal planes on a diagram.

$r_1 = 5 \quad r_2 = -5$

The focal length of a thick lens is

$$f = \frac{-n r_1 r_2}{n(n-1)(r_1 - r_2) - (n-1)^2 t}$$

if r is the radius of the spherical lens, we have

$r_1 = +r$, $r_2 = -r$ and $t = 2r$

$$f = \frac{-n r(-r)}{n(n-1)(r-(-r)) - (n-1)^2 2r}$$

$$= \frac{+n r^2}{n(n-1)2r - (n-1)^2 2r}$$

$$f = \frac{n r^2}{2r[n(n-1) - (n-1)^2]} = \frac{n r}{2(n-1)} = \frac{1.5 \times 5}{2(1.5-1)}$$

$f = 7.5$ cm

$$\alpha = \frac{t r_1}{n(r_1 - r_2) - (n-1)t} = \frac{2r \times r}{n(r-(-r)) - 2r(n-1)}$$

$$\alpha = 5 \text{ cm}$$

$$\beta = \frac{t r_2}{n(r_1 - r_2) - (n-1)t} = \frac{2r(-r)}{n(r-(-r)) - 2r(n-1)}$$

$$\beta = -r = -5 \text{ cm}$$

$$AF_1 = -f\left[1 + \frac{(n-1)t}{n r_2}\right] = -7.5\left[1 + \frac{(1.5-1)\times 10}{1.5 \times (-5)}\right]$$

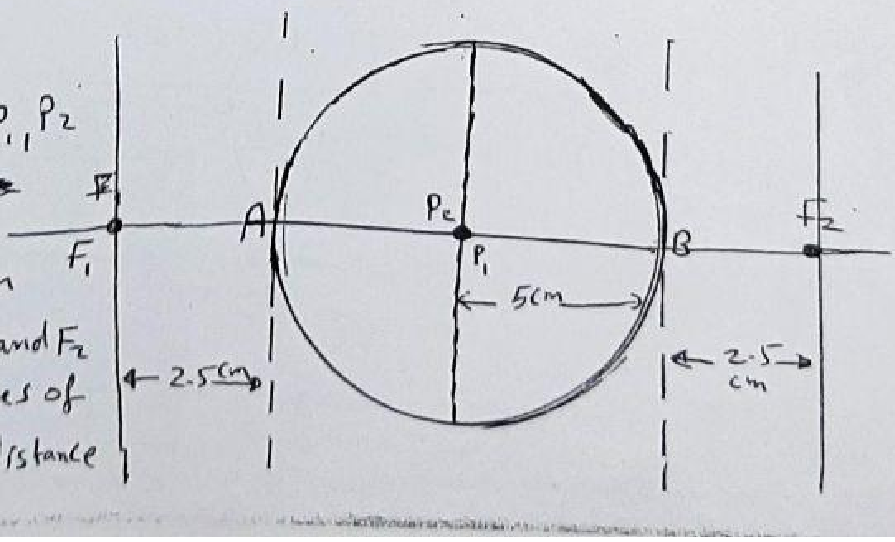
$$= -2.5 \text{ cm}$$

$$BF_2 = f\left[1 - \frac{(n-1)t}{n r_1}\right] = 7.5\left[1 - \frac{(1.5-1)\times 10}{1.5 \times 5}\right]$$

$$= 2.5 \text{ cm}$$

~~The~~ Two principal points P_1, P_2 are coincident with the center of spherical lens of radius 5cm

Two focal points F_1 and F_2 are on both the sides of the lens at equal distance (2.5cm)



Example (3)

A convex lens of thickness 4 cm has radii of Curvature 6 cm and 10 cm. Find the focal length and the positions of the focal points and the principal points. The refractive index = 1.5.

$t = 4\,cm$, $r_1 = 6\,cm$, $r_2 = -10\,cm$, $n = 1.5$

$$f = \frac{-n r_1 r_2}{n(n-1)(r_1 - r_2) - (n-1)^2 t}$$

$$= \frac{-1.5 \times 6 \times (-10)}{1.5(1.5-1)[6-(-10)] - (1.5-1)^2 \times 4}$$

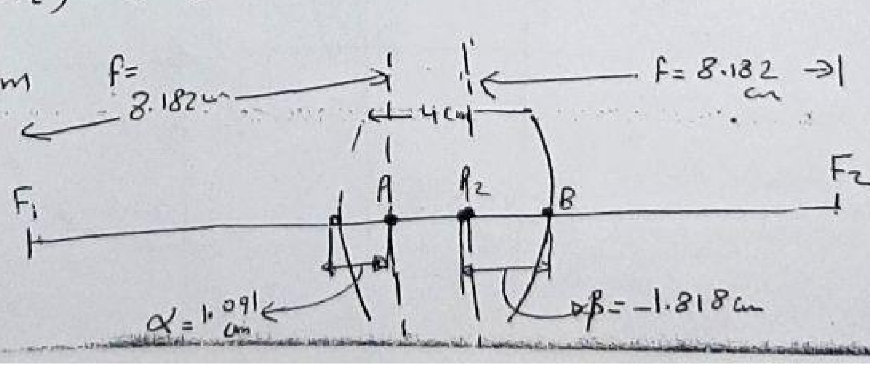
$$= 8.182\,cm$$

$$\alpha = \frac{r_1 t}{n(r_1 - r_2) - (n-1)t} = \frac{4 \times 6}{1.5[6-(-10)] - 4(1.5-1)}$$

$$\alpha = 1.091\,cm$$

$$\beta = \frac{r_2 t}{n(r_1 - r_2) - (n-1)t} = \frac{4 \times (-10)}{1.5[6-(-10)] - 4(1.5-1)}$$

$$\beta = -1.818\,cm$$



Compound lenses: العدسات المركبة

The compound lens consists of two thin lenses of focal lengths f_1 and f_2 respectively, separated by a distance a.

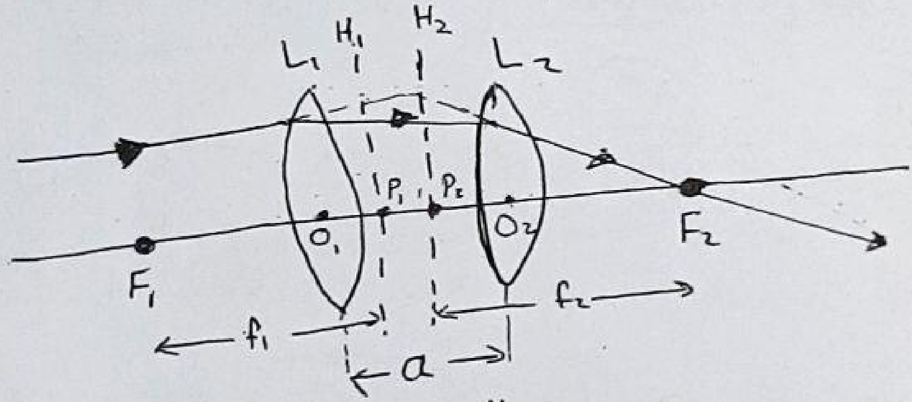
The focal length of compound lens is given by:

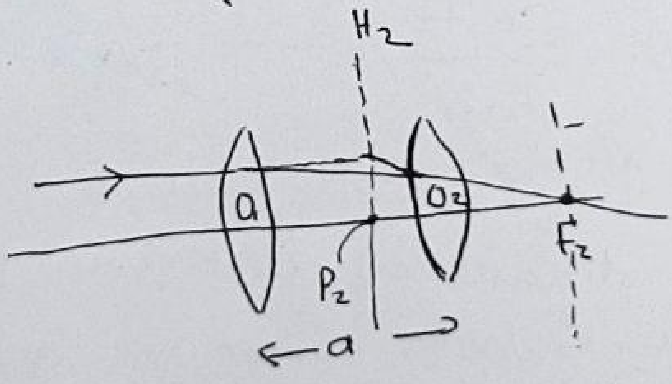
$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{a}{f_1 f_2}$$

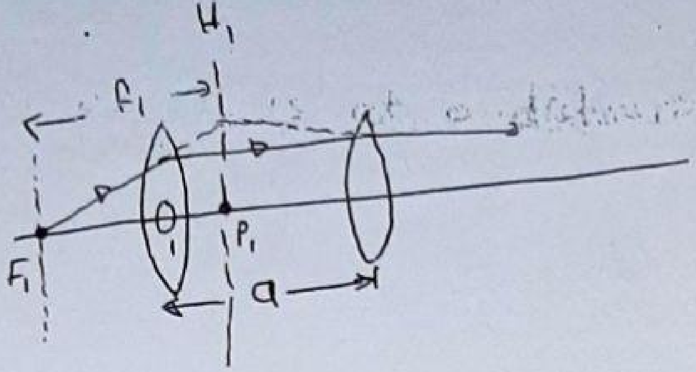
* اذا كانت العدستين Contact تماس

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

In the special case where the lenses are in contact







$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$ Two thin lenses in contact

rincipal points: The distance of the first principal point P_1 from the first (convex lens) is given by:

$$O_1P_1 = \alpha = \frac{af_1}{f_1+f_2-a} = \frac{af}{f_2}$$

اذا كعفن
بعد يؤري كامل
ويطلب f_1

The distance of second principal point P_2 from the second lens:

$$\beta = O_2P_2 \Longrightarrow \beta = \frac{-af_2}{f_1+f_2-a} = \frac{-fa}{f_1}$$

ocal points: The distance of first focal point F_1 from the first lens O_1 is given by

$$O_1F_1 = -f\left(1 - \frac{a}{f_2}\right)$$

The distance of second focal point (F_2) from the second lens

$$O_2F_2 = f\left(1 - \frac{a}{f_1}\right).$$

If P_1 and P_2 are the powers of the combinations

$$\boxed{P = P_1 + P_2 - a P_1 P_2}$$

رئيسي ، أساسي

Cardinal points: النقاط الرئيسية

Points P_1, P_2 ; F_1, F_2 ; N_1, N_2 are called cardinal points of the lens system.

