33.7 Differences between the Eye and the Camera Lens

Lens Camera	Human eye
1. It is mechanically and electrically operated	It works naturally.
2. The shutter works on the stimulation of light before photograph can be taken.	The eye lids remain open continuously as the rectina forms series of constantly changing pictures with continuous motion.
3. The lens is made of fixed focal length.	The focal length of the lens can be varied with the help of the ciliary muscles.
4. It is non-living because of the absence of cells.	It is living because of the presence of cells.
5. It has fixed focal length.	It has variable focal length effected by the ciliary muscle.

33.8 Types of Microscope

Microscope is one of the earliest optical instruments. During the seventeen century, it existed as single lenses called *magnifying glasses* and more research was carried out after Robin Hooke's discovery of "cells" the existence of which are microscopic in nature in 1648. Microscope is mostly used in viewing tiny and near objects and they exist in different forms.

Classification of microscope

1. Simple microscope

Simple microscope is (normally) used to view an object using convex lens, and the image formed is usually virtual. To view an object, the object has to be placed nearer to the lens, since the purpose of using a magnifying glass is to produce an erect and magnified image.

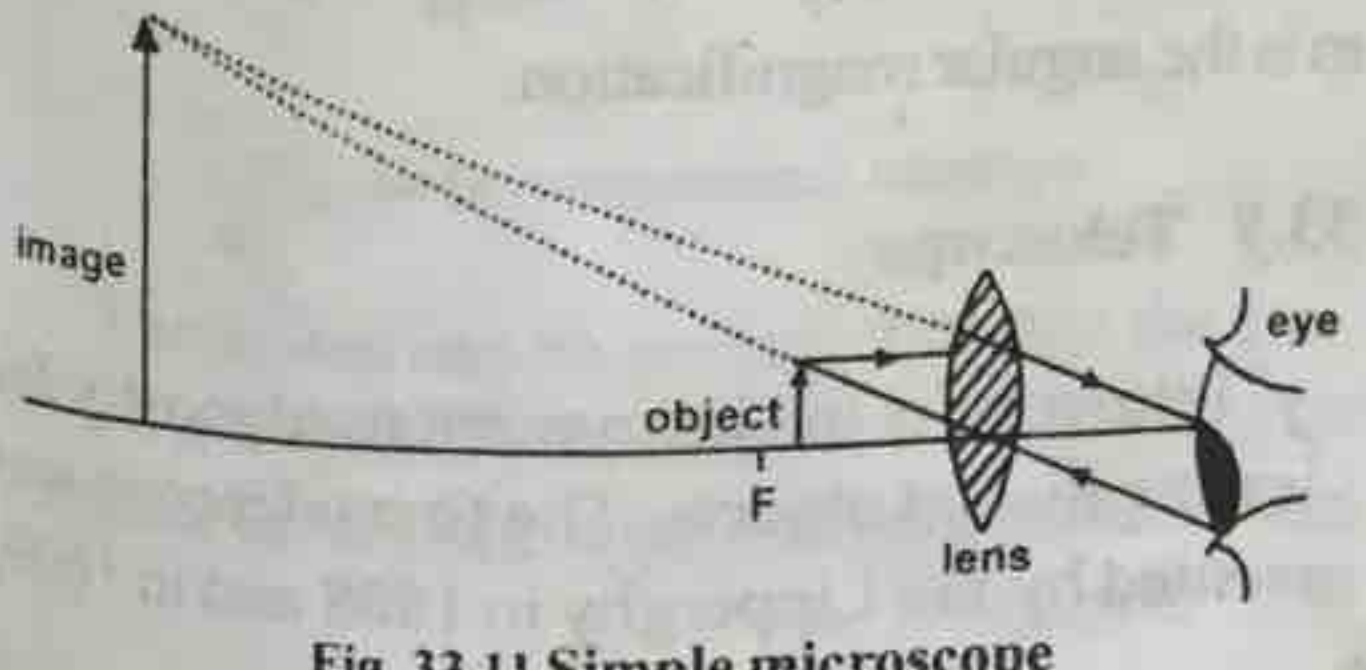

Fig. 33.11 Simple microscope

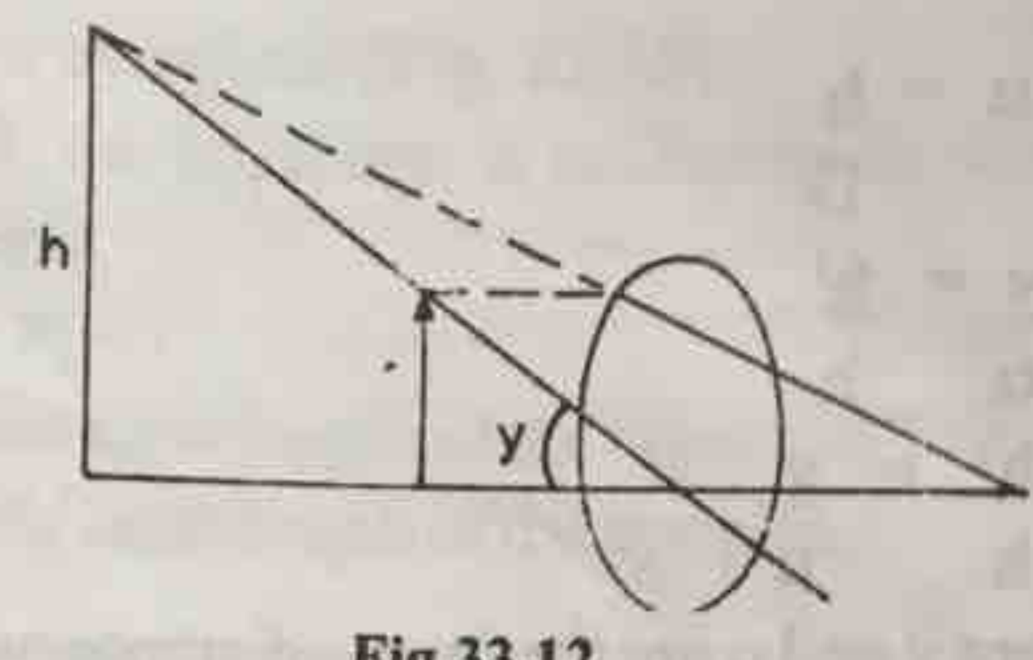

Fig 33.12

Suppose an object of height ***h*** is placed at point B and viewed by the eye, then the visual angle y is given by:

$$\tan y = \frac{h^{I}}{D}$$

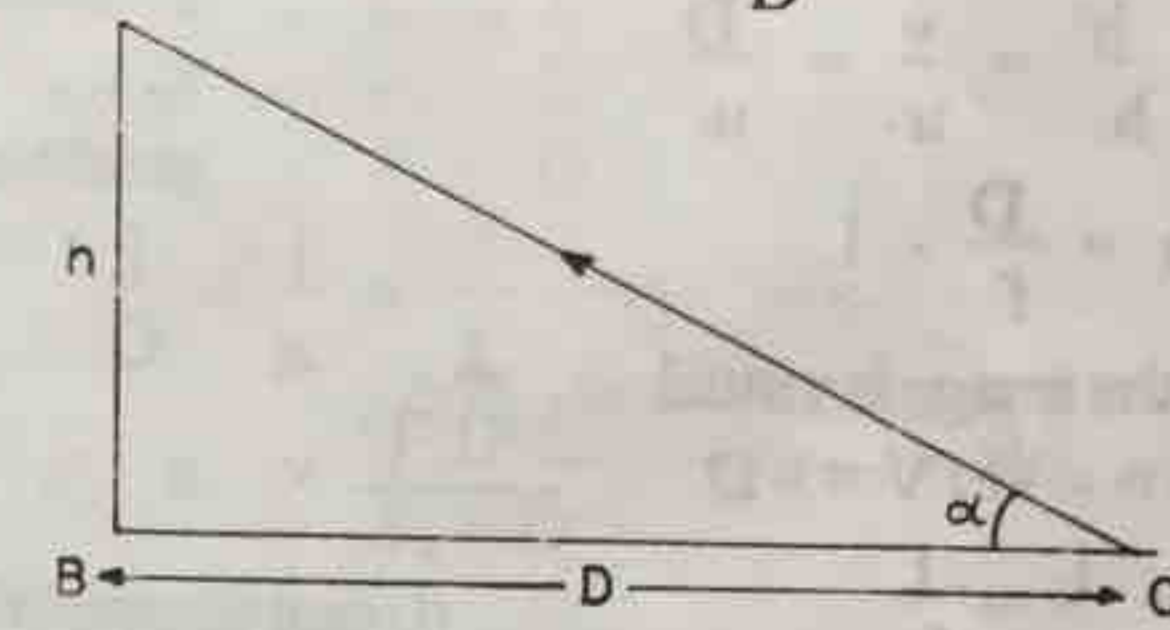

Fig. 33.13

$$\tan \alpha = \frac{h}{D}$$

Figure 33.13 shows when an object is seen without being aided by a microscope.

Angular magnification: This is defined as the ratio of angle substended at the eye by the image aided by the microscope to the angle substended at the unaided eye by the object placed at the near point; $M = \frac{y}{\alpha}$

Visual angle: The length of image formed by the eye unaided is proportional to the angle substended at the eye by the object. This is known as *visual angle*, $\theta \alpha L$.

$$\frac{\theta_1}{L_1} = \frac{\theta_2}{L_2} = \frac{\theta_3}{L_3} = \ldots\ldots \frac{\theta_n}{L_n}$$

From the above,

$$\tan y = \frac{h_1}{D} \text{ and } \tan \alpha = \frac{h}{D}$$

For small angle, $\tan y = y$,

$\tan \alpha = \alpha$.

