PART-II

PHYSICS

Class XII

Chapter 9- Ray Optics and Optical Instruments

1 Mark Questions

Question 1.
Aglasslens of refractive index 1.5 is placed in a trough of liquid. What must be the refractive index of the liquid in order to mark the lens disappear?
Answer:
In order to make the lens disappear the refractive index of liquid must be equal to 1.5 i.e. equal to that of glass lens.

Question 2.
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?
Answer:
The lens in the liquid will act like a plane sheet of glass
∴ Its focal length will be infinite (∞)

∴ Its focal length will be infinite (∞)

$$\because \quad \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{[By Lens Maker's formula}$$

$$\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\text{Here } \mu_1 = \mu_2 \quad \therefore \frac{1}{f} = 0 \qquad \Rightarrow f = \infty$$

Question 3.
How does the power of a convex lens vary, if the incident red light is replaced by violet light?
Answer:
According to Lens Maker's formula

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

$$\because \quad \mu_{violet} > \mu_{red}$$

∴ power of the lens will be increased.

Question 4.
How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced with red light?
Answer:
We know that λ red > λ violet, therefore μ red < μ violet and hence δ red < δ violet.
When incident violet light is replaced with red light, the angle of minimum deviation of a glass decreases.

Question 5.
Why does the bluish colour predominate in a clear sky?
Answer:
Blue colour of the sky : The scattering of light by the atmosphere is a colour dependent. According to

Rayleigh's law, the intensity of scattered light I∝1λ4, blue light is scattered much more strongly than red light. Therefore, the colour of sky becomes blue. The blue component of light is proportionately more in the light coming from different parts of the sky. This gives the impression of the blue sky.

Question 6.
How does the angle of minimum deviation of a glass prism of refractive index 1.5 change, if it is immersed in a liquid of refractive index 1.3?
Answer:

Here ${}^a\mu_g = 1.5$ and ${}^a\mu_w = 1.3$

$\because \quad \delta = (\mu - 1)\,A$

For deviation in air, $\mu = \frac{\mu_g}{\mu_a} = \frac{1.5}{1} = 1.5$

$\therefore \quad \delta = (1.5 - 1) \times 60^\circ = 30^\circ$

For deviation in water, $\mu = \frac{\mu_g}{\mu_w} = \frac{1.5}{1.3} = 1.15$

$\therefore \quad \delta = (1.15 - 1) \times 60^\circ = 0.15 \times 60^\circ = 9^\circ$

Hence angle of deviation is decreased.

Question 7.
You are given following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope?

Lenses	Power (P)	Aperture
L_1	3D	8 cm
L_2	6D	1 cm
L_3	10D	1 cm

Answer:
Objective – Less power and more aperture. So L_1
Eyepiece – More power and less aperture. So L_3.

Question 8.
Two thin lenses of power + 4D and – 2D are in contact. What is the focal length of the combination?
Answer:

$$P = P_1 + P_2 = 4 + (-2) = +2D$$

Since focal length $f = \frac{1}{P}$

$$\therefore \quad f = \frac{1}{2} = 0.5 \text{ m} = \mathbf{50\ cm}$$

Question 9.
Two thin lenses of power + 6D and – 2D are in contact. What is the focal length of the combination?
Answer:

$$P_{eq} = P_1 + P_2 = 6 - 2 = +4D$$

$$\therefore \quad \text{Focal length} = \frac{100}{4} = \mathbf{+\ 25\ cm}$$

Question 10.
A glass lens of refractive index 1.45 disappears when immersed in a liquid. What is the value of refractive index of the liquid?
Answer:
The value of refractive index of the liquid should be 1.45 so that the glass lens of refractive index 1.45 disappears when immersed in a liquid.

Question 11.
State the conditions for the phenomenon of total internal reflection to occur.
Answer:
Two essential conditions for total internal reflection are :

1. Light should travel from an optically denser medium to an optically rarer medium.
2. The angle of incidence in the denser medium must be greater than the critical angle for the two media.

Question 12.
Calculate the speed of light in a medium whose critical angle is 30°.
Answer:

$$\because \quad n = \frac{1}{\sin C} = \frac{1}{\sin 30^\circ} \qquad \therefore\ n = 2$$

$$\Rightarrow \quad n = \frac{c}{v} = 2 \qquad \Rightarrow \frac{3 \times 10^8}{v} = 2$$

$\therefore$ Speed of light, v = 1.5×10^8 ms^{-1}

Question 13.
A converging lens is kept coaxially in contact with a diverging lens — both the lenses being of equal focal lengths. What is the focal length of the combination?
Answer:
Focal length of the combination is Infinity.

Question 14.
When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a decrease in the energy carried by the light wave? Justify your answer.
Answer:
No, the energy carried by the lightwave remains the same.
Reason : As energy E = hv
...where [h is planck's constant and ν is frequency that does not change when light travels from one medium to another.
Here frequency remains same.

Question 15.
When monochromatic light travels from one medium to another its wavelength changes but frequency remains the same. Explain.
Answer:
If v_1 and v_2 denote the velocity of light in medium 1 and medium 2 respectively and λ_1 and λ_2 denote the wavelength of light in medium 1 and medium 2. Thus

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} \quad \text{or} \quad \frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2}$$

The above equation implies that when a wave gets refracted into denser medium ($v_1 > v_2$) the wavelength and the speed of propagation decreases but the frequency v (=v/λ) remains the same
.
Question 16.
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?
Answer:
When the refractive index of glass of biconvex lens is equal to the refractive index of the liquid in which lens is immersed
or $\mu_1 = \mu_g$

Question 17.
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?
Answer:

$$\text{As } \mu = \frac{\sin i}{\sin r} = \frac{c}{v} \qquad \text{or } v = \frac{\sin r}{\sin i} \times c$$

For a given angle of incidence $v \propto \sin r$,

$$v_A \propto \sin 15°, \quad v_B \propto \sin 25°, \quad v_C \propto \sin 35°$$

But $\sin 15° < \sin 25° < \sin 35°$

$$\therefore \quad v_A < v_B < v_C$$

∴ Velocity of light is minimum in medium A.

Question 18.
How would a biconvex lens appear when placed in a trough of liquid having the same refractive index as that of the lens?
Answer:
A biconvex lens appears plane glass when placed in a trough of liquid having the same refractive index as that of the lens.

Question 19.
Two thin lenses of power -4D and 2D are placed in contact coaxially. Find the focal length of the combination.
Answer:
Power of combination = – 4D + 2D = – 2D

$$P = -2D \qquad P = \frac{1}{f} \qquad f = \frac{100}{-2} \text{ cm}$$

∴ Focal length, f = – 50 cm

Question 20.
Two thin lenses of power -2D and 2D are placed in contact coaxially. What is the focal length of the combination?
Answer:
Power of combination = -2D + 2D = 0

$$\therefore \text{Focal length} = \frac{1}{\text{Power}} = \frac{1}{0} = \infty \text{ (infinite)}$$

Question 21.
Write the relationship between angle of incidence 'i', angle of prism 'A' and angle of minimum deviation for a triangular prism.
Answer:

$$i = \frac{(A + \delta_m)}{2} \text{ or } A + \delta_m = 2i$$

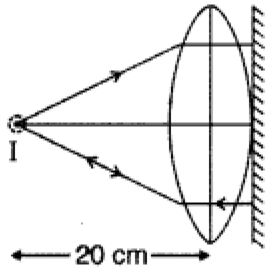
where [δ_m is angle of minimum deviation]

Question 22.
When red light passing through a convex lens is replaced by light of blue colour, how will the focal length of the lens change?
Answer:
Focal length of lens will decrease $\mu v > \mu r$

Question 23.
If the wavelength of light incident on a convex lens is increased, how will its focal length change?
Answer:

$$\text{Focal length will increase, } \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

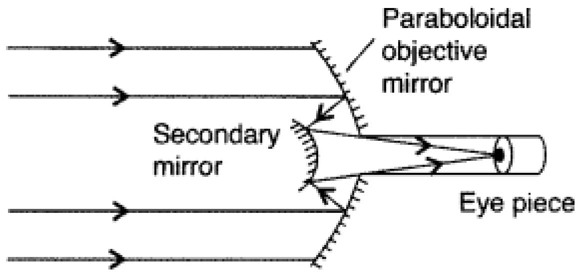
Question 24.
A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens?
Answer:
Focal length of lens = 20 cm



(Hint: Rays coming out of lens are incident normally on plain mirror and hence reflected rays will trace the path of incident ray, hence forming image on the object itself, thus object and image overlapping each other at F of convex lens.)

2 Mark Questions

Question 1.
Draw a ray diagram of a reflecting type telescope. State two advantages of this telescope over a refracting telescope.
Answer:
(*i*)



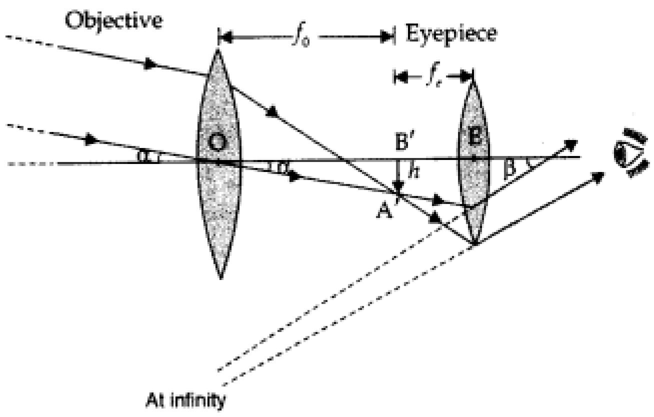
Cassegrain reflecting type telescope

(ii) Advantages of reflecting telescope over a refracting telescope:

1. Due to large aperture of the mirror used, the reflecting telescopes have high resolving power.
2. This type of telescope is free from chromatic aberration (formation of coloured image of a white object).
3. The use of paraboloidal mirror reduces the spherical aberration (formation of non-point, blurred image of a point object).
4. Image formed by reflecting telescope is brighter than refracting telescope.

5. A lens of large aperture tends to be very heavy and therefore difficult to make and support by its edges. On the other hand, a mirror of equivalent optical quality weights less and can be supported over its entire back surface.

Question 2.
Draw a ray diagram of an astronomical telescope in the normal adjustment position. State two drawbacks of this type of telescope.
Answer:
(i) Magnifying power m = −f0fe. It does not change with increase of aperature of objective lens, because focal length of a lens has no concern with the aperature of lens.



