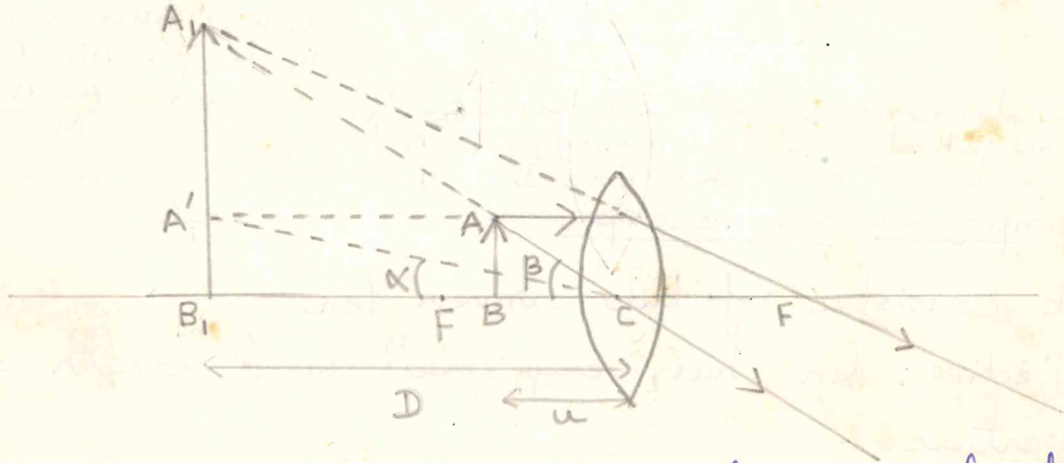
VIII [C]

Optical instruments

I Simple microscope or magnifying glass (image at least distance of distinct vision)

1. It consists of a convex lens of small focal length.
2. A virtual, erect and magnified image is formed at the least distance of distinct vision from the eye held close to the lens.



Magnifying power is also known as angular magnification.

Magnifying power of a simple microscope is defined as the ratio of the angle subtended by the image at the eye to the angle subtended by the object at the eye when both the image and the object are at the least distance of distinct vision from the eye.

$$M = \beta/\alpha$$

Since the angles α and β are small

$$M = \frac{\tan\beta}{\tan\alpha}$$

$$= \frac{AB}{BC}\ \frac{B_1C}{A'B_1}$$

$$M = \frac{B_1C}{BC} \quad [\because A'B_1 = AB]$$

$$M = \frac{-v}{-u} = \frac{v}{u}$$

According to lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$.

Multiply by v on both sides

$$\therefore \frac{v}{f} = 1 - \frac{v}{u}$$

$$\frac{v}{f} = 1 - M$$

$$M = 1 - \frac{v}{f}.$$

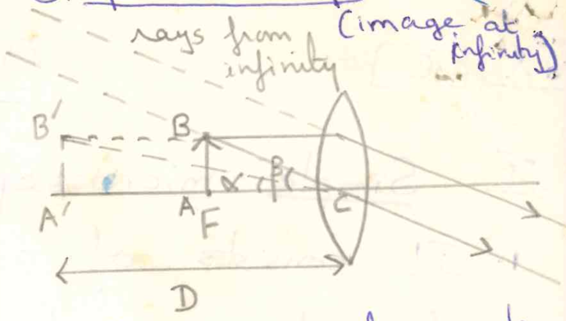
Since $v = -D$

$$\boxed{M = 1 + \frac{D}{f}}$$

As f decreases, M increases

Note: The magnification m and magnifying power M become equal only when $v = D$.

Simple microscope



Magnifying power of a simple microscope is defined as the ratio of the angle subtended by the image to the angle subtended by the object when object is at the least distance of distinct vision and image at infinity.

$$M = \frac{\tan\beta}{\tan\alpha} = \frac{AB}{AC} \cdot \frac{A'C}{A'B'} = \frac{D}{f_e}$$

