Chapter 9. Ray Optics and Optical Instruments

Reflection, Refraction and Dispersion of light

1.A biconvex lens made of a transparent material of refractive index 1.25 is immersed in a water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason. [All India 2014]

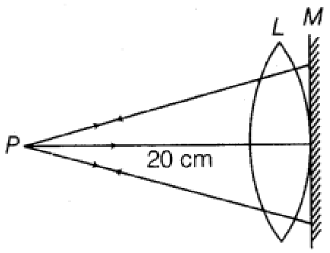
Ans. When a lens is placed in a liquid, where refractive index is more than that of the material of lens, then the nature of the lens changes. So, when a biconvex lens of refractive index 1.25 is immersed in water (refractive index 1.33), i.e. in the liquid of higher refractive index, its nature will change. So, biconvex lens will act as biconcave lens or diverging lens.

2.A biconvex lens made of a transparent material of refractive index 1.5 is immersed in a water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason. [Ail India 2014]

Ans. A biconvex lens acts as a converging lens in air because the refractive index of air is less than that of the material of the lens. The refractive index of water is less than the refractive index of the material of the lens (1.5). So, its nature will not change, it behaves as a converging lens.

3.A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens? [All India 2014]

Ans. The adjacent figure shows a convex lens L in contact with a plane mirror P is the point object kept in the front of this combination at a distance of 20 cm from it.



Since, the image is coinciding with the object itself, the rays from the object after refraction from the lens fall normally on the mirror M and form an image coinciding with the object itself. So, the image is formed at the focus of the lens. So, focal length of the lens is 20 cm.

4.Write the relationship between angle of incidence i, angle of prism A and angle of minimum deviations from a triangular prism. [Delhi 2013]

Ans. The relation between the angle of incidence /', angle of prism, A and the angle of minimum deviation, A_m for a triangular prism is given by

$$i = \frac{A + \Delta_m}{2}.$$

5.How does focal length of a lens change when red light incident on it is replaced by violet light? Give reason for your answer. [Foreign 2012]

Ans.The refractive index of the material of a lens increases with the decrease in wavelength of the incident light. So, focal length will decrease with decrease in wavelength according to the formula.

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Thus, when we replace red light with violet light then due to increase in wavelength the focal length of the lens will decrease

6.Name the physical quantity which remains same for microwaves of wavelength 1 mm and UV-radiation of 1600 A in vacuum. [Delhi 2012]

Ans. Both microwave and UV-rays are a part of the electromagnetic spectrum. Thus, the physical quantity that remains for both types of radiation will be their speeds equal to c. $c=3\times10^8 m/s$

7.Under what condition, does a biconvex lens of glass having a certain refractive index act as a plane glass sheet when immersed in a liquid? [Delhi 2012]

Ans. When refractive index of lens is equal to the refractive index of liquid.

8.For the same value of angle of incidence, the angles of refraction in three media A, B and C are 15°, 25° and 35° respectively. In which medium, would the velocity of light be minimum? [All India 2012]

From Snell's law, $\mu = \frac{\sin i}{\sin r} = \frac{c}{v}$

$\Rightarrow$ $v \propto \sin r$ for given value of i

$\Rightarrow$ Smaller angle of refraction, smaller the velocity of light in medium.

Velocity of light is minimum in medium, A as angle of refraction is minimum, i.e. 15°. **(1)**

9.When monochromatic light travels from one medium to another, its wavelength changes but frequency remains the same. Explain. [Delhi 2011]

Ans.Because refractive index for a given pair of media depends on the ratio of wavelengths and velocity of light in two medium and not on frequency

10.The refractive index of diamond is much greater than that of glass. How does a diamond cutter make use of this fact? [HOTS; All India 2011C]

Ans. The refractive index of diamond is much higher than that of glass. Due to high refractive index, the critical angle for diamond air interface is low. The diamond is cut suitably so that the light entering the diamond from any face suffers multiple total internal reflections at the various surfaces.

11.If a ray of light propagates from a rarer to a denser medium, how does its frequency change? [All India 2011c]

Ans. Frequency remains unchanged when light travels from one transparent medium to another transparent medium.

12.State the criteria for the phenomenon of total internal reflection of light to take place. [Delhi 2011,2010, 2008C]

Ans. Following are the criteria for total internal reflection

(i) Light must pass from a denser to a rarer medium.

(ii) Angle of incidence must be greater than critical angle

13.A lens behaves as a converging lens in air and a diverging lens in water (g = 4/3). What

will be the condition on the value of refractive index (g) of the material of the lens? [Delhi 2011c]

Ans. Refractive index of the material **of** lens is less than the refractive index **of** water.