$$y = \frac{h^{I}}{D}$$

$$\alpha = \frac{h}{D}$$

$$\frac{y}{\alpha} = \frac{h'}{h}$$

$$\frac{h'}{h} = \frac{v}{u}$$

where v and u are the image distance and object distance formed by the lens respectively.

$$\frac{h'}{h} = m \text{ [m = linear magnification]}$$

Since $m = \frac{v}{f} - 1$ [magnification]

Then, $\frac{h'}{h} = \frac{v}{u} = \frac{D}{u}$

$$\therefore \quad m = \frac{D}{f} - 1$$

Since the image is virtual

D = - Ve, V = - D

$$-\frac{1}{D} + \frac{1}{u} = \frac{1}{f}$$

$$-1 + \frac{D}{u} = \frac{D}{f}$$

$$\frac{D}{U} = 1 + \frac{D}{f}$$

$$M = 1 + \frac{D}{F}$$

Compound microscope

The compound microscope was invented some years after the simple magnifying glass was produced. It has a higher magnification compared to the simple glass. The compound microscope is produced by using two converging lens of short focal length. The lens diameter must be small because the curvature of the surface is large and the field of view is small. The two lenses used are classified according to their positions: The lens near the object is called *the objective* or *object piece* while the one nearer to the eye is called *eyepiece.* The object is placed at a distance greater than the focal length, in front of the objective, and an inverted image, I is formed in front of the eyepiece at a distance less than the focal length of the eyepiece. The eye piece is then adjusted so that a large virtual image, I_2 is formed.

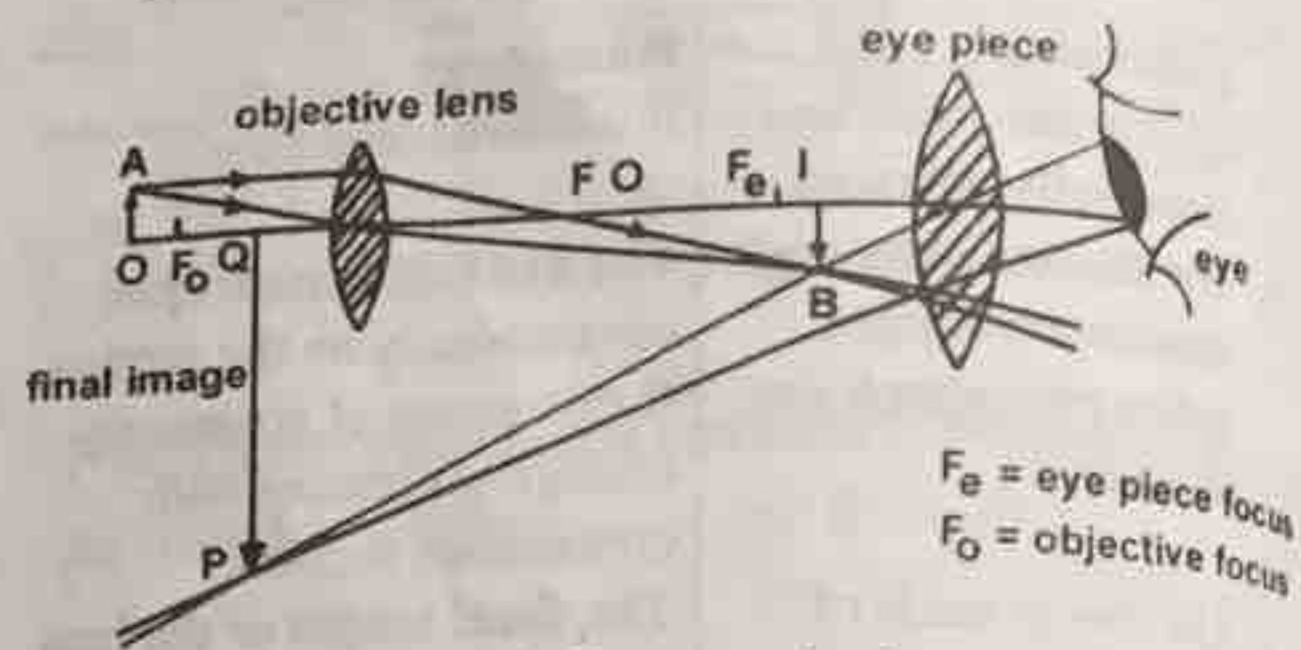

Fig. 33.14 Compound microscope

angular magnification, $m = \frac{\tan y}{\tan \alpha} = \frac{h_2/D}{h_1/D}$

$$\therefore m = \frac{h_2}{h_1}$$

$$\frac{h_2}{h_1} = \frac{b_2}{b_1}$$

$\frac{b_2}{b_1} =$ magnification of the eye piece $[M_e] = \frac{h_2}{h}$ while $\frac{h_1}{h} =$ magnification of the objective piece $[M_o]$

Then, $M = M_o \times M_e$

Since magnification, $M = \frac{V}{f_o} + 1$ [v = image distance]

