Aberration

Aberration

* The departure of real image from an ideal image in respect to it's actual
* Shape, size, and position are called aberration

Types of Aberration;

(I) Monochromatic aberration;

(a) Spherical aberration

(b) Coma

(c) Astigmation

(d) Curvature of the field.

(e) Distortion

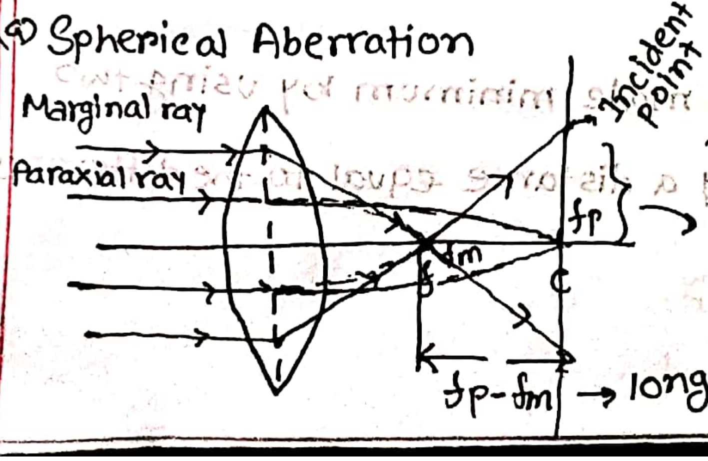
(II) Chromatic aberation

(i) Monochromatic Aberration; (একবর্ণী আলোর জন্য যে বিচ্যুতি)

The defects due to wide angle incidence and peripheral incidence, which occurs even with monochromatic light are called monochromatic aberration.

$\boxed{\text{Important}}$ $\boxed{\text{Definition and figure}}$

(a) Spherical Aberration



fm = focal length of marginal ray.

fp = focal " " paraaxial ray.

→ Lateral. spherical aberration.

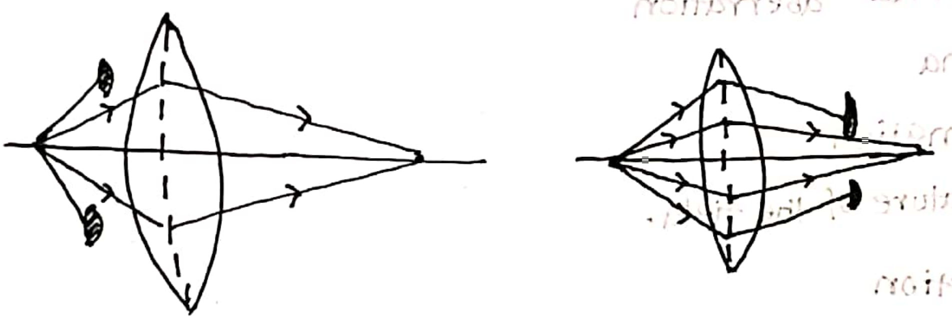
fp-fm → longitudinal spherical aberration.

Aberration lens এর একটা সহজাত ত্রুটি।

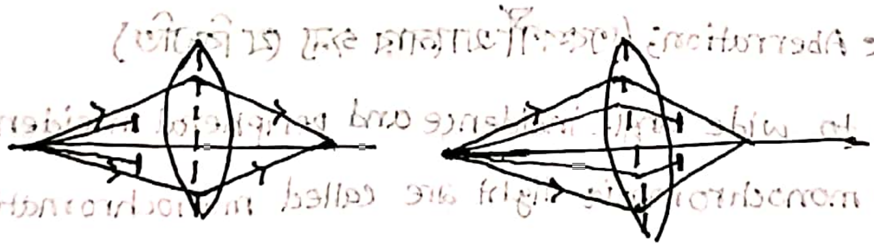
Definition: H.W

Reduction of Spherical Aberration;

(i) This aberration can be minimized by using stops. The stop used can be such as to permit either the axial rays of light or the axial rays of light or the marginal rays of light.



Use of stops to permit the axial ray.

