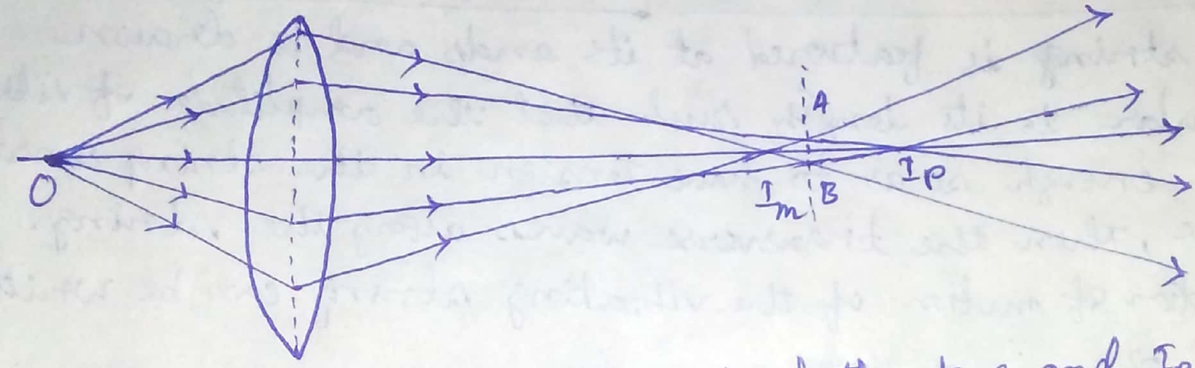
Aberrations:- The deviations from the actual size, shape and position of an image are called the aberrations produced by the lens. The aberrations produced by the variation of refractive index with wavelength of light are called chromatic aberrations. The other aberrations are caused even if monochromatic light is used and they are called monochromatic aberrations.

Spherical aberrations in a lens:- The presence of spherical aberration in the image formed by a single lens is shown in figure.



O is a point object on the axis of the lens and I_p and I_m are the images formed by the paraxial and marginal rays respectively. The image is not sharp at any point on the axis. However, if the screen is placed perpendicular to the axis at AB, the image appears to be a circular patch of diameter AB. At positions on the two sides of AB, the image patch has a larger diameter. This patch of diameter AB is called the circle of least confusion which corresponds to the position of best image. The distance $I_m I_p$ measures the longitudinal spherical aberration. The radius of the circle of least confusion measures the lateral spherical aberration. When the aperature of the lens is relatively large compared to the focal length of the lens, the cones of the rays of light refracted through the different zones of the lens surface are not brought to focus at the same point I_m and the axial rays come to focus at a farther point I_p. Thus, for an object point O on the axis, the image extends over the length $I_p I_m$. This effect is called spherical aberration and arises due to the fact that different annular zones have different focal lengths.

The spherical aberration produced by the lens depends on the distance of the object point and varies approximately as the square of the distance of the object ray above the axis of the lens. The spherical aberration produced by a convex lens is positive and that produced by a concave lens is negative.

Reducing spherical aberration:- Spherical aberration produced by lenses is minimised or eliminated by the following methods

1. Spherical aberration can be minimised by using stops, which reduce the effective lens aperture. The stop used can be such as to permit either the axial rays of light or the marginal rays of light. However, as the ~~light~~ amount of light passing through the lens is reduced, correspondingly the image appears less bright.

2. The longitudinal spherical aberration produced by a thin lens for a parallel incident beam is given by

$$x = \frac{\rho_2}{f_2}\left[\frac{K^2\mu^2 + K(\mu+2\mu^2+2\mu^3)+\mu^3-2\mu^2-2}{2\mu(\mu-1)^2(1-K)^2}\right] \quad \text{---(i)}$$

where x is the longitudinal spherical aberration, ρ is the radius of the lens aperture and f_2 is the second principal focal length. $K = \frac{R_1}{R_2}$; where R_1 and R_2 are the radii of curvature. For given value of μ, f_2 and ρ the condition ~~of~~ for minimum spherical aberration is