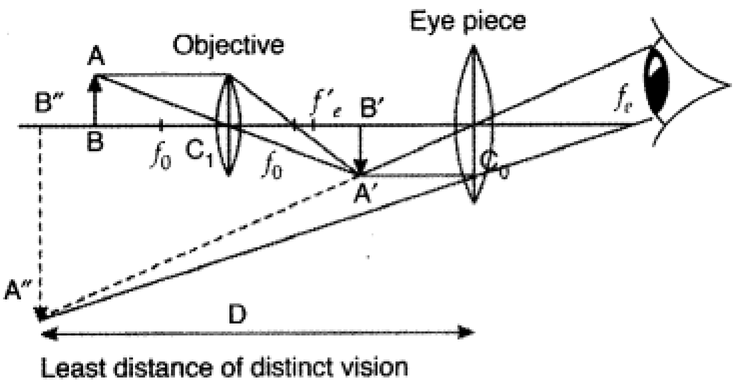
Astronomical telescope in normal adjustment

(ii) Drawbacks :

- Images formed by these telescopes have chromatic aberrations.
- Lesser resolving power.
- The image formed is inverted and faintes.

Question 3.
Draw a ray diagram of a compound microscope. Write the expression for its magnifying power.

Answer:



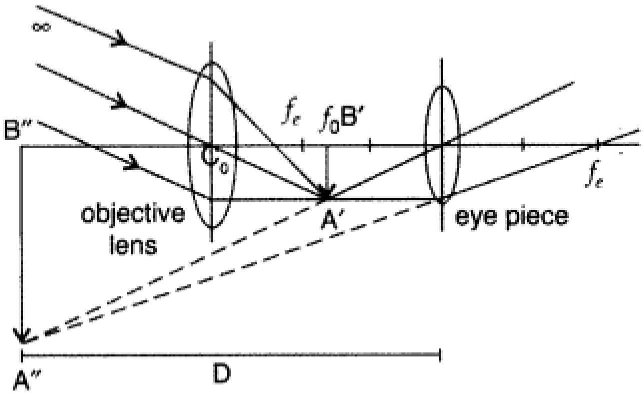
Compound microscope

When the final image is formed at the least distance of distinct vision

$$M = -\frac{v_0}{u_0}\left(1+\frac{D}{f_e}\right) \Rightarrow M = -\frac{L}{f_0}\left(1+\frac{D}{f_e}\right)$$

where $\left[L = v_0 = \right.$ **the length of the microscope tube or the distance between the two lenses**

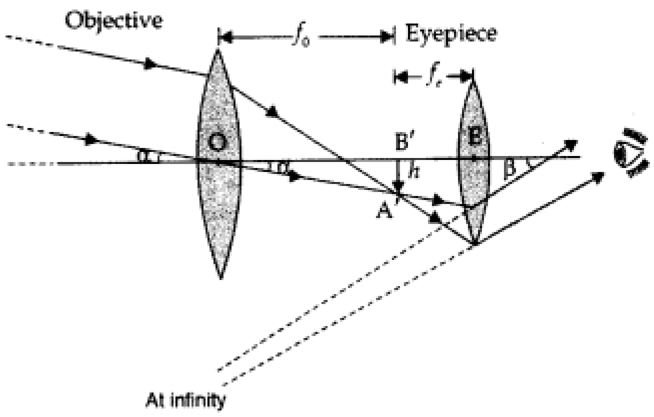
Question 4.
Draw a labelled ray diagram of an astronomical telescope in the near point position. Write the expression for its magnifying power.
Answer:



Least distance of distinct vision

$$\text{Magnifying power (MP)}, \ m = -\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$$

Question 5.
Draw a labelled ray diagram, showing the image formation of an astronomical telescope in the normal adjustment position. Write the expression for its magnifying power
Answer:
(i) Magnifying power m = −f0fe. It does not change with increase of aperature of objective lens, because focal length of a lens has no concern with the aperature of lens.

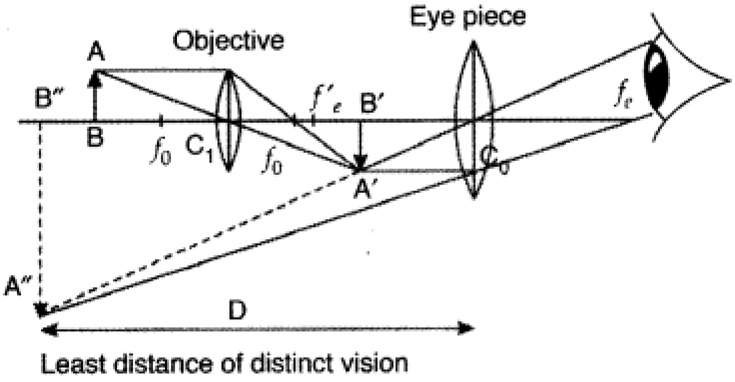


Astronomical telescope in normal adjustment

(ii) Drawbacks :

- Images formed by these telescopes have chromatic aberrations.
- Lesser resolving power.
- The image formed is inverted and faintes.

Question 6.
Draw a ray diagram for the formation of image in a compound microscope. Write the expression for its magnifying power.
Answer:



Compound microscope

When the final image is formed at the least distance of distinct vision

Question 7.
A ray of light passing through an equilateral triangular glass prism from air undergoes minimum deviation when angle of incidence is 3/4th of the angle of prism. Calculate the speed of light in the prism.
Answer:

Given : $i = \frac{3}{4}$ A where $\begin{bmatrix} i = \text{angle of incidence} \\ A = \text{angle of prism} \end{bmatrix}$

We know, $\mu = \dfrac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$

...where [δ_m = angle of minimum deviation

or $\dfrac{C_1}{C_2} = \dfrac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$

or $\delta_m = 2i - A = 2 \times \frac{3}{4} A - A = \frac{A}{2}$

$\delta_m = \frac{60°}{2} = 30°$. $\Rightarrow \dfrac{C_1}{C_2} = \dfrac{\sin 45°}{\sin 30°} = \sqrt{2}$

Question 8.
Calculate the distance of an object of height h from a concave mirror of focal length 10 cm, so as to obtain a real image of magnification 2.
Answer:
Given : f = -10 cm; Magnification, m = 2
To calculate : u = ?

We have : $\frac{h_1}{h_0} = \frac{-v}{u}$

Mirror formula : $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

As image formed is to be real

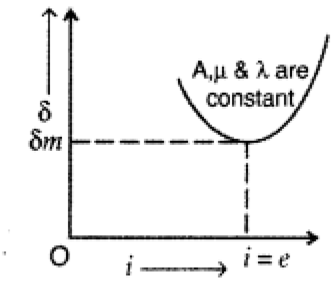
$\frac{v}{u} = 2$ or $v = 2u$

or $\frac{-1}{10} = \frac{1}{2u} + \frac{1}{u}$ or $\frac{-1}{10} = \frac{3}{2u}$

or $u = -15$

∴ **Object distance = 15 cm**

Question 9.
Define refractive index of a transparent medium. A ray of light passes through a triangular prism. Plot a graph showing the variation of the angle of deviation with the angle of incidence.
Answer:
Refractive index of a transparent medium is the ratio of the speed of light in free space to the speed in the given medium.



Graph of i – δ

Question 10.
(i) What is the relation between critical angle and refractive index of a material?

(ii) Does critical angle depend on the colour of light? Explain.

Answer:

(i) $\mu = \frac{1}{\sin i_c}$

(ii) For a given medium μ depends on the colour,

μ for violet $\mu_v > \mu_r$,

$\therefore$ Critical angle $i_c = \sin^{-1}\left(\frac{1}{\mu}\right)$ is greater for red colour.

Question 11.
The radii of curvature of the faces of a double convex lens are 10 cm and 15 cm. If focal length of the lens is 12 cm, find the refractive index of the material of the lens.
Answer:
Given : R_1 = 10 cm,
R_2 = -15 cm,
f = 12 cm
Using lens maker's formula, we have

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

$$\Rightarrow \frac{1}{12} = (n-1)\left(\frac{1}{10} - \frac{1}{-15}\right)$$

$$\Rightarrow \frac{1}{12} = (n-1)\left(\frac{3+2}{30}\right)$$

$$\Rightarrow (n-1) = \frac{30}{5} \times \frac{1}{12} = \frac{1}{2}$$

$$\therefore n = 1 + \frac{1}{2} = \frac{3}{2} = 1.5$$

Refractive index of the material of the lens :

Question 12.
(a) The bluish colour predominates in clear sky.
(b) Violet colour is seen at the bottom of the spectrum when white light is dispersed by a prism.
State reasons to explain these observations.
Answer:
(a) The scattering of light by the atmosphere is colour dependent. According to Rayleigh's law, the intensity of scattered light, I∝1λ4
Blue light is scattered much more strongly than red light. The blue component of light is proportionately more in the light coming from different parts of the sky. This gives the impression of the blue sky.

(b) As refractive index of prism is different for different colours, therefore, different colours deviate through different angles on passing through the prism. As $\lambda_{violet} < \lambda_{red}$ therefore $\mu_{violet} > \mu_{red}$. Hence $\delta_{violet} >$

δ_{red} maximum deviation is of violet colour. That is why violet colour, is seen at the bottom of the spectrum when white light is dispersed by a prism.

Question 13.
A biconvex lens has a focal length 2/3 times the radius of curvature of either surface. Calculate the refractive index of lens material.
Answer:
Given : $f = \frac{2}{3}$ R, R_1 = R, R_2 = – R
Using the *lens maker's formula* :

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

$$\Rightarrow \frac{1}{(^2/_3 R)} = (n-1)\left(\frac{1}{R} - \frac{1}{(-R)}\right)$$

$$\Rightarrow \frac{3}{2R} = (n-1)\frac{2}{R} \Rightarrow \quad (n-1) = \frac{3}{2R} \times \frac{R^2}{2R} = \frac{3}{4}$$

$$\therefore \quad n = \frac{3}{4} + 1 = \frac{7}{4} = \mathbf{1.75}$$

Question 13.
(i) Why does the Sun appear reddish at sun-set or sun-rise?
(ii) For which colour the refractive index of prism material is maximum and minimum?
Answer:
(i) During Sunrise or sunset, the Sun is near the horizon. Sunlight has to travel a greater distance. So shorter waves of blue region are scattered away by the atmosphere. Red waves of longer wavelength are least scattered and reach the observer. So the Sun appears reddish.
(ii) Refractive index of prism material is maximum for violet colour and refractive index of prism material is minimum for red colour.

