RAY OPTICS

3. OPTICAL INSTRUMENTS

POINTS TO REMEMBER

1. **Simple Microscope :**A simple microscope consists of a single convex lens of short focal length.The image is virtual, erect and magnified and it is formed on the same side of the object at the least distance of distinct vision 'D'

   Magnification $m = 1 + \frac{D}{f}$

   If the image is formed at infinity (V = ∝), $m = \frac{D}{f}$

2. **Compound Microscope:** It consists of two convex lenses of different focal lengths. The lens of smaller focal length (f_0) is nearer to the object and is called objective. The other lens of large focal length (f_e) is nearer to the eye and it is called eye piece. The final image is virtual, magnified and inverted with respect to the object and it is formed at the LDDV.

   If the length of the microscope L, $m = \frac{L}{u_0}\left(1 + \frac{D}{f_e}\right)$

   If the final image is at infinity, $m = \frac{L}{u_0}\left(\frac{D}{f_e}\right) = \frac{L}{f_0}.\frac{D}{f_e}$ or

   $m = \frac{v_0 D}{f_0 f_e}$

3. **Astronomical telescope:** It consists of two convex lens of different focal lengths which are coaxially arranged at the ends of the tube. A lens of larger focal length (f_0) is towards the object called objective. The other lens of small focal (f_e)length is towards the eye and it is called eyepiece. the final image which is magnified virtual and inverted with respect to the original object is formed at near point.

   In the normal adjustment position, $m = \frac{f_0}{f_e}$

   When the image is at near point, $m = \frac{f_0}{u_e}$ Or $m = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$

   Length of the telescope = $l = f_0 + u_e = f_0 + \left(\frac{f_e D}{f_e + D}\right)$

4. **Terrestrial Telescope:**In order to make the final image erect, another convex lens of smaller focal length is placed in between the objective and eyepiece. This is called erecting lens

   Magnification $m = \frac{f_0}{f_e}$

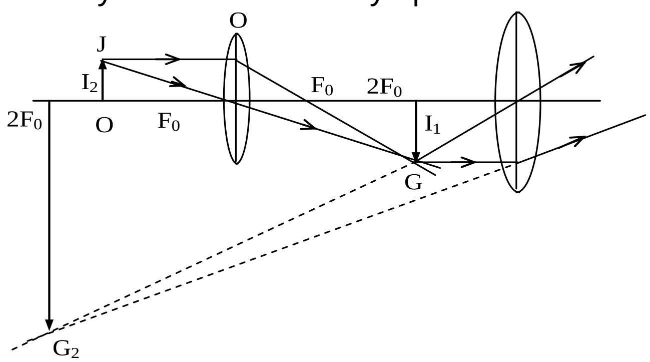
   Length of the telescope $L = f_0 + f_e + 4f$ Where f = focal length of erecting lens.

LONG ANSWER QUESTIONS

1. With the help of ray diagram illustrate the formation of the final image of an object in a compound microscope. Derive an expression for its magnifying power. Microscopes in which objects are illuminated by ultraviolet light and images observed on a fluorescent screen can give greater magnification than the microscopes that use visible light. Why?

A. **Construction**

It consists of two convex lenses of different focal lengths which are arranged coaxially at the ends of a tube. The distance between the lenses can be adjusted by rack and pinion arrangement. The lens of smaller focal length is nearer to the object and is called objective. The other lens of large focal length is nearer to the eye and it is called eye piece.



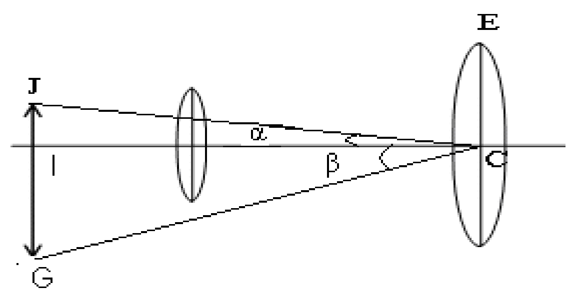
Working

Let the object OJ is placed in front of the objective in between F_0 and $2F_0$ of the objective. A real, magnified and inverted image I_1G_1 is formed beyond $2F_0$ on the other side of the objective. This image I_1G_1 acts like an object for the eye piece.The distance between the lenses is adjusted such that the image I_1G_1 is formed below the focus of the eye piece; so that the eyepiece behaves like a simple microscope.

