DEPARTMENT OF PHYSICS

INDO – AMERICAN COLLEGE CHEYYAR

III B.SC PHYSICS – ODD SEMESTER

OPTICS– BPH51

Syllabus:

UNIT – I: GEOMETRICAL OPTICS Spherical aberration in lenses – Methods of minimizing spherical aberration – Condition for minimum spherical aberration in the case of two lenses separated by a distance – Chromatic aberration in lenses – Condition for achromtism of two thin lenses (in contact and out of contact) – coma – astigmatism – Ramsden's and Huygens's eyepieces – Constant deviation spectrometer – Calculation of characteristic wave number of spectral lines.

INTRODUCTION:

The light energy propagated as wave motion, a ray can be defined as an imaginary line drawn in the direction in which the wave travelling. In the case of refection and refraction, the light energy is propagated along the wave normal. The rays are directed and obey the laws of reflection and refraction. Therefore, the ray concept is of great importance in the study of geometrical optics.

LENS:

A lens is a portion of a transparent medium bounded by two spherical surfaces or by one spherical surface and a plane surface. Lenses are usually made of glass.

Types of lenses:

The types of lenses are,

1. Double or bi-convex lens
2. Plano convex lens
3. Concavo - convex lens
4. Double concave or bi – concave lens
5. Plano concave lens
6. Convexo – concave lens

Optic centre: The optic centre of a lens is a point on the principal axis through which all the rays will pass, when the incident and emergent paths are parallel to each other.

Cardinal points: A thick lens or a system of lenses arranged co – axially, has six important reference points called as cardinal points. They are two principal foci (or two focal points), two principal points and two nodal points.

Principal foci: A lens has two principal focal points F_1 and F_2. They are called the principal foci.

Principal points: The principal points of a thick lens or a system of lenses are defined as the points of intersection of the two principal planes with the principal axis, and drawn perpendicular to the principal axis.

ABERRATIONS:

For on image formed by a lens these are variations in the calculated and the actual values of size, shape and distance of the image. These are known as aberrations of a lens.

These aberrations are not due to deflection manufacture of lenses, but only due to the application of same laws of refraction to both plane and spherical surfaces.

Generally aberrations are classified into two types.

i). Monochromatic aberrations when the light used is monochromatic.

ii). Chromatic aberrations when a composite light (white light) is used.

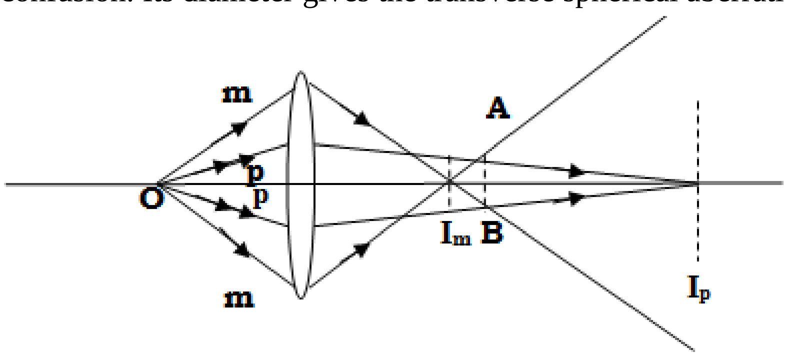
Types of monochromatic aberrations: The monochromatic aberrations are classified as (a) spherical aberrations (b) coma (c) astigmatism (d) curvature of the field and (e) distortion.

Spherical aberration:

The marginal rays and the paraxial rays are not brought to focus at the same point. Therefore the image is not sharp. This is called spherical aberration in a lens. It is because the more deviation for marginal is more than for paragraphs.

In the case of a convex lens the marginal rays are converged at a near point (I_m) and the paraxial rays are converged at a far – off point (I_p). The distance I_m I_p is called the longitudinal spherical aberration.

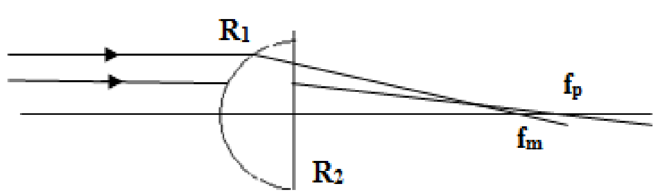
AB is the smallest circular patch of image of the object point O. AB is known as the circle of least confusion. Its diameter gives the transverse spherical aberration.



METHODS TO MINIMIZE SPHERICAL ABERRATION:

Stops: Apertures or stops can be used either to stops marginal rays or paraxial rays. In this case, a sharp image is possible. But the intensity of the image is decreased. Therefore this method is not generally used.

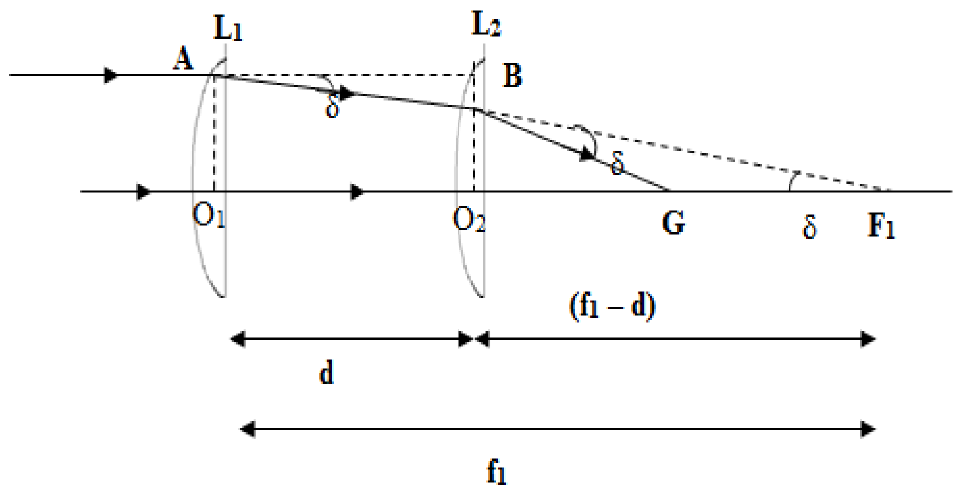
Crossed lens: A crossed lens is a double convex lens of μ = 1.5 with proper values of radii of curvatures. If R_1 and R_2 are the radii of curvatures then for a crossed lens $R_1/R_2 = 1/6$, if $\mu = 1.5$



