SPHERICAL ABERRATION

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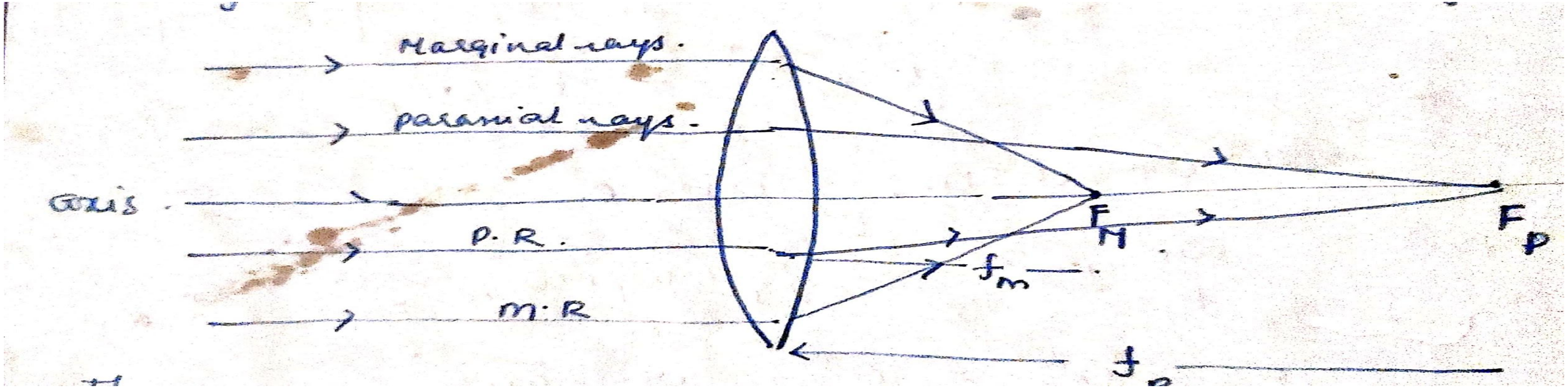
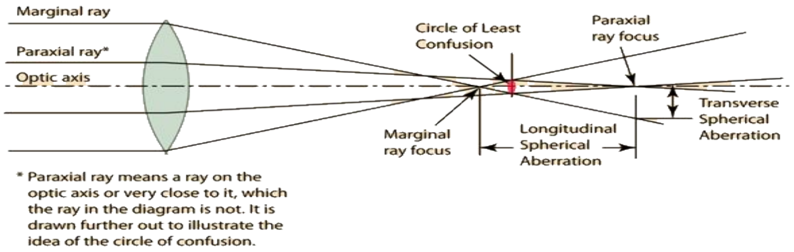
SPHERICAL ABERRATION

Light rays parallel and close to the principal axis are called **Paraxial Rays.** These rays after refraction through the lens meet the principal axis at a point F_p called **Paraxial focus.** The rays away from the axis are called **Marginal rays.** These rays after passing through the lens, meet at a point F_M on the axis called **Marginal Focus.**



- The rays from intermediate zones of the lens come to focus in between F_M & F_P .
- The distance ‘ f_m ‘ & ‘ f_p ‘ of the points F_M & F_P from the centre of the lens are called Marginal focal length & Paraxial focal length respectively.
- The paraxial focal length $f_P > f_M$. This means focal length changes from zone to zone is called **Longitudinal Spherical Aberration.**
- The distance from F_M to F_P along the axis is a measure of Longitudinal or Axial Spherical Aberration.

