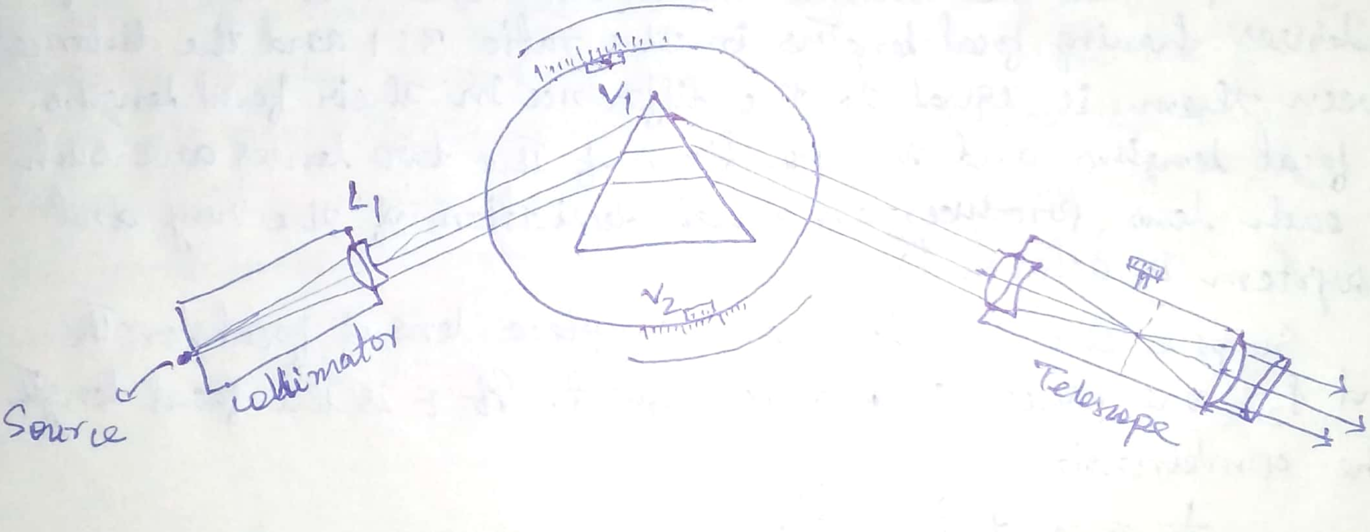
spectrometer: It consists mainly of three parts

(1) ~~collimeter~~ collimator

② Prism table

③ Telescope

collimator: It consist of an achromatic lens L_1 such that the slit S_0 is at its focus. The slit is placed infront of a source of light and the width of the slit can be adjusted. The slit acts as a source of light and the rays coming out of the lens L_1 are parallel.



prism table: The table can be adjuted and its position can be read with the verniers V_1 and V_2. The table can be rotated about a vertical axis and its ~~coincides~~ axis coincides with the axis of rotation of the telescope. A prism is placed on the table. A parallel beam of light is incident on the prism and the emergent beam is also parallel.

Telescope: It is an astronomical telescope fitted with a Ramsden's eyepiece and cross wires. when a parallel beam of light coming out of the prism falls on the objective, the spectrum produced is viewed through the eyepiece. If a photograph is to be taken, the eyepiece is replaced by a photographic plate.

The eyepiece of the telescope is adjusted such that the crosswires are clearly visible. The telescope is focused on the distant object. The parallax between the image and the crosswire is removed. Thus, the Telescope is set for parallel rays.

The table can be levelled with the help of a spirit level. For accurate work the three level screws provided with the prism table are adjusted.