14.A converging lens axially in contact with a diverging lens; both the lenses being of equal focal lengths. What is the focal length of the combination? [All India 2010]

Combined focal length of a lens combination

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \text{ (For two thin lenses in contact)}$$

As, $f_2 = -f_1$

(focal lengths are equal, one is convex and other is concave)

$$\Rightarrow \frac{1}{f} = 0 \Rightarrow f = \infty.$$

(1)

15.A glass lens of refractive index 1.45 disappears when immersed in a liquid What is the . value of refractive index of the liquid? [Delhi 2010]

When a lens immersed in a liquid disappears then, $\mu_{\text{liquid}} = \mu_g = 1.45$ **(1)**

16.Calculate the speed of light in a medium whose critical angle is 30°. [Delhi 2010]

Critical angle is the angle of incidence for which angle of refraction becomes 90°. Here, in this case refractive index, $\mu = \frac{1}{\sin i_C}$

$\because$ Refractive index, $\mu = \frac{c}{v} = \frac{1}{\sin i_C}$

$$\Rightarrow v = c \sin i_C = 3 \times 10^8 \times \sin 30°$$

$$= 3 \times 10^8 \times \frac{1}{2} = 1.5 \times 10^8 \text{ m/s}$$

(1)

17.Why does the sky appear blue? [Foreign 2010]

Due to large scattering of visible light of smaller wavelength (blue colour) as intensity of scattered light $\propto \frac{1}{\lambda^4}$.

(1)

18.Under what condition does the formation of rainbow occur? [All India 2010C]

Ans. Availability of rain drops causes refraction, dispersion and total internal reflection of sun light results in the form of rainbow and the back of the observer should be towards the sun.

19.Two thin lenses of power + 6 D and -2D are in contact. What is the focal length of the combination? [All India 2010]

Resultant power of the combination,

$$P = P_1 + P_2 = 6 - 2 = 4\text{D}$$

$$\therefore \quad \frac{1}{f} = 4 \Rightarrow f = \frac{1}{4}\text{ m} = 25\text{ cm}$$

20.Two thin lenses of power + 4 D and -2D are in contact. What is the focal length of the combination? [All India 2010]

Refer to ans. 19, (f = 50 cm).

21.Two thin lenses of power + 5D and -2.5D are in contact. What is the focal length of the combination? [All India 2010]

Refer to ans. 19, (f = 40 cm).

22.Why are convex mirrors used as side view mirrors in cars? [Delhi 2009c]

Ans. Because convex mirror forms virtual, erect and smaller image of object irrespective of relative position of object from mirror and therefore, its field of view is very wide.

23.A converging lens of refractive index 1.5 is kept in a liquid medium having same refractive index. What would be the focal length of the lens in this medium? [hots; Delhi 2008]

As the lens is placed in same medium as that of the lens, the ray will pass without any deviation.

In liquid, $\frac{1}{f} = \left(\frac{\mu_g}{\mu_s} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Given, $\mu_g = \mu_s$

$$\therefore \quad \frac{1}{f} = \left(\frac{\mu_g}{\mu_g} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = 0 \quad \text{or} \quad f = \infty$$ **(1)**

24.How does the power of convex lens vary if the incident red light is replaced by violet light? [Delhi 2008]

From lens maker's formula, $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

We can write

$$P = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

For same lens when only medium is changed

$\Rightarrow \quad P \propto (\mu - 1)$

Also, $\quad \mu \propto \frac{1}{\lambda \text{ (wavelength)}}$

$\therefore \quad P \propto \frac{1}{\lambda}$

Due to decrease of wavelength (red to violet), the refractive index of glass increases and hence power of lens increases. **(1)**

25.Explain giving reason why the sun looks reddish at sunrise or sunset? [Foreign 2008]

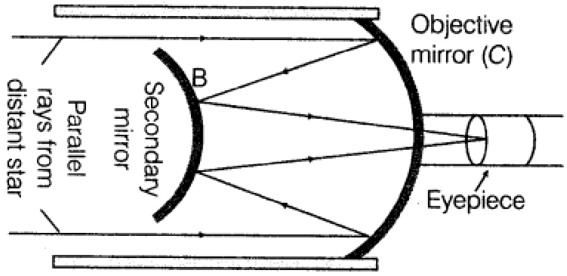
Intensity of scattered light $\propto \frac{1}{\lambda^4}$ (Rayleigh criteria).

Red light have got highest wavelength in visible spectrum, therefore scatters least and hence, red light from sun able to reach on the earth at the time of sunrise and sunset. Therefore, the sun appears reddish at the time of sunrise and sunset. **(1)**

2 Marks Questions

1.Draw a ray diagram of a reflecting type telescope. State two advantages of this telescope over a refracting telescope. [Delhi 2014 C; All India 2008C; Delhi 2008]

Ans.



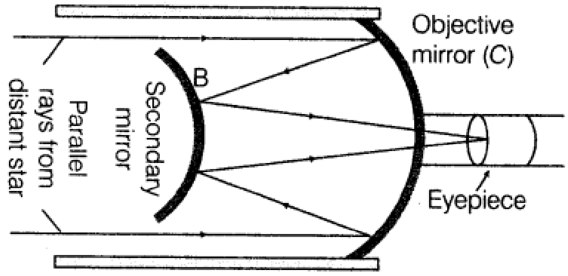
Advantages

(i) Reflecting telescopes have high resolving power due to a large aperture of mirrors.

(ii) Due to availability of paraboloidal mirror, the image is free from chromatic and spherical aberration.

2.Draw a schematic diagram of refracting telescope. Write its two important limitations. [Delhi 2014c]

Ans.



Limitations of refracting telescope over a reflecting type telescope.

(i) Refracting telescope suffers from chromatic aberration uses large sized lenses.

(ii) It is difficult and expensive to make such large sized lenses.

3.Draw a ray diagram for the formation of image by a compound microscope. Write the expression for total magnification when the image is formed at infinity. [Delhi 2014c]

Ans. A compound microscope consists of two convex lenses coaxially separated by some distance. The lens nearer to the object is called the objective. The lens through which the final image is viewed is called the eyepiece. The focal length of objective lens is smaller than eyepiece.