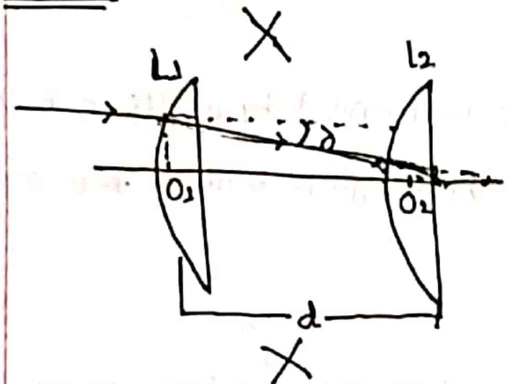


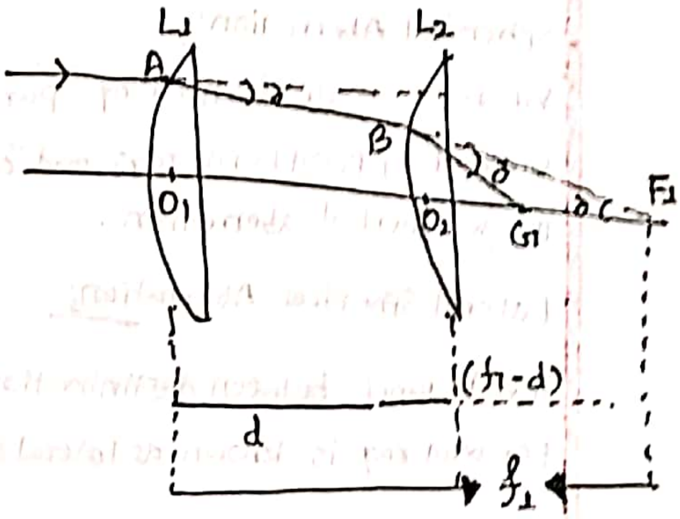
to permit the marginal ray.

(ii) Sprecial aberration can also be made minimum by using two plano-~~of~~ convex lens separated by a distance equal to the difference in their focal length.

$d = \cancel{f} f_1 - f_2$

Proof:





Hence, distance between O_1 & $O_2 = d$.

$O_1F_1 = f$

$O_2F_1 = f_1 - d$;

Hence; $\angle F_1BG = \delta$

$\angle BF_1G = \delta$

and from;

ΔBGF_1

$BG = GF_1$

$O_2G = GF_1$ (approximately).

$O_2G = \frac{1}{2} O_2F_1$.

$O_2G = \frac{1}{2}(f_1 - d)$

for 2nd lens;

F_1 is the virtual object

G is real image

$\therefore \frac{1}{v} - \frac{1}{u} = \frac{1}{f_2} = \frac{1}{O_2G} - \frac{1}{O_2F_1} = \frac{1}{f_2}$.

$= \frac{2}{f_1 - d} - \frac{1}{f_1 - d} = \frac{1}{f_2}$

Lateral spherical aberration:

Spherical Aberration:

When an image formed by paraxial rays is surrounded by a diffuse halo formed by peripheral rays and consequently the image is blurred, we call the image spherical aberration.

Lateral Spherical Aberration:

The distance between destinination point of marginal ray and focus point of paraxial ray is known as lateral spherical aberration.

Longitudinal spherical abberration:

The distance between focus point of marginal ray and paraxial ray is called longitudinal spherical aberration.

Date: 03-02-2020

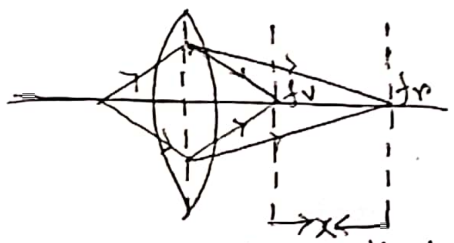
LECTURE-2

Chromatic aberrations:

Aberration that occur due to dispersion of light are called chromatic aberrations.

Chromatic aberation occurs with light that contains at least two wavelengths.

$d = f_1 - f_e$.



longitudinal
or
axial chromatic aberration

When a beam of white light is passed through a lens, the beam gets dispersed and ray of light of different colors (wavelength) come to focus at different point of the axis.

The violet ray of light come to focus at a point nearer the lens. and the red ~~to~~ rays come to focus at a farther point.

The size of the image increases from violet to red.

f_v = focus for violet ray.

f_r = focus for red ray.

the variation of the image distance from the lens with refractive index measures axial or chromatic aberration. and the variation of the size of image measures lateral chromatic aberration.

Expansion ~~of~~ for chromatic aberration;

The distance $f_r - f_v = x$ is axial or longitudinal C.A.