N_1 and N_2 are called Nodal points, as the medium on either side of the lens system is air, N_1 and N_2 coincide with principal points P_1 and P_2.

Example :- Two convex lenses of focal length 12 cm and 4 cm are separated by 8 cm. Find the positions of the Cardinal points.

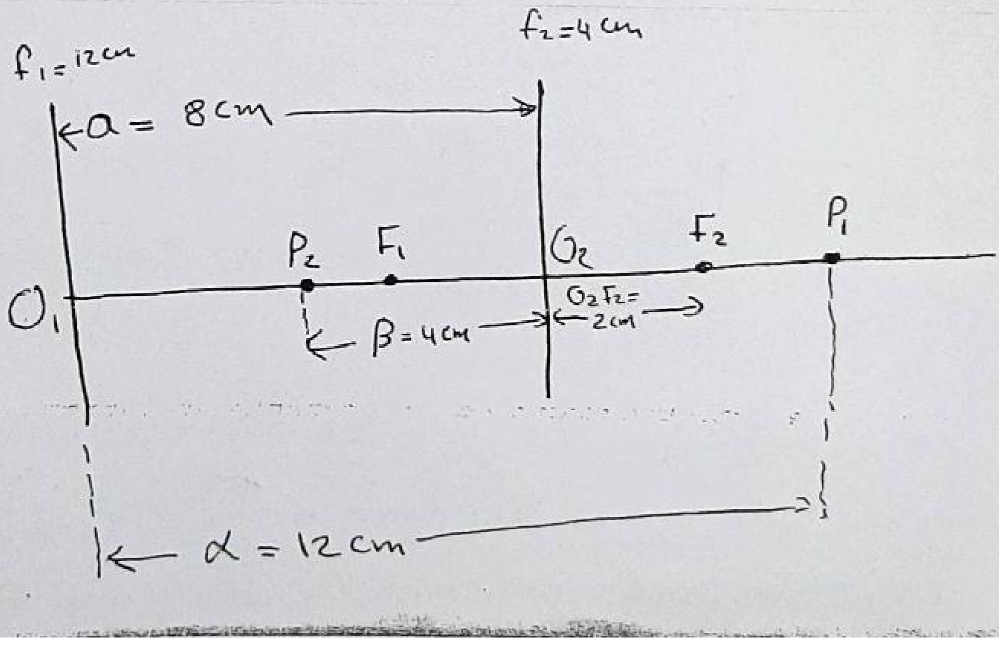
$$\alpha = O_1P_1 = \frac{af_1}{f_1+f_2-a} = \frac{8\times12}{12+4-8} = 12\text{ cm}$$

$$\beta = O_2P_2 = \frac{-af_2}{f_1+f_2-a} = \frac{-8\times4}{12+4-8} = -4\text{ cm}$$

$$P_2F_2 = f = \frac{f_1f_2}{f_1+f_2-a} = \frac{12\times4}{12+4-8} = 6\text{ cm}$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{a}{f_1f_2}$$

$$P_1F_1 = -f = \frac{-f_1f_2}{f_1+f_2-a} = -6\text{ cm}$$



$f_1 +$ $r_1 = +$ $r_2 = -$

Example: A thin Convex lens of focal length 30 cm (F_1) is placed at a distance of 20 cm (a) from a thin Concave lens (عدسة) of 50 cm focal length (F_2). Calculate the equivalent focal length (f) and the cardinal points of the system.

$$f_1 = 3.0 \text{ cm} \quad \text{and} \quad f_2 = -50 \text{ cm} \; ; \; a = 2 \text{ cm}$$

f ?

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{a}{f_1 f_2}$$

$$f = \frac{f_1 f_2}{f_1 + f_2 - a} = \frac{30 \times (-50)}{30 + (-50) - 20} = 37.5 \text{ cm}$$

cobnt
* اذا كانت العدستين f the ،
ملتصقة a=0 متلاصقتين
$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ f
and Power
$P = P_1 + P_2$
$Q_1F_1 = f$
$Q_2F_2 = f$

Cardinal points:

$$\alpha = O_1P_1 = \frac{af}{f_2} = \frac{20 \times 37.5}{-50} = -15 \text{ cm}$$

1st principal point lies at distance of 15 to the left of Convex lens O_1.

$$\beta = O_2P_2 = \frac{-af}{f_1} = \frac{-20\times 37.5}{30} = -25 \text{ cm}$$

The second principal point P_2 lies at distance of 25 to the left of concave lens O_2.

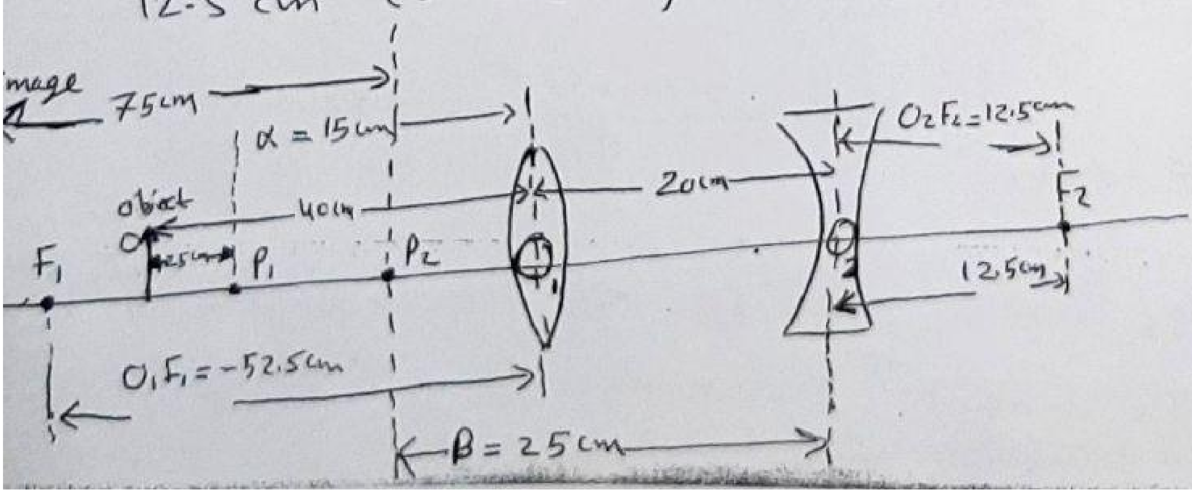
Focal points

$$O_1F_1 = -f\left(1-\frac{a}{f_2}\right) = -37.5\left(1-\frac{20}{-50}\right) = -52.5 \text{ cm}$$

The first focal point (F_1) lies at distance of 52.5 cm to the left of convex lens O_1.

$$O_2F_2 = f\left(1-\frac{a}{f_1}\right) = 37.5\left(1-\frac{20}{30}\right) = 12.5 \text{ cm}$$

The second focal point (F_2) lies at distance of 12.5 cm to the right of concave lens O_2.



IF an object is at a distance of 40 cm (u) from the convex lens. Find the position (v) of final image and its magnification.

The object O is at distance of 40 cm from lens O_1 as in ~~above~~ Fig. Let u and v be the distance of the object and image from P_1 and P_2 respectively.