Question 14.
Find the radius of curvature of the convex surface of a plano-convex lens, whose focal length is 0.3 m and the refractive index of the material of the lens is 1.5.
Answer:
Given : f = 0.3 m = 30 cm,
$R_1 = \infty$ (for plane surface), R_2 = ? n = 1.5
Applying *lens maker's formula,* we have

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

$$\Rightarrow \frac{1}{30} = (1.5-1)\left(\frac{1}{\infty} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{30 \times 0.5} = \left(\frac{-1}{R_2}\right) \qquad \Rightarrow R_2 = -15 \text{ cm}$$

∴ Radius of curvature = -15 cm.

Question 15.
(i) Out of blue and red light which is deviated more by a prism? Give reason.
(ii) Give the formula that can be used to determine refractive index of material of a prism in minimum deviation condition.
Answer:
(*i*) Since $\lambda_{red} > \lambda_{blue}$ Hence $n_{blue} > n_{red}$
$\therefore$ Blue light is deviated more by a prism than red.

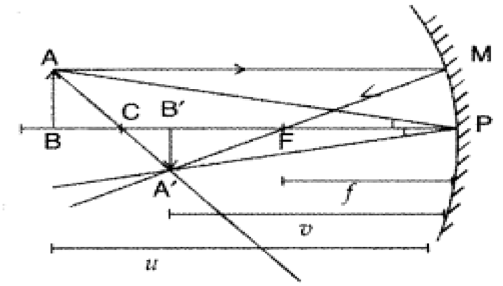
(*ii*) Refractive index, $n = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\dfrac{A}{2}}$

...where $\begin{bmatrix} A = \text{Angle of prism} \\ \delta_m = \text{Angle of minimum deviation} \end{bmatrix}$

Question 16.
Two convex lenses of same focal length but of aperture Ar and A2 (A2 < A-,), 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.
Answer:
Resolving power of a telescope is given by R.P.
$= \dfrac{A}{1.22\lambda}$.
From the given condition, the ratio of resolving power of two astronomical telescopes will be R.P, A,
$\dfrac{R.P_1}{R.P_2} = \dfrac{A_1}{A_2}$. ...[as λ is same
Telescope with large aperture (A_1) should be preferred as it increases the resolution by collecting more light.

4 Mark Questions

Question 1.
With the help of a suitable ray diagram, derive the mirror formula for a concave mirror.
Answer:
Consider a concave mirror of focal length/, radius of curvature R receiving light from an object AB placed between F and C as shown in the figure. The image will be formed as shown in the ray diagram.



Using Cartesian sign convention, we find
Object distance, BP = – u
Image distance B'P = – v
Focal length, FP = – l
Radius of curvature, CP = -R = -2f

Now $\Delta A'B'C \sim \Delta ABC$

$$\therefore \quad \frac{A'B'}{AB} = \frac{CB'}{BC} = \frac{CP - B'P}{BP - CP} = \frac{-R + v}{-u + R} \qquad \ldots(i)$$

As $\angle A'PB' = \angle APB \quad \therefore \Delta A'B'P \sim \Delta ABP$

$$\text{Consequently,} \quad \frac{A'B'}{AB} = \frac{B'P}{BP} = \frac{-v}{-u} = \frac{v}{u} \qquad \ldots(ii)$$

From equations (*i*) and (*ii*), we have

$$\frac{-R + v}{-u + R} = \frac{v}{u} \qquad \Rightarrow -uR + uv = -uv + vR$$

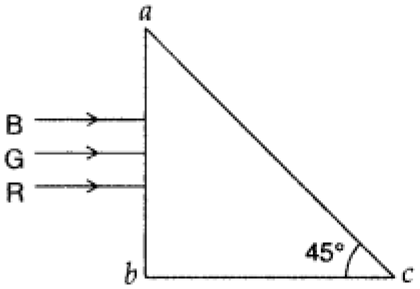
$$\Rightarrow \quad vR + uR = 2uv$$

Dividing both sides by uvR, we have $\frac{1}{u} + \frac{1}{v} = \frac{2}{R}$

But $R = 2f$ $\qquad \therefore \frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

This proves the mirror formula for a concave mirror.

Question 2.
Three light rays red (R), green (G) and blue (B) are incident on a right B angled prism 'abc' Q at face 'ab'. The R refractive indices of the material of the prism for red, green and blue wavelengths are 1.39, 1.44 and 1.47 respectively. Out of the three which colour ray will emerge out of face 'ac'? Justify your answer. Trace the path of these rays after passing through face 'ab'.



Answer:
Critical angle i_c for total internal reflection is related to refractive index μ as

$$i_c = \sin^{-1}\left(\frac{1}{\mu}\right)$$

Critical angle for :

$$\text{Red}: i_r = \sin^{-1}\left(\frac{1}{1.39}\right) = 46^\circ$$

$$\text{Green}: i_g = \sin^{-1}\left(\frac{1}{1.44}\right) = 43.9^\circ$$

$$\text{Blue}: i_b = \sin^{-1}\left(\frac{1}{1.47}\right) = 42.8^\circ$$

Incident angle in the surface ac is 45° for all the three colours. So red colour will undergo refraction while the other two colours will undergo total internal reflection in a.c. It is indicated in the figure. All the three colours will undergo total internal reflection if they are incident normally on one of the faces of an equilateral prism as shown in Figure 3. This is due to the reason that the incident angle on the second surface will be greater than critical angle for all the colours.

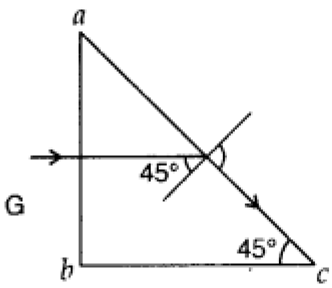


Figure 1

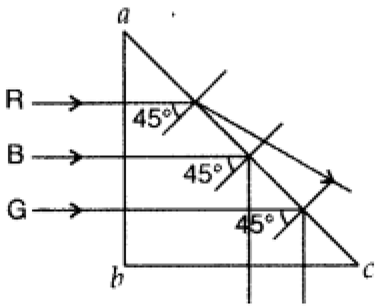


Figure 2

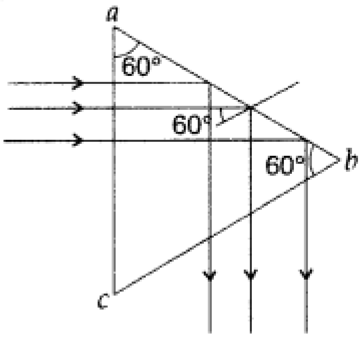
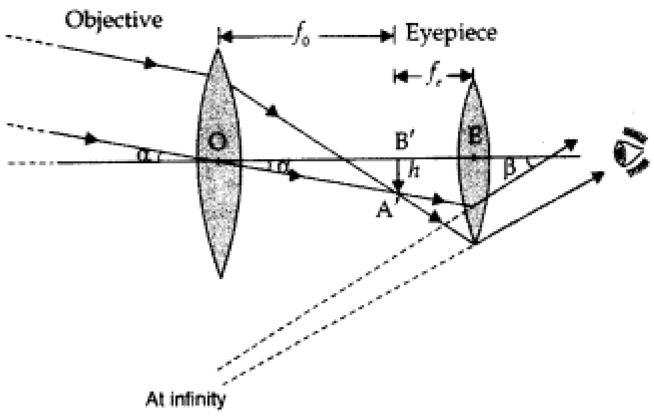


Figure 3

Question 3.
(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 1 D. What is its magnifying power in normal adjustment?

Answer:
(i) Magnifying power m = −f0fe. It does not change with increase of aperature of objective lens, because

focal length of a lens has no concern with the aperature of lens.



Astronomical telescope in normal adjustment

(ii) Drawbacks :

- Images formed by these telescopes have chromatic aberrations.
- Lesser resolving power.
- The image formed is inverted and faintes.

(*ii*) Magnifying power, $m = \frac{f_0}{f_e}$

Given : Power of eyepiece, $P_e = 10$ D,

i.e., $f_e = 10$ cm

Power of objective, $P_0 = 1$ D, *i.e.*, $f_0 = 100$ cm

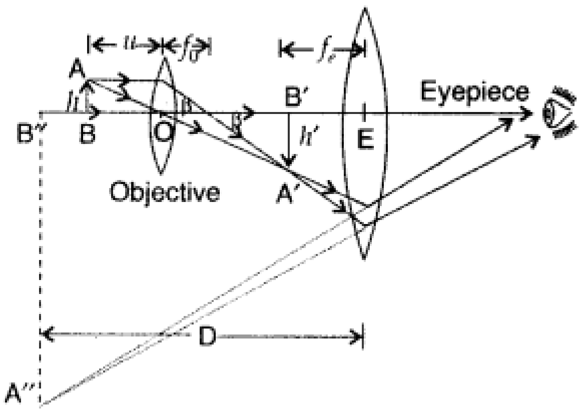
$\therefore$ **Power in normal adj.,** $m = \frac{100}{10} = \mathbf{10}$

Question 4.
(i) Draw a neat labelled ray diagram of a compound microscope. Explain briefly its working.
(ii) Why must both the objective and the eye-piece of a compound microscope have short focal lengths?

Answer:

(i)

(a) Ray diagram of a compound microscope : A schematic diagram of a compound microscope is shown in the figure. The lens nearest the object, called the objective, forms a real, inverted, magnified image of the object. This serves as the object for the second lens, the eyepiece, which functions essentially like a simple microscope or magnifier, produces the final image, which is enlarged and virtual. The first inverted image is thus near (at or within) the focal plane of the eyepiece, at a distance appropriate for final image formation at infinity, or a little closer for image formation at the near point. Clearly, the final image is inverted with respect to the original object.



Magnification due to a compound microscope.
The ray diagram shows that the (linear) magnification due to the objective, namely h'/h, equals

$$m_0 = \frac{h'}{h} = \frac{L}{f_0} \qquad \ldots(i)$$

$$\because \tan\beta = \left(\frac{h}{f_0}\right) = \left(\frac{h'}{L}\right)$$

Here h' is the size of the first image, the object size being h and f_0 being the focal length of the objective. The first image is formed near the focal point of the eyepiece. The distance L, i.e., the distance between the second focal point of the objective and the first focal point of the eyepiece (focal length f_e) is called the tube length of the compound microscope.