The focal length of a lens: $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

$= \frac{1}{R_1} - \frac{1}{R_2} = \frac{1}{f(\mu-1)}$

For, Violet rays;

$\frac{1}{f_v} = (\mu_v - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$= \frac{1}{f_v} = (\mu_v - 1) \times \frac{1}{f(\mu-1)}$ - (II)

Similarly for red rays;

$\frac{1}{f_r} = \frac{(\mu_r - 1)}{f(\mu-1)}$ — (III)

(II) - (III)

$\frac{1}{f_v} - \frac{1}{f_r} = \frac{(\mu_v - 1)}{f(\mu-1)} - \frac{(\mu_r - 1)}{f(\mu-1)}$

$\therefore \frac{f_r - f_v}{f_v f_r} = \frac{(\mu_v - \mu_r)}{f(\mu-1)}$

Let $f_v f_r = f^2$ [$\because f$ is the mean focal length],

$\frac{f_r - f_v}{f^2} = \frac{\mu_v - \mu_r}{f(\mu-1)}$

$= f_r - f_v = \left(\frac{\mu_v - \mu_r}{\mu - 1}\right) f$

when, $w = \frac{\mu_v - \mu_r}{\mu - 1}$ is called dispersive power of the material.

$f_r - f_v = w \cdot f$.

Elimination of Chromatic aberration:

Achromatism:

Elimination of the chromatic aberration in a system of lens is called achromatism.

Condition for achromatism:

$\frac{w}{f} + \frac{w'}{f'} = 0$ or,

$\frac{w}{w'} = -\frac{f}{f'}$

অবতল
↳ একটা উত্তল ও অন্যটা negative বলে, যথাক্রমে positive ও negative.

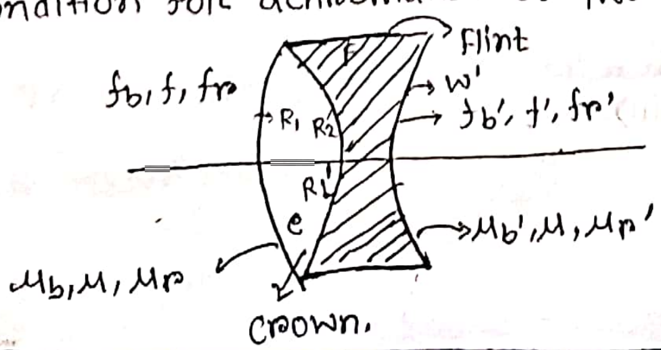
Chromatic aberration can be reduced by using two ~~different~~ thin coaxial lens made of different materials. (convex → crown glass, concave → flint glass)

The ratio of the dispersive power of two lens is equal to the ration of the focal length of the two lens.

(ii) $d = \frac{f_1 + f_2}{2}$

Chromatic aberration can be reduced by using ~~the~~ two thin co-axial lensees made of same materials and separated by a distance that must be equal to the mean focal length of the two lenses.

⊞ Condition for achromatism of two lenses placed in contact:



Let, μ_b, μ, μ_r and μ_b', μ', μ_r' be the refractive indices from blue, Yellow and red ray of light of the two materials.

f_b', f, f_r and f_b', f, f_r' are corresponding focal length of the two lens;

$$\frac{1}{f} = (\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

For 1st lens;

$$\frac{1}{f} = (\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{R_1} - \frac{1}{R_2} = \frac{1}{f(\mu-1)} \quad \text{— (I)}$$

and, $$\frac{1}{f_b} = (\mu_b-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad \text{— (II)}$$

$$\frac{1}{f_r} = (\mu_r-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad \text{--- (III)}$$

using (I) in (II) & (III)

$$\frac{1}{f_b} = \frac{\mu_b-1}{(\mu-1)f} \quad \text{— (IV)}$$

$$\frac{1}{f_r} = \frac{\mu_r-1}{(\mu-1)f} \quad \text{--- (V)}$$

For 2nd lens;

$$\frac{1}{f'} = (\mu'-1)\left(\frac{1}{R_1'}-\frac{1}{R_2'}\right)$$

$$\Rightarrow \frac{1}{R_1'} - \frac{1}{R_2'} = \frac{1}{f'(\mu'-1)} \quad \text{— (VI)}$$

and, $$\frac{1}{f_b'} = \frac{\mu_b'-1}{(\mu'-1)\times f} \quad \text{.... (VII)}$$

$$\frac{1}{f_r'} = \frac{\mu_r'-1}{(\mu'-1)\times f} \quad \text{..... (VIII)}$$

F_b & F_r be the focal length of the combination for blue and red rays.