The more curved surface R1 is in the object side and the less curved surface R2 is in the image side. To some extent, it is a better method of minimizing the deviation. But the spherical aberration cannot be completely eliminated.

iii). by suitable combination of a convex lens and concave lens, the spherical duration can be considering reduced.

iv). with two Plano convex lenses placed coaxially at a suitable distance apart, the spherical aberration can be very much minimized. L_1 and L_2 are two Plano convex lenses of focal lengths f_1 and f_2. They are coaxially placed are distance d apart so that both of then produce the same angle of deviation.



For a parallel ray at A,

$\Delta BAC = \delta$, F_1 is the principal focus of L_1.

$\Delta F_1BG = \Delta BAC = \delta$

In ΔBGF_1, $BG = GF_1$

If B is very near to the axis,

$BG \sim O_2G$: $O_2G = GF_1$.

G is the midpoint of O_2 and F_1. Let f_2 be the focal length of the lens L_2.

$$1/u + 1/v = 1/f_2 \qquad (1)$$

For L_2, the image of L_1 acts as the object. Therefore u is the distance of a virtual object at F_1 and so has –ve sign.

$- 1/u + 1/v = 1/f_2$ (2)

$u = O_2F_1 = (f_1 – d)$ (3)

$V = O_2G = ½ O_2F_1$

$V = ½ (f_1 –d)$ (4)

Substituting (3) and (4) in (2),

$- 1/ (f_1- d) + 1/f_1 – d/2 = 1/f_2$

$- 1/ (f_1 – d) + 2/ (f_1 – d) = 1/f_2$

$2/f_1 – d – 1/ (f_1 – d) = 1/f_2$

$1/ (f_1 – d) = 1/f_2$

$f_2 = f_1 – d$

Or $d = f_1 – f_2$

This is the condition for the arrangement to **minimize spherical aberration.**

APLANATIC POINTS:

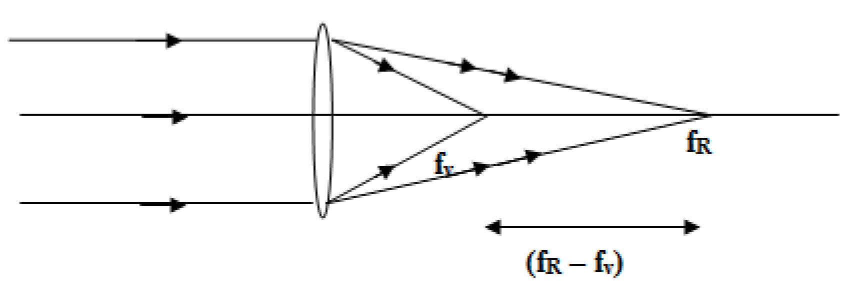
Aplanatic points of a lens are defined as a pair of conjugate points on the principal axis such that all light rays starting from one point are refracted from the other point. (One point is inside the lens and the other is outside the lens.) They are also defined as a pair of conjugate points free from the defects of spherical aberration and coma.

APLANATIC LENS:

Aplanatic lens is a spherical convex lens which is free from both spherical aberration and coma. Such a lens is used as an objective of a compound microscope.

CHROMATIC ABERRATION:

When white light is used, the image formed by a lens is a patch of colours and it is not sharp and clear. This is known as chromatic aberration.



A parallel beam of white light is incident on a convex lens. Dispersion takes place. The violet rays are focused at a near point f_v and the red rays are focused at a far of point f_R, the other coloured images are in between them. The distance $(f_R – f_v)$ is called the longitudinal chromatic aberration. Let f, f_v and f_R be the focal length of the lens for the mean ray, violet and red respectively. Let μ, μ_R and μ_v be the respective values of refractive index of the lens. Let R_1 and R_2 be the radii curvatures of the lens.

We know that

$$1/f = (\mu - 1) (1 / R_1 + 1 / R_2) \quad (1)$$

$$\therefore \quad (1 / R_1 + 1 / R_2) = 1 / f (\mu - 1) \quad (2)$$

$$1 / f_v = (\mu_v – 1) (1 / R_1) + (1 / R_2) = (\mu_v – 1) / f(\mu - 1) \quad (3)$$

$$1 / f_R = (\mu_R – 1) (1 / / R_1) + (1 / R_2) = (\mu_R – 1) / f(\mu - 1) \quad (4)$$

$$\therefore \quad (1 / f_v - 1 / f_R) = (\mu_v – \mu_R) / f(\mu - 1) = \omega / f \quad (5)$$

Where ω is the dispersive power of the lens, L.H.S of (5)

$$1/f_v – 1/ f_R = f_R – f_v/ f_v f_R = (f_R – f_v)/f^2 \quad (6)$$

Where f is the mean value of f_v and f_R

$$(f_v – f_R)/f^2 = \omega/f$$

Or $$(f_R – f_v) = \omega f \quad (7)$$

This is the expression for the longitudinal chromatic aberration of a convex lens.