4.A convex lens of focal length 25 cm is placed coaxially in contact with a concave lens of focal length 20 cm. Determine the power of the combination. Will the system be converging or diverging in nature? [Delhi 2013]

Given, focal length of convex lens,
$f_1 = +25$ cm $= +0.25$ m and focal length of concave lens, $f_2 = -20$ cm $= -0.20$ m
Equivalent focal length of convex and concave lens,

$$F = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{25} + \frac{1}{-20} = -\frac{1}{100}$$

$\therefore \quad F = -100$ cm $= -1$ m

Now, the power of lens $P = \frac{1}{f}$

For convex lens, $P_1 = \frac{1}{f_1} = \frac{1}{0.25}$

For concave lens, $P_2 = \frac{1}{f_2} = \frac{1}{-0.20}$

Hence, power of the combination

$$P = P_1 + P_2 = \frac{1}{0.25} + \frac{1}{-0.20} = \frac{100}{25} + \frac{100}{-20}$$

$$= \frac{400 - 500}{100} = \frac{-100}{100} = -1\text{D}$$

Here, the focal length of the combination $= 100$ cm $= -1$ m
Since, the focal length is in negative, so the system will be diverging in nature. **(2)**

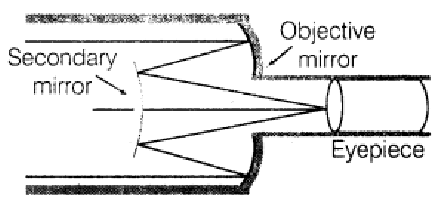
5.Draw a schematic arrangement of a reflecting telescope (Cassegrain) showing how rays

coming from a distant object are received at the eyepiece. Write its two important advantages over a refracting telescope. [Delhi 2013C]

Ans. Diagram of a reflecting telescope (Cassegrain) is shown as below:

Advantages of reflecting telescope over a refracting telescope are given as below:

(i) A reflecting telescope reflects all wavelengths of light at the same angle, so there are no colour halos.



(ii) A mirror has only one surface to be figured, so it is easier to control the shape.

(iii) A mirror reflects the light, so the material that is made from does not have to be transparent ultraviolet light reflects equally well.

6.Two convex lenses of same focal length but of apertures A_x and A_2 ($A_2 < A_r$), are used as the objective lenses in two astronomical telescopes having identical eyepieces. What is the ratio of their resolving power? Which telescope will you prefer and why? Give reason. [Delhi 2011]

Resolving power of telescope, $R_p = \frac{A}{1.22\lambda}$

where, A = aperture or diameter of the objective telescope

and λ = wavelength of the objective.

$\Rightarrow \quad R \propto A$

$\therefore$ Ratio of resolving powers of two telescopes $\frac{R_1}{R_2} = \frac{A_1}{A_2}$

$\because \quad A_2 > A_1$

$\therefore \quad R_2 > R_1$ **(1)**

The larger the aperture of objective, higher the resolving power of telescope. As well more gathering of light to form the image and hence, brighter image would be obtained. **(1)**

7.Define the resolving power of a telescope. Write any two advantages of a reflecting telescope over a refracting telescope. [Delhi 2010 c]

Resolving power of a microscope is defined as the reciprocal of its limit of resolution (d) i.e.

RP of microscope = $1/d$

where, limit of resolution is equal to the smallest distance between two closest objects whose vivid or clean image can be seen through the microscope and given by $d = \frac{\lambda}{2\mu \sin\theta}$

$\therefore$ Resolving power of microscope = $\frac{2\mu \sin\theta}{\lambda}$

where, λ = wavelength of light used, **(1)**

θ = semivertical angle of the cone formed by object at objective

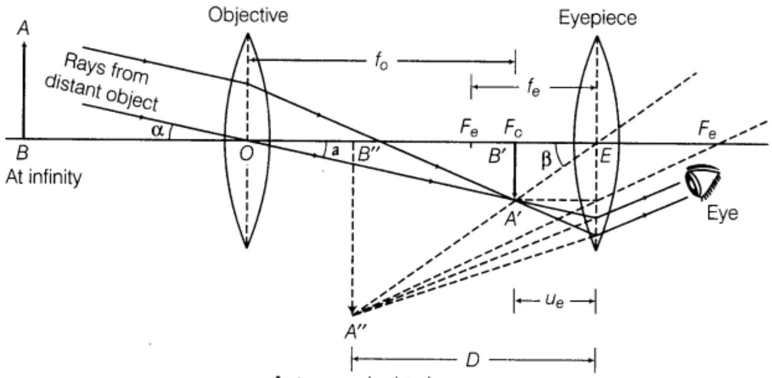
and μ = refractive index of molecule between object and lens.

(a) Resolving power increases with the increase of μ.