As the first inverted image is near the focal point of the eyepiece, we use for the simple microscope to obtain the (angular) magnification me due to it when the final image is formed at the near point, is

$$m_e = 1 + \frac{D}{f_e} \qquad \ldots(ii)$$

When the final image is formed at infinity, the angular magnification due to the eyepiece, me = (D//e)

$$m_e = (D/f_e) \qquad \ldots(iii)$$

Thus, the total magnification from equation (i) and (iii), when the image is formed at infinity, is

$$m = m_0 m_e = \left(\frac{L}{f_0} \times \frac{D}{f_e}\right)$$

(b) Resolving power of a microscope :

$$\text{Resolving power (RP)} \propto \frac{\mu \sin\theta}{\lambda}$$

(i) The focal length of the objective lens has no effect on the resolving power of microscope.
(ii) When the wavelength of light is increased, the resolving power of a microscope

decreases because $RP \propto \frac{1}{\lambda}$

(ii) The magnifying power of a compound microscope is given by,

$$m = m_0 \times m_e = \frac{v_0}{u_0} \times \left(1 + \frac{D}{f_e}\right)$$
$$= \frac{f_0}{u_0 - f_0} \times \left(1 + \frac{D}{f_e}\right)$$

Angular magnification (m_0) of objective will be large when u_0 is slightly greater than f_0. Since microscope is used for viewing very close objects, so u0 is small. Consequently f_0 has to be small.
Moreover, the angular magnification (m_e) of the eyepiece will be large if f_0 is small.

7 Marks Questions

Question 1.
An illuminated object and a screen are placed 90 cm apart. Determine the focal length and nature of the lens required to produce a clear image on the screen, twice the size of the object.
Answer:
According to the question,

$$u + v = 90 \text{ cm} \qquad \ldots(i)$$
$$\frac{v}{u} = 2 \qquad \Rightarrow v = 2u \qquad \ldots(ii)$$

From equations (*i*) and (*ii*), we get

$$v = 2 \times 30 \text{ cm} = 60 \text{ cm}$$
$$\text{As, } f = \frac{uv}{u - v} \qquad \ldots\text{Here}\begin{bmatrix} u = 30 \text{ cm} \\ v = 60 \text{ cm}\end{bmatrix}$$
$$\therefore \quad f = \frac{-1800}{-30 - (+60)} = \frac{-1800}{-90} = 20 \text{ cm}$$

Nature of lens : Convex lens of focal length 20 cm is required.

Question 2.
The image obtained with a convex lens is erect and its length is four times the length of the object. If the focal length of the lens is 20 cm, calculate the object and image distances.
Answer:

$$f = 20 \text{ cm}, \qquad m = 4$$
$$m = \frac{v}{u} = 4 \qquad \therefore v = 4u \qquad \ldots(1)$$

Using the lens formula :

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$
$$\Rightarrow \quad \frac{1}{20} = \frac{1}{4u} - \frac{1}{u} \qquad \Rightarrow \frac{1}{20} = \frac{1-4}{4u} = \frac{-3}{4u}$$
$$\Rightarrow \quad -60 = 4u \qquad \therefore u = -15 \text{ cm}$$

Putting the value of u in eqn (i), we get v = – 60 cm

∴ Object distance, u = 15 cm and
Image distance, v = 60 cm.

Question 3.
A convex lens is used to obtain a magnified image of an object on a screen 10 m from the lens. If the magnification is 19, find the focal length of the lens. Draw a ray diagram to show refraction of a ray of monochromatic light passing through a glass prism.
Deduce the expression for the refractive index of glass in terms of angle of prism and angle of minimum deviation.
Answer:
Given : u = -10 m, m = 19
For real image m = -19

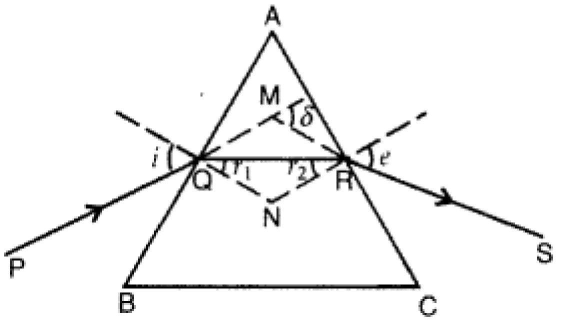
$$\therefore \quad m = \frac{v}{u} = -19 \qquad \Rightarrow v = -19\,\mu$$

We have for a lens,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \qquad \Rightarrow \frac{1}{f} = \frac{1}{10} + \frac{19}{10}$$

$$\Rightarrow \frac{1}{f} = \frac{20}{10} \qquad \Rightarrow f = \mathbf{0.5\ m}$$

Ray diagram : The minimum deviation Dm, the refracted ray inside the prism becomes parallel to its base, we have



$\delta = D_m$, *i.e.,* which implies $r_1 = r_2$

$r_1 + r_2 = A$

or $2r = A$, $\Rightarrow r = A/2$

In the $\delta = i + e - A$

$D_m = 2i - A$ or $i = \frac{(A + D_m)}{2}$

The refractive index of the prism is

n_{21} (Refractive index of 2 w.r.t. 1)

$$= \frac{n_2}{n_1} = \frac{\sin\left[\frac{(A+D_m)}{2}\right]}{\sin\left[\frac{A}{2}\right]}$$

For a small angle prism, *i.e.,* a thin prism, D_m is also very small and we get

$$n_{21} = \frac{\sin\left[\frac{(A+D_m)}{2}\right]}{\sin\left[\frac{A}{2}\right]} \approx \frac{\frac{(A+D_m)}{2}}{\frac{A}{2}}$$

$$\boxed{D_m = (n_{21} - 1)\,A}$$

Question 3.
Use the mirror equation to show that
(a) an object placed between / and 2/ of a concave mirror produces a real image beyond 2f.
(b) a convex mirror always produces a virtual image independent of the location of the object.
(c) an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image.

Answer:

(a) Using *mirror formula*, $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$

Now for a concave mirror, $f < 0$ and for an object on the left, $u < 0$

$$\therefore \; 2f < u < f \quad \text{or} \quad \frac{1}{2f} > \frac{1}{u} > \frac{1}{f}$$

$$\Rightarrow \; -\frac{1}{2f} < -\frac{1}{u} < -\frac{1}{f}$$

$$\Rightarrow \; \frac{1}{f} - \frac{1}{2f} < \frac{1}{f} - \frac{1}{u} < \frac{1}{f} - \frac{1}{f} \;\therefore\; \frac{1}{2f} < \frac{1}{v} < 0$$

This implies that v < 0, formed on left. Also the above inequality implies 2f > v

$|2f| < |v|$ ...[$\because$ **2f and v are –ve**

i.e., the real image is formed beyond 2f.

(b) For a convex mirror, f > 0 and for an object on left, u < 0. From the mirror formula, 1v=1f−1u This implies that 1v > 0 or v > 0 v

This shows that whatever be the value of u, a convex mirror forms a virtual image on the right.

(c) From mirror formula : 1v=1f−1u

For a concave mirror, f < 0 and for an object located between the pole and focus of a concave mirror, f < u < 0

$$\therefore \; \frac{1}{f} > \frac{1}{u} \quad \text{or} \quad \frac{1}{f} - \frac{1}{u} > 0 \quad \text{or} \quad \frac{1}{v} > 0$$

i.e., a virtual image is formed on the right

$$\text{Also } \frac{1}{v} < \frac{1}{|u|} \qquad \text{or } v > |u|$$

$$\therefore \; |m| = \frac{v}{|u|} > 1$$

i.e., image is enlarged

Question 4.

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.

Answer:

Given f_0 = 4 cm, f_e = 10 cm, u_0 = -6 cm

Magnifying power of microscope

$$M = \frac{|v_0|}{|\mu_0|}\left(1+\frac{D}{f_e}\right)$$

From lens formula, $\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0}$

$$\Rightarrow \frac{1}{v_0} = \frac{1}{f_0} + \frac{1}{\mu_0} = \frac{1}{4} + \frac{1}{(-6)} = \frac{3-2}{12} = \frac{1}{12}$$

$\therefore \; v_0 = 12$ cm

$$m = \frac{-12}{6}\left(1+\frac{25}{10}\right) = 2 \times 3.5 = -7$$

Negative sign shows that image is inverted

Length of microscope, $L = |v_0| + |\mu_e|$

For eye lens, $\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e} \Rightarrow \qquad \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e}$

$$\therefore \; \frac{1}{u_e} = \frac{-1}{25} - \frac{1}{10} \quad \Rightarrow \quad u_e = \frac{-50}{7} = 7.14 \text{ cm}$$

$\therefore \; L = |v_0| + |\mu_e| = 12 + 7.14 = \mathbf{19.14\ cm}$

Question 5.

A giant refracting telescope at an observatory has an objective lens of focal length 15 m. If an eyepiece lens of focal length 1.0 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 × 10^6 m and the radius of the lunar orbit is 3.8 × 10^6 m.

Answer:

Given : f_0 = 15 m, f_e = 1.0 cm = 0.01 m

(*i*) Angular magnification, $m = \frac{f_0}{f_e} = \frac{15}{0.01} = 1500$

(ii) Let d be the diameter of the image in metres Then angle subtended by the moon will be

$$\alpha = \frac{\text{Diameter of moon}}{\text{Radius of lunar orbit}} = \frac{3.42 \times 10^6}{3.8 \times 10^8}$$

Angle subtended by the image formed by the objective will also be equal to a and is given by

$$\alpha = \frac{\text{Diameter of image of moon}}{f_0} = \frac{d}{15}$$

$$\therefore \quad \frac{d}{15} = \frac{3.42 \times 10^6}{3.8 \times 10^8}$$

$\therefore$ Diameter of image of moon,

$$d = \frac{3.42 \times 10^6 \times 15}{3.8 \times 10^8} = \frac{51.3}{3.8} \times 10^{-2}$$

$$= 13.5 \times 10^{-2} = \mathbf{13.5\ cm}$$

Question 6.
A convex lens made up of glass of refractive index 1.5 is dipped, in turn,
(i) a medium of refractive index 1.6,
(ii) a medium of refractive index 1.3.
(a) Will it behave as a converging or a diverging lens in the two cases?
(b) How will its focal length change in the two media?
Answer:

Given : ${}^a\mu_g = 1.5$

Let f_{air} be the focal length of the lens in air
According to lens maker formula :

$$\frac{1}{f_{air}} = ({}^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f_{air}(1.5-1)}$$

$$\Rightarrow \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f_{air}(0.5)} = \frac{2}{f_{air}}$$

(*a*) *When lens is dipped in medium A :*

Here ${}^a\mu_A = 1.6$ ...(Given)

$$\frac{1}{f_A} = ({}^A\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

...where [f_A is the focal length of the lens, when dipped in medium A

$$\frac{1}{f_A} = \left(\frac{{}^a\mu_g}{{}^a\mu_A} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{f_A} = \left(\frac{1.5}{1.6} - 1\right)\frac{2}{f_{air}}$$

$$\Rightarrow \frac{1}{f_A} = \left(\frac{1.5 - 1.6}{1.6}\right)\frac{2}{f_{air}} = \frac{-1 \times 2}{16 f_{air}} = -\frac{1}{8 f_{air}}$$

$$\therefore f_A = -8 f_{air}$$

As the sign of f_B is opposite to that of f_{air}, the lens will behave as a diverging lens.
(b) When lens is dipped in medium B :

Here ${}^a\mu_B = 1.3$

Let f_B be the focal length of the lens, when dipped in medium B.

$$\frac{1}{f_B} = ({}^B\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{f_B} = \left(\frac{{}^a\mu_g}{{}^a\mu_B} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{f_B} = \left(\frac{1.5}{1.3} - 1\right)\left(\frac{2}{f_{air}}\right) = \left(\frac{1.5 - 1.3}{1.3}\right)\frac{2}{f_{air}}$$

$$= \frac{2}{13} \times 2 = \frac{4}{13}$$

$$\therefore f_B = \frac{13}{4} = 3.25 f_{air}$$

As the sign of f_B is same as that of /air, the lens will behave as a converging lens.

