Ray Optics 23

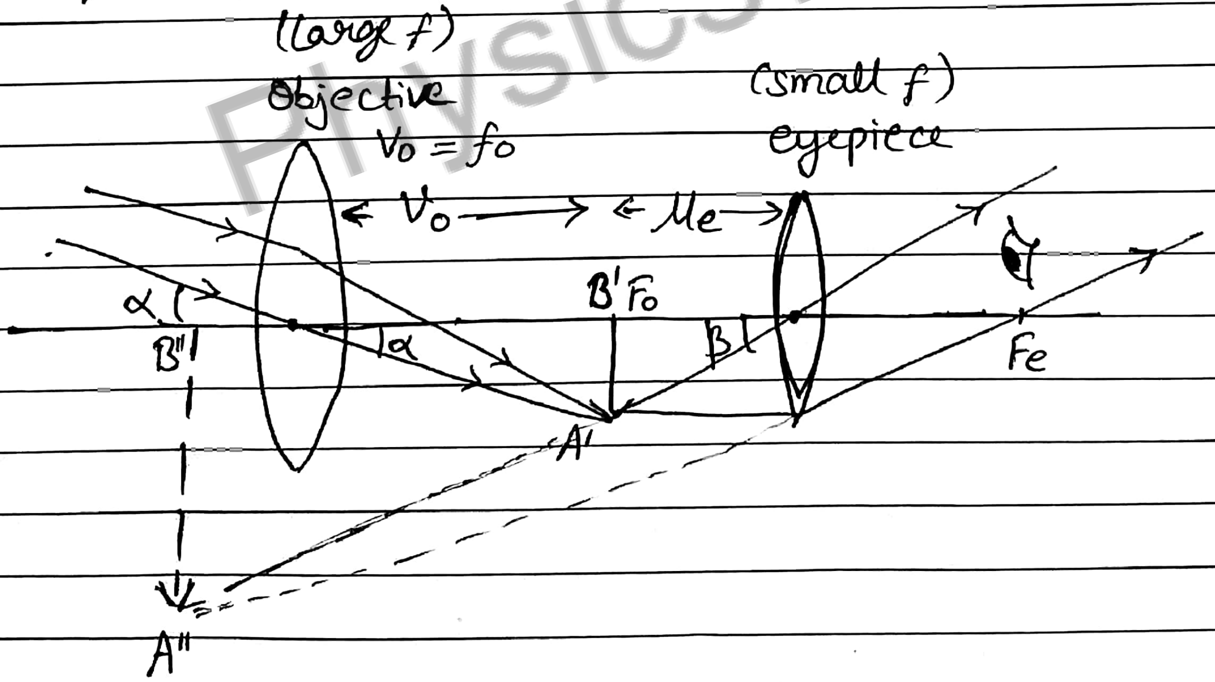
Telescope

A Telescope is used to look at distant Objects like stars, planets etc.

Magnifying Power of Telescope (M)

$$M = \frac{\text{Visual Angle formed by final image}}{\text{Visual Angle formed by Object}} = \frac{\beta}{\alpha}$$

Refracting Type Telescope



Objective is of large Aperture & large focal length so that it can collect more light & intensity of image is more.

length of Telescope $l = |f_0| + |u_e|$

$$\tan\alpha \approx \alpha = \frac{A'B'}{f_0} \qquad \tan\beta \approx \beta = \frac{A'B'}{u_e}$$

$$M = \frac{\beta}{\alpha} = \frac{A'B'/u_e}{A'B'/f_0} = \frac{f_0}{u_e}$$

$$\boxed{M = \frac{f_0}{u_e}}$$

Case I: Max Magnification
final image at D by eyepiece

$v = -D$
$u = -u_e$
$f = f_e$

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

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

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

$$M = \frac{f_0}{u_e} = f_0\left(\frac{1}{f_e} + \frac{1}{D}\right) = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$\boxed{M_D = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)}$$