$$\frac{1}{F_b} = \frac{1}{f_b} + \frac{1}{f_b'} = \frac{(\mu_b - 1)}{(\mu - 1) f} + \frac{(\mu_b' - 1)}{(\mu' - 1) f'} \quad \text{——} \quad (ix)$$

and $$\frac{1}{F_r} = \frac{1}{f_r} + \frac{1}{f_r'} = \frac{\mu_r - 1}{(\mu - 1) \times f} + \frac{\mu_r' - 1}{(\mu' - 1) \times f} \quad \text{——} (x)$$

$F_b = F_r$

or, $\frac{1}{F_b} = \frac{1}{F_r}$

$$\Rightarrow \frac{\mu_b - 1}{(\mu - 1) f} + \frac{\mu_b' - 1}{(\mu' - 1) f'} = \frac{\mu_r - 1}{(\mu - 1) f} + \frac{(\mu_r' - 1)}{(\mu' - 1) f}$$

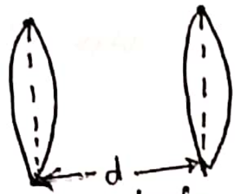
$$= \frac{\mu_b - \mu_r}{(\mu - 1) f} = \frac{(\mu_r' - \mu_b')}{(\mu' - 1) f'}$$

$$= \frac{\mu_b - \mu_r}{(\mu - 1) f} = \frac{\mu_b' - \mu_r'}{(\mu' - 1) f}$$

$$= \frac{w}{f} = -\frac{w'}{f'}$$

$$= \frac{w}{f} + \frac{w'}{f'} = 0;$$

$$= \frac{w}{w'} + \frac{f}{f'} = 0;$$



$$d = \frac{f_1 + f_2}{2}$$

Condition for achromatism of two thin lenses separated by a finite distance.

Let, f_1 and f_2 be the focal length of 2 lenses separated by d.

They are made by same material. μ, μ_b, μ_r are refractive index for mean rays, blue rays and red rays.

Scanned with CamScanner

f_r, f_r' and f_b, f_b' are the focal length of two lenses for red and blue ray.

When 2 lenses are separated by a distance d, the mean focal length is

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{1}{f_1 f_2}$$

$$\frac{1}{F_b} = \frac{1}{f_b} + \frac{1}{f_b'} - \frac{d}{f_b f_b'}$$

$$\frac{1}{F_r} = \frac{1}{f_r} + \frac{1}{f_r'} - \frac{d}{f_r f_r'}$$

Where, F, F_r, F_b are the focal lengths of the combinations for the mean ray, red ray and the blue rays.

but, $$\frac{1}{f_r} = \frac{(\mu_r - 1)}{(\mu - 1) f_1} \quad \text{---(I)}$$

$$\frac{1}{f_r'} = \frac{(\mu_r - 1)}{(\mu - 1) f_2} \quad \text{---(II)}$$

$$\frac{1}{f_b} = \frac{(\mu_b - 1)}{(\mu - 1) f_1} \quad \ldots (III)$$

$$\frac{1}{f_b'} = \frac{(\mu_b - 1)}{(\mu - 1) f_2} \quad \text{---(IV)}$$

$$\frac{1}{f_b} = \frac{1}{f_b} + \frac{1}{f_b'} - \frac{d}{f_b f_b'}$$

$$= \frac{(\mu_b - 1)}{(\mu - 1) f_1} + \frac{(\mu_b - 1)}{(\mu - 1) f_2} - d \times \frac{(\mu_b - 1)}{(\mu - 1) f_1} \times \frac{(\mu_b - 1)}{(\mu - 1) f_2},$$

$$= \frac{\mu_b - 1}{\mu - 1}\left(\frac{1}{f_1} + \frac{1}{f_2}\right) - \frac{(\mu_b - 1)^2}{(\mu - 1)^2} \cdot \frac{d}{f_1 f_2} \quad \text{---(V)}$$

Similarly for red,

$$= \frac{\mu_r - 1}{\mu - 1}\left(\frac{1}{f_1} + \frac{1}{f_2}\right) - \frac{(\mu_r - 1)^2}{(\mu - 1)^2} \frac{d}{f_1 f_2} \cdots (VI)$$