Hence the final image is virtual, magnified and inverted with respect to the object OJ and it is formed at the LDDV.

Magnifying Power

It is defined as the ratio between the angle subtended by the image formed at LDDV at the eyepiece and the angle subtended by the object at the eyepiece when the object is imagined at LDDV.



$$m = \frac{\beta}{\alpha} = \frac{\mathrm{T}an\,\beta}{\mathrm{T}an\,\alpha}$$

$$\mathrm{T}an\,\beta = \frac{IG}{CI} \quad \text{and} \quad \mathrm{T}an\,\alpha = \frac{IJ}{CI}$$

$$m = \frac{IG}{IJ} \quad \text{(OR)} \quad m = \frac{IG}{OJ}$$

Also, $m = m_e\, m_0$ (OR) $m = m_0 m_e$

If the object is at infinity then

$$m = \frac{V_0}{u_0} \times \frac{D}{f_e}$$

$$m = \frac{V_0}{u_0}\left(1 + \frac{D}{f_e}\right)$$

If the object OJ is adjusted such that the image formed by it is very close to the eyepiece, then V_0 is taken as the distance between the lenses or the length of the microscope L

$$\therefore m = \frac{L}{u_0}\left(1+\frac{D}{f_e}\right)$$

If the final image is at infinity

$$m = \frac{L}{u_0}\left(\frac{D}{f_e}\right) = \frac{L}{f_0}.\frac{D}{f_e}$$

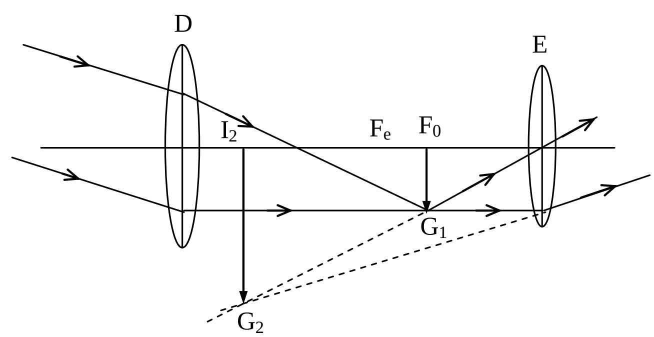
Wavelength of ultraviolet light is greater than that of visible light. Since $\mu \propto \frac{1}{\lambda}$.

The refractive index of the ultraviolet light is less than that of visible light. Thus the ultraviolet light deviates less at objective and produces the image near to the eye piece than that produced by visible. Hence the angle α made by the ultraviolet light at eyepiece is more than that made by visible light. Since β is constant and $m \propto \alpha$ hence the microscopes in which objects are illuminated by ultraviolet light can give greater magnification than the microscopes that use viable light.

2. **Explain the constructional working of an astronomical telescope. Calculate its magnifying power when the image is formed at the least distance of distinct vision. How does the magnifying power of a telescope change on decreasing the aperture of the objective?**

A. **Construction**

An astronomical telescope is used to observe the heavenly bodies like sun, stars etc.It consists of two convex lenses of different focal lengths which are coaxially arranged at the ends of the tube. The distance between the lenses can be adjusted by rack – pinion arrangement. A lens of larger focal length is towards the object called objective. The other lens of small focal length is towards the eye and it is called eyepiece.



Working

Parallel light rays from a distant object after refraction from the objective form a real, diminished and inverted image I_1G_1 at the principal focus (f_0) of the objective. This image acts like an object for the eyepiece. The distance between the lenses is adjusted so that the image I_1G_1 is formed below the focus of the eye piece. Hence the final image which is magnified virtual and inverted with respect to the original object is formed at near point.

Magnifying Power

Magnification is defined as the ratio between the angle subtended by the image at the eyepiece and the angle subtended by the object at the objective.