(b) Resolving power decreases as resolving power $\propto 1/\lambda$. **(1/2 × 2 = 1)**

8.Draw a labelled ray diagram of an astronomical telescope in the near point position. Write the expression for its magnifying power. [All India 2008]

Ans. Ray diagram of an astronomical telescope in the near point position is

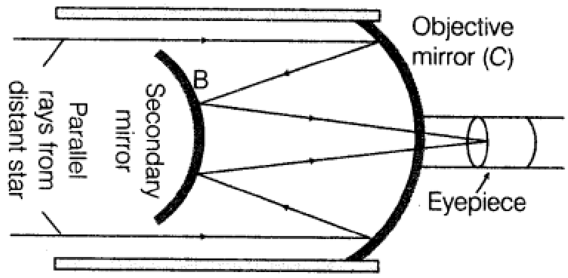


Astronomical telescope

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

where f_o, f_e focal length of objective and eye lens and D = least distance of distinct vision.

9.Draw a ray diagram of an astronomical telescope in the normal adjustment position. State two drawbacks of this type Of telescope. [Delhi 2008]



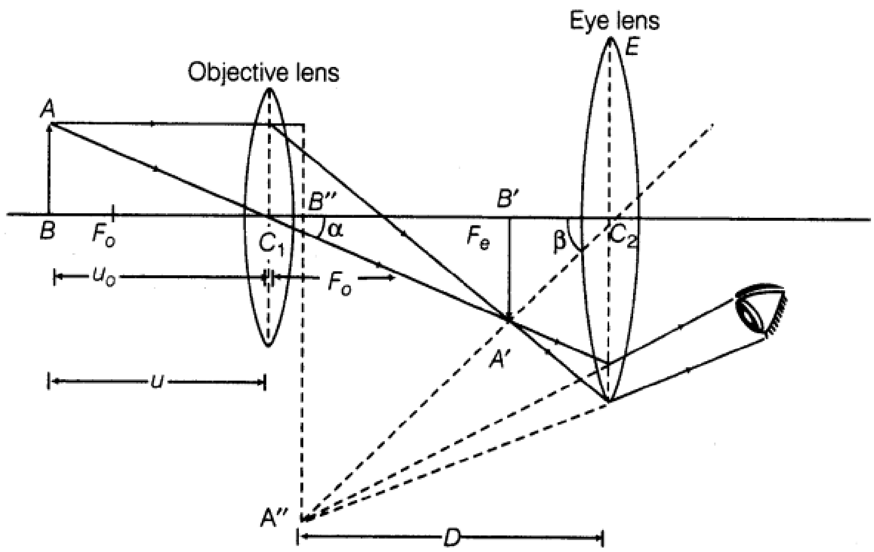
Drawbacks

(i) Image formed by these telescopes have chromatic and spherical aberration.

(ii) The length of telescope is very large in normal adjustment.

10.Draw a ray diagram of compound microscope. Write the expression for its magnifying power. [Delhi 2008]

Ans.



Magnifying power of a compound microscope

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

where, L = length of telescope

f_o = focal length of objective and

f_e = focal length of eye lens **(1)**

11.(i) Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision, (ii) The total magnification produced by a compound microscope is 20. The magnification produced by the eyepiece is 5. The microscope is focussed on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm. Calculate the focal length of the objective and the eyepiece. [Delhi 2014 C]

(*i*) Refer to ans. 3. **(1)**

(*ii*) Given, Magnification, $M = 20$

Magnification of eyepiece, $m_e = 5$

Least distance vision, $D = 20$ cm

Distance between objective and eyepiece, $L = 14$ cm

We know that,

Magnification, $M = m_e \times m_o$

$$\Rightarrow \quad m_o = \frac{m}{m_e} = \frac{20}{5} = 4$$

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

where, f_e is focal length of eyepiece.

$$\Rightarrow \quad 5 = 1 + \frac{20}{f_e} \quad \Rightarrow \quad f_e = 5 \text{ cm}$$ **(1)**

Using lens formula for eyepiece,

$$\frac{1}{u_e} = \frac{-1}{20} - \frac{1}{5} = \frac{-5}{20} = \frac{-1}{4}$$

$u_e = -4$ cm

(objective distance for eyepiece)

$$L = v_o + |u_e|$$

$$\Rightarrow \quad v_o = L - |u_e| = 14 - 4 = 10 \text{ cm}$$

Magnification produced by objective,

$$m_o = -\frac{v_o}{u_o}$$

Object distance for objective,

$$u_o = \frac{-v_o}{m_o} = \frac{-10}{4} = -2.5 \text{ cm}$$

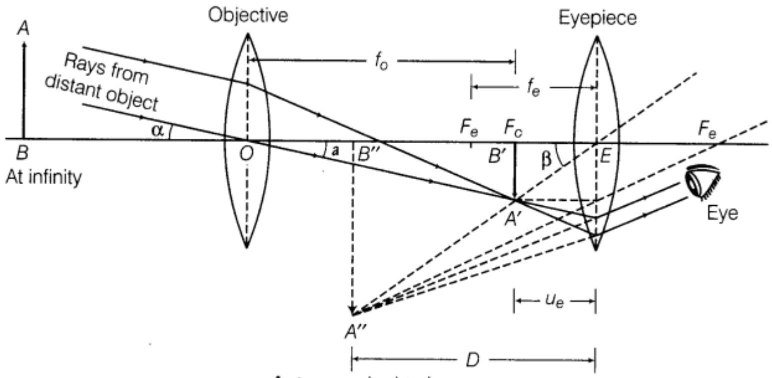
Using lens formula for objective,

$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$$

$$= \frac{1}{10} - \frac{1}{-2.5} = \frac{1}{10} + \frac{1}{2.5}$$

$f_o = 2$ cm

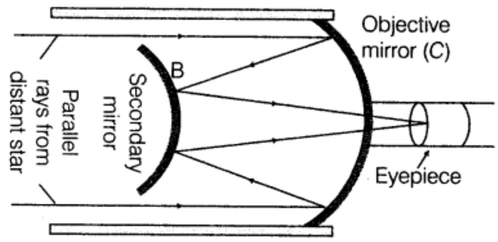
12.Draw a labelled ray diagram of a refracting telescope. Define its magnifying power and write the expression for it. Write two important limitations of a refracting telescope over a reflecting type telescope. [All India 2013]



Astronomical telescope

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

where f_o, f_e focal length of objective and eye lens and D = least distance of distinct vision.