ACHROMATIC LENSES:

Achromatic lenses are the combination of two lenses in which chromatic aberration is removed.

Achromatism: The removal of chromatic aberration is known as achromatism.

CONDITION FOR ACHROMATISM OF TWO LENSES IN CONTACT:

In convex lens and concave lens, the order of chromatic aberration is opposite. Therefore these two lenses can be kept in contact coaxially, to remove chromatic aberration.

Let f_1, fv_1 be the focal lengths of a convex lens for the mean ray, violet and red rays. Let μ_1, μv_1 and μR_1 be the refractive indices of the lens for these colours. Let R_1 and R_1 be its radii of curvatures. Let ω_1 be the dispersive power of the material of the convex lens.

$1/f_1 = (\mu_1 – 1) (1/R_1) + (1/R_1)$ (1)

$(1/R_1 +1/R_1) = 1/f_1 (\mu_1 – 1)$ (2)

$1/fv_1 = (\mu v_1 – 1) (1/R_1 + 1/R_1) = (\mu V_1 – 1)$ (3)

$1/fR_1 = (\mu R_1 – 1) (1/R_1 + 1/R_1) = (\mu R_1 – 1)/f_1 (\mu_1 – 1)$ (4)

For a concave lens let f_2, fv_2 and fR_2 be the focal lengths and μ_2, μv_2 and μR_2 are the refractive indices for mean by violet and red rays. Let $R_2$and R_2be the radii of curvatures.

Let ω_2 be the dispersive power of the material of the concave lens.

$1/f_2 = (\mu_2 – 1) (1/R_2 + 1/R_2)$ (5)

$(1/R_2 + 1/R_2) = 1/f_2 (\mu_2 – 1)$ (6)

$1/fv_2 = (\mu v_2 – 1) (1/R_2 + 1/R_2) = (\mu v_2 – 1)/f_2 (\mu_2 – 1)$ (7)

$1/fR_2 = (\mu R_2 – 1) (1/R_2 + 1/R_2) = (\mu R_2 – 1)/f_2 (\mu_2 – 1)$ (8)

Let F_V and F_R be the focal lengths of the combination for violet of red rays.

$1/F_V = 1/fv_1 + 1/fv_2 = (\mu v_1 – 1)/f_1 (\mu_1 – 1) + (\mu v_2 – 1)/f_2 (\mu_2 – 1)$

$1/F_R = 1/fR_1 + 1/fR_2$

$= (\mu R_1 – 1)/f1 (\mu_1 – 1) + (\mu R_2 – 1)/f_2 (\mu_2 – 1)$ (9)

For the combination to produce achromatism, the condition is,

$F_V = F_R$

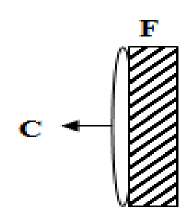
$1/F_V =1/F_R$ (10)

$(\mu V_1 – 1)/f1 (\mu_1 – 1) + (\mu v_2 – 1)/f_2 (\mu_2 – 1) =(\mu R_1 – 1)/f_1(\mu_1 – 1) +(\mu R_2 – 1)/f_2 (\mu_2 – 1)$

$(\mu v_1 – 1)/f_1 (\mu_1 – 1) – (\mu R_1 – 1)/f_1 (\mu_1 – 1) + (\mu v_2 – 1)/f_2 (\mu_2 – 1) – (\mu R_2 – 1)/f_2 (\mu_2 – 1) = 0$

$1/f_1 (\mu_1 – 1) [\mu v_1 – \mu R_1] + 1/f_2 (\mu_2 – 1) [\mu v_2 – \mu R_2] = 0$

$(\mu v_1 – \mu R_1)/f_1 (\mu_1 – 1) + (\mu v_2 – \mu R_2)/f_2 (\mu_2 -1) = 0$



$\omega_1/ f_1 + \omega_2/f_2 = 0$ (11)

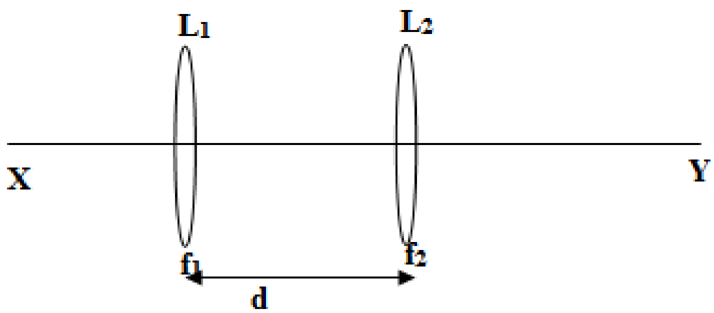
Or $\omega_1/f_1 = -\omega_2/f_2$

i.e., $\boldsymbol{\omega_1/\omega_2 = - f_1/f_2}$ (12)

ω_1 and ω_2 are +ve quantities.

Therefore f_1 is +ve the f_2 must be –ve. Ie, the achromatism combination in contact must have a convex lens and a concave lens. Further if convex lens is made of crown glass, the concave lens must be made of flint glass.

CONDITION FOR ACHROMATISM WHEN TWO CONVEX LENSES OF THE SAME MATERIAL ARE KEPT COAXIALLY APART :(out of contact)



L_1 and L_2 are convex lenses kept coaxially at a distance d apart. They are made of the same material of dispersive power ω. Let f_1 and f_2 be the focal length of L_1 and L_2 for mean rays and f_v and f_R be their focal lengths for violet and red rays. Let μ, μ_v and μ_R be the refractive indices of the lenses for mean ray, violet and red rays. Let R_1 and R_1 be the radii of curvatures of L_2. Let f_v and f_R be the focal length of L_2 for violet and rays.