When the image is at near point

$$m = \frac{\beta}{\alpha} = \frac{\mathrm{T}an\beta}{\mathrm{T}an\alpha}$$

$$\mathrm{T}an\beta = \frac{IG}{u_e} \text{ and } \mathrm{T}an\alpha = \frac{IG}{f_0}$$

$$m = \frac{f_0}{u_e}$$

For the eyepiece, $\frac{1}{f_e} = \frac{1}{u_e} - \frac{1}{v_e}$

But v_e = D

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

$$m = f_0\left(\frac{1}{f_e} + \frac{1}{D}\right) \Rightarrow m = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$

Length of the telescope = $l = f_0 + u_e$

$$l = f_0 + \left(\frac{f_e D}{f_e + D}\right)$$

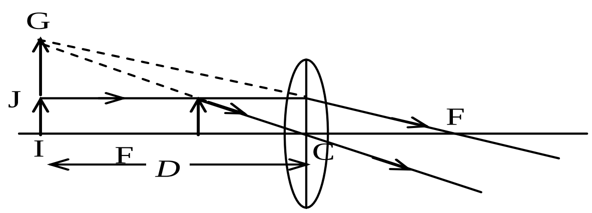
The magnifying power of a telescope decreases on decreasing the aperture of the objective

SHORT ANSWER QUESTIONS

1. Explain the working of a simple microscope and find an expression for its magnifying power.

A. This is also called as magnifying glass or reading lens.It increases the visual angle.

Construction: A simple microscope consists of a single convex lens of short focal length.The lens is arranged in a circular metallic frame provided with a handle.



Working: A small object OJ is placed between optic centre C and the principal focus F of the convex lens. The image is virtual, erect and magnified and it is formed on the same side of the object at the least distance of distinct vision 'D

Magnifying Power : Magnifying power is defined as the ratio between the angles subtended by the image at the lens (eye) and the angle subtended by the object at the lens(eye) when both are at LDDV.

Magnifying power $m = \frac{\beta}{\alpha} = \frac{\mathrm{T}an\beta}{\mathrm{T}an\alpha}$

$$\mathrm{T}an\beta = \frac{IG}{CI} \text{ and } \mathrm{T}an\alpha = \frac{IJ}{CI}$$

$$\therefore m = \frac{IG}{IJ} \qquad (\because IJ = OJ)$$

$$m = \frac{IG}{OJ} = \frac{v}{u} = \frac{D}{u}$$

Also $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

Since the image is virtual, image distance is taken as –ve.

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

Multiplying throughout with D

$$\frac{D}{f} = \frac{D}{u} - \frac{D}{v} \qquad \Rightarrow m = 1 + \frac{D}{f}$$

Where V = D least distance of distinct vision.

If the image is formed at infinity (V = ∝)

$$\frac{D}{u} = \frac{D}{v} + \frac{D}{f} \qquad \Rightarrow \quad m = \frac{D}{f}$$

2. The angle subtended at the eye by an object is equal to the angle subtended at the eye by the virtual image produced by a simple microscope. In what sense does a simple microscope produce angular magnification?

A. Magnifying power of a microscope is given by $m = \frac{\tan\alpha}{\tan\beta} = \frac{-D}{-U}$

A simple microscope produces an angular magnification if the distance between the nearest point and the eye (D) is more when compared with the object distance (U). -D and –U values denote that the measurement is in opposite direction.

3. Magnifying power of a microscope is inversely proportional to the focal length of the lens. What then stops us from using a convex lens of smaller and smaller focal length and achieving greater magnifying power?

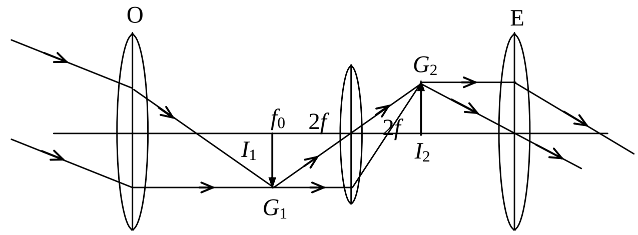
A. If the focal length of the lens is smaller, then its magnifying power is more. But images formed by a single lens possess several defects like spherical aberration and astigmatism. The images of large magnification are more defective. Hence through the magnifying power is inversely proportional to focal length, we can't use the lens of small length.

4. An object is first seen in red light and then in blue light through a microscope. In which case is the magnifying power greater? Explain?

A. The magnifying power is directly proportional to the angle of deviation. For the red light the angle of deviation is less, when compared to the angle of deviation of blue. So the magnifying power is more for red light rather than the blue light.

5. Explain the construction and working of a terrestrial telescope with the help of a ray diagram

A. **<u>Description and Working</u>:** The final image in an astronomical telescope is inverted. This inversion is not desirable in a terrestrial telescope. In order to make the final image erect, another convex lens of smaller focal length is placed in between the objective and eyepiece. This is called erecting lens.