Question 7.

A converging lens has a focal length of 20 cm in air. It is made of a material of refractive index 1.6. It is immersed in a liquid of refractive index 1.3. Calculate its new focal length.

Answer:

According to lens maker formula :

$$\frac{1}{f_{air}} = ({}^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{20} = (1.6 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{20 \times 0.6} = \frac{1}{12}$$

It is immersed in a liquid of refractive index 1.3

${}^a\mu_W = 1.3$

$$\frac{1}{f_W} = ({}^W\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{f_W} = \left(\frac{{}^a\mu_g}{{}^a\mu_W} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{f_W} = \left(\frac{1.6}{1.3} - 1\right) \times \frac{1}{12}$$

$$= \left(\frac{1.6 - 1.3}{1.3}\right) \times \frac{1}{12} = \frac{3}{13} \times \frac{1}{12} = \frac{1}{52}$$

New focal length, f_w = 52 cm

Question 8.
A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in
(i) a medium of refractive index 1.65,
(ii) a medium of refractive index 1.33.
(a) Will it behave as a converging or a diverging lens in the two cases?
(b) How will its focal length change in the two media?
Answer:

Given : ${}^{a}\mu_{g} = 1.5$

$$\frac{1}{f_{air}} = ({}^{a}\mu_{g} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

...where [f_{air} is the focal length of the lens in air

$$\therefore \quad \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f_{air}({}^{a}\mu_{g} - 1)} = \frac{1}{f_{air}(1.5 - 1)}$$

$$= \frac{1}{f_{air}(0.5)} = \frac{2}{f_{air}} \quad ...(i)$$

(*i*) *When lens is dipped in medium A :* ${}^{a}\mu_{A} = 1.65$ **...(Given)**

$$\frac{1}{f_A} = ({}^{A}\mu_{g} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

...where [f_A is the focal length of the lens when dipped in the medium A

$$\Rightarrow \frac{1}{f_A} = \left(\frac{{}^{a}\mu_{g}}{{}^{a}\mu_{A}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{f_A} = \left(\frac{1.5}{1.65} - 1\right) \times \frac{2}{f_{air}}$$

$$= (0.9090 - 1) \times \frac{2}{f_{air}}$$

$$= \frac{(-0.09090) \times 2}{f_{air}} = -\frac{0.18}{f_{air}}$$

$$\therefore \quad f_A = -5.5\, f_{air}$$

Hence the lens will behave as a diverging lens.
(ii) When lens is dipped in medium B : aμB=1.33

$$\frac{1}{f_B} = ({}^B\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

...where f_B is the focal length of the lens in medium B

$$= \left(\frac{{}^a\mu_g}{{}^a\mu_B} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= \left(\frac{1.5}{1.33} - 1\right)\left(\frac{2}{f_{air}}\right)$$

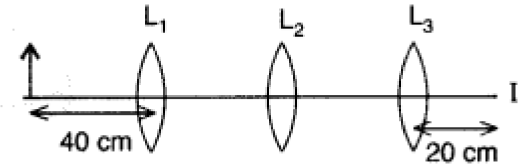
$$= \frac{0.17 \times 2}{1.33 f_{air}} = \frac{0.34}{1.33 f_{air}}$$

$$\therefore\ f_B = \frac{133}{34} = 3.91\ f_{air}$$

Hence the lens will behave as a converging lens.

Question 9.

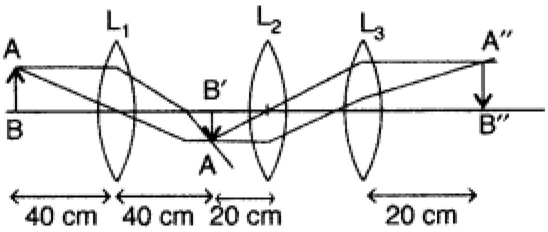
You are given three lenses L_1 L_2 and L_3 each of focal length 20 cm. An object is kept at 40 cm in front of L_1, as shown. The final real image is formed at the focus T of L_3. Find the separations between L_1, L_2 and L_3.



Answer:

For lens L_1

$f_1 = 20$ cm, $\qquad u_1 = -40$ cm



As $\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1}$ $\qquad \therefore \frac{1}{20} = \frac{1}{v_1} - \frac{1}{-40}$

$\Rightarrow v_1 = 40$ cm

For lens L_3

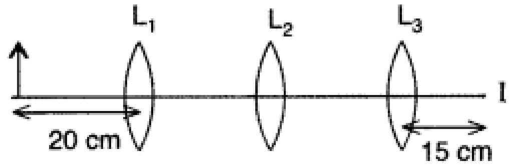
$f_3 = 20$ cm, $\qquad v_3 = 20$ cm,

$$\frac{1}{f_3} = \frac{1}{v_3} - \frac{1}{u_3} \Rightarrow \frac{1}{20} = \frac{1}{20} - \frac{1}{u_3} \quad \Rightarrow u_3 = \infty$$

This shows that for lens L_2 the object should be at focus of that lens.

Hence the distance between L_1 and $L_2 = v_1 + f_2 = 40 + 20 = 60$ cm
It clearly indicates that the distance between L_2 and L_3 can have any value.

Question 10.
You are given three lenses L_1 L_2 and L_3 each of focal length 15 cm. An object is kept at 20 cm in front of L_1, as shown. The final real image is formed at the focus 'I' of L_3. Find the separations between L_1, L_2 and L_3.



Answer:
Let f_1 f_2 and f_3 be the focal length of three lenses.
For lens L_1 : u = 20 cm

$$\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1} \Rightarrow \frac{1}{v_1} = \frac{1}{15} - \frac{1}{20} \Rightarrow v_1 = 60 \text{ cm}$$

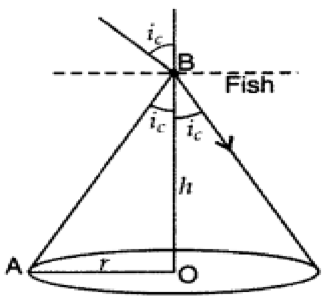
Now for lens L_3, $v_3 = 15$ cm, $f_3 = 15$ cm, $u_3 = ?$

$$\frac{1}{f_3} = \frac{1}{v_3} + \frac{1}{u_3} \Rightarrow \frac{1}{u_3} = \frac{1}{15} - \frac{1}{15} = 0 \therefore u_3 = \infty$$

It shows that lens infinite.
Hence for lens L_1, image is formed at a distance of 15 cm from L_2
∴ the focus of L_2 i.e. $u_2 = 15$ cm
Now, to calculate the distance between L_1 and L_2,
$u_1 + H_2 = 60 + 15 = 75$ cm
Distance between L_2 and $L_3 = v_2 + v_3 = \infty$ or can be any value.

Question 11.
A fish in a water tank sees the outside world as if it (the fish) is at the vertex of a cone such that the circular base of the cone coincides with the surface of water. Given the depth of water, where fish is located, being 'h' and the critical angle for water-air interface being 'i_c', find out by drawing a suitable ray diagram the relationship between the radius of the cone and the height 'h'.
Answer:
Let the fish beat point B, and OA is the base of the water

In ΔOAB, $\tan i_c = \frac{r}{h} \quad \Rightarrow i_c = \tan^{-1}\left(\frac{r}{h}\right)$



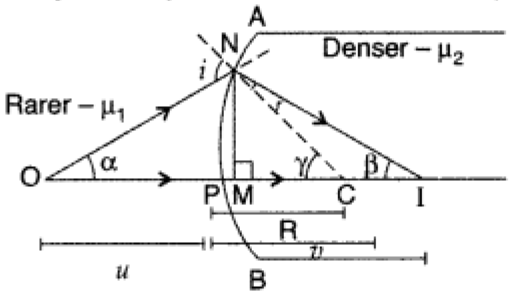
Draw a ray diagram to show the formation of the image of an object placed on the axis of a convex refracting surface, of radius of curvature 'R', separating the two media of refractive indices "n_1 and 'n_2' ($n_2 > n_1$). Use this diagram to
deduce the relation n2v−n1u=n2−n1R, where u and v represent respectively the distance of the object and the image formed.

In ΔNOC, i is an exterior angle,

$\therefore \quad i = \alpha + \gamma$

Similarly, from ΔNIC, we have

$\gamma = r + \beta \qquad \Rightarrow r = \gamma - \beta$



Suppose all the rays are paraxial
Then the angles i, r, a, P and y will be small

$$\therefore \quad \gamma = \tan\gamma = \frac{NM}{OM} = \frac{NM}{OP} \qquad \text{...[} \because \textbf{ P is close to M}$$

$$\beta = \tan\beta = \frac{NM}{MI} = \frac{NM}{PI} \text{ and}$$

$$\gamma = \tan\gamma = \frac{MP}{MC} = \frac{NM}{PC}$$

From *Snell's law of refraction,* $\dfrac{\sin i}{\sin r} = \dfrac{\mu_2}{\mu_1}$

As i and r are small

$$\therefore \quad \frac{i}{r} = \frac{\mu_2}{\mu_1} \qquad \Rightarrow \mu_1 i = \mu_2 r$$

$$\Rightarrow \quad \mu_1(\alpha + \gamma) = \mu_2(\gamma - \beta)$$

$$\Rightarrow \quad \mu_1\left[\frac{NM}{OP} + \frac{NM}{PC}\right] = \mu_2\left[\frac{NM}{PC} - \frac{NM}{PI}\right]$$

$$\Rightarrow \quad \mu_1\left[\frac{1}{OP} + \frac{1}{PC}\right] = \mu_2\left[\frac{1}{PC} - \frac{1}{PI}\right]$$

$$\Rightarrow \quad \frac{\mu_1}{OP} + \frac{\mu_1}{PC} = \frac{\mu_2}{PC} - \frac{\mu_2}{PI} \Rightarrow \frac{\mu_1}{OP} + \frac{\mu_2}{PI} = \frac{\mu_2 - \mu_1}{PC}$$

Using new Cartesian sign convention, we find
Object distance, OP = – u,
Image distance, PI = tv

Radius of curvature, PC = + R

$$\therefore \quad \frac{\mu_1}{-u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R} \Rightarrow \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \quad \ldots(i)$$

Here given $\mu_1 = n_1$ and $\mu_2 = n_2$

So equation becomes $\boxed{\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}}$

Fill in the Blanks

Q.1. Which of the colour of white light deviated most when passes through a prism is **---------------(Red light,Violet light)**

Q.2. For a total internal reflection is **------------------------(Light travels from denser to rarer medium)**

Q.3. Mirage is a phenomenon due to**----------------------(total internal reflection of light).**

Q.4. Critical angle of glass is θ_2 and that of water is θ_2. The critical angle for water and glass surface would be ($\mu_g = 3/2$, $\mu_w = 4/3$)**--------------(greater than θ_2)**

Q.5. A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will**-------------(become infinite)**

Q.6. Which of the following forms a virtual and erect image for all positions of the object is------------------ **(Concave lens,Convex mirror)**

Multiple choice questions

1. Which of the following lights deviates the most when it passes through a prism?

a. Red Light
b. Violet Light
c. Neither (a) nor (b)
d. Both (a) and (b)

Answer: (b) Violet Light

Explanation: Violet Light deviates the most when it passes through a prism.