- If a screen with its plane ⊥r to the principal axis is moved in between F_M & F_P, the image is in the form of a circular disc of varying size.
- In between F_M & F_P the size of the circle is minimum at one point where the paraxial rays and marginal rays cross each other. This circle is known as **“Circle of Least Confusion”** .



http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/aber.html

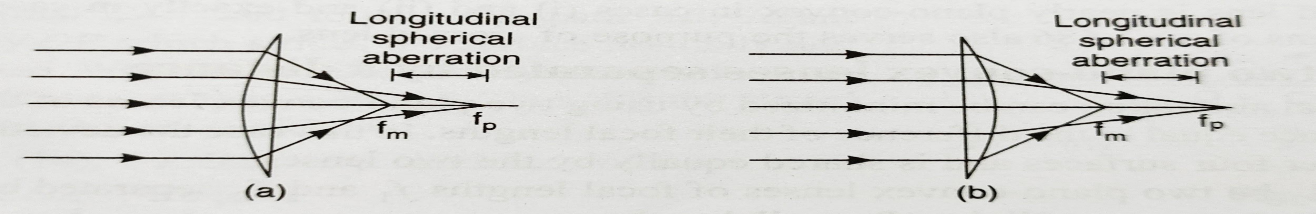
- The radius of the circle measures the measures the Transverse or Lateral Spherical Aberration.
- The Spherical Aberration for a convex lens is taken as +ve and for a concave lens it is -ve.

ELIMINATION :

Spherical Aberration can be minimised or eliminated by the following methods.

1. **<u>By using stops</u>** : Spherical Aberration is due to larger aperture of the lens. It may be reduced by using stops. By using stops ,Paraxial rays are allowed , Marginal rays are cut out or vice versa.
2. **<u>By using Crossed Lenses</u>** : Spherical Aberration can be minimised by using a crossed lens i.e A convex lens whose surface have radius of curvature in the ratio of 1:6 and $\mu=1.5$. The lens surfaces must be curved in opposite direction , the more convex side should face the more parallel beam.

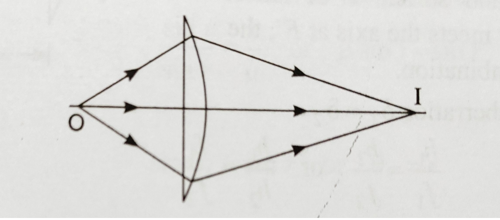
3) **<u>By using Plano-Convex lens</u>** : Spherical Aberration can be reduced by using a Plano-convex lens. Spherical Aberration is due to greater deviation of marginal rays. Spherical Aberration becomes minimum when the total deviation of the rays is divided equally between the two surfaces of the lens . The rays from the distant object are made to fall on convex surfaces . Then the S.A is minimum.



⇒ If they are made to fall on the plane surface. The entire deviation is produced only at the spherical surface and spherical aberration is maximum.

⇒ ∴ To minimize the spherical aberration by a plano-convex lens , the convex side should face face the incident light or the emergent light whichever is more parallel to the axis.

4) **By using a Convex-Concave lens combination** : Spherical Aberration for a concave lens is +ve. The spherical aberration for a concave lens is negative . By using suitable combination of convex & concave lenses. Spherical Aberration is made minimum.



5) **By using two Plano-Convex lenses separated by a suitable distance** : Consider a system of two co-axial plano convex lenses of focal lengths f1 & f2 separated by a distance x. A ray PQ parallel to the principal axis meet the 1st lens at a height 'h1' and suffers a deviation 'δ1'(=h1/f1) at the first lens. It meets the principle axis at 'F1' if 2nd lens is absent.

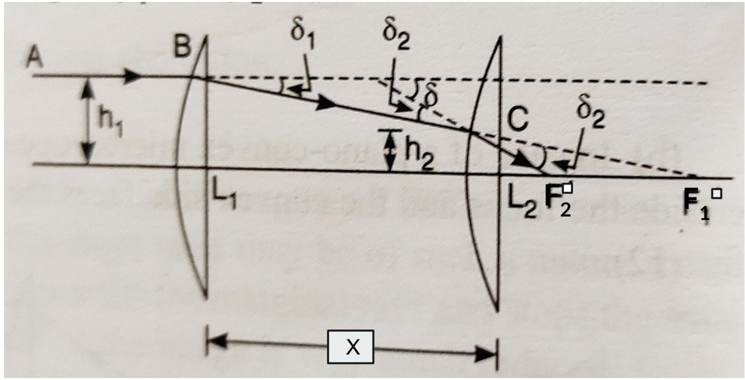
Due to the 2nd lens, it suffers another deviation $\delta_2 = (h_2/f_2)$ and meets the axis at F_2. The spherical Aberration is minimum when the total deviation the equally shared between the two lenses.