This is arranged at twice the focal length from the image due to the objective. An erect image of same size is formed at twice its focal length on the other side of the lens which acts like an object for the eyepiece. This is formed at the focus of the eye piece so that the final image is formed at infinity.

Magnification $m = \frac{f_0}{f_e}$

Length of the telescope $L = f_0 + f_e + 4f$,Where f = focal length of erecting lens.

6. Comparison of a telescope and a microscope.

A.

Microscope	Telescope
1. It is used to see very small objects. 2. It s objective is of small focal length and of small aperture 1. It produces linear magnification i.e., size of the image is larger than that of the object.	1. It is used to see distant objects. 2. Its objective is of large focal length and of large aperture. 3. It produces angular magnification i.e., the image is nearer to the eye but the size does not increase.

7. Distinguish between an astronomical telescope and a terrestrial telescope.

A.

Astronomical telescope	Terrestrial telescope
1.It is used to view the object of space. 2.The image is inverted. 3. The intensity of image is greatger.	1. It is used to view the distant objects on earth 2. The image is in erect position 3. The intensity of image is lesser than Astronomical.

8. How will the magnifying power of an astronomical telescope be affected on increasing?

i) The focal length and ii) The aperture of its objective.

A. The magnifying power of an astronomical telescope depends on both the focal length and aperture of the objective.

The magnifying power of an astronomical telescope is inversely proportional to the focal length of the lens and directly proportional to the aperture of the objective. The greater the aperture the greater is the magnifying power of the lens.

VERY SHORT ANSWER QUESTIONS

1. What should be the position of an object relative to a biconvex lens, so that it behaves like a magnifying lens? Where is its image formed?

A. A biconvex lens behaves like a magnifying glass when the object is placed between the optic centre and the principal focus of the lens. Then a virtual, erect and magnified image is formed on the same side of the object.

2. What is the position of the object relative to the objective of a compound microscope? Where is its image formed?

A. In a compound microscope the object is placed in front of the objective in between F_0 and $2F_0$ of the objective. A real, magnified and inverted image is formed beyond $2F_0$ on the other side of the objective.

3. What is normal adjustment of a telescope? In what way it is better?

A. The telescope is said to be in the normal adjustment position when the final image is formed at infinity. In this position, the eye receives parallel rays and hence the final image is observed by the eye in its most relaxed position.

4. Two lenses of foal lengths 5 cm and 50 cm are to be used for making a telescope. Which will you use for the objective?

A. For constructing a telescope, focal length of objective should be greater than that of eye-piece. Therefore the lens of coal length 50 cm is used as the objective.

5. What is the use of erecting lens in a terrestrial telescope? What is its magnification?

A. In a terrestrial telescope, erecting lens is used to make the final image formed erect. The magnifying power of erecting lens is one.

6. Which gives brighter image– Astronomical telescope or terrestrial telescope? Justify your answer.

A. Astronomical Telescope. The magnifying power of the astronomical telescope is high

SOLVED PROBLEMS

1. The focal length of a converging lens is 8 cm. Find its magnifying power, when it is used as a reading lens to form the image at near point.

A. f = 8 cm: D = 25 cm

When the image is formed at near point, the magnifying power of a simple microscope

$$m = 1 + \frac{D}{f} = 1 + \frac{25}{8} = 4.125$$

2. A microscope consists of two convex lenses of focal lengths 2 cm and 5 cm placed 20 cm apart. Where the object must be placed so that the final virtual image is at a distance of 25 cm from the eye?

A. For the eyepiece, focal length, $f_e = +5cm; v_e = -25cm; u_e = ?$ But , $\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e}$

$$\frac{1}{5} = \frac{1}{-25} - \frac{1}{u_c}; \frac{1}{u_c} = -\frac{1}{25} - \frac{1}{5} = -\frac{6}{25}; u_e = -\frac{25}{6}cm$$

Also, $v_0 + u_e = 20cm$

$$v_0 = 20 - u_e = \frac{95}{6}cm$$

For the objective, $v_0 = +\frac{95}{6}cm;\ f_0 = +2cm; u_o = ?$

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

$$\Rightarrow \frac{1}{2} = \frac{6}{95} - \frac{1}{u} \Rightarrow u = -2.29cm$$

The object is to be placed at a distance of 2.29 cm to the left side of the objective.

3. The focal lengths of the objective and eyepiece of a telescope are 60cm and 5 cm respectively. Find its magnifying power i) for normal adjustment and ii) when the image is formed at near point.

