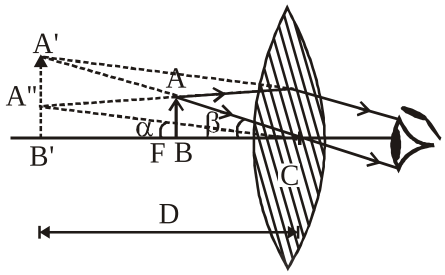
OPTICAL INSTRUMENTS

Simple Microscope

It is just one lens of short focal length. It is also known as 'simple magnifier' or magnifying glass'.

Magnifying power of a 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 are placed at least distance of distinct vision (D). D is usually taken as 25 cm for a normal person.

$$M = 1 + \frac{D}{f} \qquad ...(1)$$



In case the eye is placed behind the lens at a distance 'a', then the above relation is modified as follows:

$$M = 1 + \frac{D - a}{f}$$

But usually the eye is placed very close to the lens. Hence the equation (1) is applicable. So, smaller the focal length of the lens, greater will be the magnifying power. The simple microscope may be used in such a way that the image is formed at infinity. Then,

$$M = \frac{D}{f} \qquad ...(2)$$

It is clear from comparison of equations (1) and (2) that

(i) The maximum angular magnification is obtained when the image is at the near point, ie at least distance of distinct vision (D) and

(ii) The minimum angular magnification is obtained when the image is at infinity.

Compound Microscope

The magnification produced by the compound microscope is the product of the magnification produced by the eyepiece and objective.

$$M = M_e \times M_o$$

where M_e and M_o are the magnifying powers of the eyepiece lens and objective lens respectively.

$$M_e = 1 + \frac{D}{f_e}$$ where f_e is the focal length of the eyepiece.

$$M_o = \frac{v_o}{u_o}$$

where v_o is the distance of intermediate image from the objective lens and u_o is the distance of the object from the objective lens. Then

$$M = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right)$$

The object is placed very close to the principla focus of the objective lens. Therefore u_o is nearly equal to f_o.

Moreover, the focal length of the eyepiece is small. So, the intermediate image is formed very close to the eyepiece. Hence v_o is nearly equal to the length L of the microscope tube. Here L is the separation between the two lenses.

$$M = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

It is clearly from the above equation that smaller the focal lengths of the objective and eyepiece, larger is the magnifying power.

If the image forms at infinity the expression for magnifying power is further simplified as below. In this case, the microscope is said to be in normal adjustment.

$$\therefore \qquad M = M_o \times M_e = -\frac{L}{f_o} \times \frac{D}{f_e}$$

If the object is not placed close to the focus of objective lens, then we can get value of $\frac{v_o}{u_o}$ as shown below.

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o} \text{ or } \frac{v_o}{v_o} - \frac{v_o}{u_o} = \frac{v_o}{f_o} \quad \text{ or } -\frac{v_o}{u_o} = -1\frac{v_o}{f_o} \text{ or } \frac{v_o}{u_o} = 1 - \frac{v_o}{f_o}$$

Astronomical Refraction Telescope

(a) When the image is formed at infinity, the magnifying power is $M = -\frac{f_o}{f_e}$

Hence, for high angular magnification, the objective should have a large local length and the eyepiece a small focal length. It may be noted that the separation of the lenses is $f_o + f_e$.

(b) When the final image is formed at the least distance of distinct vision, the magnifying power is modified as follows.

$$M = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

Terrestrial Telescope

For observing erect image of terrestrial objects, an inverting lens of focal length f is placed between the objective and the eyepiece. This lens increases length by the telescope of 4f, but does not cause any change in magnification. Length of telescope becomes $f_o + 4f + f_e$

The adjustment of the telescope is called normal adjustment, when image forms at infinity. Then, Magnifying power $M = \frac{f_o}{f_e}$.

If the final image is formed at the least distance of distinct vision, then magnifying power is

$$M = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

Galilean Telescope

Here the eye piece is a concave lens.

Length of telescope tube is $f_o - f_e$, where f_o and f_e represent the focal lengths of the objective (convex) and eyepiece (concave) respectively. Magnifying power is the ratio of the focal lengths of the objective and eyepiece as in other cases.

The main disadvantage of the Galilean telescope is that the field of view of this telescope is small as compared to the other terrestrial telescope and the astronomical telescope. However the advantage is smaller length of the telescope.