$$\delta_1 = \delta_2$$

Assuming that the angles are very small,

$$h_1/f_1 = h_2/f_2$$

$$\Rightarrow h_1/h_2 = f_1/f_2 \qquad \text{-----------} \ (1)$$



Δles BL_1F_1 & CL_2F_2 are similar

$$h_1/h_2 = BL_1/CL_2 = L_1F_1/L_2F_1 = L_1F_1 - L_1L_2$$

$$= \quad f_1/(f_1 - x) \qquad \text{------------}(2)$$

From eqs (1) & (2)

we have $f_1/f_2 = f_1/(f_1 - x)$

$\Rightarrow \quad f_2 = f_1 - x$

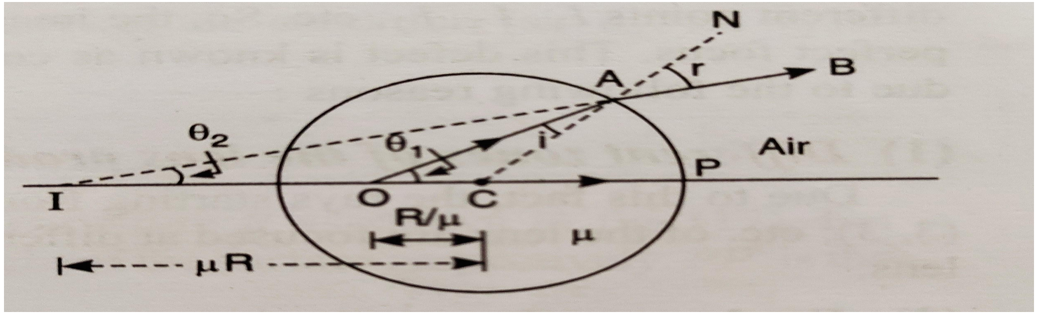
$\Rightarrow \quad \mathbf{x = f_1 - f_2}$

∴ The condition for no spherical aberration is the distance between the two lenses must be equal to difference in their focal lengths.

THANK YOU

6) <u>By using an Aplanatic lens</u> :   A spherical lens which is free from the defects of Spherical aberration & Coma is called an Aplanatic lens.

⇒ A pair of conjugate points free from Spherical aberration & Coma are called Aplanatic points.



⇒ Consider a glass sphere of refractive index μ and radius 'R' . An object 'O' is placed at a distance R/μ from centre 'C' . OA is the incident ray and AB is the refracted ray . The ray AB appears to diverge from 'I' which is image of 'O'. $\angle AOC = \theta 1$; $\angle AIC = \theta 2$

Then $\sin(i)/\sin(r) = \mu 2/\mu 1 = 1/\mu$ -------- (1) $\triangle$le AOC $\sin(i)/\sin\alpha = (R/\mu)$ R = $1/\mu$ --------(2) from (1) & (2) $\sin(i)/\sin(r) = \sin(i)/\sin\alpha$

$r = \alpha$ --------(3) In $\triangle$le AOI the exterior angle $\alpha = r-i+\beta$

$\Rightarrow$ $r = r-i+\beta$ $\Rightarrow$ $i=\beta$ ($\because$ from (3)) From $\triangle$le ACI , $\sin\beta / CA = \sin(r) / CI$ $\Rightarrow$ $\sin(i) / CA = \sin(r) / CI$

$\Rightarrow$ $CI / CA = \sin(r) / \sin(i)$ $\Rightarrow$ $CI = \mu R$ from (1) i.e When the object is placed at a distance R/μ from the centre , the image is formed at a distance μR from the centre . Such two points are called Aplanatic points. Then the image is free from Spherical Aberration