Huygen's Eyepiece: This eyepiece is a ~~ach~~ achromatic and the spherical aberration is also eliminated. It consists of two lenses having focal lengths in the ratio 3:1 and the distance between them is equal to the difference in their focal lengths. The focal lengths and the positions of the two lenses are such that each lens produces an equal deviation of the ray and the system is achromatic

Suppose the field lens and eye~~piece~~ lens of focal lengths f_1 and f_2 are placed D distance apart. If F is the focal length of the combination

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

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Differentiating

$$-\frac{dF}{F^2} = \frac{df_1}{f_1^2} - \frac{df_2}{f_2^2} + D\left(\frac{df_1}{f_1^2 f_2} + \frac{df_2}{f_1 f_2^2}\right)$$

As the dispersive power

$$\omega = \frac{dF}{F} = -\frac{df_1}{f_1} = -\frac{df_2}{f_2}$$

$$\frac{\omega}{F} = \frac{\omega}{f_1} + \frac{\omega}{f_2} - D\left(\frac{\omega+\omega}{f_1 f_2}\right)$$

For achromatism $\frac{\omega}{F} = 0$

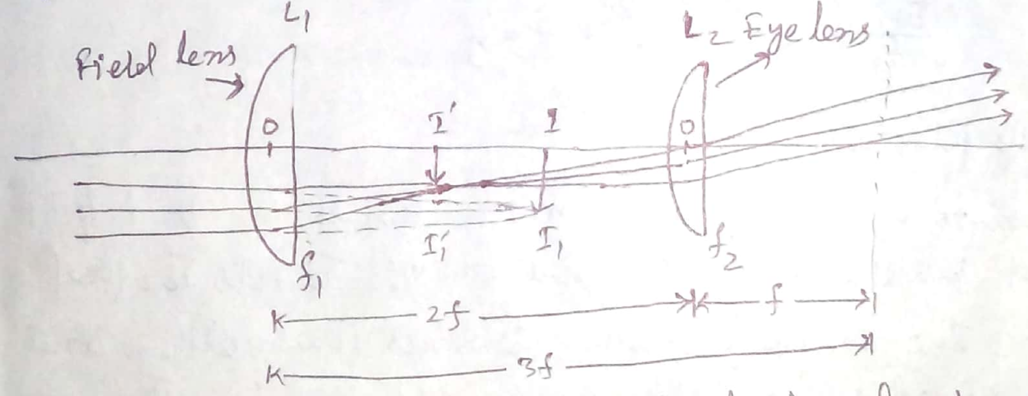
$$\therefore \frac{\omega}{f_1} + \frac{\omega}{f_2} - \frac{2D\omega}{f_1 f_2} = 0$$

$$\frac{1}{f_1} + \frac{1}{f_2} - \frac{2D}{f_1 f_2} = 0$$

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

$$\Rightarrow D = \frac{f_1+f_2}{2}$$

Huygen's constructed an eyepiece consisting of two plano-convex lenses of focal lengths 3f and f placed at a distance of 2f from each other.



II_1 is the image of the distant ~~object~~ object formed by the objective in the absence of the field lens. With the field lens, the rays get refracted on passing through it and the image $I'I_1'$ is formed. This image lies at the focus of the eye lens so that the final image is seen at infinity. The focal length of the combination.

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{3f} - \frac{2f}{3f^2}$$

$$\frac{1}{F} = \frac{2}{3f}$$

$$F = \frac{3}{2}f$$

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The equivalent lens must be placed behind the field lens at a distance $= \frac{F\times d}{f_2} = \frac{F\times 2f}{f} = \frac{\frac{3}{2}f\times 2f}{f} = 3f$

i.e. 3f from the field lens or at a distance f behind the eye lens.

Huygens eyepiece is known as the negative eyepiece because the real inverted image formed by the objective lies behind the field lens and this image acts as a virtual object for the eye lens. This eyepiece cannot be used to examine directly an object or a real image formed by the objective. The eyepiece is used in microscopes or other optical instruments using white light only.