For the combination to be achromatic;

$$F_b = F_r$$

$$\therefore \frac{1}{F_r} = \frac{1}{F_b}$$

$$\therefore \frac{(\mu_r-1)}{(\mu-1)}\left[\frac{1}{f_1}+\frac{1}{f_2}\right] - \frac{(\mu_r-1)^2}{(\mu-1)^2}\frac{d}{f_1 f_2} = \frac{(\mu_b-1)}{(\mu-1)}\left(\frac{1}{f_1}+\frac{1}{f_2}\right) - \frac{(\mu_b-1)^2}{(\mu-1)^2}\cdot\frac{d}{f_1 f_2}.$$

$$\therefore \left(\frac{1}{f_1}+\frac{1}{f_2}\right)\left(\frac{\mu_r-\mu_b}{\mu-1}\right) = \frac{d}{f_1 f_2}\cdot\frac{(\mu_r-1)^2-(\mu_b-1)^2}{(\mu-1)^2}$$

$$= \frac{d}{(\mu-1)^2 f_1 f_2}\left[\mu_r^2 - 2\mu_r - 1 - \mu_b^2 + 2\mu_b + 1\right]$$

$$= \frac{d}{(\mu-1)^2 f_1 f_2}\left[(\mu_r^2-\mu_b^2) - 2(\mu_r-\mu_b)\right]$$

$$= \frac{d}{(\mu-1)^2 f_1 f_2}\left[(\mu_r-\mu_b)(\mu_r+\mu_b) - 2(\mu_r-\mu_b)\right]$$

$$= \frac{d}{(\mu-1)^2 f_1 f_2}\left[(\mu_r-\mu_b)(\mu_r+\mu_b-2)\right]$$

$$\mu_b + \mu_r = 2\mu.$$

then;

$$\frac{\mu_r-\mu_b}{\mu-1}\left(\frac{1}{f_1}+\frac{1}{f_2}\right) = \frac{d(\mu_r-\mu_b)}{(\mu-1)^2 f_1 f_2}(2\mu-2)$$

$$\therefore \frac{1}{\mu-1}\cdot\left(\frac{1}{f_1}+\frac{1}{f_2}\right) = \frac{2d}{(\mu-1) f_1 f_2}$$

$$= \frac{f_1+f_2}{f_1 f_2} = \frac{2d}{f_1 f_2}$$

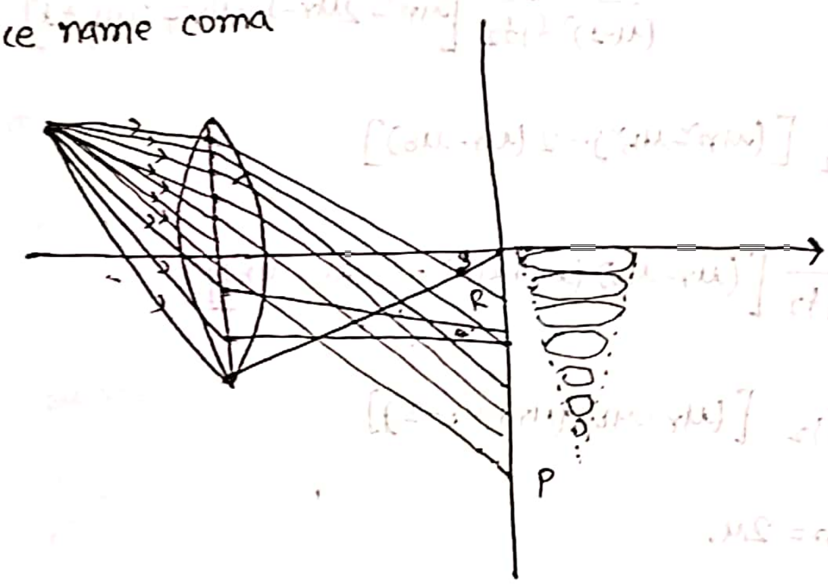
$$d = \frac{f_1+f_2}{2}$$

(5) Coma:

The effect of rays from an object point not situated on the axis of the lens results in an aberration called coma.

Spherical abberation refers to object points situated on the axis whereas comatic aberration refers to object points situated off the axis.