Then $U = OO_1 - O_1P_1 = -(40 - 15) = -25\ cm$

From lens formula

لدينا صورة [illegible]

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

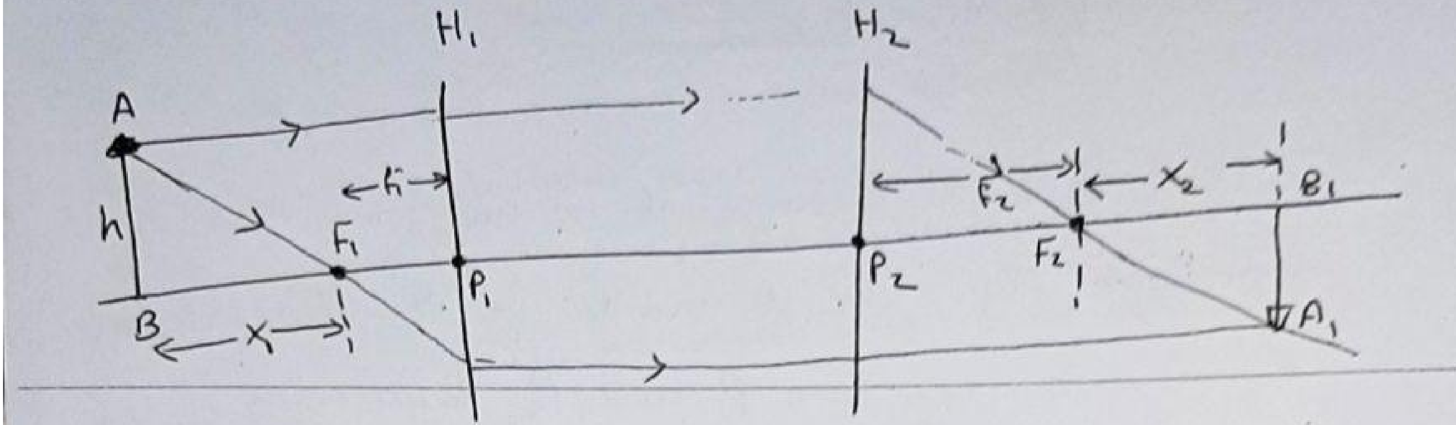
$$\frac{1}{V} - \frac{1}{(-25)} = \frac{1}{37.5}$$

$V = -75$ cm. The image lies at a distance of 75 cm to the left of P_2.

$$\text{Magnification} = \frac{-V}{u} = \frac{-75}{-25} = 3$$

قانون نيوتن في العدسات

Newton's formula for a convex lens system:



$x_1 x_2 = f_1 f_2$) Newton's formula for a co-axial lens system.

Dispersion of light: تشتت الضوء

Dispersion through a prism:

A beam (شعاع) of ~~the~~ white light, when it passes (يمر) through a prism (منشور) is split (ينشق) up into the constituent colours (مكونات الالوان). This phenomenon (ظاهرة) is called dispersion (تشتت). The coloured band obtained on the screen is called spectrum (سبكترم). It is found that violet is deviated more than the red. Hence the refractive index of glass is greater for the violet than for the red, i.e., $\boxed{n_v > n_r}$. Thus, as the wavelength increases, the refractive index decreases.

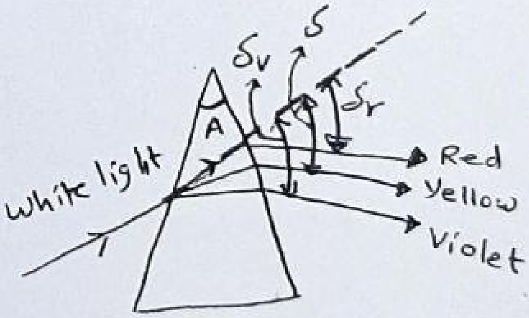
Angular dispersion. التشتت الزاوي

Let δ_v, δ_r and δ be the deviations of violet, red and yellow rays and n_v, n_r and n, the refractive indices of the material of a thin prism for them respectively. The angle of the prism A is small. Then

$$\delta_v = (n_v - 1)A$$

$$\delta_r = (n_r - 1)A$$

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



صح جداً ذكر الانحراف

The difference in deviation for any two colours is called $\boxed{\text{angular dispersion}}$ between the two colours. The angular dispersion between violet and red rays is given by,

$\delta_v = (n_v - 1)A$

$\delta_r = (n_r - 1)A$

$$\text{angular dispersion} = \delta_v - \delta_r = (n_v - n_r)A$$

زاوية رأس المنشور

قدرة التشتت

$\boxed{\text{Dispersive power}}$ (ω). It is defined as the ratio of angular dispersion ~~to~~ to the deviation of mean ray.

∴ The dispersive power of the material of a prism between red and violet rays is given by.

$$\omega = \frac{\delta_v - \delta_r}{\delta} = \frac{(n_v - n_r)A}{(n-1)A} = \frac{n_v - n_r}{n-1} = \frac{dn}{n-1}$$

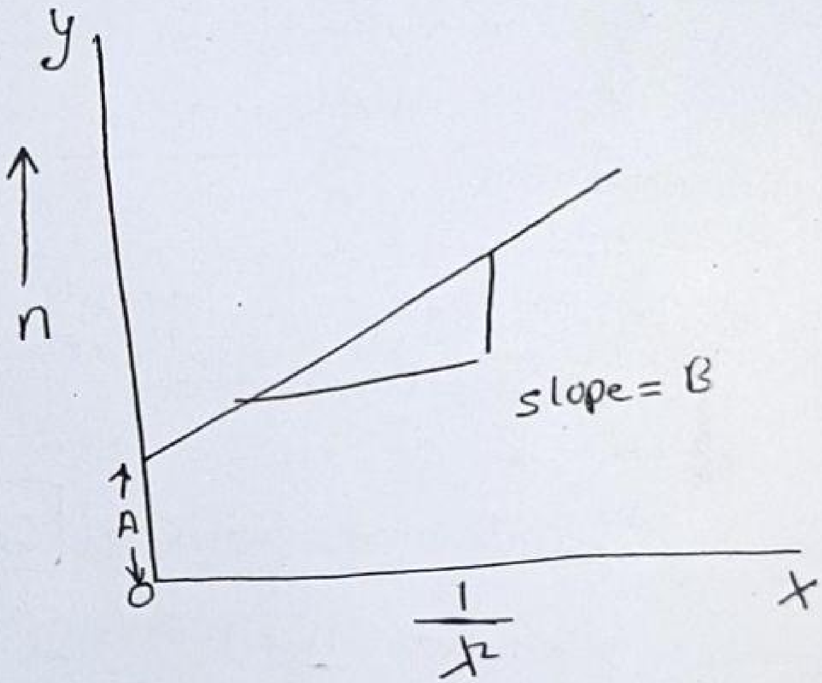
Example: A $\boxed{\text{hollow}}$ 60° prism is filled with carbon disulfide whose index of refraction for $\boxed{\text{blue}}$ light is 1.652, for $\boxed{\text{red}}$ light 1.618. What is the angular dispersion?

$$\therefore \text{angular dispersion} = (n_b - n_r)A$$
$$= (1.652 - 1.618)60 = 2.04^\circ$$

Cauchy's Formula:-

Cauchy showed that the relation the refractive index (n) and the wavelength of a light can be represented by the equation

$$n = A + \frac{B}{\lambda^2}$$



A and B are called Cauchy's constants. The values A and B depend on the medium. The equation shows that the refractive index of the medium decreases with increase in wavelength of light. A and B are called Cauchy's constants. The values of A and B depend on the medium.

The graph between n and $\frac{1}{\lambda^2}$, it is a straight line. The intercept on the y-axis gives the value of A. The slope of the line gives the value of B.

Differentiating $n = A + \frac{B}{\lambda^2}$ w.r.t. λ,

$$\frac{dn}{d\lambda} = -\frac{2B}{\lambda^3} \Longrightarrow$$

$\frac{dn}{d\lambda}$ is the dispersive power of the medium.

Hence, dispersive power is inversely proportional to the cube of the wavelength.

Example: calculate the values of $\boxed{\text{Cauchy's}}$ constants for crown glass given that $n_C = 1.514$, $n_F = 1.524$, $\lambda_C = 656.3$ nm and $\lambda_F = 486.2$ nm

$$n = A + \frac{B}{\lambda^2}$$

$$1.514 = A + \frac{B}{(656.3 \times 10^{-9})^2} \quad \text{--- (1)}$$

$$1.524 = A + \frac{B}{(486.2 \times 10^{-9})^2} \quad \text{--- (2)}$$

solving (1) and (2) we get :

$A = 1.502$, $B = 5.236 \times 10^{-15}\ m^2$.

~~Deviation~~ التفسير الفيزيائي للتشتت

physical interpretation of dispersion :

In order to explain the varation of refractive index (n) with wavelength (λ) by the electromagnetic theo- we must take take account of the molecular structure of matter.

when an electromagnetic wave (e.m.w.) is incident on an atom or a molecule, the periodic electric force of the wave sets the bound charges into vibratory motion.
حركة اهتزازية

The frequency with which these charges are forced to vibrate is equal to the frequency of the wave.
The phase of this motion relative to that of impressed المؤثرة electric force.