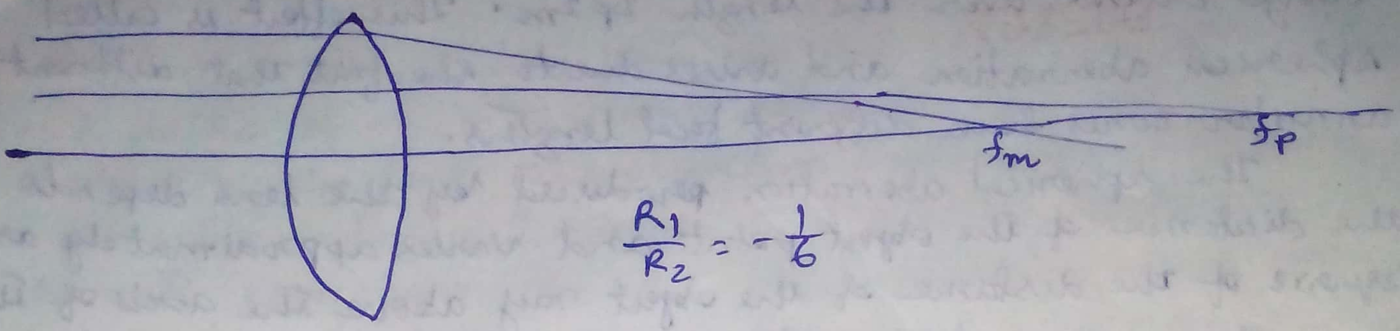
$$\frac{dx}{dK} = 0$$

Differentiating equation (i) and equating the result to zero.

$$K = \frac{R_1}{R_2} = \frac{\mu(2\mu-1)-4}{\mu(2\mu+1)} \quad \text{——— (ii)}$$

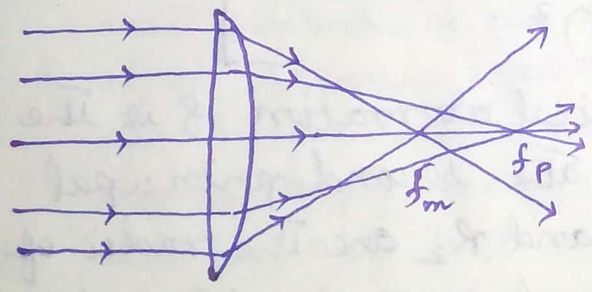
For a lens whose material has a refractive index $\mu = 1.5$, $K = -\frac{1}{6}$

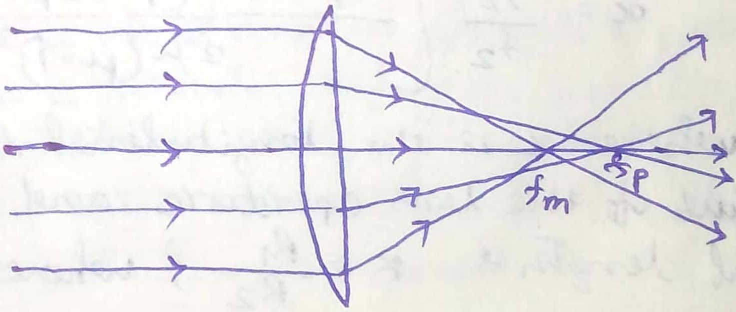
Thus, the lens which produces minimum spherical aberration is biconcave and the radius of curvature of the surface facing the incident light is one-sixth the radius of curvature of other face



3. Plano-convex lenses are used in optical instruments so as to reduce the spherical aberration. When the curved surface of the lens faces the incident or emergent light whichever is more parallel to the axis the spherical aberration is minimum. The spherical aberration in a crossed lens $\left(\frac{R_1}{R_1} = -\frac{1}{6}\right)$ in only 8% less than that of a plano-convex lens having the same focal length and ~~the~~ radius of the lens aperture.

The spherical aberration will, however be very large if the plane surface faces the incident light. If the deviation If the deviation of the marginal rays of light is made min^m the focus f_m for a parallel incident beam will shift towards f_p the focus for the paraxial rays of light and the spherical aberration will be minimum.





4. Spherical aberration can also be made minimum by using two plano-convex lenses separated by a distance equal to the difference in their focal length.