In case of spherical aberration, the image is a circle of varying diameter along the axis and in case of comatic aberration the image is comet-shaped and hence name coma

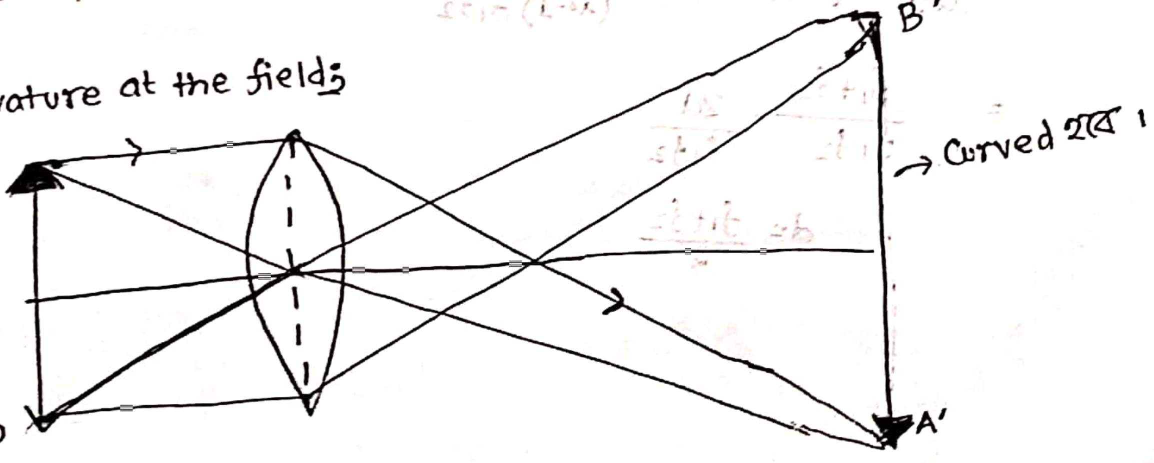


Reduction of coma:

(i) can be correct by properly choosing the radius of curvature.

(ii) Use stop at proper position.

(6) Curvature at the field:



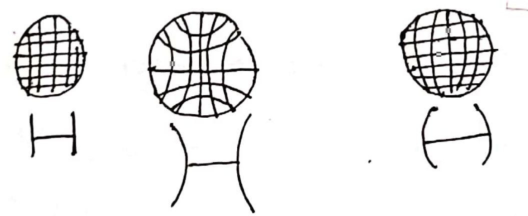
The image of an extended object due to a single lens is not a flat one but still it will be a curved surface. The central portion of the image nearer the ~~focus~~ axis is in focus. but outer region of the image away from the axis are blurred. This defect is called the curvature of the field.

(ii) Reduction of curvature of the field:

① can be minimized by introducing suitable stops on the lens axis.

Distortions:

The variation in the magnification produced by a lens for different axial distance results in an aberration called distortion.



(a) object (b) Pin-cushion distortion (c) Barrel shaped distortion

Away from the axis are blurred. This defect is called the curvature of the field.

In pin-cushion distortion, the magnification increases with the increasing axial distance (b)

In barrel shaped distortion the magnification decreases with the increasing axial distance (c).

Reduction of distortion;

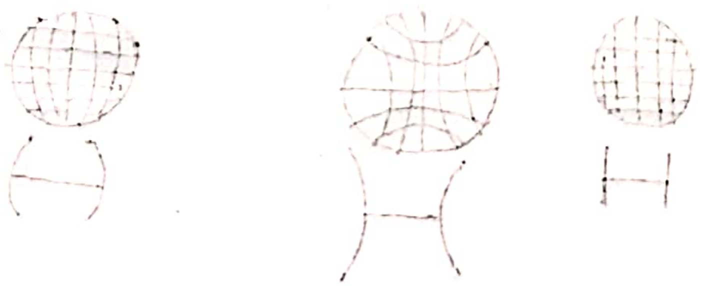
(i) To diminate this distortion, a stop is placed in between two symmetrical lens, so that the pin cushion distortion produced by the first lens is compensated by the barell ~~st~~ shaped distortion produced by the second lens.

First CT syllabus completed;

Interferance;

(1) Monochromatic light
(2) Coherent source
(3) Interference
(4) constructive interference
(5) Destructive interference

H.W



Condition for interference;

(i) The 2 beams of light ~~when~~ which interfere must be coherent, must originate from the same source of light

(ii) two interfering waves must have the same amplitude, otherwise the intensity will not be zero at the region of destructive interference.

(iii) The original source must be monochromatic. other wise dark & bright both lines will be colored.