Limitations of refracting telescope over a reflecting type telescope.

(i) Refracting telescope suffers from chromatic aberration uses large sized lenses.

(ii) It is difficult and expensive to make such large sized lenses.

13.Draw a ray diagram showing the image formation by a compound microscope. Hence, obtain expression for total magnification when the image is formed at the infinity. [Delhi 2013]

Ans. A compound microscope consists of two convex lenses coaxially separated by some distance. The lens nearer to the object is called the objective. The lens through which the final image is viewed is called the eyepiece. The focal length of objective lens is smaller than eyepiece.

14.A compound microscope uses an objective lens of focal length 4 cm and eyepiece lens of focal length 10 cm. An object is placed at 6 cm from the objective lens. Calculate the magnifying power of the compound microscope. Also, calculate the length of the microscope. [All India 2011]

Ans.

For compound microscope,

$f_o = 4$ cm, $f_e = 10$ cm

$u_o = -6$ cm, $v_e = -D = -25$ cm

For objective lens,

$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$$

$$\frac{1}{4} = \frac{1}{v_o} + \left(\frac{1}{6}\right) \Rightarrow \frac{1}{v_o} = \frac{1}{4} - \frac{1}{6} = \frac{1}{12}$$

$$v_o = 12 \text{ cm}$$

$\therefore$ Magnifying power M

$$= -\left(\frac{v_o}{u_o}\right)\left(1 + \frac{D}{F_e}\right)$$

$$= -\left(\frac{12}{6}\right)\left(1 + \frac{25}{10}\right) = -2\left(\frac{7}{2}\right) = -7$$

Magnifying power $M = -7$

Length of microscope $= |v_o| + |u_e|$

where, $v_o = 12$ cm

For eye lens,

$v_e = -25$ cm, $f_e = 10$ cm, $u_e = ?$

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

$$\Rightarrow \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{-25} - \frac{1}{10}$$

$$\frac{1}{u_e} = \frac{-2-5}{50} = -\frac{7}{50}$$

$$u_e = -\frac{50}{7} \text{ cm} = -7.14 \text{ cm}$$

$\therefore$ Length of microscope

$= |v_o| + |u_e| = 12 + 7.14 = 19.14$ cm

NOTE

1. The separation between objective and eye lens is known as length of microscope.
2. The image formed by objective is an object for eye lens.

15.A giant reflecting telescope at an observatory has an objective lens of focal length 15 m. If an eyepiece lens of focal length 0 cm is used, find the angular magnification of the telescope. If this telescope is used to view the moon, what is the diameter of the image of the moon formed by the objective lens? The diameter of the moon is 3.42 x 10^6 m and the radius of the lunar orbit is 3.8 X 10^8 m. [All India 2011]

Ans.

For astronomical telescope,

$$f_o = 15\text{ m} = 1500\text{ cm}$$
$$f_e = 1\text{ cm}$$

Angular magnification $m = -\frac{f_o}{f_e}$ **(1/2)**

$$= -\frac{15 \times 100\text{ cm}}{1\text{cm}} = -1500$$ **(1)**

NOTE As clear from the figure of astronomical telescope, angle subtended by moon at the objective must be equal to the angle subtended by image formed by objective on the objective lens.

∴ The angle subtended by moon at objective

$$\alpha = \frac{D}{\text{Radius of lunar orbit}}$$

$$\alpha = \frac{3.42 \times 10^6\text{ m}}{3.8 \times 10^8\text{ m}} \quad \ldots(i)$$

Also, then angle subtended by image formed by objective on itself

$$\alpha = \frac{d}{f_o} \quad \ldots(ii)$$

where, d = diameter of image

From Eqs. (i) and (ii), we get

$$\frac{3.42 \times 10^6}{3.8 \times 10^8} = \frac{d}{1500}$$ $\left(1\frac{1}{2}\right)$

$$\frac{\times \quad 0^6}{3.8 \times 10^8} \quad 13.5$$

16.Two convex lenses of focal length 20 cm and 1 cm constitute a telescope. The telescope is focused on a point which is 1 m away from the objective. Calculate the magnification produced and the length of the tube if the final image is formed at a distance 25 cm from the eyepiece. [Delhi 201 ic]

Ans.