2. Which of the following phenomena of light results in a mirage?

a. Refraction of light
b. Reflection of light
c. Total internal reflection
d. Diffraction of light

Answer: (c) Total internal reflection

Explanation: Total Internal Reflection results in a mirage.

3. For which of the following is the field of view maximum?

a. Concave mirror
b. Convex mirror
c. Plane mirror
d. Cylindrical mirror

Answer: (b) Convex Mirror

Explanation: For convex mirrors, the field of view is maximum.

4. What happens when the light is refracted into a medium?

a. Both frequency and wavelength of the light increase
b. The wavelength increases but the frequency remains unchanged
c. Both wavelength and frequency decrease
d. The wavelength decreases but the frequency remains constant

Answer: (b) The wavelength increases but the frequency remains unchanged

Explanation: When the light is refracted into a medium its wavelength increases but the frequency remains unchanged.

5. If a glass prism is dipped in water, what happens to its dispersive power?

a. Increases
b. Decreases
c. Does not change
d. No effect

Answer: (b) Decreases

Explanation: If a glass prism is dipped in water, its dispersive power decreases.

6. What should be increased to increase the angular magnification of a simple microscope?

a. The power of the lens
b. The focal length of the lens
c. Lens Aperture
d. Object Size

Answer: (a) The power of the lens

Explanation: The power of the lens should be increased to increase the angular magnification of a simple microscope.

7. Which of the following phenomenon is used in optical fibre?

a. Refraction
b. Diffraction
c. Scattering
d. Total Internal Reflection

Answer: (d) Total Internal Reflection

Explanation: Total Internal Reflection is used in optical fibre.

8. Which of the following statements is true for total internal reflection?

a. Light travels from rarer medium to denser medium
b. Light travels from denser medium to rarer medium
c. Light travels in water only
d. Light travels in the air only

Answer: (b) Light travels from denser medium to rarer medium

Explanation: For total internal reflection, the light must travel from a denser medium to a rarer medium.

9. A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then what is its focal length?

a. Focal Length will become zero
b. Focal Length will become infinite
c. Focal length will reduce, but not become zero
d. Remains unchanged

Answer: (b) Focal Length will become infinite

Explanation: The focal length of the lens becomes infinite.

10. For a telescope, the larger the diameter of the objective lens

a. Greater the resolving power
b. Greater the magnifying power
c. Smaller the resolving power
d. Smaller the magnifying power

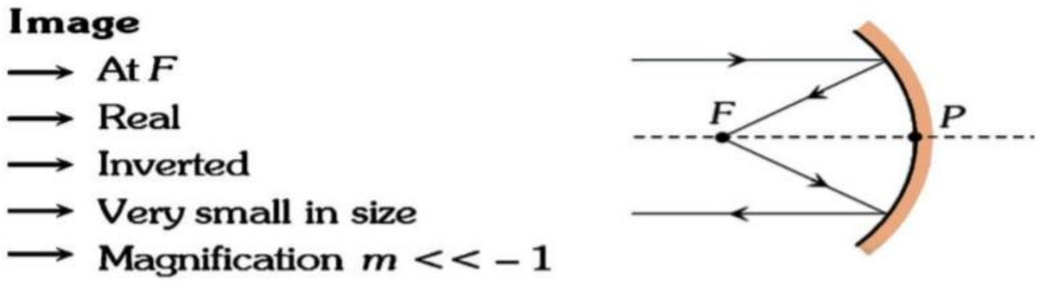
Answer: (a) Greater the resolving power

Explanation: For a telescope, the larger the diameter of the objective lens, the greater the resolving power.

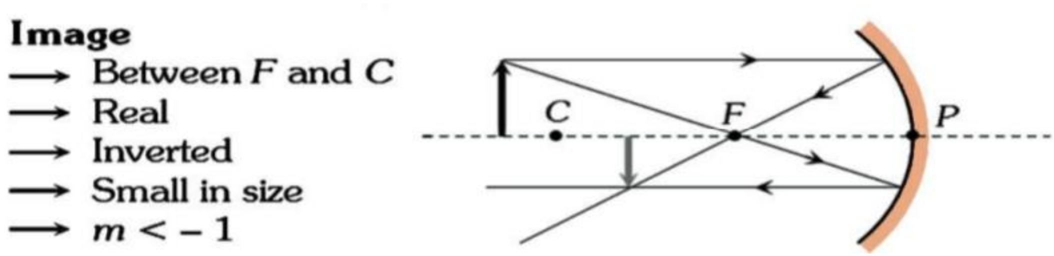
Diagrams

Image Formation by spherical Mirrors

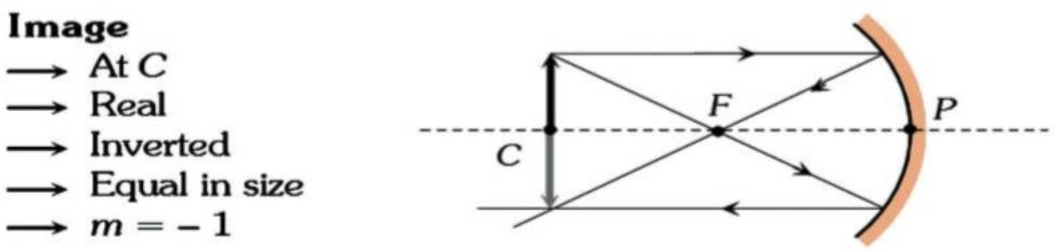
(1) When object is placed at infinite (i.e. u = ∞**)**



(2) When object is placed between infinite and centre of curvature (i.e. u> 2f)

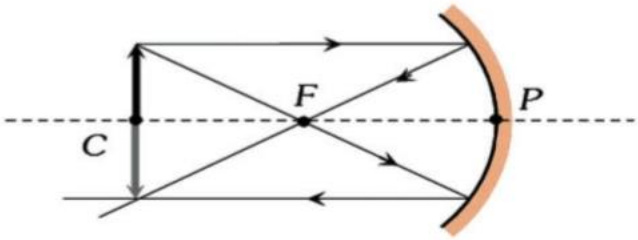


(3) When object is placed at centre of curvature (i.e. u = 2f)



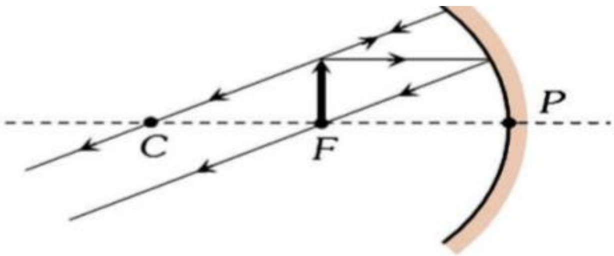
(4) When object is placed between center of curvature and focus (i.e. f< u<2f)

Image
- → At C
- → Real
- → Inverted
- → Equal in size
- → $m = -1$



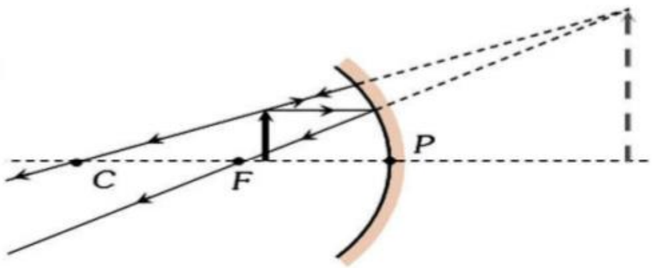
(5) When object is placed at fous (i.e. u = f)

Image
- → At ∞
- → Real
- → Inverted
- → Very large in size
- → $m >> -1$



(6) When object is placed between focus and pole (i.e. u<f)

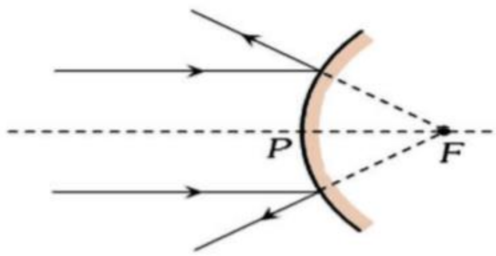
Image
- → Behind the mirror
- → Virtual
- → Erect
- → Large in size
- → $m > +1$



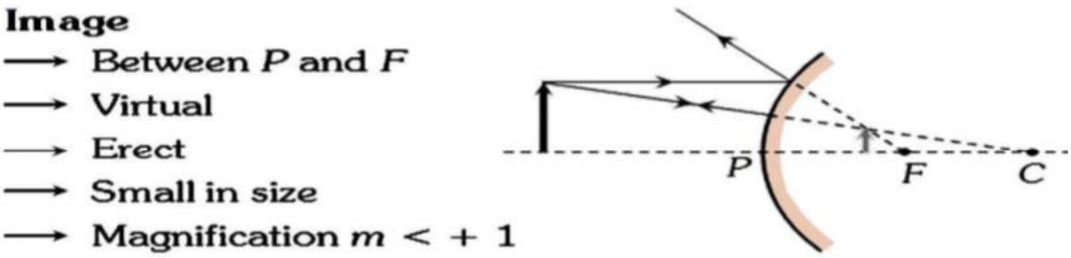
<u>**Convex mirror : Image formed by convex mirror is always virtual, erect and smaller in size.**</u>

