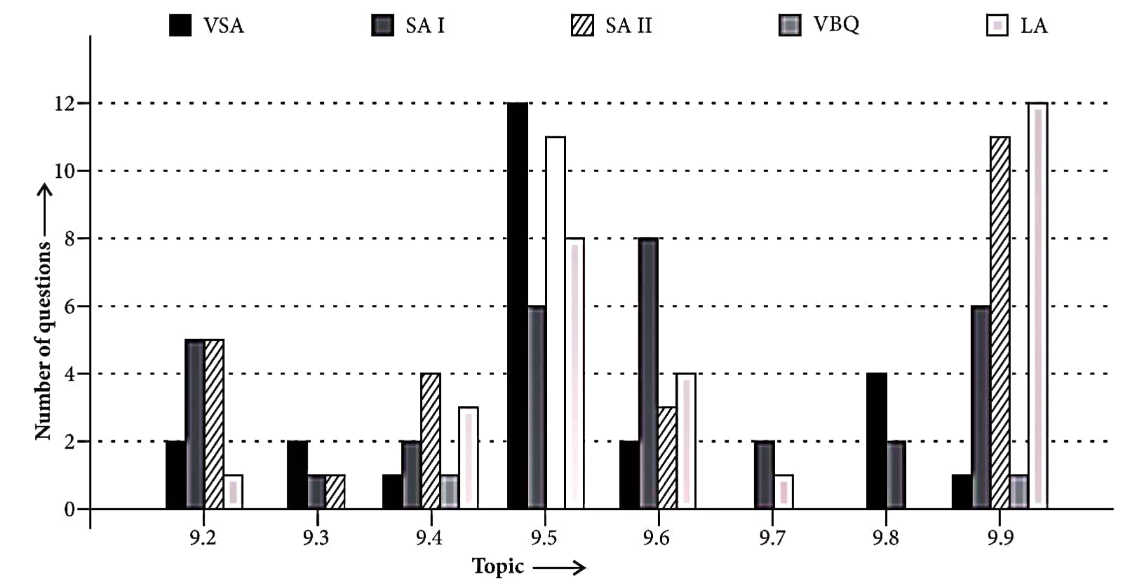
09 Ray Optics and Optical Instruments

Topicwise Analysis of Last 10 Years' CBSE Board Questions



- Maximum weightage is of *Optical Instruments.*
- Maximum VSA type questions were asked from *Refraction at spherical surface and by Lenses.*
- Maximum LA type questions were asked from *Optical Instruments.*

QUICK RECAP

Optics : It is the branch of physics which deals with the study of light and the phenomena associated with it. It is divided into two branches:

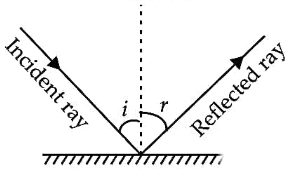
- Geometrical optics or ray optics
- Physical optics or wave optics

- **Geometrical optics or ray optics :** It treats propagation of light in terms of rays and is valid only if wavelength of light is much lesser than the size of obstacles. It deals with the formation of images by ordinary geometrical methods and the laws of reflection and refraction.

- **Physical optics or wave optics :** It deals with the theories of the nature of light and provides an explanation for different phenomena like reflection and refraction on the basis of Huygens principle, interference, diffraction and polarisation.

Reflection of light : When a light ray strikes the surface separating two media, a part of it gets reflected i.e. returns back in the initial medium. It is known as reflection. The angles which the incident ray and the reflected ray make with the normal to the surface are known as the angles of incidence and angle of reflection respectively.

- **Laws of reflection of light :** The two laws of reflection of light are as follows:
  - The incident ray, the reflected ray and the normal to the surface, all lie in the same plane.
  - The angle of incidence i is equal to the angle of reflection *r. i.e.* $i = r$



- When light is reflected from a denser medium surface, there occurs a phase change of π but no phase change occurs if it is reflected from a rarer medium surface.
- On reflection, the velocity, wavelength and frequency of light do not change. But amplitude or intensity of the reflected ray is less than that of incident ray.