2.3 تشتت

Dispersion can be explained with the concept of secondary waves. When a beam of light propagates through a transparent medium (solid or liquid), the secondary waves travelling in the same direction as the incident beam superimpose on one another. The resultant vibration will depend on the phase difference. This superimposition, changes the phase of the primary waves and this is equivalent to the change in the wave velocity. Hence, the change in phase due to interference, changes the velocity of the wave ~~medium~~ through the medium.

Also, refractive index depends upon the velocity of light in the medium. Therefore, the refractive index of the medium varies with the frequency (wavelength) of light.

$$n = 1 + \frac{Ne^2 \lambda_0^2}{8\pi^2 \epsilon_0 m c^2} + \frac{Ne^2 \lambda_0^4}{8\pi^2 \epsilon_0 m c^2 \lambda^2}$$ ← احتمال سؤال

$$A = \frac{Ne^2 \lambda_0^2}{8\pi^2 \epsilon_0 m c^2}$$

$$B = 1 + \frac{Ne^2 \lambda_0^4}{8\pi^2 \epsilon_0 m c^2}$$

$$n = A + \frac{B}{\lambda^2}$$

N = number of electrons per unit volume

e = charge of electrons

ϵ_0 = permitivity of free space

m = mass of electrons

λ_0 = ~~wave length~~ wavelength of light in free space

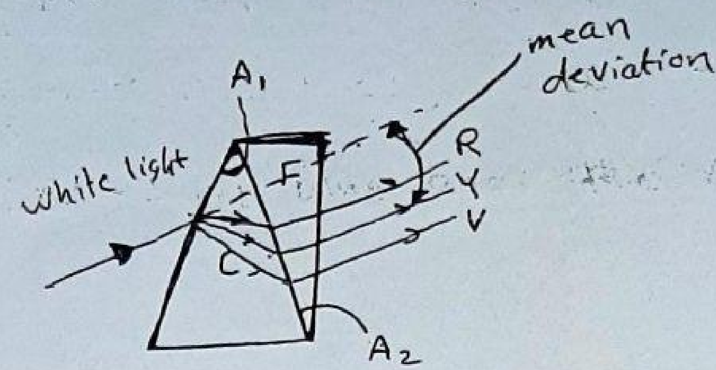
c = speed of light

اللالونية

Achromatism in prisms:

Deviation without dispersion: when a beam of white light is passed through a prism, then both deviation and dispersion are produced. A prism (منشور) that produces (ينتج) deviation (انحراف) without dispersion (تشتت) is called an achromatic prism (المنشور اللوني). مهم جداً

Consider two prisms, one of crown glass and other of flint glass with angle A_1 and A_2 respectively as in Fig.



et n_{1v}, n_{1r}, n_1 and n_{2v}, n_{2r}, n_2 be the refractive indices of the two materials for violet, red and the mean yellow rays of light.

The angular dispersion produced by crown prism

$$=(n_{1v}-n_{1r})A_1$$

Angular dispersion produced by flint prism $=(n_{2v}-n_{2r})A_2$

The condition for deviation without dispersion is :

$$(n_{1v}-n_{1r})A_1+(n_{2v}-n_{2r})A_2=0$$

or $$\frac{A_2}{A_1}=\frac{(n_{1v}-n_{1r})}{-(n_{2v}-n_{2r})}$$

The negative sign shows that the refracting angles of the two prisms in opposite directions.

The rays of different colours emerging from such combination, are found parallel to each other and hence combine to form white light.

Let ω_1 and ω_2 be the dispersive powers of crown and flint glass prisms respectively and δ_1 and δ_2 their mean deviations

$$\frac{n_{1v} - n_{1r}}{(n_1 - 1)}(n_1 - 1)A_1 + \frac{n_{2v} - n_{2r}}{(n_2 - 1)}(n_2 - 1)A_2 = 0$$

But $\dfrac{n_{1v} - n_{1r}}{n_1 - 1} = \omega_1$ and $\dfrac{n_{2v} - n_{2r}}{n_2 - 1} = \omega_2$

$$\delta_1 \omega_1 + \omega_2 \delta_2 = 0$$

$\therefore$ The deviation produced by the combination for the mean ray is

$$\delta = \delta_1 + \delta_2 = (n_1 - 1)A_1 + (n_2 - 1)A_2$$

Substituting for $A_2 = \left[-\dfrac{(n_{1v} - n_{1r})A_1}{(n_{2v} - n_{2r})}\right]$

$$\delta = (n_1 - 1)A_1 + (n_2 - 1)\left[-\frac{(n_{1v} - n_{1r})A_1}{(n_{2v} - n_{2r})}\right]$$

But $(n_1 - 1) = \dfrac{n_{1v} - n_{1r}}{\omega_1}$ and $\dfrac{n_2 - 1}{n_{2v} - n_{2r}} = \dfrac{1}{\omega_2}$

$$\therefore \delta = (n_{1v} - n_{1r}) A_1 \left(\frac{1}{\omega_1} - \frac{1}{\omega_2} \right).$$

مهم Since $n_{1v} > n_{1r}$ and $\omega_2 > \omega_1$, δ has positive value.

A_1

Example: Find the angle of a crown glass prism to be combined with a flint (A_2) glass prism of refracting angle 5° so that the resultant dispersion between C and F lines of the spectrum may be zero. Find also the deviation for the mean ray given that

$\delta =$

	Crown glass	Flint glass
n_F	1.5233	1.6385
n_C	1.5146	1.6224

Solution: Here $A_2 = 5^\circ$, $n_{1f} = 1.5233$, n_{1c} 1.5146

$n_{2f} = 1.6385$, $n_{2c} = 1.6224$; $A_1 = ?$

$$\frac{A_2}{A_1} = \frac{-(n_{1f} - n_{1c})}{(n_{2f} - n_{2c})}$$

or $\dfrac{5}{A_1} = -\dfrac{(1.5233 - 1.5146)}{(1.6385 - 1.6224)}$ or $A_1 = -9.253^\circ$

Now $n_1 = \frac{1.5233+1.5146}{2} = 1.519$

$$n_2 = \frac{1.6385+1.6224}{2} = 1.630$$

Deviation for the mean ray

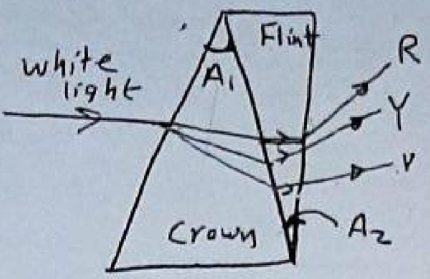
$$\delta = (n_1-1)A_1 + (n_2-1)A_2$$
$$= (1.519-1)(-9.253) + (1.630-1)5 = -1.652^\circ$$

Dispersion without Deviation:

When white light passes through a prism, it suffers deviation and dispersion. Two prisms of different material may be combined so that the resultant deviation is zero. But there will be still dispersion.

Let A_1 and A_2 be the angles of two prisms and $n_{1v}, n_{1r}, n_1, n_{2v}, n_{2r}, n_2$ be the refractive indices of the two materials for the violet, red and mean rays respectively.

The deviation produced by the two prisms for the mean ray is



$$(n_1 - 1)A_1 + (n_2 - 1)A_2 = 0$$

$$\frac{A_2}{A_1} = -\left[\frac{n_1 - 1}{n_2 - 1}\right]$$

The negative sign shows ~~that~~ that the refracting angles of two prisms are in opposite directions.

The total dispersion produced by the two prisms is

$$\theta = (n_{1v} - n_{1r})A_1 + (n_{2v} - n_{2r})A_2$$

But $A_2 = -\left[\frac{n_1 - 1}{n_2 - 1}\right] A_1$

$$\theta = (n_{1v} - n_{1r})A_1 - \frac{(n_{2v} - n_{2r})(n_1 - 1)}{n_2 - 1} A_1$$

$$= (n_1 - 1)A_1 \left[\frac{n_{1v} - n_{1r}}{n_1 - 1} - \frac{n_{2v} - n_{2r}}{n_2 - 1}\right]$$

$$\theta = (n_1 - 1)A_1 [(\omega_1 - \omega_2)]$$

Here, ω_1 and ω_2 are dispersive powers of the materials of the two prisms.