$1/f_1 = (\mu - 1)\,(1/R_1 + 1/R_1)$ (1)

$(1/R_1 + 1/R_1) = 1/f_1\,(\mu - 1)$ (2)

$1/f_v = (\mu_v - 1)\,(1/R_1 + 1/R_1) = (\mu_V - 1)/f_1\,(\mu - 1)$ (3)

$1/f_R = (\mu_R - 1)\,(1/R_1 + 1/R_2) = (\mu_R - 1)/f_1\,(\mu - 1)$ (4)

$1/f_2 = (\mu - 1)\,(1/R_2 + 1/R_2)$ (5)

$(1/R_2 + 1/R_2) = 1/f_2\,(\mu - 1)$

$1/f_v = (\mu_v - 1)\,(1/R_2 + 1/R_2) = (\mu_V - 1)/f_2\,(\mu - 1)$ (6)

$1/f_R = (\mu_R - 1)\,(1/R_2 + 1/R_2) = (\mu_R - 1)/f_2\,(\mu - 1)$ (7)

Let F_v and F_R be the focal length of the combination for violet rays and red rays.

$1/F_v = 1/f_v + 1/f_v - d/f_v\,f_v$ (8)

$1/F_V = (\mu_v - 1)/f_1\,(\mu - 1) + (\mu_v - 1)/f_2\,(\mu - 1) - d\,(\mu_v - 1)/f_1(\mu - 1\,).(\mu_v - 1)/f_2\,(\mu - 1)$

$1/F_V = (\mu_v - 1)/\,(\mu - 1)\,(1/f_1 + 1/f_2) - (\mu_v - 1)^2/f_1\,f_2\,(\mu - 1)^2.\,d$

Similarly,

$1/F_R = (\mu_R - 1)/ (\mu - 1)\ (1/f_1 + 1/f_2) - (\mu_R - 1)^2/f_1\ f_2\ (\mu - 1)^2.\ d$

For achromatism, $F_V = F_R$

$$1/F_V = 1/F_R$$

$$(\mu_v - 1)/ (\mu - 1)\ [1/f_1 + 1/f_2] - (\mu_v - 1)^2/\ f_1f_2\ .d = (\mu_R -1)^2 / f_1f_2\ (\mu - 1)^2$$

$$(1/f_1+1/f_2)\ [(\mu_v - \mu_R)/ (\mu - 1)\ ] = d / f_1\ f_2(\mu - 1)^2\ [(\mu_v - 1)^2 - (\mu_R - 1)^2]$$

$$(1/f_1+1/f_2)\ (\omega) = d / f_1f_2\ (\mu - 1)^2\ [(\mu_v -1+\mu_R-1)(\mu_v - \mu_R)$$

$$(1/f_1+1/f_2)\ \ \omega = d / f_1f_2\ (\mu_v - \mu_R - 2)$$

$$(1/f_1+1/f_2) = d / f_1f_2\ (\mu_v+\mu_R-2)/ (\mu - 1)$$

But $\mu_v + \mu_R = 2\mu$

$$(1/f_1+1/f_2) = d / f_1f_2\ (2\mu -2)/ (\mu - 1) =d$$

$$(1/f_1+1/f_2) =d / f_1f_2\ 2(\mu - 1)/(\mu - 1) = 2d / f_1f_2$$

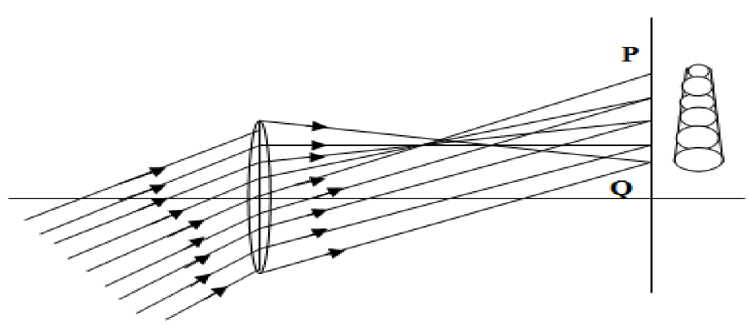
$$(f_1+f_2) =2d$$

$$d = f_1+f_2/ 2$$

This is the condition for **achromatism** when two convex lenses of the same material are kept coaxially apart.

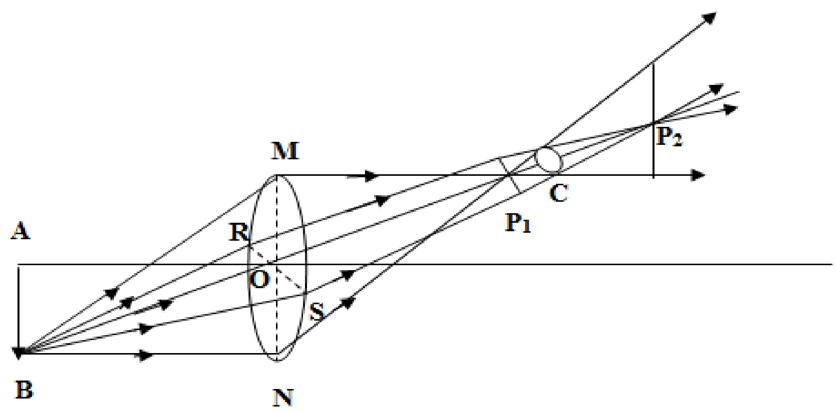
COMA:

The effect of rays from an object point not situated on the axis of the lens results in an aberration called **coma.** Comatic aberration is similar to spherical aberration, because both fail to bring all rays from a point to focus at the same point. Spherical aberration refers to object points situated on the axis whereas comatic aberration refers to object points situated off the axis. In the case of **spherical aberration,** the image is a **circle** of varying diameter along the axis and in the case of **comatic aberration** the image is **comet shaped** and hence the name **coma.**