$$\therefore \boxed{M = D/f_e}$$

II Compound microscope

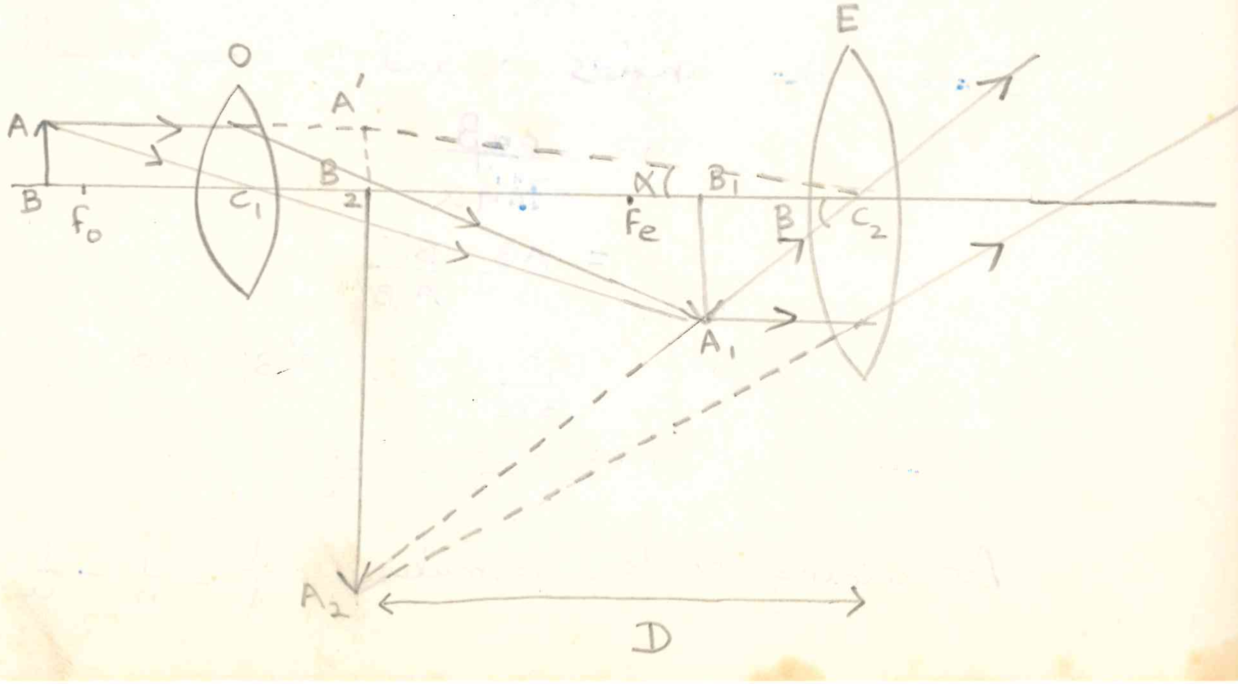
(1) It consists of two convex lens.

(2) Objective lens has very small focal length and small aperture.

(3) Eyepiece has moderate focal length and large aperture

(4) The two lens are held at the free ends of two coaxial tubes.

(5) The final image is formed at A_2B_2 which is inverted with respect to AB but erect with respect to A_1B_1



Magnifying power of a compound microscope is defined as the ratio of the angle subtended by the final image at the eye to the angle subtended by the object at the eye when both the object and image are at the least distance of distinct vision from the eye.

$$\text{Magnifying power } (M) = \beta/\alpha$$

Since the angles are small.

$$M = \frac{\tan\beta}{\tan\alpha}$$

$$= \frac{A_2B_2}{B_2C_2}\,\frac{B_2C_2}{A'B_2}$$

$$= \frac{A_2B_2}{AB} \quad [\because A'B_2 = AB]$$

Multiply and divide by A_1B_1

$$M = \frac{A_2B_2}{A_1B_1}\,\frac{A_1B_1}{AB}$$

$$M = m_e\, m_o$$

$$m_e = 1 + D/f_e$$

$$\text{and } m_o = \frac{A_1B_1}{AB} = \frac{B_1C_1}{BC_1} = \frac{v_o}{-u_o}$$

$$\boxed{M = \frac{v_o}{-u_o}\left[1 + \frac{D}{f_e}\right]}$$

Since the object is placed very close to the focus of lens O

$$\therefore u_o = BC_1 = f_o$$

Also the image A_1B_1 is very close to the eyepiece

$$\therefore v_o = B_1C_1 \simeq C_1C_2 = L$$

$$\therefore M = \frac{L}{-f_o}\left[1 + \frac{D}{f_e}\right]$$

Note: The magnifying power of a compound microscope when the image is formed at infinity is $M = \frac{L}{-f_o}\left[\frac{D}{f_e}\right]$ $[\because m_e = D/f_e]$

For large magnifying power f_o and f_e have to be small. [$f_o < f_e$ to increase the field of view]

Application: It is used for observing highly magnified images of tiny objects.