Cardinal points of a Huygens eyepiece:

The first principal point is a distance α from the field lens

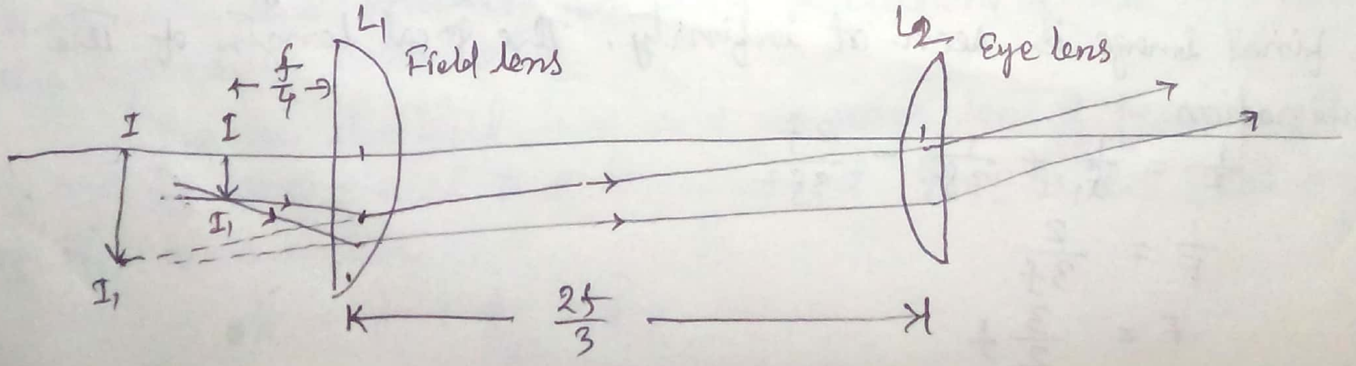
$$\alpha = \frac{Fd}{f_2} = \frac{\frac{3}{2}f\times 2f}{f} = 3f$$

The second principal point is at a distance β from the eye lens.

$$\beta = -\frac{Fd}{f_1} = \frac{\frac{3}{2}f\times 2f}{3f} = -f$$

Ramsden Eyepiece:

It consists of two plano-convex lenses of equal focal length separated by the distance equal to two-thirds the focal length of either. The convex faces are towards each other and the eyepiece is placed beyond the image formed by the objective. In this eyepiece crosswires are provided and it is ~~objective~~ used in optical instruments where accurate quantitive measurements are made.



Let F be the focal length of the equivalent lens

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

$$\frac{1}{F} = \frac{1}{f} + \frac{1}{f} - \frac{2/3 f}{f^2}$$

$$\frac{1}{F} = \frac{2}{f} - \frac{2}{3f} = \frac{4}{3f}$$

$$F = \frac{3}{4} f$$

The equivalent lens must be placed at a distance $\frac{3}{4} f$ behind the field lens at a distance α from it.

$$\alpha = \frac{F \times d}{f_2} = \frac{F}{f} \times \frac{2}{3} f = \frac{3/4 f}{f} \times \frac{2}{3} f = f/2$$

Thus, equivalent lens is in between the field lens and the eye lens. As the focal length of the eyepiece is $3/4 f$, the image of the object due to the objective must be formed at a distance $f/4$ in front of the field lens. This image will act as an object for the eyepiece and the final image will be formed at infinity. The cross wires must be placed at the position where the image due to the objective is formed. This is the advantage of Ramsden eyepiece over the Huygens eyepiece.

Cardinal points of a Ramsden eyepiece:

The first principal point is at a distance α from the field lens

$$\alpha = \frac{Fd}{f_2} = \frac{3/4 f}{f} \times \frac{2}{3} f = f/2$$

The second principal point is at a distance β from the eye lens

$$\beta = -\frac{Fd}{f_1} = -\frac{3/4 f}{f} \times \frac{2}{3} f = -f/2$$

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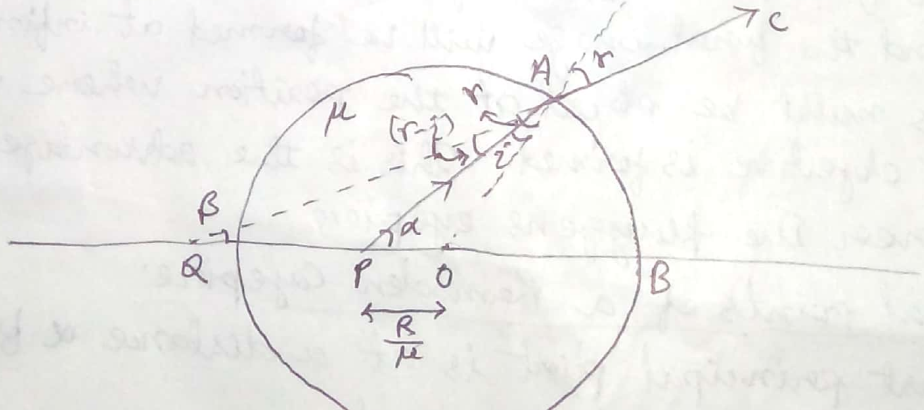
comparison of Eyepieces:

Huygens eyepiece	Ramsden Eyepiece
1. It is a negative eyepiece. The image formed by the objective lies in between the two lenses. Therefore no cross wires can be used.	1. It is a positive eyepiece. The image formed by the objective lies in front of the field lens. Therefore cross wires can be used.
2. The condition for min^m spherical aberration is satisfied.	2. The condition for min^m spherical aberration is not satisfied.
3. It satisfies the condition for achromatism.	3. It doesnot satisfy the condition for achromatism but can be made acromatic by using an achromatic doublet.
4. It is achromati for all colours	4. It is achromatic for only two chosen colours.
5. The eye-clearance is too small and less comfortable	5. The eye clearance is 5% high.

Aplanatic lens: A spherical lens which is free from the defects of spherical aberration and coma is called an aplanatic lens. A pair of conjugate points free from spherical aberration and coma are called aplanatic points.



Let 'O' be the centre of curvature of the lens of refractive index μ and radius of curvature R. P is a point on the axis of the lens such that $PO = R/\mu$. It can be shown that all rays passing through the point P appear to diverge through the point Q irrespective of the slope angle made by the incident rays. PA is the incident ray and AC is the refracted ray. The ray AC appears to diverge from the point Q which is the image of P. Let i and r be the angles of incidence and refraction and α and β the slope angles made by the incident and refracted rays.

Then $\dfrac{\sin i}{\sin r} = \dfrac{1}{\mu}$ --- (i)

In ΔAPO, $\dfrac{\sin i}{\sin \alpha} = \dfrac{PO}{R} = \dfrac{R}{\mu R} = \dfrac{1}{\mu}$ --- (ii)

From (i) and (ii) $\dfrac{\sin i}{\sin r} = \dfrac{\sin i}{\sin \alpha}$ --- (iii)

$\angle \alpha = \angle r$

In ΔAPQ $\angle \alpha = \beta + (r - i)$ --- (iv)

$\angle r = \beta + r - i \Rightarrow i = \beta$ --- (v)

In ΔAQO, $\dfrac{\sin r}{\sin \beta} = \dfrac{\sin r}{\sin i} = \mu = \dfrac{OQ}{OA} = \dfrac{OQ}{R}$

$\Rightarrow OQ = \mu R$

Thus, if the distance of the object ~~from~~ point P is $\frac{R}{\mu}$ from the centre of curvature, then the distance of the image point Q is μR irrespective of the slope angles α and β. The object and image distances of the conjugate points that satisfy the above condition are $BP = R + \frac{R}{\mu}$ and $BQ = R + \mu R$.

An aplanatic lens is mostly used as the front lens of a high power microscope objective called the oil immersion objective. As it is not possible to place an object inside a solid spherical lens, the lens is ground a little and the object to be examined is embedded in between a drop of oil and the lens surface.

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