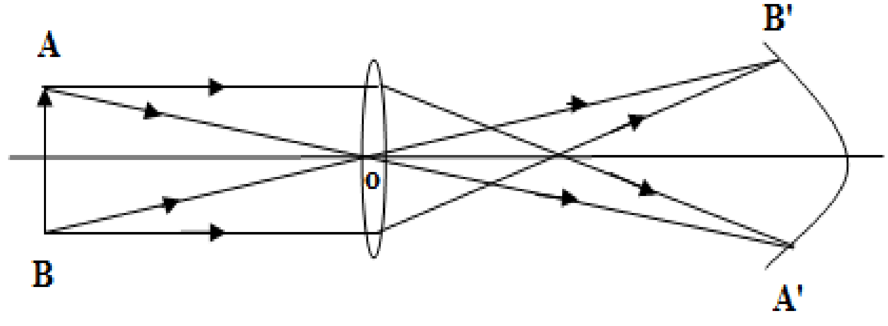
ASTIGMATISM:

Astigmatism, similar to coma, is the aberration in the image formed by the lens, of object points off the axis. The difference between astigmatism and coma, however, is that in coma the spreading of the image takes place in a plane perpendicular to the lens axis and in astigmatism the spreading takes place in a plane perpendicular to the lens axis.



CURVATURE OF THE FIELD:

The image of an extended plane object due to a single lens is not a flat one but will be a curved surface. The central portion of the image nearer the axis is in focus but the outer regions of the image away from the axis are blurred. This defect is called the curvature of the field. This defect is due to the fact the paraxial focal length is greater than the marginal focal length. This aberration is present even if the aperture of the lens is reduced by a suitable stop, usually employed to reduce spherical aberration, coma and astigmatism.



1. Very high, this device is capable of chopping a beam of light several hundred times more rapidly than can be done by the toothed wheel. Hence a shorter base line can be used.
2. The advantages can be set up in a laboratory.
3. The accurate frequency of the high frequency oscillator is known.

EYE-PIECES [OCULARS]:

Eye- piece is an important part of a telescope and microscope. Without an eyepiece**,** the image formed by the objective, cannot be observed clearly. An eye-piece consists of two Plano convex lenses they are.

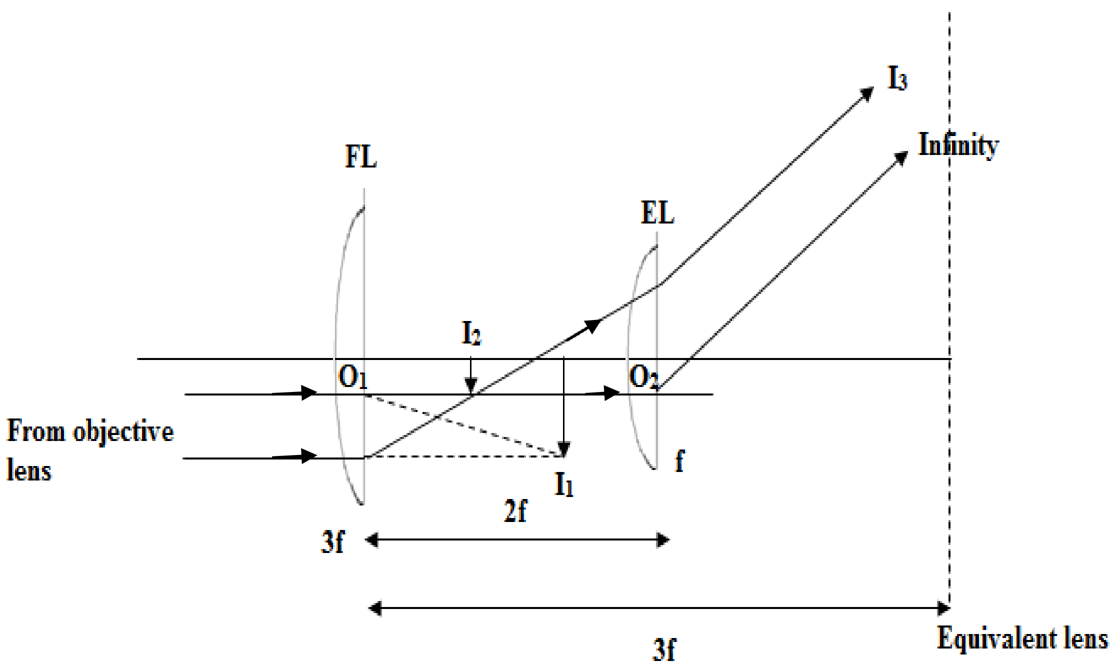
1. Field lens and
2. Eye-lens

These lenses are co-axially arranged as a suitable distance apart. The function of field lens:

1. It increases the angular object field and the angular image field.
2. Spherical and chromatic aberrations are minimized.

HUYGENS EYE- PIECE:

Huygens constructed an eye-piece with two Plano – convex lenses of focal lengths 3f, kept co-axially as a distance 2f apart.



FL is the field lens of focal length f_1 = 3f and EL is the eye-lens of focal length f_2 = f. the distance between then is d = 2f. Light rays coming from the objective from the objective lens will from an image I_1 is the absence of the field lens. I_2 is the image formed by the field lens. This image is as the principal focus of the eye-lens. Therefore the emergent rays are parallel and the final image is formed are infinity.