(1) When object is placed at infinite (i.e. u = ∞)

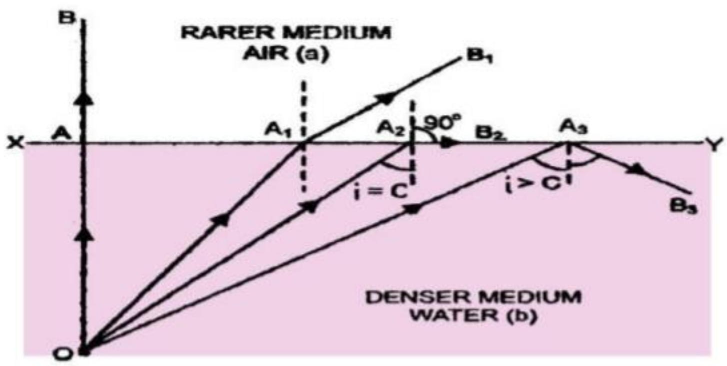
Image
- → At F
- → Virtual
- → Erect
- → Very small in size
- → Magnification $m << +1$



(2) When object is placed any where on the principal axis



Total Internal Reflection

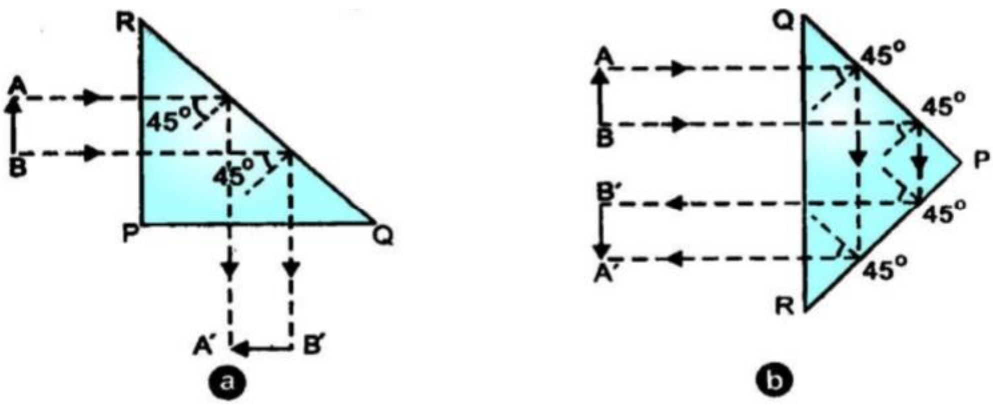


$$^{a}\mu_{b} = \frac{1}{\sin c}$$

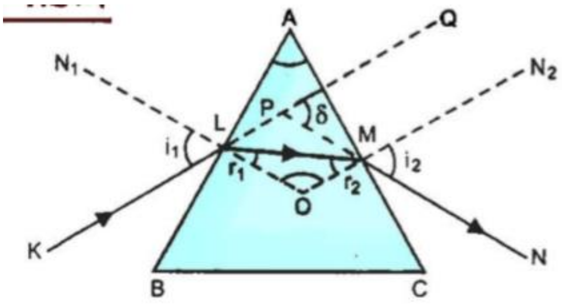
a = rarer

b = dense

Totally reflecting glass prisms



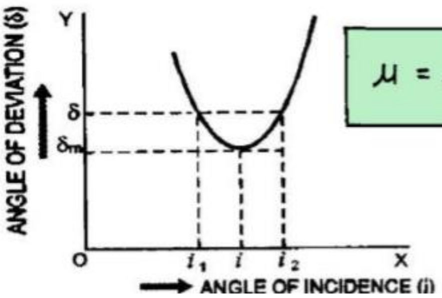
Prism



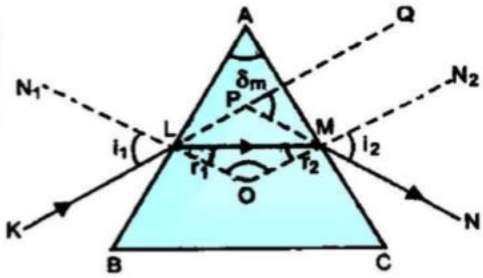
$$r_1 + r_2 = A$$

$$\delta = (i_1 + i_2) - A$$

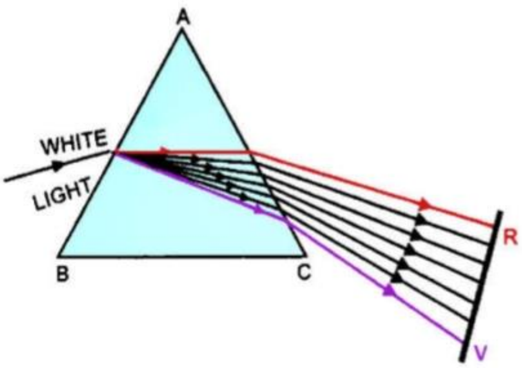
$$\delta = (\mu - 1)A$$

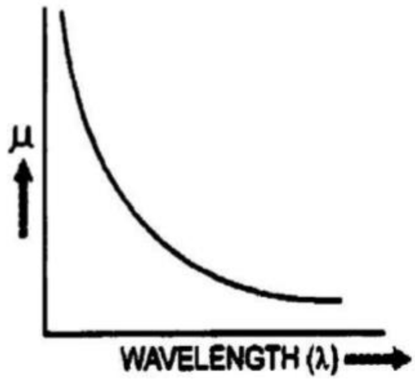


$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}$$

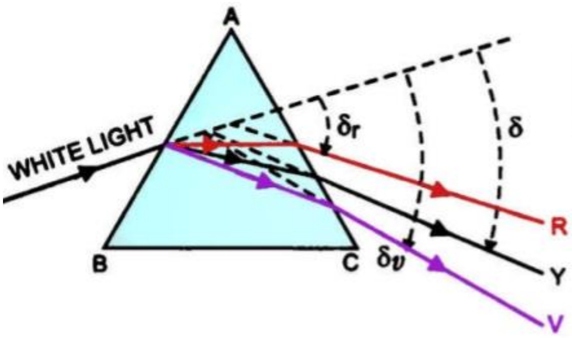


Dispersion of Light





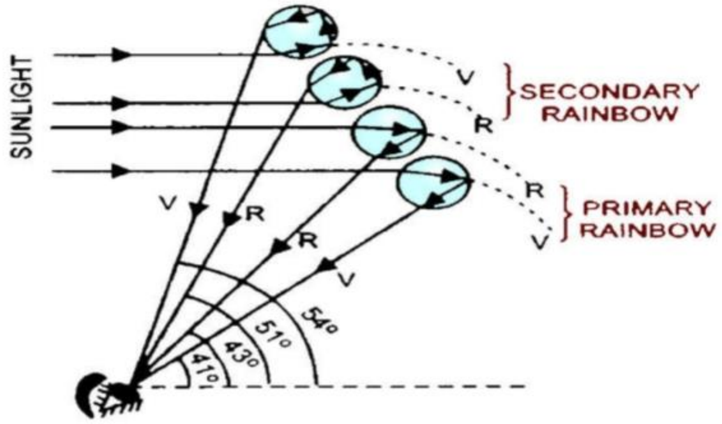
Angular Dispersion



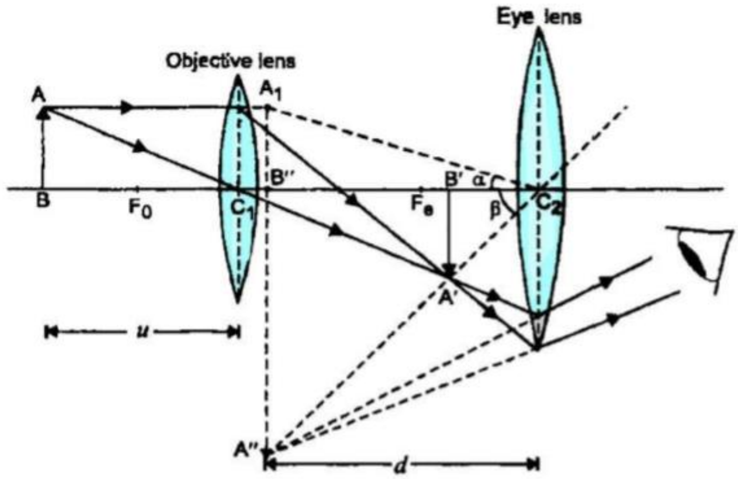
$$\text{Angular dispersion} = \delta_V - \delta_R$$

$$\delta_V - \delta_R = (\mu_V - \mu_R)A$$

Rainbow



Compound Microscope



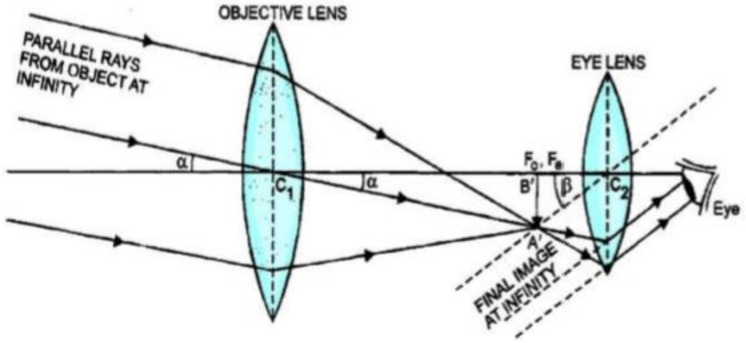
$$m = m_e \times m_o$$

$$m = -\frac{V_o}{u_o}\left(1 + \frac{d}{f_e}\right)$$

$$L = V_o + u_e$$

Astronomical Telescope

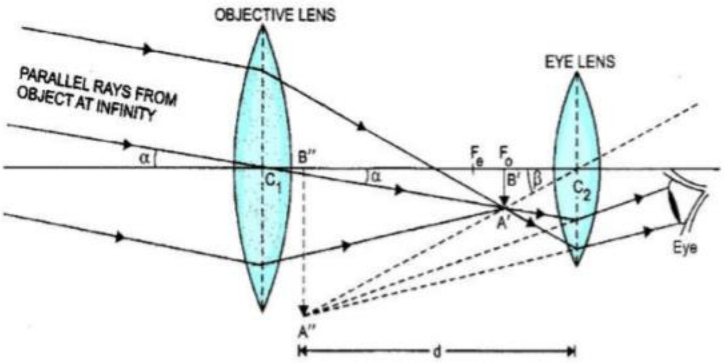
(1) Normal Adjustment



$$m = \frac{f_o}{-f_e}$$

$$L = f_o + f_e$$

(2) When the final image is formed at the least distance of distinct vision (d) form the eye