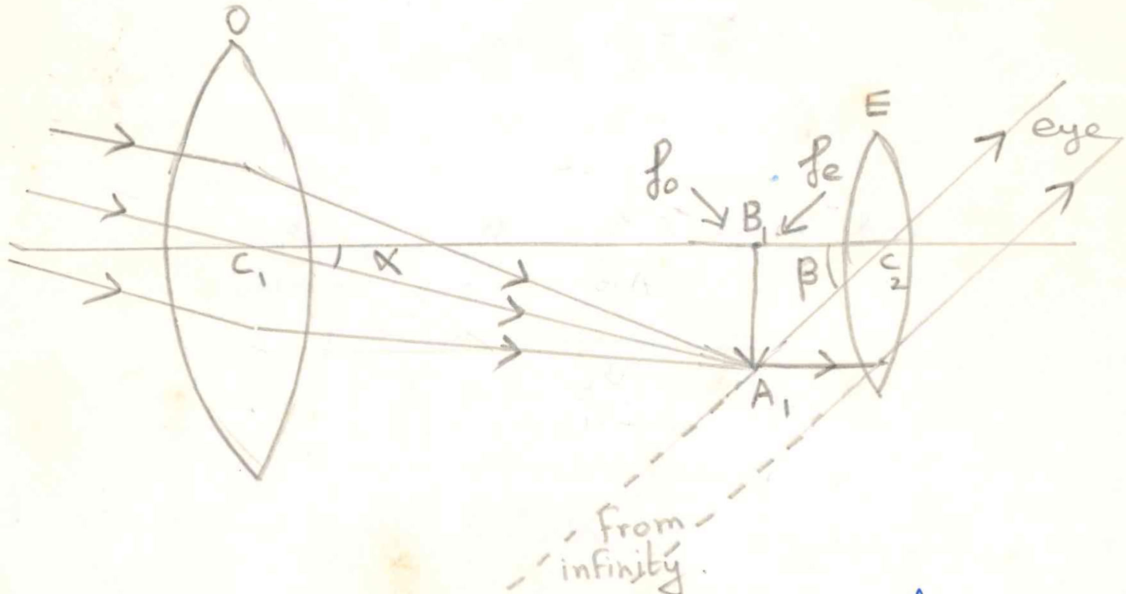
III Astronomical telescope

(1) It consists of two convex lens.

(2) The objective lens has large focal length and large aperture.

(3) The eyepiece has small focal length and small aperture.

(a) In normal adjustment (when final image is formed at infinity).



Magnifying power of an astronomical telescope in normal adjustment is defined as the angle subtended at the eye by the image to the angle subtended at the eye by the object when both the object and image lie at infinite distance from the eye.

Magnifying power $(M) = \beta/\alpha$

Since the angles are small,

$$M = \frac{\tan\beta}{\tan\alpha}$$

$$= \frac{A_1B_1}{B_1C_2} \cdot \frac{B_1C_1}{A_1B_1}$$

$$= \frac{f_o}{-f_e}$$

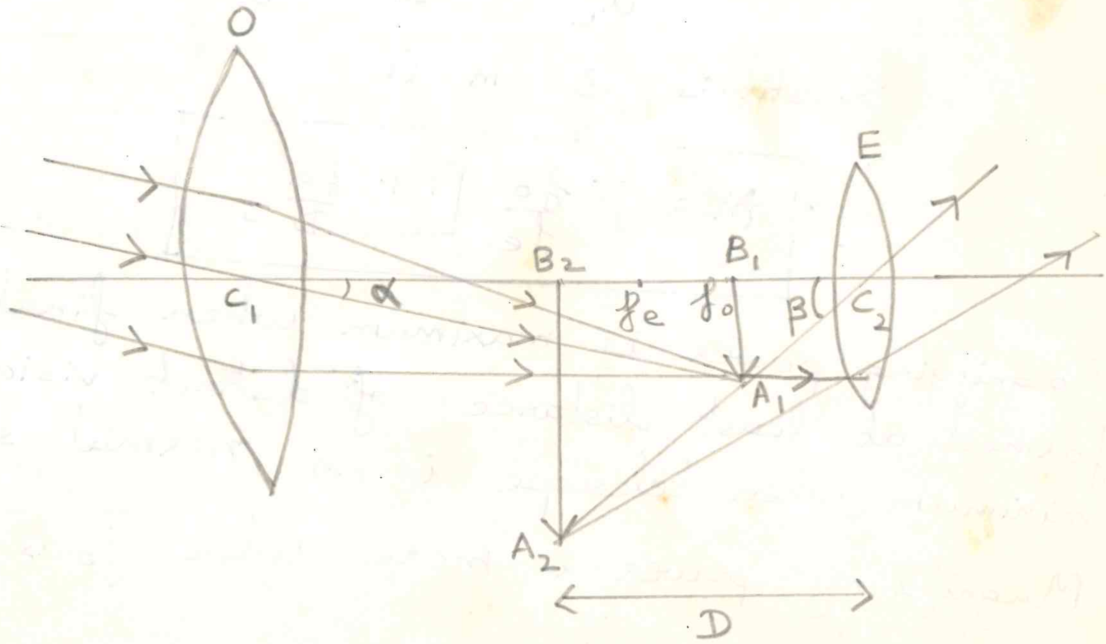
$$\therefore \boxed{M = \frac{f_o}{-f_e}}$$