Focal length of the equivalent lens:

Let f be the focal length of the equivalent lens of the two lenses, we know that

$$1 / F = 1/f_1+1/f_2 – d /f_1f_2$$

$$= 1/ 3f + 1/f – 2f / 3f.f = 1/ 3f+ 1/f – 2/ 3f$$

$$= 1/f (1/3+1 – 2/3) = 1/f(1+3-2/3)$$

$$1 / F = 2 / 3f$$

$$F = 3f / 2$$

Let α be the position of this equivalent lens from field lens. Then,

$$\alpha = F.d / f_2$$

$$= 3/2f . 2f / f =3f$$

Therefore the equivalent lens is at a distance of **α = 3f** from the field lens.

Removal of spherical aberration:

The condition for removal of spherical aberration is

$$d = f_{1\,–}\,f_2$$

$$d = 3f – f = 2f$$

The two lenses are spherical by a distance **d = 2f**. Therefore the condition minimizes spherical aberration.

Removal of chromatic aberration: The condition for removal of chromatic aberration is d = f_1 + f_2 / 2

$$= 3f + f / 2 = 4f/2 =2f$$

We know that the two lenses are a distance d=2f apart. Therefore the combination minimizes chromatic aberration also.

Cardinal points of Huygens eye-piece:

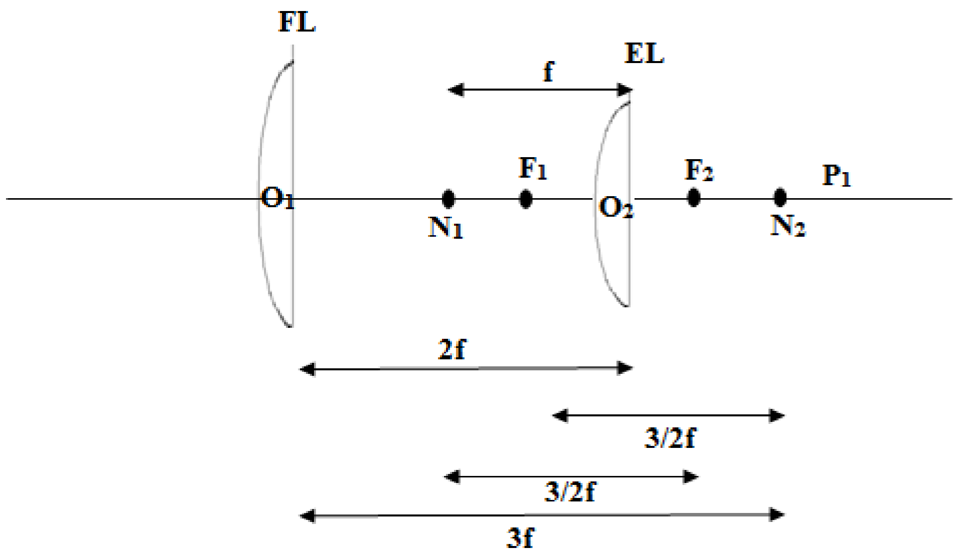
1. **Principal points:** let α be the distance of the first principal point p_1 from the field lens. Then

   $\alpha = Fd/ f_2 = 3/2f \,.\, 2f / f = 3f$ to the right of field lens

   Let β be the distance of the second principal point from the eye- lens. Then

   $\beta = - Fd / f_1 = -3/2\ f\ .2f / 3f = -f$ to the left of the eye-lens

2. **Focal points:** the focal length of the equivalent lens is F = 3/2 f. therefore the first focal point F_1 is at a distance of 3/2f from the first principal point p_1.
   Similarly the second focal point F_2 is at a distance of 3/2f from the second principal point p_2.
3. **Nodal points:** the system is in air. Therefore the same medium is surrounding the eye – piece. The nodal points N_1 and N_2 coincide with the principle points P_1 and P_2 respectively.



Conclusion:

1. The Huygens's eye-piece is a negative eye-piece. This is because; the image formed by the objective lens is behind the field lens.
2. The cross wires, must be placed in between the two lenses. They are viewed by the eye lens only and the final image is viewed by both the lenses. Therefore cross wires cannot be used in the eye-piece. This is a disadvantage.
3. This eye-piece cannot be used in telescope or microscopes for making measurements.
4. It is used in microscopes or telescopes in which white light is used.
5. The only advantage is that spherical and chromatic aberrations are minimized in this eye-piece.

RAMSDEN EYE – PIECE:

Ramsden constructed an eye-piece with two Plano-convex lenses of equal focal length (f), they are placed co-axially at a distance d = 2 / 3 (f) Apart, such that their convex surface are facing one another. Further the eye-piece is belonged the image I_1 formed by the objective lens.

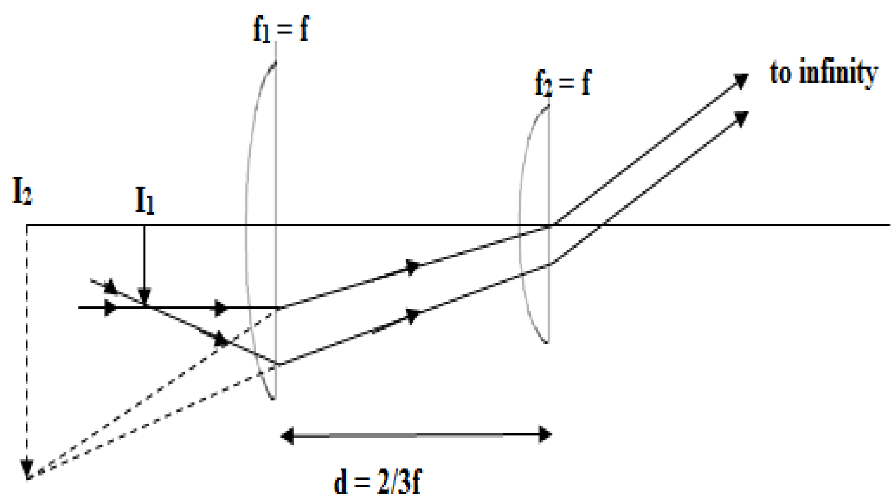
Focal length of the equivalent lens: Let F be the focal length of the equivalent lens,