Reflection by a plane mirror : The focal length and radius of curvature of plane mirror are infinite.

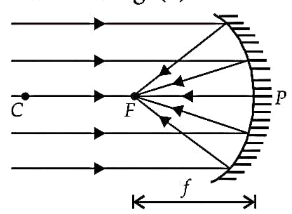
- The image formed by the plane mirror is at the same distance behind the mirror as the object is in front of it. The image formed by the plane mirror is always erect, virtual and of same size as the object.
- If the mirror moves away or towards an object by a distance d, then the image moves away or towards the object by a distance $2d$.
- If the mirror moves with speed v towards or away from fixed object, then image appears to move towards or away from the object with speed $2v$.
- When a plane mirror is rotated through an angle θ keeping the incident ray fixed, then the reflected ray rotates by angle 2θ in the same sense.
  - Deviation : It is defined as the angle between directions of incident ray and emergent ray. On reflection from a plane mirror, Angle of deviation, $\delta = 180° - 2i$
  - For normal incidence, $\delta = 180°$ $(\because\ i = 0°)$
  - **Glancing angle :** It is defined as the angle between incident ray and plane reflecting surface. If α is the glancing angle, then on reflection from a plane mirror,

  Angle of deviation, $\delta = 2\alpha$ $(\because \alpha = 90° - i)$
- When a man is standing exactly midway between a wall and a mirror, and he wants to see the full height (h) of the wall behind him in the plane mirror in front of him, the minimum length of mirror has to be $h/3$.
- When two plane mirrors are inclined at an angle θ and an object is placed between them, the number of images of an object are formed due to multiple reflections.

$n = \frac{360°}{\theta}$	**Position of object**	**Number of images**
even	anywhere	$n - 1$
odd	symmetric	$n - 1$
	asymmetric	n

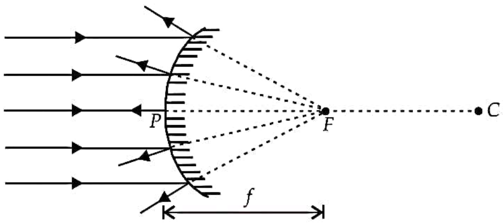
Spherical mirror : A spherical mirror is part of a spherical reflecting surface.
Spherical mirror is of two types :

- **Concave mirror :** When the reflection takes place from inner surface and outer surface is polished, the mirror is known as concave mirror. As shown in fig. (a).



Concave mirror (Fig. a)

- **Convex mirror :** When the reflection takes place from outer surface and inner surface is polished, the mirror is known as convex mirror. As shown in fig. (b).



Convex mirror (Fig. b)

where
P = Pole of mirror
F = Principal focus
C = Centre of curvature
$PC = R$ = Radius of curvature
$PF = f$ = Focal length

- **Sign conventions**
  - All distances have to be measured from the pole of the mirror.
  - Distances measured in the direction of incident light are positive, and those measured in opposite direction are taken as negative.
  - Heights measured upwards and normal to the principal axis of the mirror are taken as positive, while those measured downwards are taken as negative.
- **Spherical mirror formulae :** The focal length of a spherical mirror of radius R is given by

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

f (or R) is negative for concave or converging mirror and positive for convex or diverging mirror.

- **Transverse or linear magnification**

$$m = \frac{\text{size of image}}{\text{size of object}} = -\frac{v}{u}$$

Here –ve magnification implies that image is inverted with respect to object while +ve magnification means that image is erect with respect to object.

- **Longitudinal magnification :** When an object lies along the principal axis, then its magnification is known as longitudinal magnification. For small object, it is given by

$$m_L = -\frac{dv}{du}$$

- **Superficial magnification :** When a two dimensional object is placed with its plane perpendicular to principal axis, then its magnification is known as superficial magnification or areal magnification and is given by

$$m_S = \frac{\text{area of image}}{\text{area of object}} = m^2$$

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

where
u = distance of object from the pole of the mirror
v = distance of image from the pole of the mirror
f = distance between the focus and the pole of the mirror.