Case II: Normal adjustment (Relaxed eye)
final image at ∞ by eyepiece

$$v = \infty$$
$$u = -u_e$$
$$f = f_e$$

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

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

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

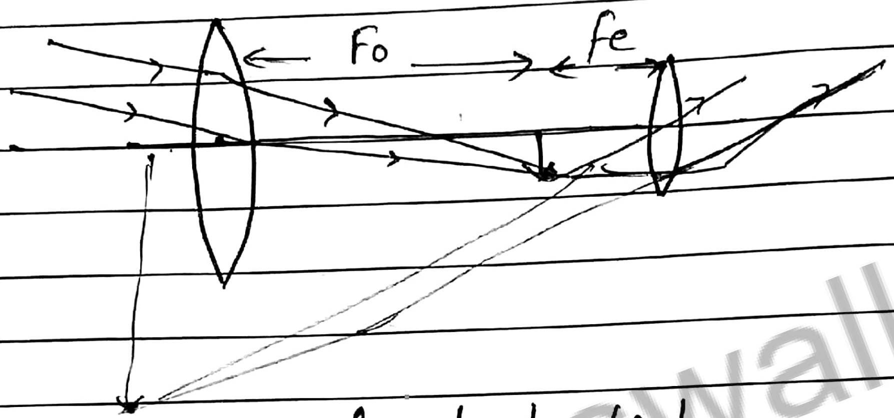
$$M = \frac{f_o}{u_e} = \frac{f_o}{f_e}$$

$$\boxed{M = \frac{f_o}{f_e}} \qquad \boxed{L = |f_o| + |f_e|}$$

Note: Telescope unlike microscope do not magnify the size of object instead it brings the object closer to the eye so that it can be viewed better.

Q1) A refracting Telescope is under normal adjustment and the Magnifying Power is 5. If the length of telescope under this condition (when final image is at ∞) is 150cm. Find F_o & F_e.

Solution



final image at ∞

$u_e = f_e$

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

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

$l = |f_o| + |f_e|$

$150 = f_o + f_e$ —(i)

$5 = \frac{f_o}{f_e}$ —(ii)

from (i) & (ii)

$150 = 5f_e + f_e$

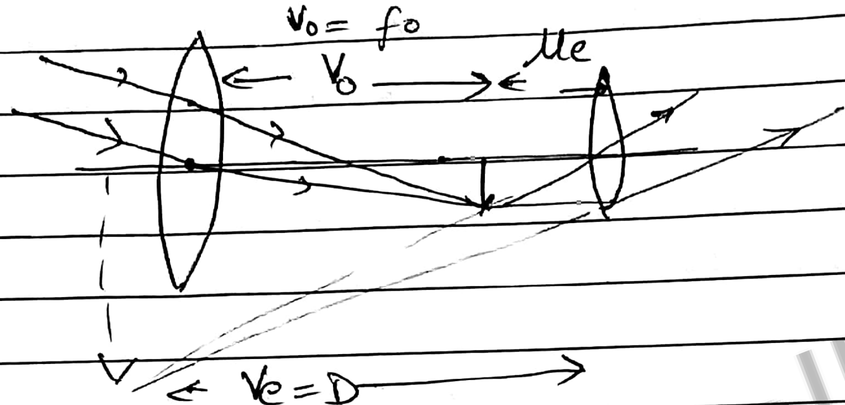
$6f_e = 150$

$f_e = \frac{150}{6}$ 25 cm

$f_o = 5f_e = 125cm$

Q2) The focal length of objective lens of refracting telescope is 100cm & that of eyepiece is 5cm. If the final image is formed at least distance of distinct vision (D = 25cm) find Magnifying Power of Telescope & length of telescope

Solution



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

final image is at D for eyepiece

$v = -D$

$u = -u_e$

$f = f_e$

$$\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} \quad \text{(i)}$$

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

$$M = \frac{100}{5}\left(1 + \frac{5}{25}\right) = 20\left(1 + \frac{1}{5}\right)$$

$$M = 20 + 4 = 24$$

$l = |v_o| + |u_e|$

$= f_o + |u_e|$ ↓ from (i)

$= 100 + \frac{25}{6}$

$= 100 + 4.166$

$= 104.16\ cm$

Disadvantages of a Refracting Telescope

⇒ For collecting more number of Rays to form image of high intensity, objective of large aperture is required. But large aperture convex lens will be i) Costly ii) produce chromatic abberations iii) difficult to manufacture

So, to eliminate these, modern Telescopes use concave mirror in place of objective lens