(i) $-$ve sign indicates that final image is inverted.

(ii) In normal adjustment distance between objective and eyelens is $f_o + f_e$.

Application: A telescope is used for observing distinct images of heavenly bodies like planets, stars etc.

(b) When final image is formed at the least distance of distinct vision.



Magnifying power of an astronomical telescope is defined as the ratio of the angle subtended at the eye by the final image at the least distance of distinct vision to the angle subtended at the eye by the object at infinity when seen directly.

$$M = \frac{\beta}{\alpha}$$

$$= \frac{\tan\beta}{\tan\alpha} \quad [\because \alpha \,\&\, \beta \text{ are small}]$$

$$= \frac{A_1B_1}{B_1C_2} \, \frac{B_1C_1}{A_1B_1}$$

$$M = \frac{f_o}{-u_e} \quad \text{— (1)}$$

According to lens formula.

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e}$$

$$\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D}$$

$$\frac{1}{u_e} = \frac{1}{f_e}\left[1 + \frac{f_e}{D}\right] \quad \text{— (2)}$$

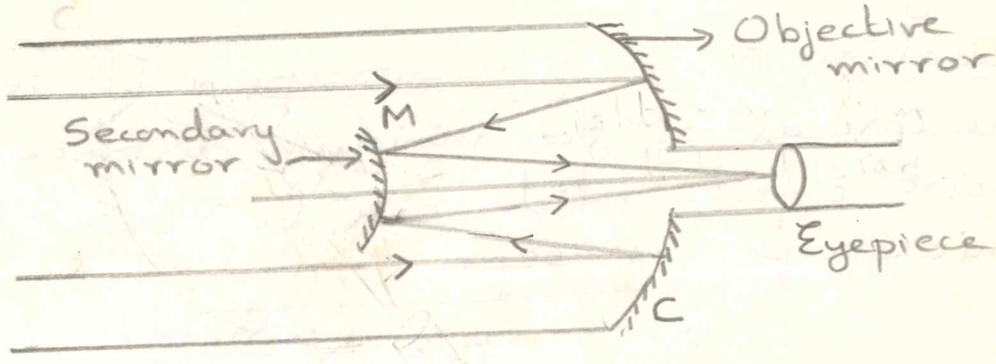
Substitute (2) in (1)

$$\boxed{M = -\frac{f_o}{f_e}\left[1 + \frac{f_e}{D}\right]}$$

(a) Magnifying power is maximum when final image is formed at least distance of distinct vision and minimum when telescope is in normal setting.

(b) Magnifying power is more when f_o is large and f_e small.

IV. Reflecting type telescope. – Cassegrain telescope



1. Light from a distant star is reflected by a large parabolic concave reflector C on to a convex mirror M.
2. The convex mirror deflects the light before it comes to focus otherwise the image would be formed inside the telescope tube
3. The convex mirror reflects the beam forming a real image I in front of the eyepiece E.
4. The eye piece is a magnifier and the final virtual and magnified image of the star is distinctly seen by the eye.
5. The magnifying power of the reflecting type telesope is given by.

$$M = \frac{f_o}{f_e}$$

Advantages of reflecting type telescope over a refracting type telescope

(a) There is no chromatic aberration as the objective is a mirror
(b) Spherical aberration is reduced using mirror as objective in the form of a paraboloid.
(c) Image is brighter as compared to refracting type telescope.
(d) Mirror requires grinding and polishing on only one side and mechanical support is much easier for a mirror than a lens
(e) High resolution can be obtained by using a mirror of large aperture.