- Practical applications of spherical mirrors
  - A convex mirror is used as a rear view mirror in vehicles like cars, motorcycles etc.
  - A convex mirror is used as a reflector in street lamps.
  - A concave mirror is used as a reflector in search light, head lights of motor vehicles, telescopes, solar cookers etc.
- A concave mirror is used in the ophthalmoscope.

Refraction of light : When a ray of light passes from one medium to another, in which it has a different velocity, there occurs a change in the direction of propagation of light except when it strikes the surface of separation of two media normally. This bending of a ray of light is known as refraction.

- The angles made by the incident ray and the refracted ray with the normal to the separating surface at the point of incidence are known as the angles of incidence and of refraction respectively.
- **Laws of refraction :** The two laws of refraction are as follows :
  - The incident ray, the normal and the refracted ray all lie in the same plane.
  - The ratio of the sine of angle of incidence to the sine of angle of refraction for any two media is constant for a light of definite colour. This constant is denoted by ${}^1\mu_2$ or μ_{21} called the refractive index of the second medium with respect to the first, the subscripts 1 and 2 indicating that the light passes from medium 1 to medium 2.

$$\frac{\sin i}{\sin r} = {}^1\mu_2$$

This is also known as Snell's law.
where i = angle of incidence,
r = angle of refraction.

- **Absolute refractive index :** Refractive index of a medium with respect to vacuum (or in practice, air) is known as absolute refractive index of the medium

$$\mu = \frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

General expression for Snell's law

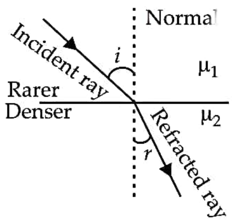
$${}^1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{\left(\frac{c}{v_2}\right)}{\left(\frac{c}{v_1}\right)} = \frac{v_1}{v_2}$$

where c is the speed of light in air, v_1 and v_2 be the speeds of light in medium 1 and medium 2 respectively. According to Snell's law,

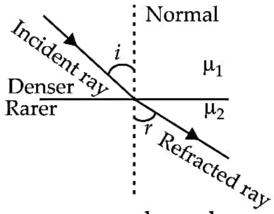
$${}^1\mu_2 = \frac{\sin i}{\sin r}; \quad \frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r}$$

or $\mu_1 \sin i = \mu_2 \sin r$

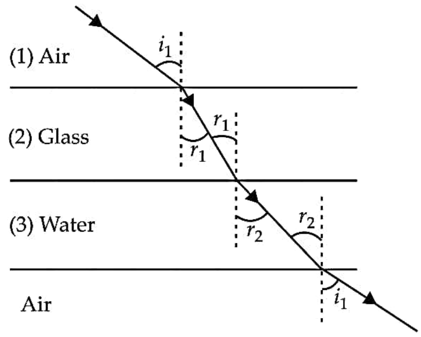
- When a light ray passes from a rarer to denser medium ($\mu_2 > \mu_1$), it will bend towards the normal as shown in the figure.



- When a light ray passes from a denser medium to rarer medium ($\mu_1 > \mu_2$) it will bend away from the normal as shown in the figure.