Given, $f_o = 20$ cm, $f_e = 1$ cm, $v_e = -25$ cm

For objective

$$u_o = -100\text{ cm}, f_o = 20\text{ cm}$$

$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o} \Rightarrow \frac{1}{20} = \frac{1}{v_o} - \frac{1}{(-100)}$$

$$\frac{1}{v_o} = \frac{1}{20} - \frac{1}{100} = \frac{5-1}{100} = \frac{4}{100}$$

$$v_o = 25\text{ cm}$$ **(1/2)**

For eye lens

$$f_e = 1\text{ cm},\ u_e = ?,\ v_e = -25$$

$$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e} \Rightarrow \frac{1}{1} = \frac{1}{-25} - \frac{1}{u_e}$$

$$1 + \frac{1}{25} = -\frac{1}{u_e} \Rightarrow \frac{26}{25} = -\frac{1}{u_e}$$

$$u_e = -\frac{25}{26}$$

$$|u_e| = 0.96\text{ cm} \quad \textbf{(1/2)}$$

Magnification

$$m = -\frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right) = -\left(\frac{25}{100}\right)\left(1 + \frac{25}{1}\right)$$

$$m = -\frac{1}{4} \times 26 = -6.5 \quad \textbf{(1)}$$

Length of telescope, $L = v_o + u_e = 25 + 0.96$

$$L = 25.96\text{ cm} \quad \textbf{(1)}$$

17.The objective of an astronomical telescope has a diameter of 150 mm and a focal length of 4.00 m. The eyepiece has a focal length of 25.00 mm. Calculate the magnifying and resolving power of telescope. (X = 6000 A for yellow Colour). [Delhi 2011C]

The diameter of objective of the telescope

$$= 150 \times 10^{-3}\text{ m}$$

$$f_o = 4\text{ m}$$

$$f_e = 25 \times 10^{-3}\text{ m} \quad \text{and} \quad D = 0.25\text{ m}$$

Magnifying power,

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

$$M = -\frac{4}{25 \times 10^{-3}}\left(1 + \frac{0.25}{25 \times 10^{-3}}\right)$$

$$M = -\frac{4000}{25}(1 + 10)$$

$$= -\frac{4000 \times 11}{25}$$

Resolving power $= \frac{1}{d\theta}$

$$d\theta = \frac{1.22\lambda}{D} = \frac{1.22 \times 6 \times 10^{-7}}{0.25}$$

$$= 2.9 \times 10^{-6}\text{ rad} \quad \textbf{(1)}$$

$$\therefore \text{ Resolving power} = \frac{1}{2.9 \times 10^{-6}} = 0.34 \times 10^{6}$$

18.(i) Draw a neat labelled ray diagram of an astronomical telescope in normal adjustment. Explain briefly its working.

(ii) An astronomical telescope uses two lenses of powers 10 D and ID. What is its magnifying power in normal adjustment? [All India 2010]

Ans.

Refer to ans. 2.

The image formed by objective lens must fall on the focus of eye lens in order to form final image at infinity.

(*ii*) As, $f_e = \frac{1}{10} = 0.1 \text{ m} = 10 \text{ cm}$

$f_e = \frac{1}{1} = 1\text{m} = 100 \text{ cm}$ **(1)**

Magnifying power in normal adjustment,

$$M = -\frac{f_o}{f_e} = -\frac{100}{10}$$

$\therefore$ $M = -10$ **(1)**

19.i) Draw a neat labelled ray diagram of a compound microscope. Explain briefly its working.

(ii) Why must both the objective and the eyepiece of a compound microscope have short focal lengths? [All India 2010]

Ans. (i) Refer to ans. 3.

The magnification by compound microscope is two step process.

Firstly, the objective gives a magnified image of the object and after that the eye piece produces the angular magnification.

(*ii*) f_o and f_e of compound microscope must be small so as to have large magnifying power as

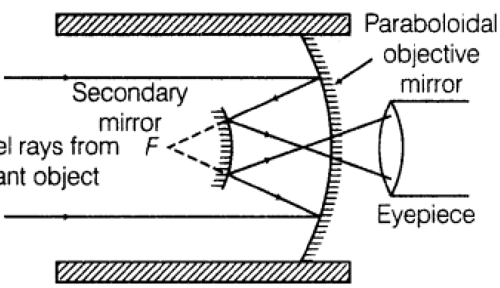
$$M = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$$ **$\left(1\frac{1}{2}\right)$**

20.Draw a schematic diagram of a reflecting telescope (Cassegrain). Write two important advantages that the reflecting telescope has over a refracting type. [Foreign 2010]

Ans.

When rays from infinity, i.e. parallel rays are reflected by a concave mirror they will tend to meet at focus after reflection.

Diagram of a reflecting telescope



$\left(1\frac{1}{2}\right)$

Refer to ans. 1 (for advantages). **$\left(1\frac{1}{2}\right)$**

21.Explain with the help of a ray diagram, the working of an astronomical telescope. The magnifying power of a telescope in its normal adjustment is If the length of the telescope is 105 cm in this adjustment, find the focal lengths of the two lenses. [Ail India 2010C]

Ans. For figure refer to ans. 2.

The parallel beam of light from distant object get focused in focal plane of objective at angle a. This image A'B' acts as an object for eye lens which lie between optical centre of eye lens and its focus. Eyepiece form virtual, erect, magnified image A" B" at least distant of distinct vision.

In normal adjustment, $M = \left|\frac{f_o}{f_e}\right| = 20$

$$f_o = 20 f_e$$

Also, length of telescope,

$$f_o + f_e = 105$$

$$20 f_e + f_e = 105 \Rightarrow 21 f_e = 105$$

$$\Rightarrow \quad f_e = 5 \text{ cm}$$

$$f_o = 20 f_e = 20 \times 5 = 100 \text{ cm} \quad \textbf{(1)}$$

5 Marks Questions

22.Draw a labelled ray diagram showing the image formation of a distant object by refracting telescope,

Deduce the expression for its magnifying power when the final image is formed at infinity.