⇓

Reflecting Telescope

⇓

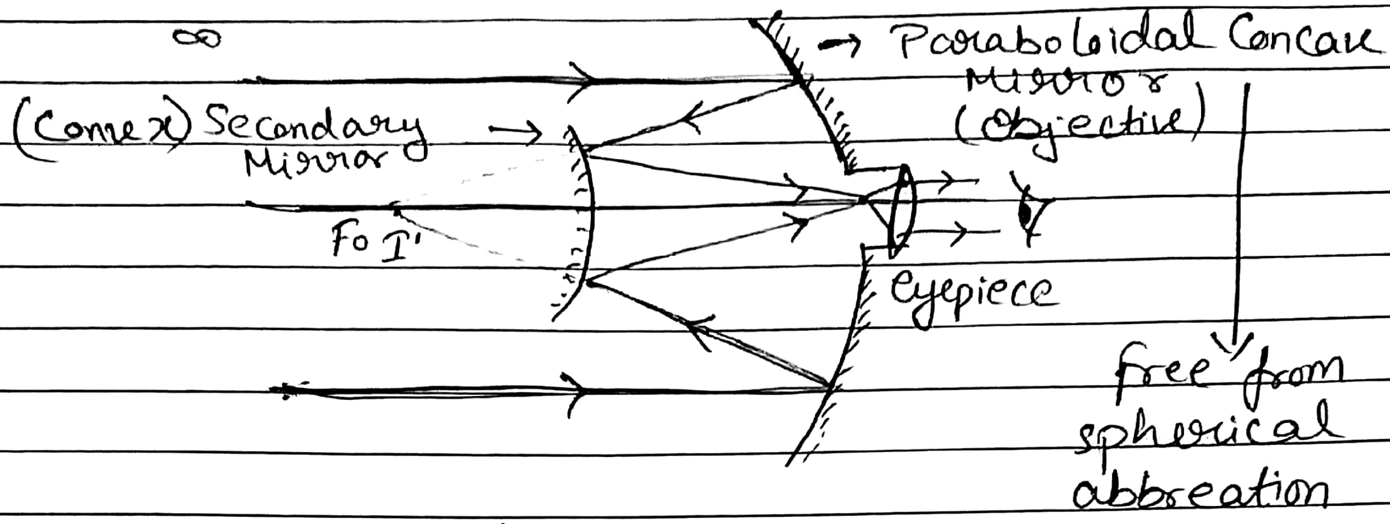
i) Free from chromatic abberations & spherical abberation.

ii) Mechanical support required is less as mirror will weigh less (of same optical quality as lens)

iii) Cheap & easy to Manufacture

Reflecting Telescope →
- Cassegrain Telescope
- Newtonian Telescope

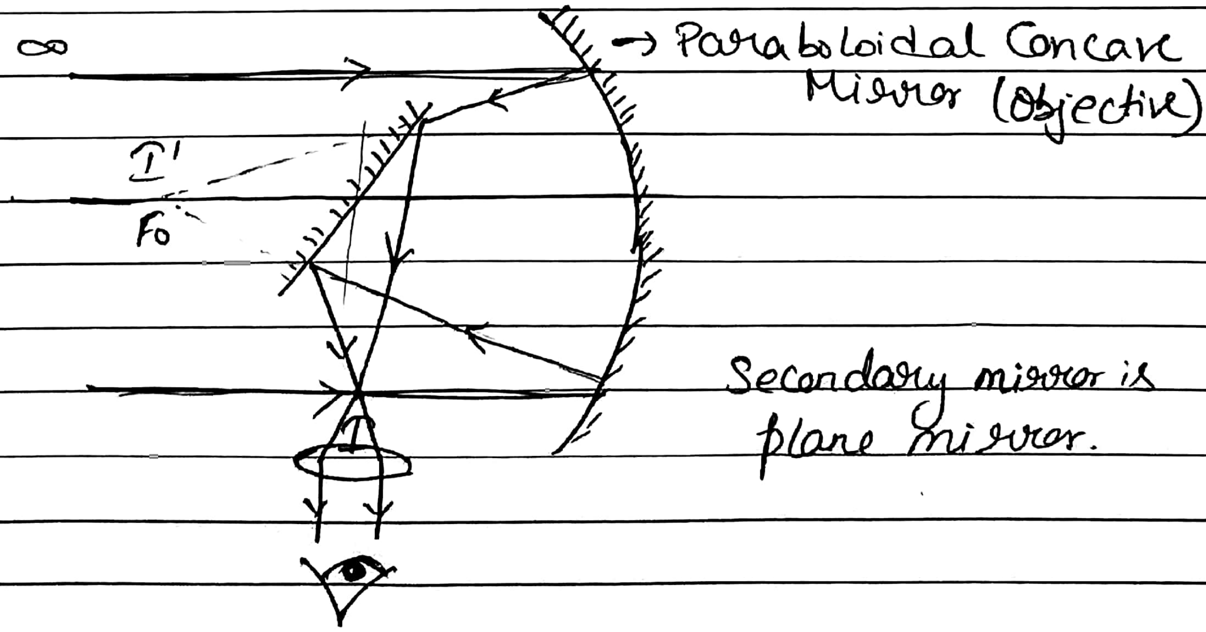
Cassegrain Telescope (Reflecting Type)



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

$$M_\infty = \frac{f_o}{f_e}$$

Newtonian Telescope (Reflecting Type)



Secondary mirror is plane mirror.