$$\therefore \ 1 / F = 1 / f_1 + 1 / f_2 - d / f_1 f_2$$

$$= 1 / f + 1 / f - 2/3\, f / ff$$

$$= 1 / f + 1 / f - 2 / 3f$$

$$= 1 / f\, [1 + 1 - 2/3] = 1 / f\, [2 - 2/3]$$



$$= 1 / f\, [6 - 2 / 3] = 4 / 3f$$

$$\therefore \ \mathbf{1 / F = 3 / 4\, f}$$

If α is the distance of the position of the equivalent lens then, $\alpha = Fd / f_2 = 3/4.f.2/3f / f = f / 2$ to the right side of the field lens.

Removal spherical aberration: The condition for minimum spherical aberration is,

$$d = f_1 - f_2 = f - f = 0$$

But d $\neq$ 0 and d = 2/3 f. Therefore the condition for minimum spherical aberration is not satisfied. But, spherical aberration is small because the two convex surfaces face one another.

Removal chromatic aberration: The condition for minimum chromatic aberration is,

$$d = f_1 + f_2 / 2$$

$$\therefore\ d = f + f / 2 = 2f / 2 = f$$

But actually d = (2 / 3).f and therefore the chromatic aberration is not minimized. However, the field lens and the eye-lens can be made of an achromatic doublet. Therefore the chromatic aberration can be reduced.

Cardinal points:

1. **Principal points:** Let α be the distance of the first principal point P_1 from the field lens.

   $$\therefore\ \alpha = Fd / f_2 = (3/4)\ f.\ (2/3)f / f = f/2$$

   This is to the right side of the field lens. Let β be the distance of the second principal point P_2 from the eye-lens.

   $$\beta = -\ Fd / f_1 = -\ (3/4)\ f.\ (2/3)f / f = -f/2$$

   Therefore P_2 is to the left side of the eye-lens.

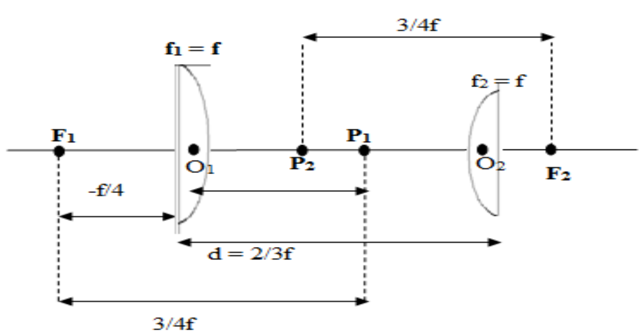
2. **Nodal points:**

   The two lenses are surrounded by the same medium i.e. air. Therefore the nodal points N_1 and N_2 coincide with the corresponding principal points P_1 and P_2 respectively.

3. **Focal points or principal foci:**

   The focal length of the equivalent lens is F = ¾ f. From the first principal points P_1, F_1 is in front of the field lens. Similarly the second principal focus F_2 is at a distance ¾ f from the second principal point. F_2 is the right side of the eye-lens.

Diagram to show cardinal points:



Conclusions:

1. Ramsden eye piece is a + ve eye piece because the image formed by the objective is in front of the field lens.
2. The combination of the two lenses does not satisfy the conditions for minimizing spherical and chromatic aberrations. This is a disadvantage.
3. Cross wires can be used to make measurements. This is an important advantage of this eye piece.
4. The spherical aberration is reduced because the two convex surfaces face one another chromatic aberration is reduced by using achromatic doublets.

Difference between Huygens and Ramsden eye piece:

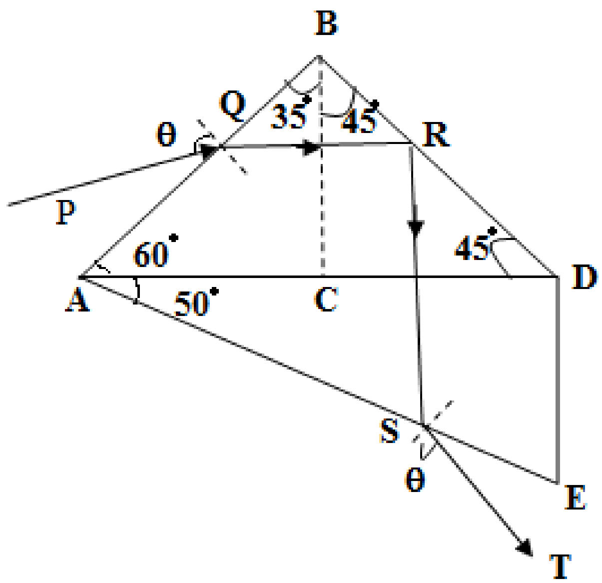
S.No	**HUYGENS EYE PIECE**	**RAMSDEN EYE PIECE**
1.	It is a negative eye piece (images formed by the objective is behind the field lens).	It is a + ve eye piece (image formed by the objective is in front of the field lens.
2.	Condition for minimum spherical is satisfied.	Condition for minimum spherical aberration is not satisfied.
3.	Condition for achromatism is satisfied.	Condition for achromatism is not satisfied.
4.	Cross wires cannot be used	Cross wires can be used.
5.	Quantitative measurements cannot be made	Quantitative measurements can be made.
6.	The field lens and the eye lens have their focal lengths in the ratio 3:1.	The field lens at the eye lens has their focal length in the ratio 1:1.