The magnification eye piece which behaves like a magnifying glass = $M = \frac{D}{f_e} - 1$

h_1 is magnification of the objective piece, h

Then $\frac{h_i}{h} = \frac{v}{f_o} - 1$

h is the magnification of the eye piece, h_1

$$\frac{h_2}{h_1} = \frac{D}{f_e} \div 1$$

Then $m = \frac{h_2}{h_1} \times \frac{h_1}{h} = \left(\frac{v}{f_o} - 1\right) \times \left(\frac{D}{f_e} - 1\right)$

$$m = m_o \times m_e = \left(\frac{D}{f_e} - 1\right) \times \left(\frac{v}{f_o} - 1\right)$$

m is the angular magnification.

33.9 Telescope

Telescope is the instrument used mostly for viewing distant objects. The first telescope was invented by Jan Lipperghy in 1608 and in 1609, Galileo made his own telescope through which he observed the satellite of Jupiter and the ring of Saturn. The telescope was extensively used in war, sea and astronomical discoveries.

There are different types of telescope:

(i) Astronomical telescope
(ii) Galilean telescope
(iii) Terrestial telescope
(iv) Prism binoculars
(v) Cassegran telescope
(vi) Gregorian telescope
(vii) Newtonian telescope
(viii) Hereshelian telescope

33.10 Astronomical Telescope

Astronomical telescope is used to view distant object, e.g. stars, solar system, etc. Like the Galilean telescope, it is made of two lenses which are the same. They are objective, and eye piece lenses. The objective lens is a converging lens of focal length, while the eye piece is of short focal length. This telescope, unlike others, produce inverted images.

The object ray passing through the objective is focused at a point F with the image inverted and diminished and the eye piece which behaves as a magnifying glass produces the image I, which serves as object to another enlarged image I_2. The length of the telescope is the sum of their focal length unlike Galilean's which is the difference.

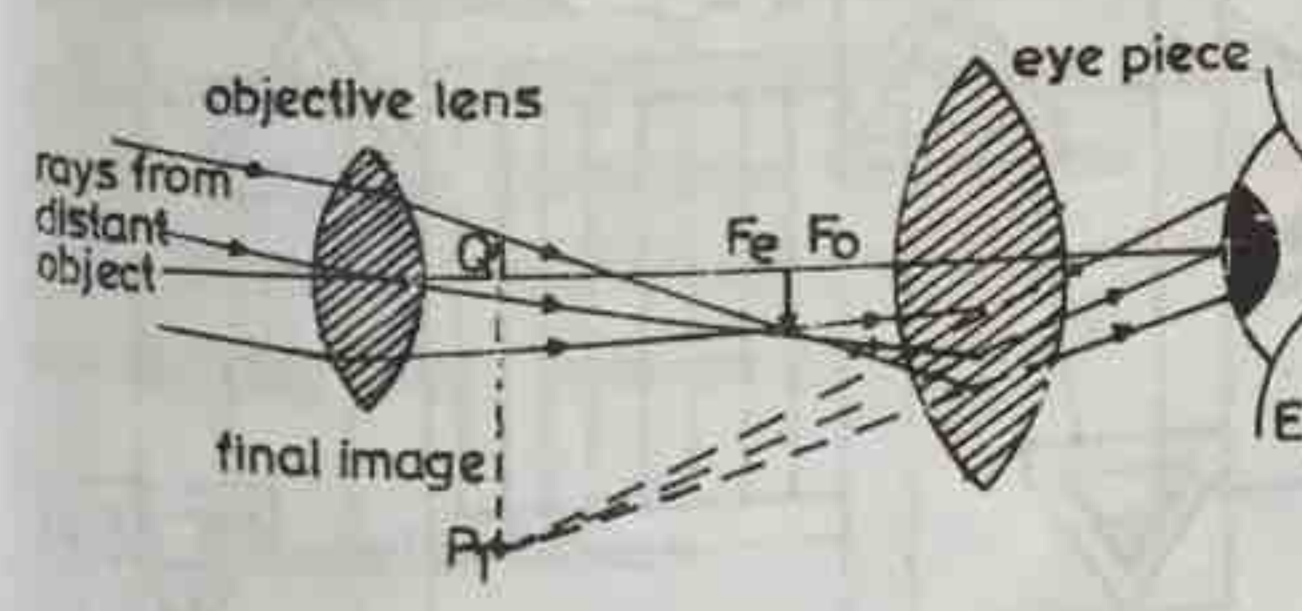

Fig. 33.15 Astronomical telescope

The lenses can be arranged so that the final image is at infinity. In such an arrangement the principal focus of the objective must coincide with that of the eye-piece (Fig. 33.16).

Thus, the telescope is said to be in *normal adjustment*.

$L = F_o + F_e$

f_o being the focal length of the objective

f_e being the local length of the eye piece.