The dispersive powers of crown and flint glasses are 0.03 and 0.05 respectively. If the difference in the refractive indices of blue and red colours is 0.015 for crown glass and 0.022 for flint glass. Calculate the angles of two prisms for $\boxed{\text{deviation}}$ of 2° (without dispersion).

$$\delta = (n_1 - 1)A_1 + (n_2 - 1)A_2$$

$$2^\circ = \frac{dn_c}{\omega_1} A_1 + \frac{dn_f}{\omega_2} A_2$$

$$2 = \frac{0.015}{0.03} A_1 + \frac{0.022}{0.05} A_2$$

$$2 = 0.5 A_1 + 0.44 A_2 \text{ ——— } (1)$$

~~2 = 0.5A₁ − 0.299~~

$$\frac{A_2}{A_1} = -\frac{n_{1b} - n_{1r}}{n_{2b} - n_{2r}}$$

$$\frac{A_2}{A_1} = -\frac{0.015}{0.022} = -0.68$$

$$\frac{A_2}{A_1} = -0.68 \text{ ——— } (2)$$

$$A_2 = -0.68 A_1$$

نعوض في معادلة (1)

The refractive indices of crown glass for red and blue light are 1.515 and 1.523 respectively; and those of flint glass for the same two colours are 1.614 and 1.632 respectively what must be the $\boxed{\text{angle}}$ of flint glass which when combined with a crown glass prism of 4° (A_1) produces (a) deviation but no dispersion (b) dispersion but no deviation. Calculate also the amount of deviation in (a) and the amount of dispersion in (b).

(a) $$\frac{A_2}{A_1} = -\frac{n_{1b} - n_{1r}}{n_{2b} - n_{2r}}$$

$\delta = (n_1 - 1)A$

$$\frac{A_2}{4} = -\frac{1.523 - 1.515}{1.632 - 1.614} = \frac{0.008}{0.018}$$

$$A_2 = -1.7^\circ$$

(b) $$\frac{A_2}{A_1} = -\left[\frac{n_1 - 1}{n_2 - 1}\right]$$

$$\frac{A_2}{A_1} = -\frac{0.519}{0.623}$$

$\cancel{A_2 = -4}$

$$\frac{A_2}{4} = -0.833$$

$$\boxed{A_2 = -3.33^\circ}$$

Since $\omega_1 \neq \omega_2$, there will be a resultant dispersion.

Example :-

Calculate

1- The $\boxed{\text{refracting angle}}$ of a flint glass prism should be combined with a crown glass prism of refracting angle 9° so that the combination may have no deviation for the D line.

2- The angular separation between the C and F line.

given that the refractive indices ~~indexes~~ of the materials are as follows:

	C	D	F
Flint	1.790 n_1	1.795	1.805
Crown	1.527 n_2	1.530	1.535

Solution :-

$A_2 = 9^\circ$, $n_1 = 1.795$, $n_2 = 1.530$, $A_1 = ?$

$$\frac{A_2}{A_1} = -\left(\frac{(n_1 - 1)}{n_2 - 1}\right)$$

$$\frac{9}{A} = -\left[\frac{1.795 - 1}{1.530 - 1}\right] \quad \text{or} \quad A_1 = -6^\circ$$

The total dispersion produced by the two prisms is

$$\theta = (n_{1F} - n_{1C})A_1 + (n_{2F} - n_{2C})A_2$$

$$= (1.805 - 1.790)(-6) + (1.535 - 1.527)9$$

$$\theta \doteq -0.090^\circ + 0.072^\circ = -0.018^\circ$$

The negative sign indicates that the resultant dispersion is in the direction of the deviation produced by the flint glass prism.

***

Example: A crown glass prism of angle 10° and dispersive power of 0.01575 is to be combined with a flint glass prism of dispersive power 0.02764. If the refractive indices of the prisms for sodium D light are respectively 1.511 and 1.621, calculate the angle of second prism. Also calculate the net dispersion produced by the combination.

$A_1 = 10^\circ$, $\omega_1 = 0.01575$, $\omega_2 = 0.02764$, $n_1 = 1.511$, $n_2 = 1.621$,

$A_2 = ?$, $\theta = ?$

$$\frac{A_2}{A_1} = -\left[\frac{n_1 - 1}{n_2 - 1}\right] \quad \text{or} \quad \frac{A_2}{10} = \left[\frac{1.511 - 1}{1.621 - 1}\right]$$

$$\therefore A_2 = -8.229^\circ$$

[illegible] $\omega_2 = (1.511 - 1)(0.01575 - 0.02764) =$ [illegible]

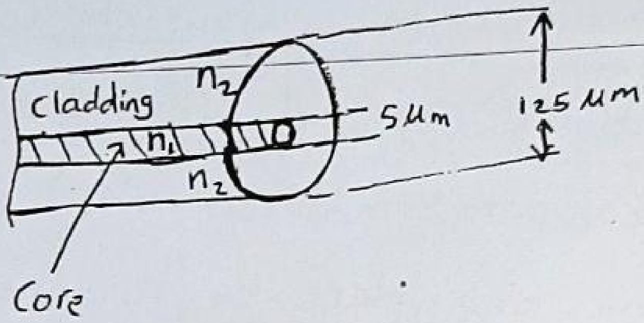
1- له تردد بصري كبير
2- صنع هذا لنقل معلومات الى مسافات بعيدة
3- هناك خسارة اقل ما يمكن
4- يستخدم في T.V

FIBRE OPTICS :

Optical frequencies are very large ($\sim 10^{15}$ Hz), as compared to the conventional radio waves ($\sim 10^{6}$ Hz) and microwaves ($\sim 10^{10}$ Hz). So a light beam acting as a carrier wave is capable of carrying far more information than radio waves and microwaves. Thus optical communication is a $\boxed{\text{superior}}$ to radio and microwave communication. Optical fibre is a hair structure made up of transparent material which can guide the light beam from one place to another by total internal reflection. The combination of low loss (~ 0.2 dB/km) and wide bandwidth available at optical frequencies make these fibres extremely attractive for the transmissi medium in communication systems. Optical fibres are replacing the copper cables previously used in telecommunications. Fibre optics is being used to transmit voice, television and digital data signals by light waves.

ibre Construction :-

An optical fibre consists of a central cylindrical core with refractive index n_1 surrounded by a layer of material, called cladding, with a lower refractive index n_2. The core transmits the light waves, and the cladding keeps the light waves within the core and strengthens the fibre.



: and the cladding are made of either glass or plastic.
diameters range from 5 to 600 μm, and cladding
eters vary from 125 to 750 μm. To keep the light
, the core, the thickness of the cladding must be of
am of one or two wavelengths of the light n
itted.

light propagation in Fibres :-

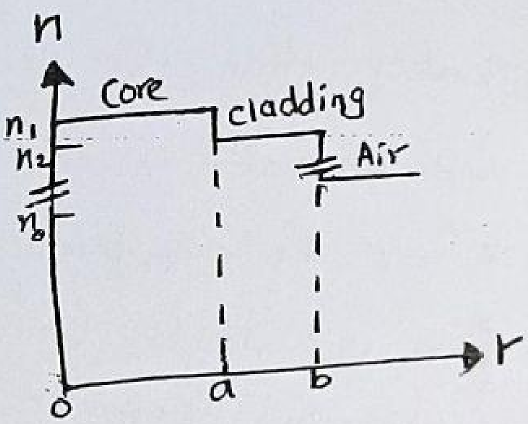
Let a = core radius and b = cladding radius.

The refractive index distribution (in the transverse direction) is given by

$$n(r) = n_1 \quad 0 < r < a \quad \text{core}$$

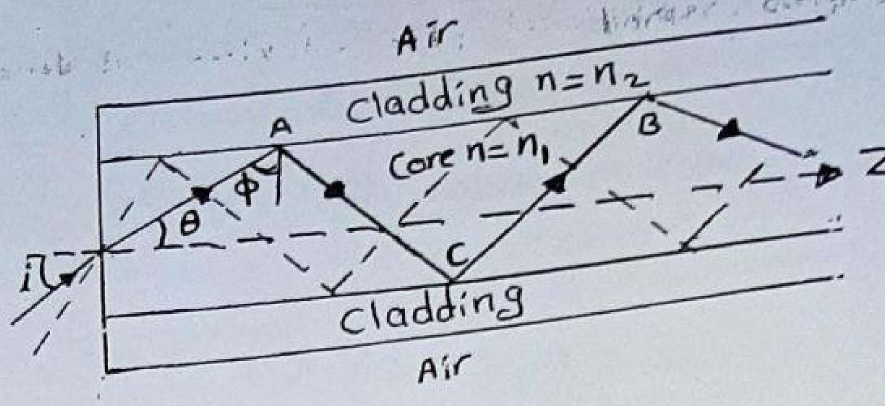
$$n(r) = n_2 \quad r > a \quad \text{cladding}$$

The variation in refractive index along the radial direction of the fibre is shown in Fig. below.



Consider a ray which is incident on the entrance aperture of the fibre making an angle ~~incidence~~ i with the axis as in Fig. below.

Let the refracted ray make an angle θ with the axis. Let ϕ be the angle incidence of the ray core-cladding interface.