CONSTANT DEVIATION SPECTROMETER:

In this spectrometer a special type of prism is used. One portion ABC is one half of a 60° prism and the other portion BCD is 45° prism. ADE is also one half of a 60° prism. Therefore in this prism, angle of ABD = 75°.

Suppose PQ is the incident ray such that the refracted ray QR is parallel to AD. The ray QR strikes the face BD at angle of 45° and is totally internally reflected along RS. The ray finally emerges in the direction ST.

in this case, the angle of incidence = angle of emergence = θ. Thus, the ray of light passes through this prism similar to a 60° prism in the minimum deviation position. The advantage of this arrangement is that the rays PQ and ST are normal to each other.



A constant deviation spectrometer has a collimator and a telescope fixed to rigid stand such that they are mutually perpendicular to one another. The prism P is placed on a table which can be rotated about a vertical axis with the help of a drum D.

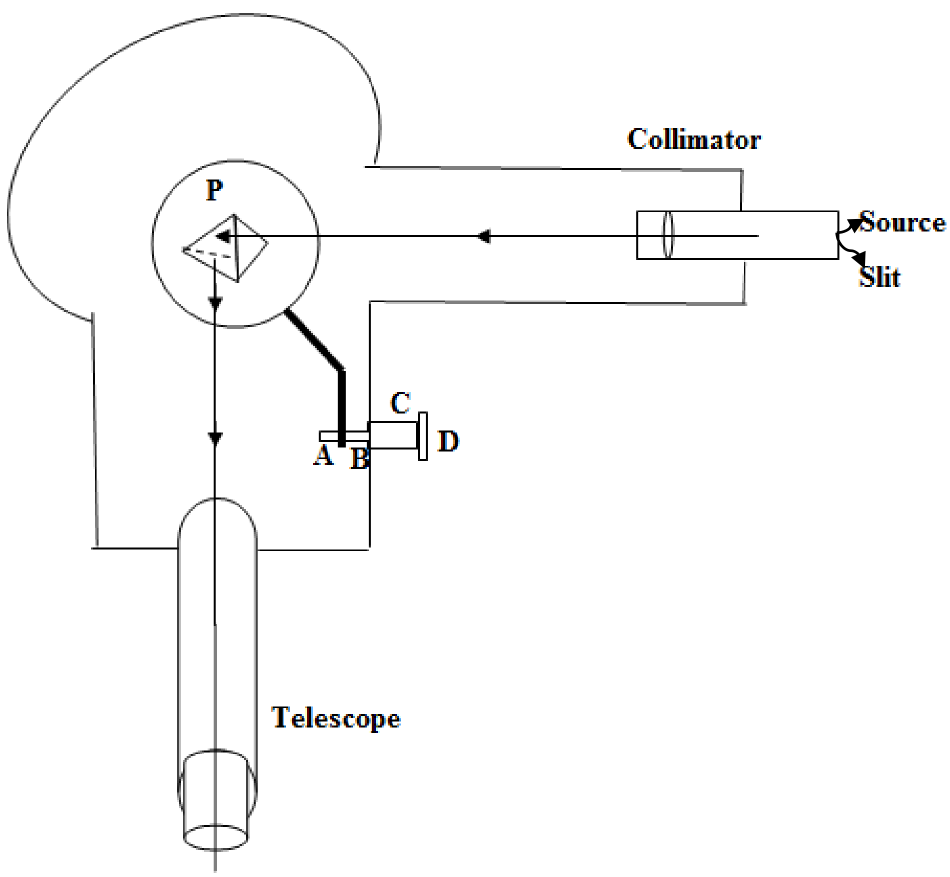
A is a spring which allows the lever B to move when the drum D is rotated. The drum D has a graduated scale, which is calibrated and the index C shows the wavelengths of the different lines directly

To start with, the slit is illuminated with sodium light. The drum D is rotated such that the index C is on a mark showing the reading 5890 A° . The prism P is placed on the table and rotated slowly with hand and such that the yellow line D_1 of sodium light is seen in the field of view of the telescope and the line coincides with the centre of the cross wires.

The prism is clamped in this position and sodium light is removed. The source whose wavelengths for different lines are to be determined, is placed before the slit, the drum D is rotated to bring the lines at the centre of the cross wires in turn and the corresponding readings as shown by the index C are read.

Therefore, with the help of this spectrometer wavelengths of spectral lines can be determined directly and in a short time. The scale is usually calibrated and standardized by using lines of known wavelengths from mercury light or a copper arc.

The constant deviation spectrometer is helpful in finding any impurity in different salts and also for radical analysis. The substance is allowed to emit radiation in a carbon arc and the wavelengths of different spectral lines are found. From the standard charts of wavelengths of the spectral lines of different substances, he nature of the radicals present in a salt can be found. If by any chance, the prism is disturbed, it can be reset by using a spectral line of known wavelength.



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7. **https://www.quora.com/What-is-the-condition-of-achromatism-when-two-lenses-are-in-contact-with-each-other**

Important questions:

2 marks:

1. **Define spherical lenses.**
2. **What is meant by achromatism?**
3. **Define cardinal points**
4. **Write about coma in lenses.**
5. **What is meant by eye pieces?**
6. **What is meant by chromatic aberration?**
7. **Define least confusion.**
8. **Explain constant deviation spectrograph.**
9. **Write astigmatism.**
10. **Write the types of lenses.**

5 marks:

1. **Explain the condition to minimize spherical aberration.**
2. **Explain 1. Curvature of field 2. Coma**
3. **Differentiate Huygen's eyepiece and Ramsden's eyepiece.**
4. **Explain Ramsden's eyepiece.**

10 marks:

1. **Explain achromatism when lenses in contact and out of contact.**
2. **Explain constant deviation spectrometer.**