Since angular magnification = $m = \dfrac{\alpha_2}{\alpha_1}$

$$\frac{\alpha_2}{\alpha_1} = \frac{h/u}{h/fo}$$

$$m = \frac{\alpha_2}{\alpha_1} = \frac{f_o}{u} \quad \text{.............. (i)}$$

using $\dfrac{1}{v} + \dfrac{1}{u} = \dfrac{1}{f_e}$

we have $v = -D$

$$\frac{1}{-D} + \frac{1}{u} = \frac{1}{f_e}$$

$$u = \frac{F_e D}{F_e + D} \quad \text{.......................(ii)}$$

Putting (ii) into (i)

$$M = \frac{F_o F_e + F_o D}{F_e D} = \frac{F_o(f_e + D)}{F_e D}$$

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

M is the angular magnification

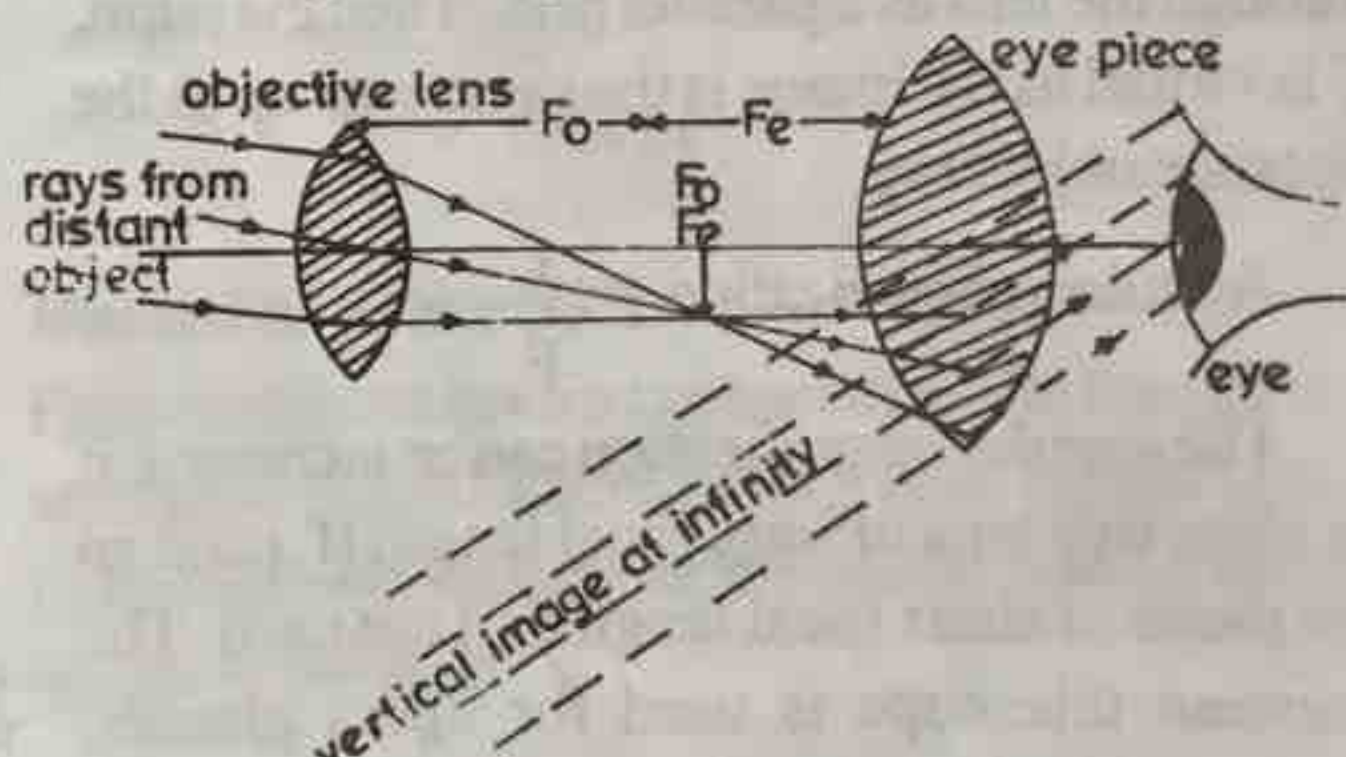

Fig. 33.16 Astronomical telescope in normal adjustment

33.11 Galilean Telescope

Galilean telescope was designed by Galileo in 1609, which he used to observe the Jupiter and the rings of the Saturn. The telescope produces an erect image like the terrestrial telescope but unlike terrestrial, it uses two different lenses, which are diverging and converging lenses.

The first lens which is objective lens is a converging lens of long focal length and the second is eye piece lens which is diverging lens of short focal length. The length of the telescope, L, is the difference between the focal length of the lenses.