A. $f_0 = 60cm;\ f_e = 5cm; D = 25cm$

i) The magnifying power for normal adjustment = $= -\frac{f_0}{f_e} = -\frac{60}{5} = -12$

ii) The magnifying power for the image at near point =

$\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right) = -\frac{60}{5}\left(1+\frac{5}{25}\right) = -14.4$

4. A graph sheet divided into squares each of size $1mm^2$ is kept at a distance of 7 cm from a magnifying glass of focal length of 8 cm. The graph sheet is viewed through the magnifying lens keeping the eye close to the lens. Find i) the magnification produced by the lens, ii) the area of each square in the image formed, iii) the magnifying power of the magnifying lens. Why is the magnification found in (i) different from the magnifying power ?

A. i) u = - 7 cm; f = +8 cm; v =?

For a lens, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$\frac{1}{+8} = \frac{1}{v} - \frac{1}{-7}; \frac{1}{v} = \frac{1}{8} - \frac{1}{7} = \frac{-1}{56}; v = -56cm$

Magnification, $M = \frac{v}{u} = \frac{-56}{-7} = +8$

ii) Each square is of size $1mm^2$ i.e., its length and breadth are each equal to 1 mm. The virtual image formed has linear magnification 8. SO its length and breadth are each equal to 8 mm. the area of the image of each square = $8 \times 8mm^2 = 64mm^2$

iii) Magnifying power of the magnifying glass i.e., simple microscope \,

$m = 1 + \frac{D}{f} = 1 + \frac{25}{8} = 4.125 \qquad (\therefore D = 25cm)$

The magnification found in(i) is different from the magnifying power because the image distance in (i) is different from the least distance of distinct vision D.

5. Find the magnifying power of a compound microscope whose objective has a focal power of 100 D and eyepiece has a focal power of 16 D when the object is placed at a distance of 1.1 cm from the objective. Assume that the final image is formed at the least distance of distinct vision 25 cm.

A. $m = \frac{v_0}{u}\left(1+\frac{D}{f_e}\right)$

$P_0 = 100D$

$f_0 = \frac{100}{p_0} = \frac{100}{100}cm = 1cm; u_0 = -1.1cm; v_0 = ?$

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

$\Rightarrow \frac{1}{1} = \frac{1}{v_0} - \frac{1}{-1.1} \Rightarrow v_0 = 11cm$

Also, $p_e = 16D$

$f_e = \frac{100}{p_e} = \frac{100}{16}cm = 6.25cm$; D = 25 cm.

$\therefore m = \frac{11}{-1.1}\left(1+\frac{25}{6.25}\right) = -10\times 5 = -50$

6. An astronomical telescope consists of two thin lenses set 52 cm apart. Its magnifying power is 25 for normal adjustment. Find the focal length of the lenses.

A. The distance between the two lenses of an astronomical telescope is

$d = f_0 + f_e = 52cm$ ------------(1)

Magnifying power, m = -25

Since the magnifying power of an astronomical telescope is negative

$m = \frac{-f_0}{f_e} = -25$

$\Rightarrow f_0 = 25 f_e$ ---------(ii)

Solving (i) and (ii) ,

$f_0 = 50cm \;\; and \;\; f_e = 2cm$

7. A telescope objective of focal length 1 m forms a real image of the moon 0.92 cm in diameter. Calculate the diameter of the moon taking its mean distance from the earth to be 38×10^4 km. If the telescope uses an eyepiece of 5 cm focal length, what would be the distance between the two lenses for i) the final image to be formed at infinity ii) The final image (virtual) at 25 cm from the eye.

A. $f_0 = 1m$; u_o = distance of the moon from the earth $= 3.8\times 10^5 km = 3.8\times 10^8 m$

Image size = Image diameter = $0.92\times 10^{-2} m$

Object size = object diameter or diameter of the moon = ?