- If a light ray passes through a number of parallel media and if the first and the last media are same. The emergent ray is parallel to the incident ray as shown in figure.



$${}^1\mu_2 = \frac{\sin i_1}{\sin r_1}, {}^2\mu_3 = \frac{\sin r_1}{\sin r_2} \text{ and } {}^3\mu_1 = \frac{\sin r_2}{\sin i_1}$$

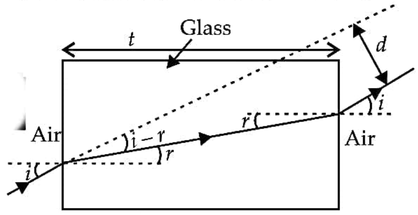
Hence,

$${}^1\mu_2 \times {}^2\mu_3 \times {}^3\mu_1 = \frac{\sin i_1}{\sin r_1} \times \frac{\sin r_1}{\sin r_2} \times \frac{\sin r_2}{\sin i_1} = 1$$

- **Lateral shift :** When the medium is same on both sides of a glass slab, then the deviation of the emergent ray is zero. That is the emergent ray is parallel to the incident ray but it does suffer lateral displacement/shift with respect to the incident ray and is given by

$$\text{Lateral shift, } d = t\,\frac{\sin(i - r)}{\cos r}$$

where t is the thickness of the slab.



- **Real depth and apparent depth :** When one looks into a pool of water, it does not appear to be as deep as it really is. Also when one looks into a slab of glass, the material does not appear to be as thick as it really is. This all happens due to refraction of light.
  - If a beaker is filled with water and a point lying at its bottom is observed by someone located in air, then the bottom point appears raised. The apparent depth is less than the real depth. It can be shown that

$$\text{apparent depth} = \frac{\text{real depth}}{\text{refractive index }(\mu)}$$

  If there is an ink spot at the bottom of a glass slab, it appears to be raised by a distance

$$d = t - \frac{t}{\mu} = t\left(1 - \frac{1}{\mu}\right)$$

where t is the thickness of the glass slab and μ is its refractive index.

- If a beaker is filled with immiscible transparent liquids of refractive indices μ_1, μ_2, μ_3 and individual depths d_1, d_2, d_3 respectively, then the apparent depth of the beaker is $= \frac{d_1}{\mu_1} + \frac{d_2}{\mu_2} + \frac{d_3}{\mu_3}$

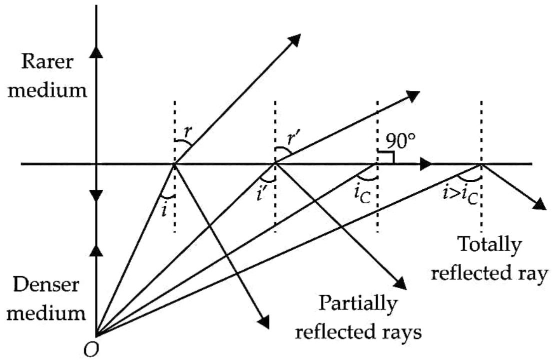
▶ **Apparent shift in the position of the sun at sunrise and sunset :** The sun is visible a little before the actual sunrise and until a little after the actual sunset due to refraction of light through the atmosphere.

Total internal reflection

It is a phenomenon of reflection of light into denser medium from the boundary of denser medium and rarer medium. Two essential conditions for the phenomenon of total internal reflection are :

▶ Light should travel from a denser to a rarer medium.

▶ Angle of incidence in denser medium should be greater than the critical angle for the pair of media in contact.



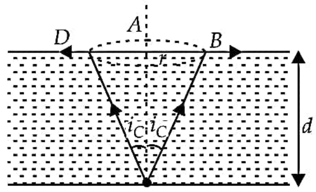
▶ **Critical angle :** It is that angle of incidence for which the angle of refraction becomes 90°. It is given by $\sin i_C = \frac{1}{{}^R\mu_D}$

If the rarer medium is air or vacuum, then $\sin i_C = \frac{1}{\mu}$. Critical angle for red light is more than that for blue light.

▶ Critical angle depends on
- Nature of medium
- Wavelength of light

▶ A diver in water at a depth d sees the world outside through a horizontal circle of radius

$$r = d \tan i_C = \frac{d}{\sqrt{\mu^2 - 1}}$$



▶ **Applications of total internal reflection**
- The brilliance of diamond is due to the phenomenon of total internal reflection.
- Mirages in deserts are also due to total internal reflection.
- The working of optical fibre is based on the phenomenon of total internal reflection.