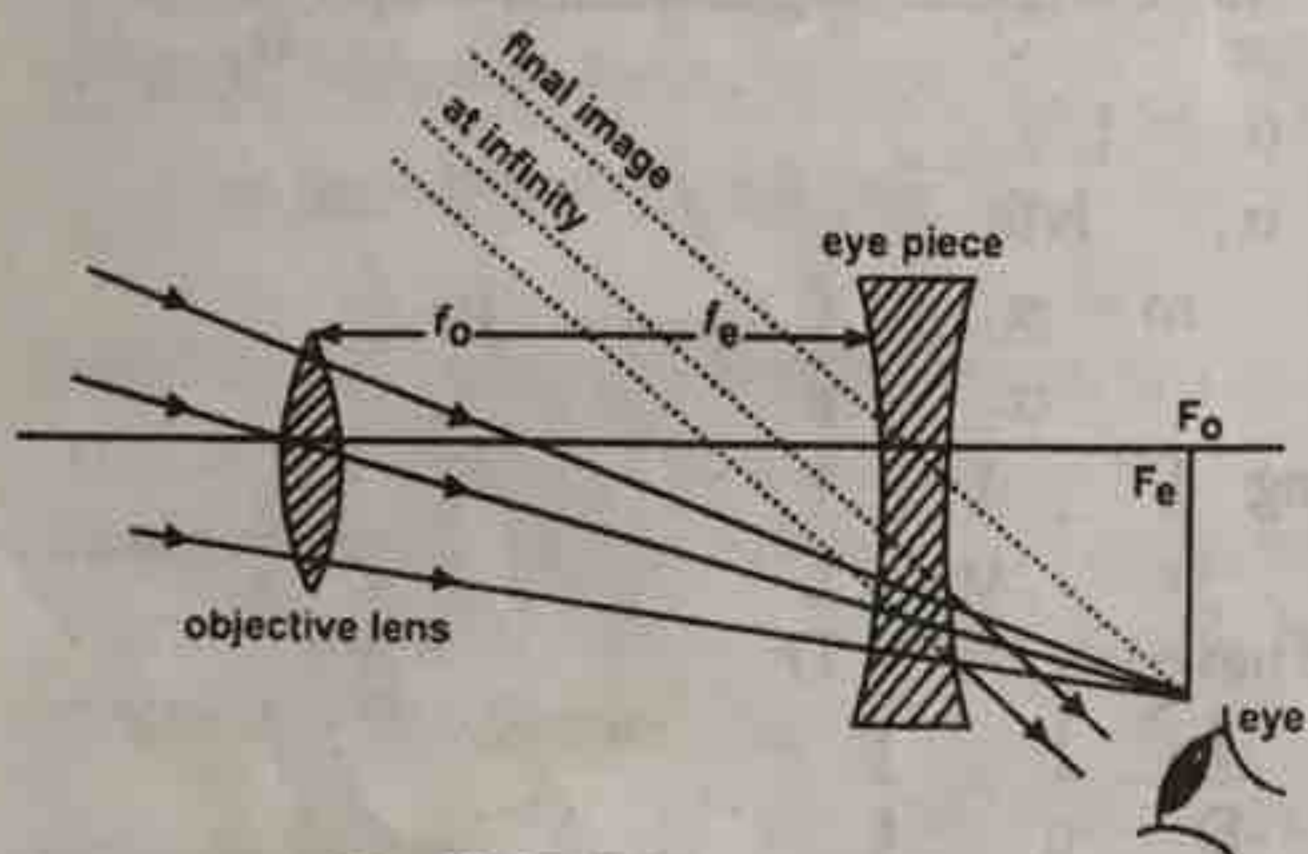

Fig. 33.17 Galilean telescope

$$L = F_o - F_e$$

f_o is the focal length of the objective lens
f_e is the focal length of the eye piece.

The image of the object ray I is formed in the absence of the diverging lens, when the eye- piece is erect; the rays falling on the image I are refracted through the lens as a parallel rays. Then the pupil, C is virtual as the image is the same way up as the distance object ray.

$$\text{Angular magnification} = \frac{f_o}{F_o}$$

The angular magnification can be increased, if an objective lens of long focal length [f_o] and an eye piece of short focal length [f_e] are used. The Galilean telescope is used for opera glasses, because of its short length compared to terrestrial telescope.

33.12 Terrestrial Telescope

This is an astronomical telescope with an additional lens in the middle to re-invert the image so that it is upright (Fig.33.18). The objective forms an image of the distant object at its principal focus. This image is taken as an object for the eye-piece.