(ii) The sum of focal lengths of the two lenses of a refracting telescope is 105 cm. The focal length of one lens is 20 times that of the other. Determine the total magnification of the telescope when the final image is formed at infinity. [All India 2014]

Ans.

(i) For figure refer to ans. 8.

When the final image is formed at infinity, angular magnification is given by

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

However, β and α are very sm ll.

$$\therefore \quad \beta \approx \tan\beta \quad \text{or} \quad \alpha \approx \tan \quad \textbf{(1)}$$

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

I is the image formed by the obje... f_e are the focal length of obje tive a eyepiece, respectively.

$$\tan\alpha = \frac{I}{f_o} \quad \text{or} \quad \tan\beta = \frac{I}{-f_e}$$

$$\therefore \quad M = \frac{-\frac{I}{f_e}}{\frac{I}{f_o}} \quad \text{or} \quad M = -\frac{f_o}{f_e} \quad \textbf{(1)}$$

(ii) Given, $f_o + f_o = 105$, $f_o = 20\ f_e$

$$f_e = \frac{105}{21} = 5$$

$$f_o = 20 \times 5 = 100 \text{ cm}$$

$$M = \frac{f_o}{f_e} = \frac{100}{5} = 20$$

23.Define magnifying power of a telescope. Write its expression. A small telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm. If this telescope is used to view a 100 m high tower 3 km away, find the height of the final image when it is formed 25 cm away from the eyepiece. [Delhi 2012]

Ans. The magnifying power of a telescope is equal to the ratio of the visual angle subtended at the eye by final image formed at least distance of distinct vision to the visual angle subtended at naked eye by the object at infinity.

When final image is at D,

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

In normal adjustment, $M = -\frac{f_o}{f_e}$

For telescope

Focal length of objective lens, $f_o = 150$ cm

Focal length of eye lens, $f_e = 5$ cm

When final image forms at $D = 25$ cm

$$\therefore \text{ Magnification, } M = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$= -\frac{150}{5}\left(1 + \frac{5}{25}\right)$$

$$= -\frac{150}{5} \times \frac{6}{5}$$

$$M = -36 \qquad \left(1\frac{1}{2}\right)$$

Let height of final image is h cm

$$\therefore \qquad \tan\beta = \frac{h}{25}$$

β = visual angle formed by final image at eye
α = visual angle subtended by object at objective

$$\tan\alpha = \frac{100\text{ m}}{3000\text{ m}} = \frac{1}{30}$$

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

$$-36 = \frac{\left(\frac{h}{25}\right)}{\left(\frac{1}{30}\right)}$$

$$-36 = \frac{h}{25}\times 30 = \frac{6h}{5}$$

$$h = -\frac{36\times 5}{6} = -30\text{ cm} \qquad \left(1\frac{1}{2}\right)$$

Negative sign indicates inverted image.

24.How is the working of a telescope different from that of a microscope? The focal lengths of the objective and eyepiece of a microscope are 1.25 cm and 5 cm. respectively. Find the position of the object relative to the objective in order to obtain an angular magnification of 30 in normal adjustment. [Delhi 2012]

Differences between telescope and microscope are given as below:

	Characteristics	Telescope	Microscope
1.	Position of object	At infinity	Near objective at a distance lying between f_o and $2f_o$
2.	Position of image	Focal plane of objective	Beyond $2f_o$ when f_o is the focal length of objective.

For microscope

$f_o = 1.25$ cm, $f_e = 5$ cm

When final image forms at infinity, then magnification produced by eye lens is given by

$$M = -\frac{L}{f_o}\cdot\frac{D}{f_e} \Rightarrow -30 = -\frac{L}{1.25}\times\frac{25}{5}$$

$$L = \frac{30\times 1.25}{5} \Rightarrow L = 7.50\text{ cm}$$

(1)

For objective lens

$v_o = L = 7.5$ cm

$f_o = 1.25$ cm, $u_o = ?$

Applying lens formula

$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o} \Rightarrow \frac{1}{1.25} = \frac{1}{7.5} - \frac{1}{u_o}$$

$$\frac{1}{u_o} = \frac{1}{7.5} - \frac{1}{1.25} = \frac{1.25 - 7.5}{7.5 \times 1.25}$$

$$= -\frac{6.25}{7.5 \times 1.25}$$

$$\Rightarrow \quad u_o = -\frac{7.5 \times 1.25}{6.25} = -1.5 \text{ cm}$$ **(3)**

The object must be at a distance of 1.5 cm from objective lens.

25. Draw a ray diagram to show the working of a compound microscope. Deduce an expression for the total magnification when the final image is formed at the near point.

In a compound microscope, an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eyepiece has a focal length of 5 cm and the final image is formed at the near point. Estimate the magnifying power of the microscope. [Delhi 2010]

Ans.For figure Refer to ans. 3.

The objective lens forms real, inverted magnified image A'B' of object AB in such a way that AB' fall some where between pole and focus of eye lens. So, A'B' acts as an object for eye lens and its virtual magnified image A" B" formed by the lens.