Let ϕ_c be the critical angle of the core-cladding interface.

$$\sin\phi_c = \frac{n_2}{n_1}$$

If ϕ is greater than the critical angle $\phi_c = (\sin^{-1}\frac{n_2}{n_1})$, then the ray undergo total internal reflection at that interface. Further, because of the cylindrical symmetry in the fibre structure, this ray will suffer total internal reflection at the lower interface also and therefore get guided through the core by repeated total internal reflection. ~~at the lower interface~~

In this way, by total internal reflection, a ray emerging on end of a fibre can travel along the fibre by multiple reflections with a fairly high intensity.

Numerical Aperture :

Let n_0 be the refractive index of the outside medium.

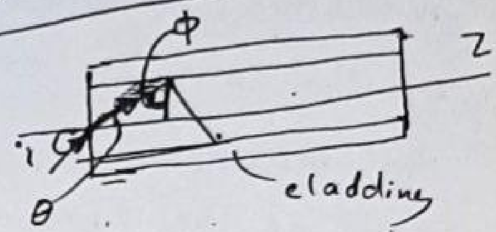
Then, using snell's law

$$\frac{\sin i}{\sin\theta} = \frac{n_1}{n_0}$$

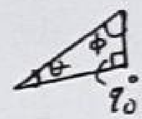
If this ray has to suffer total internal reflection at the core-cladding interface

$$\sin\phi = \cos\theta > \frac{n_2}{n_1} \implies \boxed{\sin\phi = \sin(90-\theta) = \cos\theta}$$

$$\sin\phi_c = \frac{n_2}{n}$$



$$\cos\theta = \frac{n_2}{n_1} \implies \cos^2\theta = \left(\frac{n_2}{n_1}\right)^2$$



$$\sin^2\theta + \cos^2\theta = 1$$

$$\sin^2\theta = 1 - \cos^2\theta$$

$$= 1 - \left(\frac{n_2}{n_1}\right)^2$$

$$\therefore \sin\theta = \left[1 - \left(\frac{n_2}{n_1}\right)^2\right]^{1/2} =$$

But $\sin i = \frac{n_1}{n_0}\sin\theta$

Total internal reflection will occure assuming $n_0 = 1$

$$\sin i = n_1\left[1 - \left\{\frac{n_2}{n_1}\right\}^2\right]^{\frac{1}{2}}$$

$$= \left[n_1^2 - n_2^2\right]^{1/2}$$

The maximum value of $\sin i$ for a ray to be guided is given by

$$\sin i_m = \begin{cases} (n_1^2 - n_2^2)^{\frac{1}{2}} & \text{when } n_1^2 - n_2^2 < 1 \\ 1 & \text{when } n_1^2 - n_2^2 > 1 \end{cases}$$

[illegible]

Thus, if a cone of light is incident on one end of the fibre, it will be guided through it provided the semi-angle of the cone is less than i_m.

زاوية القبول

Angle of acceptance is the maximum angle i_m with which a ray can enter the end of the fibre and still be totally internally reflected.

This angle is a measure of the light gathering power of the fibre.

We define the numerical aperture (NA) of the fibre by the following equation:

$$\boxed{NA = (n_1^2 - n_2^2)^{\frac{1}{2}}}$$

Numerical aperture of the optical fibre is a measure of the amount of light rays that can be accepted by the fibre.

Numerical aperture is the sine of angle of acceptance.

$$\boxed{NA = \sin i_m}$$

Example :- The core and the cladding of a silica optical fibre have refractive indices of $n_1 = 1.5$ and $n_2 = 1.4$. respectively.

(a) Calculate the critical angle of reflection for the core-cladding boundary

(b) Calculate the acceptance angle of the fibre.

(a)
$$\sin\phi_c = \frac{n_2}{n_1}$$
$$\therefore \phi_c = \sin^{-1}\left(\frac{1.4}{1.5}\right) = 68.96^\circ.$$

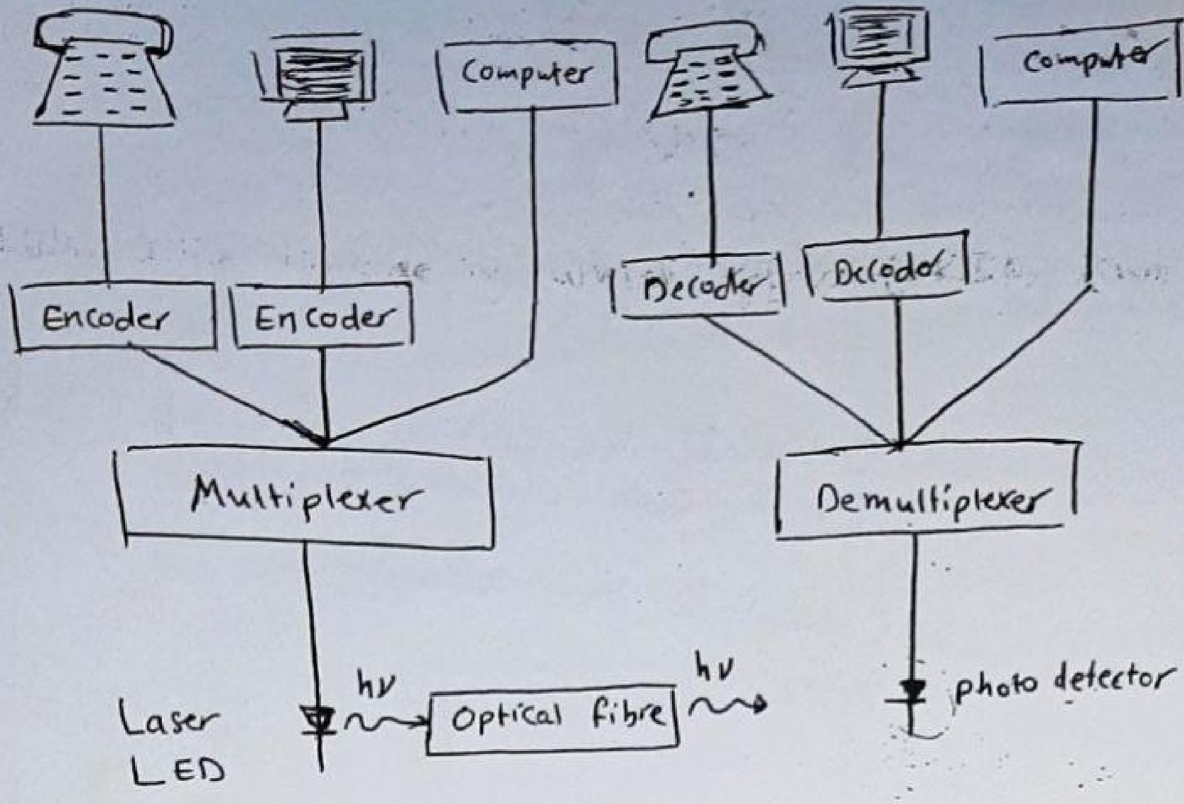
(b)
$$\sin i_m = (n_1^2 - n_2^2)^{1/2}$$
$$i_m = \sin^{-1}\left[(n_1^2 - n_2^2)^{1/2}\right]$$
$$i_m = \sin^{-1}\left[((1.5)^2 - (1.4)^2)\right] = 32.58^\circ$$

Example :- Calculate the numerical aperture and hence the acceptance angle for an optical fibre given that $n_1 = 1.45$, $n_2 = 1.40$