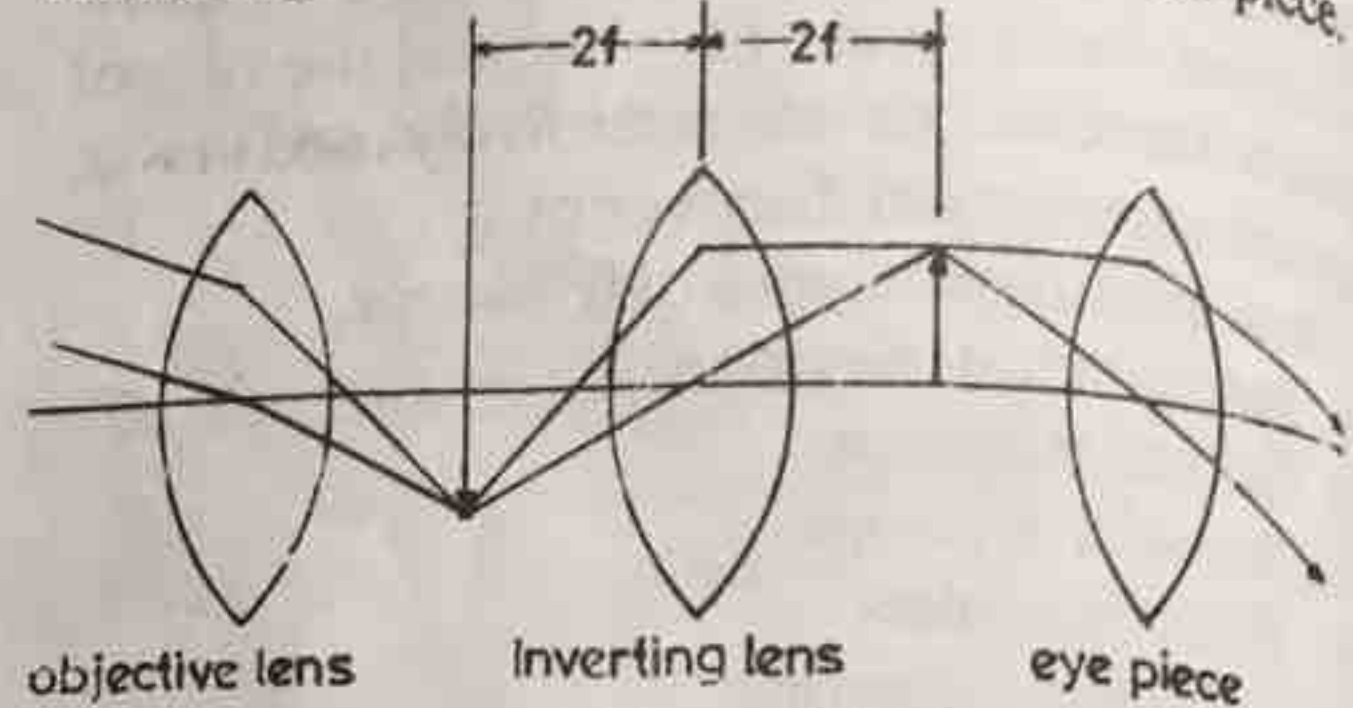

Fig. 33.18 Terrestrial telescope

33.13 Prism Binocular

Prism binoculars are essentially astronomical telescopes in compact form, i.e short telescope. It consists of converging objective and a converging eyepiece together with two total reflection prisms of 90° and 45°.

The reflecting prisms are used to make the rays from the objective reverse twice and traverse the tube of the telescope three times before reaching the eyepiece. While one prism turns the image from a distant object round for lateral inversion, another prism inverts the image so that it is erect. Thus, prism binoculars give an upright or erect image. The prisms have the additional advantage of bringing the rays from two telescopes inwards to match the distance apart from the eyes.