The magnifying power of a compound microscope is defined as the ratio of the visual angle subtended by final image at eye ((3) and the visual angle subtended by object at naked eye when both are at the least distance of distinct vision from the eye.

$$\Rightarrow \quad m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha}$$

$$= \frac{\frac{B'A'}{u_e}}{\frac{BA}{D}} = \left(\frac{B'A'}{BA}\right) \times \frac{D}{u_e} = m_o m_e u_e$$

$m = m_o m_e$, where m_o and m_e are magnification produced by objective and eye lens, respectively.

Now, $m_o = \frac{B'A'}{BA} = \frac{v_o}{-u_o}$

$$m_e = \frac{D}{u_e} = 1 + \frac{D}{f_e} \quad \text{[By lens formula]}$$

$$\therefore \quad m = -\left(\frac{v_o}{u_o}\right)\left(1 + \frac{D}{f_e}\right) \quad \textbf{(1)}$$

This is required expression.

Also, $u_o = +1.5$ cm

$f_o = 1.25$ cm, $f_e = 5$ cm

$$v_e = -D = -25 \text{ cm}$$

For objective lens,

$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o} \Rightarrow \frac{1}{1.25} = \frac{1}{v_o} + \frac{1}{1.5}$$

$$\Rightarrow \quad \frac{1}{v_o} = \frac{1}{1.25} - \frac{1}{1.5} = \frac{1.5 - 1.25}{1.5 \times 1.25}$$

$$= \frac{0.25}{1.5 \times 1.25} = \frac{1}{7.50}$$

$$v_o = 7.5 \text{ cm} \quad \textbf{(1)}$$

$\therefore$ Magnifying power,

$$m = -\left(\frac{v_o}{u_o}\right)\left(1 + \frac{D}{f_e}\right) = -\left(\frac{7.5}{1.5}\right)\left(1 + \frac{25}{5}\right)$$

$$= -5 \times 6$$

$$m = -30. \quad \textbf{(1)}$$

26.(i) (a) Draw a labelled ray diagram to show the formation of image in an astronomical telescope for a distant object.

(b) Write the three distinct advantages of a reflecting type telescope over a refracting type telescope.

(ii) A convex lens of focal length 10 cm is placed coaxially 5 cm away from a concave lens of focal length 10 cm. If an object is placed 30 cm in front of the convex lens. Find the position of the final image formed by the combined system. [All India 2009] (*i*) (*a*) **For figure** Refer to ans. 5.

(*b*) **For advantages** Refer to ans 9. **(2)**

(*ii*) $f_1 = 10$ cm, $f_2 = -10$ cm, $u = -30$ cm from convex lens.

For I lens,

$u = -30$ cm, $f = +10$ cm, $v = ?$

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{10} = \frac{1}{v} - \frac{1}{(-30)}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{10} - \frac{1}{30} = \frac{3-1}{30}$$

$$\Rightarrow v = 15 \text{ cm}$$ **(1)**

This image would be a virtual object for II lens.

For II lens,

$u_2 = +10$ cm

[∵ concave lens is at a distance of 5 cm from convex lens]

$f_2 = -10$ cm, $v = ?$

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

$$\frac{1}{-10} = \frac{1}{v} - \frac{1}{10}$$

$$\Rightarrow \frac{1}{v} = 0 \Rightarrow v = \infty$$

So, final image forms at infinity.

27.Draw the labelled ray diagram for the formation of image by an astronomical telescope.

Derive the expression for its magnifying power in normal adjustment. Write two basic features which can distinguish between a telescope and a compound microscope. [Foreign 2009]

For figure Refer to ans. 12. **(2)**

Magnifying power of astronomical telescope in normal adjustment.

$$\text{Magnifying power} = \frac{\beta}{\alpha}$$

$$= \frac{\text{Visual angle formed by final image at eye lens}}{\text{Visual angle formed by object at naked eye}}$$

$$m = \frac{\beta}{\alpha} \approx \frac{\tan\beta}{\tan\alpha} = \frac{\frac{A'B'}{B'E}}{\frac{A'B'}{OB'}}$$

$$= \frac{OB'}{B'E} = \frac{+f_o}{-u_e}$$ **(1)**

For final image at infinity, B' point must lie on focus of eye lens, i.e. $u_e = f_e$.

∴ Magnifying power in normal adjustment,

$$m = -\frac{f_o}{f_e} \quad \textbf{(1)}$$

(*i*) Telescope has objective of a large aperture and large focal length whereas microscope have objective of small aperture and focal length.

(*ii*) The relative distance between objective and eye lens may change in telescope whereas the separation between objective and eye lens in compound microscope remain fixed. **(1)**

28.(i) Draw a ray diagram for the formation of image by a compound microscope. Define

its magnifying power. Deduce the expression for the magnifying power of the microscope.

(ii) Explain

- Why must both the object and the eyepiece of a compound microscope have short focal lengths?
- While viewing through a compound microscope, why should our eyes be positioned not on the eyepiece but a short distance away from it for best viewing? [Foreign 2008]

Ans. (i) For figure Refer to ans. 3.

For magnifying power refer to ans. 25

(ii) (a) Refer to ans. 19 (ii).

(b) When eyes are positioned at short distance away from eyepiece, then the image formed at infinity can be seen which is more suitable and comfortable for viewing by the relaxed eye