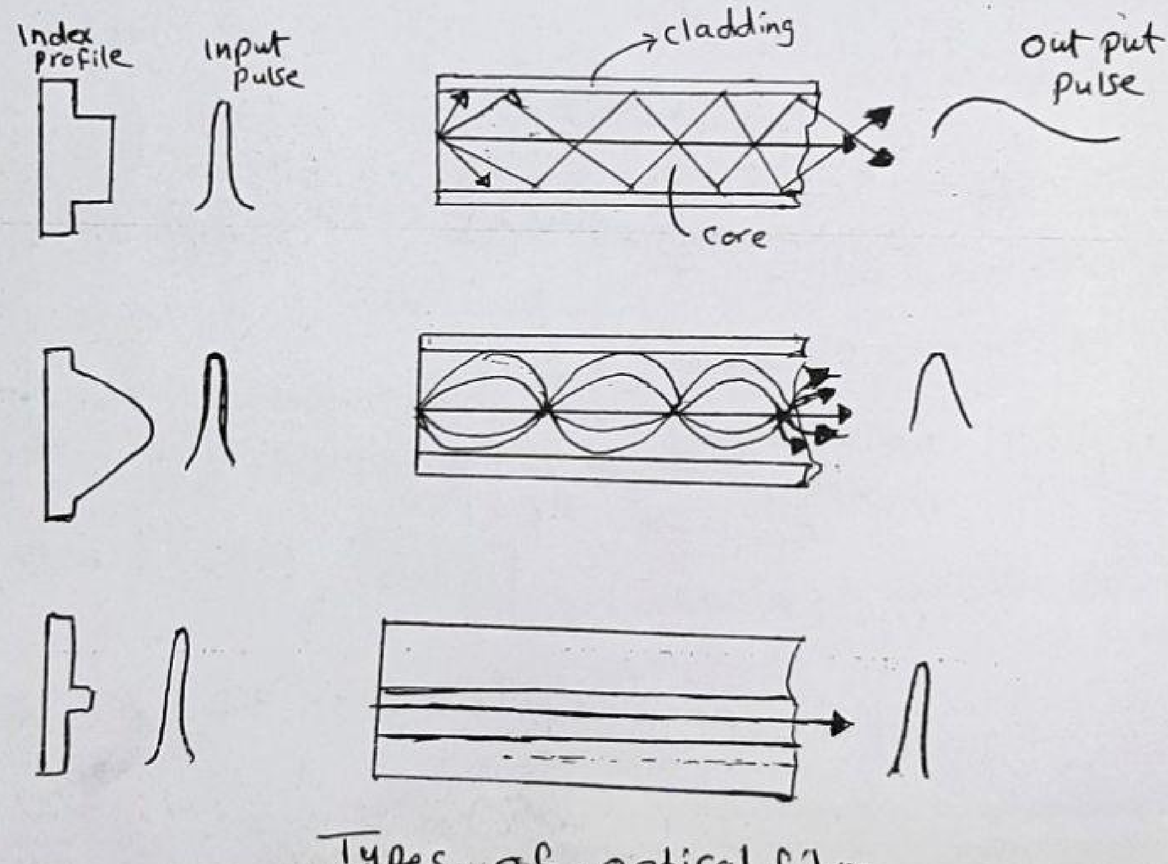
$$NA = (n_1^2 - n_2^2)^{1/2} = \left[(1.45)^2 - (1.40)^2\right]^{1/2} = 0.37$$

Acceptance angle i_m is given by

$$i_m = \sin^{-1}(n_1^2 - n_2^2)^{1/2} = \sin^{-1} 0.3775 = 22.18^\circ$$



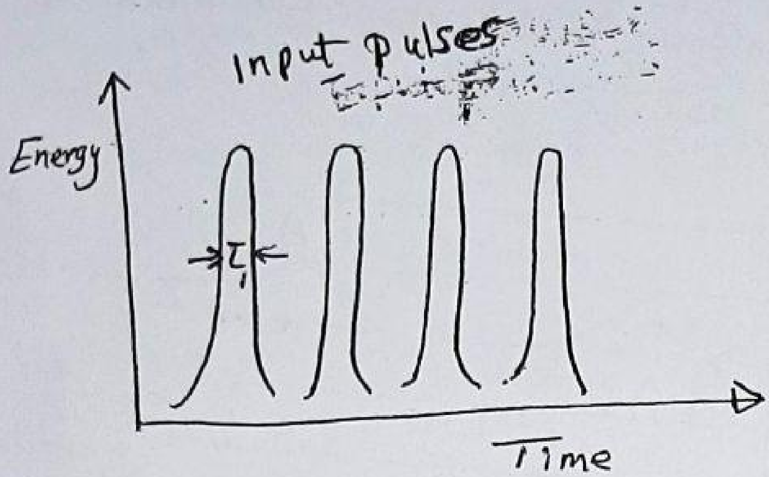
Fibre optic communication System

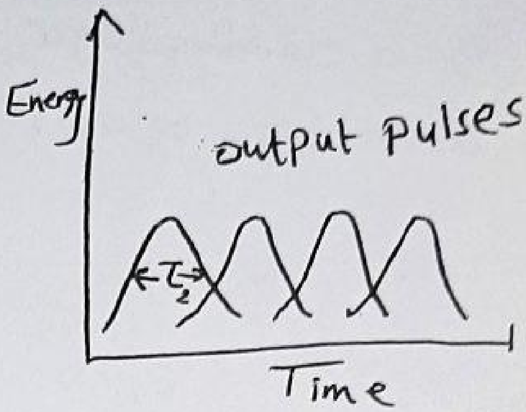


Types of optical fibre

Pulse dispersion in step index fibres :

In the fibre shown in Fig. below, the rays making larger angles with the axis have to traverse a longer optical path length and take a longer time to reach the output end. Consequently (وتبعا), the pulse broadens as it propagates through the fibre.

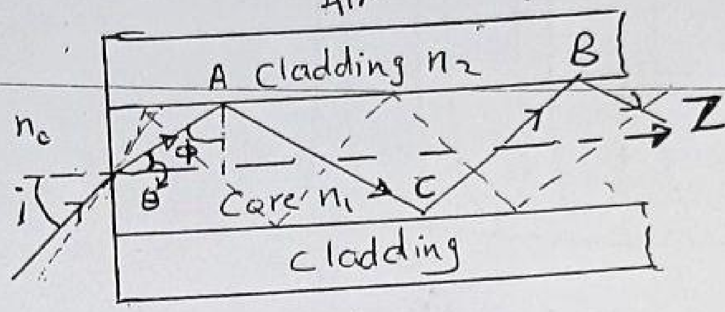




The output pulses then no longer exactly match the input pulses a in Fig. A series of pulses each of width τ_1 after transmission through the fibre emerges as a seri of pulses of width $\tau_2 (> \tau_1)$. If the broadening of the pulses is large, then adjacent pulses will overlap at the output end and may not be resolvable. This phenomenon is called "pulse dispersion". No information can be retrieved. Thus the smaller pulse dispersion, the greater will be the information carrying capacity of the system.

Therefore, for a very high information carrying system, it is necessary to reduce the pulse dispersion.

Let us calculate the amount of dispersion in a step index fibre. Step-index fibre consists of a transparent core of glass of uniform refractive index n_1 surrounded by a cladding layer of uniform lower refractive index n_2 as in Fig. below.



onsider a ray making an angle θ with the Z-axis. The speed of light in a medium of refractive index n_1 is $\frac{c}{n_1}$). The distance AB is traversed in time

$$\tau = \frac{AC + CB}{c/n_1} = \frac{n_1 AB}{c}$$

The ray path repeats itself. Hence the time taken by a ray to traverse a length ℓ of the fibre is

$$\tau_{max} = \frac{n_1 \ell}{c}$$, ℓ = nonaxial path (مسار غير محوري), $\ell = \frac{L}{\cos\theta}$

L = axial path (مسار محوري)

We assume that all rays lying between θ and θ_c are present. Time taken by rays corresponding to $\theta = 0$ is

$$\tau_{min} = \frac{n_1 L}{c}$$

Time taken by rays corresponding to $\theta = \theta_c = \cos^{-1}\left(\frac{n_2}{n_1}\right)$ is

$$\tau_{max} = \frac{n_1 l}{c} = \frac{n_1 L}{c \cos\theta}, \quad \cos\theta = \frac{n_2}{n_1}$$

$$\tau_{max} = \frac{n_1^2 L}{n_2 c}$$

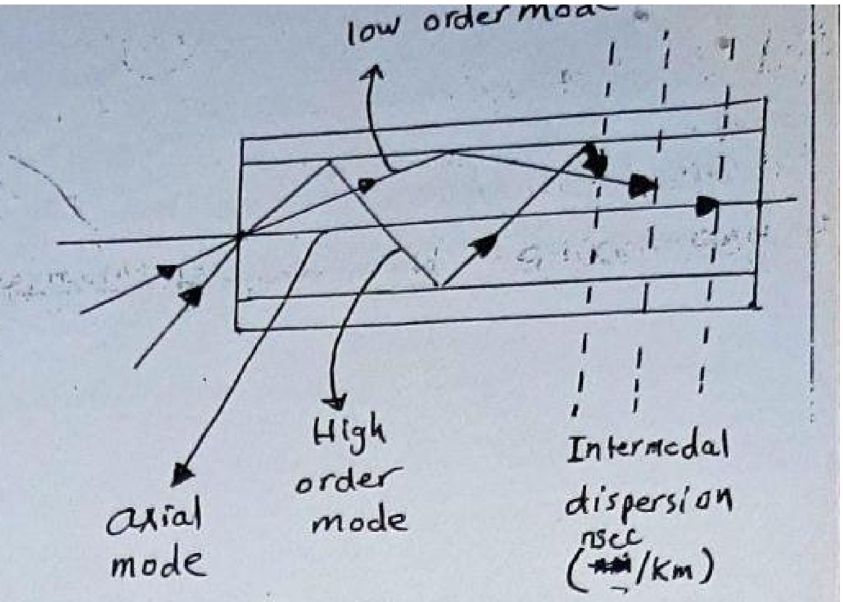
Let all the input rays be excited simultaneously. Then the rays at the output end occupy a time interval of duration

$$\Delta\tau = \tau_{max} - \tau_{min} = \frac{n_1 L}{c}\left(\frac{n_1}{n_2} - 1\right) = \frac{n_1 L \Delta}{c}$$

$\Delta = (n_1 - n_2)/n_2$, L = length of the fibre.