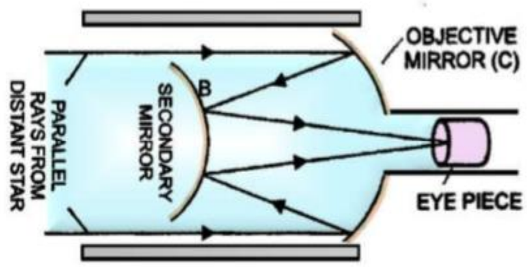


$$m = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{d}\right)$$

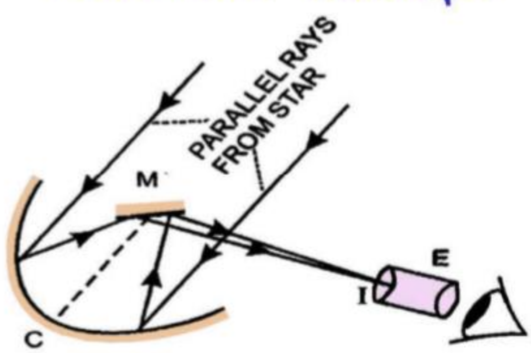
$$L = f_o + u_e$$

Reflecting type Telescope

(Cassegrainian Telescope)

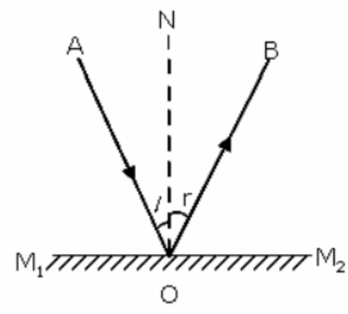


Newtonian Telescope



SUMMARY

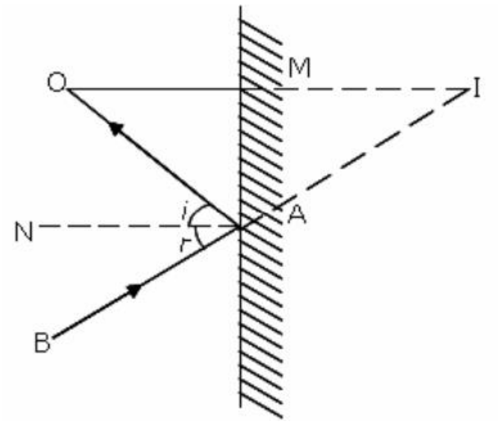
- **Laws of Reflection:**



The reflection at a plane surface always takes place in accordance with the following two laws:
(i) The incident ray, the reflected ray and normal to surface at the point of incidence all lie in the same plane.
(ii) The angle of incidence, i is equal to the angle of reflection r, i. e.,

$$\angle i = \angle r$$

- **Formation of Image by the Plane Mirror:**



The formation of image of apoint object O by a plane mirror is represented in figure. The image formed *I* has the following characteristics:
(i) The size of image is equal to the size of object.
(ii) The object distance = Image distance i.e., OM = MI.
(iii) The image is virtual and erect.
(iv) When a mirror is rotated through a certain angle, the reflected ray is rotated through twice this angle.

- **Reflection of Light from Spherical Mirror:**
  a) A spherical mirror is a part cut from a hollow sphere.
  b) They are generally constructed from glass.
  c) The reflection at spherical mirror also takes place in accordance with the laws of reflection.

- **Sign Convention:**
  Following sign conventions are the new cartesian sign convention:
  (i) All distances are measured from the pole of the mirror & direction of the incident light is taken as positive. In other words, the distances measured toward the right of the origin are positive.
  (ii) The distance measured against the direction of the incident light are taken as negative. In other words, the distances measured towards the left of origin are taken as negative.
  (iv) The distance measured in the upward direction,
  perpendicular to the principal axis of the mirror, are taken as positive & the distances measured in the downward direction are taken as negative.

- **Focal Length of a Spherical Mirror:**

a) The distance between the focus and the pole of the mirror is called focal length of the mirror and is represented by *f.*
b) The focal length of a concave mirror is positive and that of a convex mirror is positive and that of a convex mirror is negative.
c) The focal length of a mirror (concave or convex) is equal to half of the radius of curvature of the mirror, i.e., $f = \frac{R}{2}$.

- **Principal Axis of the Mirror:**
  The straight line joining the pole and the centre of curvature of spherical mirror extended on both sides is called principal axis of the mirror.
- **Mirror Formula:**

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

  Where u= distance of the object from the pole of mirror
  v = distance of the image from the pole of mirror
  f = focal length of the mirror

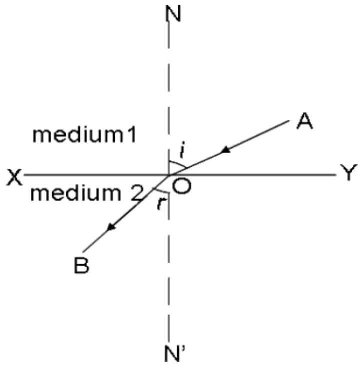
  $$f = \frac{r}{2}$$

  Where *r* is the radius of curvature of the mirror.
- **Magnification:**
  It is defined as the ratio of the size of the image to that of the object.
  Linear magnification,

  $$m = \frac{I}{O} = -\frac{v}{u} = \frac{f - v}{f} = \frac{f}{f - u}$$

  Where *I* size of image and *O*= size of object.
- Magnification, m is positive, implies that the image is real and inverted.
- Magnification, m is negative, implies that the image is virtual and erect.
- **Refraction:**
  When a ray of light falls on the boundary separating the two media, there is a change in direction of ray. This phenomenon is called refraction.
- **Laws of Refraction.**
  (i) The incident ray normal at the point of incidence and refracted ray all lie in one plane.
  (ii) For the same pair of media and the same colur of light, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant i.e.,

  $$\frac{\sin i}{\sin r} = {}_a\mu_b$$



  Where ${}_a\mu_b$ is a constant known as Refractive Index of the medium b with respect to the medium a, i is the angle incidence in medium a and r is the angle of refraction in medium b.

- **Principle of Reversibility of Light:**

  As light follows a reversible path,

  $$\frac{\sin r}{\sin i} = {}_b\mu_a$$

  Multiplying we get,

  $${}_a\mu_b \, X \, {}_b\mu_a = \frac{\sin i}{\sin r} x \frac{\sin r}{\sin i} = 1$$

  $${}_a\mu_b = \frac{1}{{}_b\mu_a}$$

- **Methods to Determine Refractive Index of a Medium:**

  Refractive index of a medium can also be determined from the following:

  (i) $\mu = \dfrac{\text{Velocity of light in air}}{\text{Velocity of light in the medium}}$

  (ii) $\mu = \dfrac{1}{\sin c}$

  Where c is the critical angle.

- **Critical Angle:**

  The Critical angle is the angle of incidence in a denser medium corresponding to which the refracted ray just grazes the surface of separation.

- **Apparent Depth of a Liquid:**

  If the object be placed at the bottom of a transparent medium, say water, and viewed from above, it will appear higher than it actually is.

  The refractive index μ in this case is:

  Refractive index of the medium, $\mu = \dfrac{\text{Real Depth}}{\text{Apparent Depth}}$

- **Refraction through a Single Surface:**

  If μ_1, μ_2 are refractive indices of first and second media, R the radius of curvature of spherical surface, formula is

  $$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R}$$

  where u and v are the distances of the object and the image from the centre of the refracting surface of radius of curvature R respectively.

- **Refraction through a Thin Lens**

  If R_1 and R_2 are radii of curvature of first and second refracting surfaces of a thin lens of focal length f, then lens-makers formula is

  $$\frac{1}{f} = \left(\frac{\mu_2 - \mu_1}{\mu_1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

If the lens is surrounded by air, $\mu_1 = 1$ and $\mu_2 = \mu$, then

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

- **Thin lens formula:**

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

- **Magnification Produced by a Lens:**

$$m = \frac{I}{O} = \frac{v}{u}$$

Where I is size of image and O is size of object.

- **Power of a Lens:**

The power of a lens P is its ability to deviate the ray towards axis.

$$P = \frac{1}{f(\text{ in metres})} \, Diopters$$

$$= \frac{100}{f(in \text{ cm})} \, Diopters$$

- **Focal Length of Thin Lenses:**

The focal length (f) of thin lenses of focal lengths f_1, f_2, f_3.................placed in contact of each other is,

$$\frac{1}{f} = \frac{1}{f_1'} + \frac{1}{f_2'} + \frac{1}{f_3'} + \ldots..$$

- **Refraction Through Prism**:

When a ray of monochromatic light is refracted by a prism, the deviation δ produced by the prism is

$$\delta = i + e - A$$

Where i = angle of incidence

e = angle of emergence

A = angle of the prism

- **Angle of Deviation:**

The angle of deviation δm is minimum, when ray passes symmetrically through the prism. The refractive index μ of the prism is

$$\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin \frac{A}{2}}$$

- **Dispersion:**

The splitting of white light into constituent colours is called the dispersion. A prism causes deviation as well as dispersion.

- **Optical Instruments**:

Optical instruments are the devices which help human eye in observing highly magnified images of tiny objects, for detailed examination and in observing very far objects whether terrestrial or astronomical.

- **Human Eye**:
  a) It is the most familiar and complicated optical instrument provided by nature to living beings. In this device, light enters through a curved front surface, called cornea, passes through the pupil – central hole in the iris.
  b) The light is focused by the eye lens on the retina.
  c) The retina senses light intensity and colour and transmits the electrical signals via optical nerves to the brain.
  d) Brain finally processes the information.
- **Microscope**:
  a) A simple microscope is a short focal length convex lens.
  b) The magnifying power of a simple microscope is
  $$M = 1 + \frac{D}{f}$$
  c) The magnifying power, M of a compound microscope is
  $$M = M_0 x M_e = \frac{v}{u}\left(1 + \frac{D}{f_e}\right)$$
  Where, M_o and M_e denotes the linear magnifying of the objective and eye lens.
- **Telescope:**
  a) The magnifying power, M of refracting telescope is
  $$M = \frac{f_0}{f_e}$$
  $$L = (f_0 - f_e)$$
  Where L is the length of the telescope.
  b) For the final image is formed at the least distance of distant vision, the magnifying power is
  $$M = \frac{f_0}{f_e}(1 + \frac{F_e}{D})$$
  c) The resolving power of a telescope
  $$\theta = \frac{1.22\lambda}{d}$$
  Where, λ = wavelength of light, θ = angle subtended by the point object at the objective and d = diameter of the objective of the telescope.