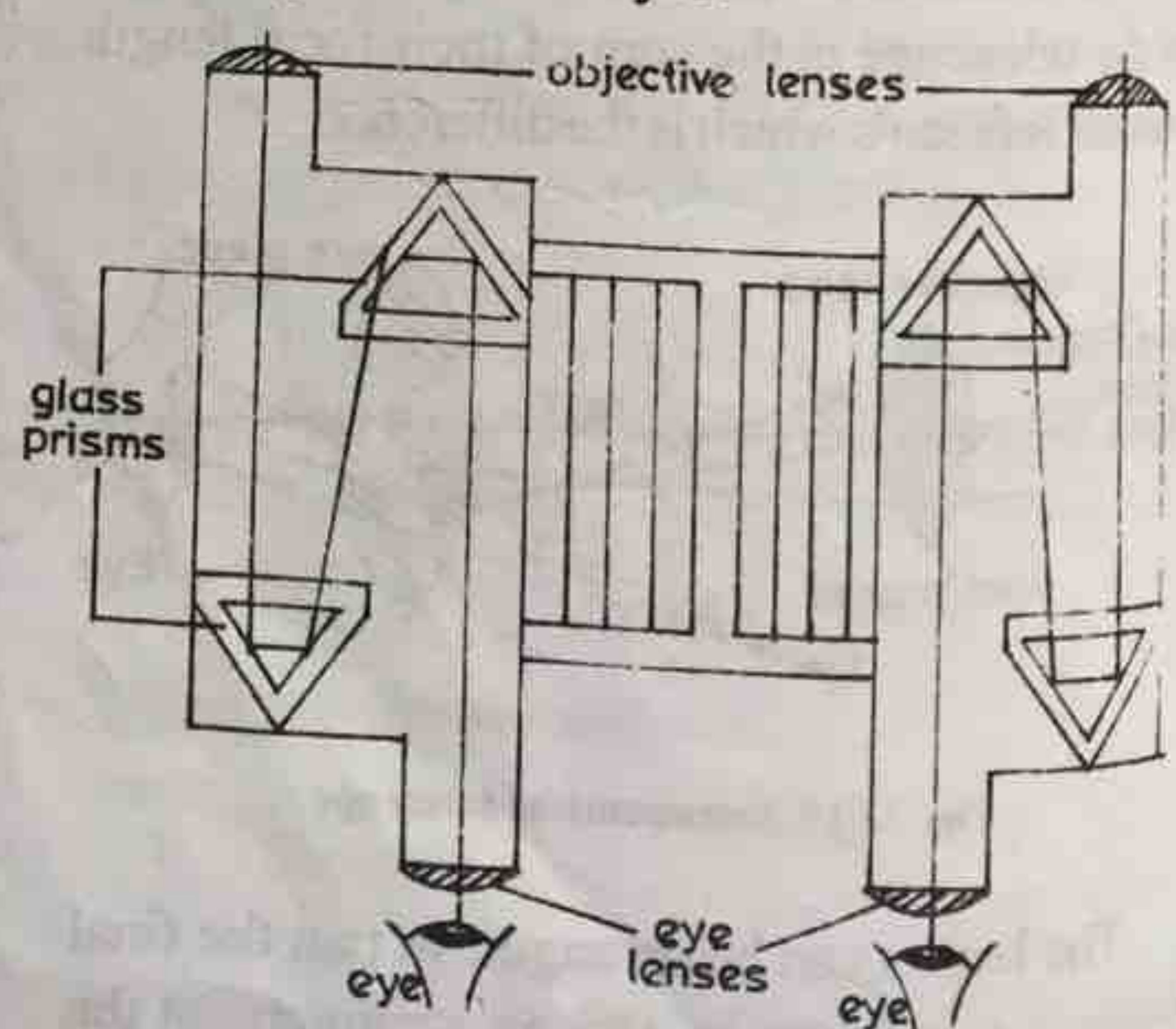

Fig. 33.19 Prism binocular

33.14 Persistence of Vision

When a bright light is viewed and then switched off, the *sensation of vision* continues for a short period after the light is removed.

In a dim light, the iris or diaphragm round the pupil of the eye opens, increasing the size of the pupil and allowing more light to enter the eye. In bright light, the iris automatically decreases in size. This reduces the amount of light entering the pupil, and thus protecting the eye from excesive brightness and possible damage to the retina. This is called *persistence of vision*. This phenomenon makes possible the showing of cinema films, which are succession of rapid, still pictures on a screen.

33.15 Accommodation

When a normal eye is at rest, parallel rays from a distant object are re-focused on the retina. Thus, the ability of the eye-lens to focus points at different distances on the retina is known as *accommodation*.

When a person with normal vision looks at a distant object at infinity, the lens brings parallel rays to a focus on the retina. Thus, the furthest point which the eye can see distinctly is called *far point* of the eye. For normal vision, far point is at inifinity

When a near object is viewed, rays are again focused on the retina. Thus, nearest point at which an object is clearly seen by an eye is known as the *near point*. For normal vision, near point is about 25cm (0.25m) from the eye. This is the limit to which the ciliary muscles can operate.

33.16 Binocular Vision

Binocular vision provides two images of the same object which are slightly different in perspective. The brain combines the two images and gives an impression of depth or solidity which is missing if only one eye is used.

Binocular vision is possible only if the fields of view of the two eyes overlap. This clearly depends on the position of the eyes in the head. For instance, small birds, such as the blackbird, have their eyes at the sides of the head. In this case, each eye views space independently of the other, i.e, the visual fields are entirely separate.

Birds of prey, such as the hawk or owl, have their eyes in front of the head, so that the bird has *stereoscopic vision*.

Worked example 33.1

An astronomical telescope has an objective lens of focal length of 100cm and a simple eyepiece lens of focal length 5cm and it is used in normal adjustment. Calculate the: (i) angular magnification (ii) distance between the two lenses.

Solution

(i) Angular magnfication $(m) = \frac{f_o}{f_e} = \frac{100}{5}$

$= 20$

(ii) Distance between lenses $= f_o + f_e$

$f_o = 100cm$

$f_e = 5cm$

Distance $= f_o + f_e$

$= 100 + 5$

$= 105cm$

Worked example 33.2

Four times a magnified virtual image is formed of an object placed 12cm from a converging lens. Calculate the position of the image and the focal length of the lens.

Solution

$$\text{Magnfication } (m) = \frac{\text{image distance}}{\text{object distance}}$$

$$4 = \frac{\text{image distance}}{12}$$

image distance = 48cm

$U = 12$

$U = -48$ since it is virtual