We know that,

$\frac{Object\ diameter}{Image\ diameter} = \frac{Obvject\ distance}{Image\ distance} \Rightarrow \frac{Diameter\ of\ the\ moon}{Image\ diameter} = \frac{3.8\times 10^8}{1}$

$\therefore$ Diameter of the moon $= 3.8\times 10^8 \times$ Image diameter $= 3.8\times 10^8 \times 0.92\times 10^{-2} m = 3496km$

i) For normal adjustment, the distance between the two lenses,

$f_0 + f_e = 100 + 5 = 105cm$

ii) For the final image at 25 cm from the eye, the distance between the lenses

$= f_0 + \left(\frac{Df_e}{D+f_e}\right) = 100 + \left(\frac{25\times 5}{25+5}\right) = 104.2cm$

8. In an astronomical telescope the focal lengths of the objective and the eye piece are 100 cm and 5 cm respectively. If the telescope is focused on a scale 2 m from the objective the final image is formed at 25 cm from the eye. Calculate i) the magnification and ii) the distance between the objective and the eyepiece

A. $f_0 = 100cm;\ f_e = 5cm\ ;\ u_0 = -2m = -200cm;\ v_0 = ?$

But, $\frac{1}{+100} = \frac{1}{v_0} - \frac{1}{-200} \Rightarrow v_0 = 200cm$

$m_0 = \frac{v_0}{u} = \frac{200}{-200} = -1$

$v_e = -25cm;\ u_e = ?$

$\frac{1}{+5} = \frac{1}{-25} - \frac{1}{u_e} \qquad \Rightarrow u_e = -\frac{25}{6}cm$

Magnification of the eyepiece, $m_e = \frac{v_e}{u_e} = \frac{-25\times 6}{-25} = 6$

i) Magnification of the telescope = $m_0 \times m_e = -1\times 6 = -6$

ii) Distance between the objective and the eyepiece = $v_0 + |u_e| = 200 + \frac{25}{6} = 204.2cm$

UNSOLVED PROBLEMS :

1. The focal length of a convex lens is 10 cm. Find its magnifying power when it is used as a magnifying glass to form the image at i) near point and ii) far point.

A. f = 10cm, D = 25 cm

i) For image at near point

$$m = \left(1 + \frac{D}{f}\right) = 1 + \frac{25}{10} = 1 + 2.5 = 3.5$$

ii) For image at infinity $m = \frac{D}{f} = \frac{25}{10} = 2.5$

2. A microscope consists of two convex lenses of focal lengths 1.0 cm and 6.25 cm placed 15.0 cm apart. Where the object must be placed so that the final virtual image is at a distance of 25 cm from the eye?

A. Focal length of objective = $f_0 = 2cm$

Focal length of eyepiece = $f_e = 6.25cm$

Distance between lenses = $d = v_0 + u_e = 15cm$

For eyepiece,

Object distance = u_e

Image distance = $v_e = -D = -25cm$

From $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \quad \Rightarrow \frac{1}{f_e} = \frac{1}{u_e} + \frac{1}{v_e} = \frac{1}{u_e} - \frac{1}{25}$

$$\Rightarrow \frac{1}{u_e} = \frac{1}{6.25} + \frac{1}{25} = \frac{(4+1)}{25} = \frac{5}{25} = \frac{1}{5}$$

$\therefore \; u_e = 5cm$

From $v_0 + u_e = 15 \Rightarrow v_0 = 15 - v_e = 15$-5 = 10 cm

For objective,

Object distance u_0

Image distance = $v_0 = 10cm$

From $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$$\Rightarrow \frac{1}{f_0} = \frac{1}{u_0} + \frac{1}{v_0} \Rightarrow \frac{1}{2} = \frac{1}{u_0} + \frac{1}{10}$$

$$\Rightarrow \frac{1}{u_0} = \frac{1}{2} - \frac{1}{10} = \frac{5-1}{10} = \frac{4}{10}$$

$$\therefore\ u_0 = \frac{10}{4} = 2.5cm$$

3. A compound microscope is of magnifying power 100. The magnifying power of its eyepiece is 4. Find the magnification of its objective.

A. M= 100

Magnification of objective = m_0

Magnification of eye piece = $m_e = -4$

M = $m_0 \times m_e$

$\Rightarrow m_0 = \frac{M}{m_e} = \frac{100}{4} = -25$ Here negative sign indicated final image is virtual.

4. The two lenses of a compound microscope are of focal lengths 2cm and 5 cm. If an object is placed at a distance of 2.1 cm from the objective of focal length 2cm ,the final image forms at the least distance of distinct vision of a normal eye. Find i) the image distance of the image formed by the objective. ii) the magnification of the objective iii) the distance between the objective and eyepiece and iv) the magnifying power of the microscope.