For example $n_1 = 1.500$ and $n_2 = 1.489$. The delay, $\frac{\Delta\tau}{L}$, the turns out to be $\frac{37\,ns}{km}$. In other words, a sharp pulse of light entering the system will be spread out in time 37 ns for each kilometer of fibre traversed. Moreover traveling at a speed $v = \frac{c}{n_2} = 2 \times 10^8\,m/sec$. It will spread in space over a length of 7.4 m/km.

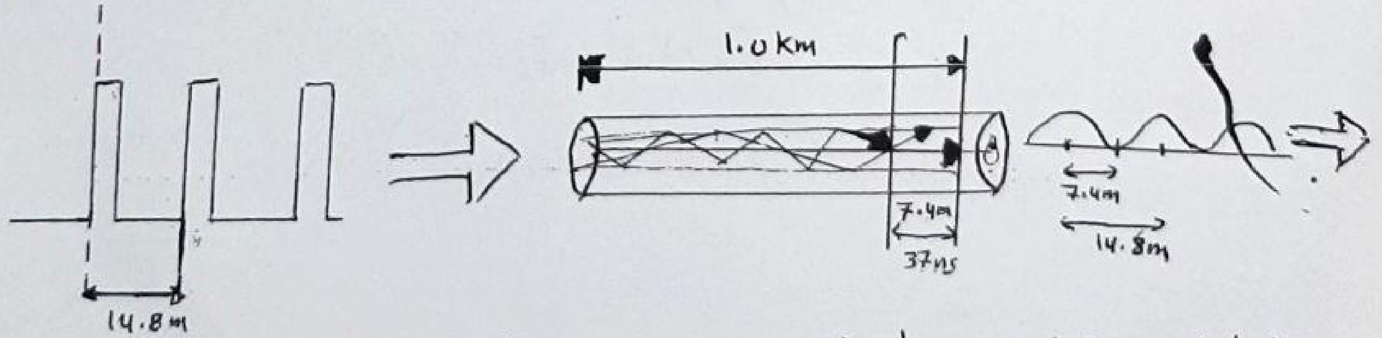
hundreds, even thousands of different ray paths or modes by which energy can propagate down the core as in Fig.



Higher-angle rays travel longer paths, reflecting from side to side, they take longer to get to the end of the fibre than do rays moving along the axis.

Information to be transmitted is usually digitized in some coded fashion and then sent along the fibres as ~~a flood~~ flood of millions or bits per second.

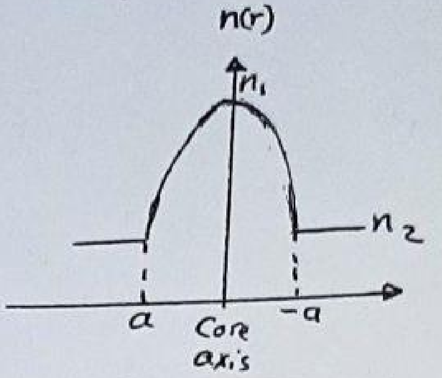
The total time delay between the arrival of the axial ray and the slowest ray is $\Delta\tau = \tau_{max} - \tau_{min}$



The spreading of an input signal due to intermodal ~~dispersio~~ dispersion

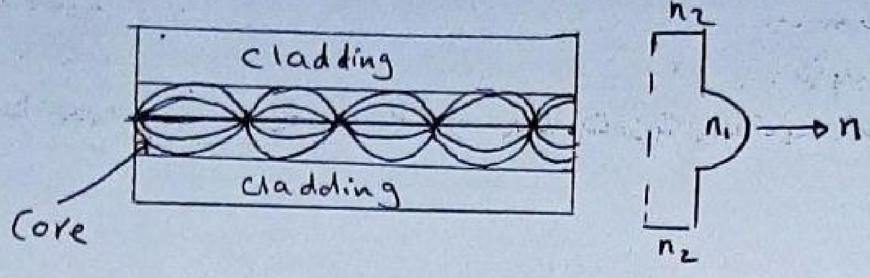
Graded Index fibre (GRIN) :-

GRIN fibre is one in which refractive index varies radially, decreasing continously in parabolic manner, from a maximum value of n_1 at the centre of the core to a constant of n_2 at the core - cladding interface.



graded index fibre

In a graded -index fibre, light rays travel at different speeds in different parts of the fibre because the refractive index varies throughout the fibre. Near the outer edge the refractive index is lower. As a result, rays near the outer edge travel faster than rays in the centre of the core. Because of this all the rays arrive at the ~~same~~ ~~time~~ end of the fibre at approximately the same time. In effect light rays in these fibres are continuously refocussed as the travel down the fibre. All rays (in paraxial approximation) take the same amount of time in traversing the fibre. This leads to small pulse dispersions.



GIRN fibre

Refractive index profile

The pulse dispersion is given $\Delta\tau = \tau_{max} - \tau_{min} = \frac{n_2 L}{2C} \Delta^2$

where $\Delta = \frac{n_1 - n_2}{n_2}$

For aparabolic ~~aparabolic~~ index fibre the pulse dispersion is reduced by a factor of about 200 in comparison to the step index fibre. It is because of this reason that first and second generation optical communication systems used near parabolic index fibres.

Single Mode Fibres:

In ~~genral~~ optical fibres can be divided into two broad categories, Single mode and multimode. Mode means simply the various paths. light can take in a fibre In single-mode fibres, only one mode is allowed to propagate in the fibre.

Multimode means that several paths are available. If the diameter of the fibre (or if the refractive index difference between the core and the cladding) becomes very small, in a fibre, rays making only certain discrete angles θ are possible. If the core radius ~~a~~ a or $n_1 - n_2$ decreases then the possible value of θ also decreases.

If the combinations of these two fibre parameters are such that the following quantity (often called the V-number of the fibre) defined as

$$V = \frac{2\pi}{\lambda_0} a \sqrt{n_1^2 - n_2^2} \quad , \quad a = \text{core radius}$$

$$V = \frac{2\pi a}{\lambda_0} NA \quad , \quad NA = (n_1^2 - n_2^2)^{1/2}$$

is Less than 2.4045, then only one guided mode is possible and the fibre is known as single mode fibre.

Only a single ray path is possible in a single mode fibre. Hence, the dispersion caused due to the differences in the transit time of different rays ~~rays~~ in a multimode fibre would be completely absent.

The dispersion in a single-mode fibre is due to absorption by the material of the core. figures of 10 G bits/sec over 10 km have been reported.

Since the core of a single-mode fibre is very small, launching light into the fibre is a difficult task.

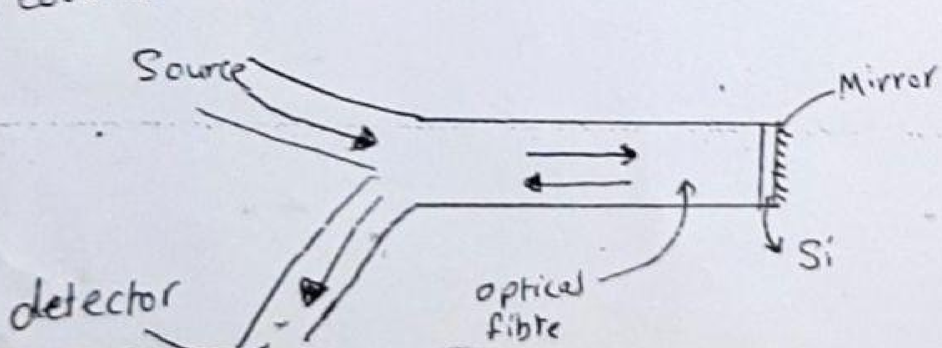
Single-mode fibres are expected to be in common use for high-capacity communication links in the near future.

Fibre optics Sensors :-

Fibre optic sensors are used for sensing and measuring of acoustic fields, magnetic fields, current, rotation, acceleration strain, pressure, temperature and so on.

1- Magnetic field sensors are based on attachment of fibre to amagnetostrictive material along its length in the presence of magnetic field induces a change in the optical path in an optical fibre by means of longitudinal strain in the fibre. This can be detected and measured using an ~~[illegible]~~ interferometer.

2- Fibre optic Temperature Sensor is shown in Fig. below.
The optical fibre merely acts to carry the light beam to and from the sensing area. It consists of a multimode fibre coated at one end with a thin layer of silicon which is then covered with areflective coating.



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