A. $f_0 = 2cm,\ fe = 5cm$

Object distance for objective $= u_0 = 2.1cm$

Image distance for objective = v_0

Object distance for eye piece = u_e

Image distance for eye piece = $v_e = -D = -25cm$

i) From $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \quad \Rightarrow \frac{1}{f_0} = \frac{1}{u_0} + \frac{1}{v_0} \Rightarrow \frac{1}{2} = \frac{1}{2.1} + \frac{1}{u_0} \Rightarrow v_0 = 42.cm$

ii) Magnification fo objective $= m_0 = \frac{v_0}{u_0} = \frac{42}{2.1}$ = 20

iii) Distance b/w lenses = $d = V_0 + u_e$

$$From \frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow \frac{1}{f_e} = \frac{1}{u_e} + \frac{1}{v_e} = \frac{1}{u_e} - \frac{1}{25} \Rightarrow u_e = \frac{25}{6}$$

$$\therefore d = v_0 + u_e = 42 + \frac{25}{6} = 46.17cm$$

iv) Magnification of microscope

$$= M = m_0 \times m_e = 20 \times \left(1 + \frac{D}{f_e}\right) = 20\left(1 + \frac{25}{5}\right) = -120$$ (Negative sign indicate final image is virtual)

5. The focal lengths of the eyepiece and the objective of an astronomical telescope are 2 cm and 100 cm respectively. Find the magnifying power of the telescope for normal adjustment and the length of the telescope.

A. $f_0 = 100cm, \; f_e = 2cm$

In normal adjustment position , magnification is given by

$m = \frac{f_0}{f_e} = \frac{100}{2} = -50$ (Negative sign indicate final image is virtual)

Length of telescope = L $= f_0 + f_e = 100 + 2 = 102cm$

6. The focal length of the objective and eyepiece of a telescope are 60 cm and 5 cm respectively. The telescope is focused on an object 360 cm from the objective and the final image is formed at a distance of 30 cm from the eye of the observer. Calculate the length of the telescope,

A. $f_0 = 60cm, \; f_e = 5cm$

For objective,

Object distance = $u_0 = 360cm$

Image distance = v_0

From $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow \frac{1}{f_0} = \frac{1}{u_0} + \frac{1}{v_0} \Rightarrow \frac{1}{60} = \frac{1}{360} + \frac{1}{v_0}$

$\therefore v_0 = \frac{360}{5} = 72cm$

For eye piece,

Oobject distance = u_e

Image distance = $v_e = -30cm$

From $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow \frac{1}{f_e} = \frac{1}{u_e} + \frac{1}{v_e} \Rightarrow \frac{1}{5} = \frac{1}{u_e} - \frac{1}{30} \Rightarrow u_e = 4.2918cm$

Length of telescope $= L = v_0 + u_e = 72 + 4.2918 = 76.30cm$

7. The magnifying power of an astronomical telescope for normal adjustment is 10 and the length of the telescope is 110 cm. Find the magnifying power of the telescope when the image is formed at the least distance of distinct vision for normal eye.

A. In normal adjustment position,

Magnification = M = $\frac{f_0}{f_e} = 10 \Rightarrow f_0 = 10 f_e$

Length of telescope $= L = f_0 + f_e = 110cm$

$\Rightarrow 10 f_e + f_e = 110$

$\Rightarrow 11 f_e = 110 \Rightarrow f_e = \frac{110}{11} = 10cm$

$f_0 = 10 f_e = 10(10) = 100cm$

Magnification for image at near point ,

$$M = m_0 \times m_e = \frac{-f_0}{f_e} \times \left(1 + \frac{f_e}{D}\right) = \frac{-100}{10}\left[1 + \frac{10}{25}\right] = -14$$

ASSESS YOURSELF

1. The aperture and focal length of the objective of a microscope are small why?

A. Here size of the object is very small .To have more intensity the focal length of the objective of a microscope should be small.

2. The aperture and focal length of the objective of a telescope are large. Why?

A. To have more intensity the aperture of the objective of a telescope should be large.Focal length of the objective of a telescope should be large for larger angular magnification.

3. The magnifying powers of an astronomical telescope and a terrestrial telescope are same. Why?

A. For astronomical telescope , magnifying power $m = m_0 m_e$

For terrestrial telescope, magnifying power
$m = m_0 m_e \times Magnification\, by\ errecting\, lens$

But for erecting lens m = 1

Hence the magnifying powers of an astronomical telescope and a terrestrial telescope are same.

4. When the intensities of the images formed by astronomical and terrestrial telescope are compared, which image is of greater intensity?

A. The intensity of the image formed by astronomical telescope has greater intensity.