Refraction from a spherical surface

The portion of a refracting medium, whose curved surface forms the part of a sphere, is known as spherical refracting surface. Sign conventions for spherical refracting surface are the same as those for spherical mirrors.

▶ Spherical refracting surfaces are of two types :
- Convex refracting spherical surface
- Concave refracting spherical surface

▶ When the object is situated in rarer medium, the relation between μ_1 (refractive index of rarer medium) μ_2 (refractive index of the spherical refracting surface) and R (radius of curvature) with the object and image distances is given by

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

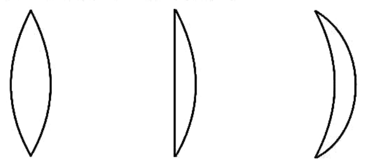
▶ When the object is situated in denser medium, the relation between μ_1, μ_2, R, u and [illegible] be obtained by interchanging μ_1 an[illegible] that case, the relation becomes

$$-\frac{\mu_2}{u} + \frac{\mu_1}{v} = \frac{\mu_1 - \mu_2}{R} \text{ or } -\frac{\mu_1}{v} + \frac{\mu_2}{u} = \frac{\mu_2 - \mu_1}{R}$$

▶ These formulae are valid for both convex and concave spherical surfaces.

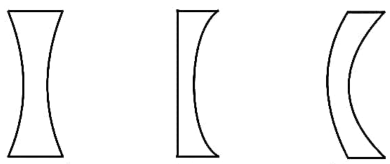
Lens : A lens is a portion of a transparent refracting medium bound by two spherical surfaces or one spherical surface and the other plane surface. Lenses are divided into two classes :

- **Convex lens or converging lens :** When a lens is thicker in the middle than at the edges it is known as convex lens or converging lens. These are of three types :
  - Double convex lens or biconvex lens
  - Plano convex lens
  - Concavo convex lens



Biconvex lens   Plano convex lens   Concavo convex lens

- **Concave lens or diverging lens :** When the lens is thicker at the edges than in the middle it is known as concave lens or diverging lens. These are of three types :
  - Double convex lens or biconcave lens
  - Plano concave lens
  - Convexo concave lens

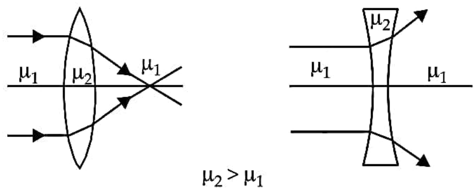


Biconcave lens   Plano concave lens   Convexo concave lens

- **Sign Conventions :** The sign conventions for thin lenses are the same as those of spherical mirrors except that instead of the pole of the mirror, we now use optical centre of a lens.
- **Lens maker's formula**

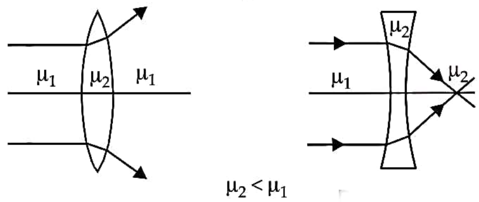
$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where R_1 and R_2 are radii of curvature of the two surfaces of the lens and μ is refractive index of material of lens w.r.t. medium in which lens is placed. This formula is valid for thin lenses. It is valid for both convex and concave lenses. As per sign convention, for a convex lens, R_1 is positive and R_2 is negative and for a concave lens, R_1 is negative and R_2 is positive.
- When the refractive index of the material of the lens is greater than that of the surroundings, then biconvex lens acts as a converging lens and a biconcave lens acts as a diverging lens as shown in the figure :



$\mu_2 > \mu_1$

- When the refractive index of the material of the lens is smaller than that of the surrounding medium, then biconvex lens acts as a diverging lens and a biconcave lens acts as a converging lens as shown in the figure.



$\mu_2 < \mu_1$

- **Thin lens formula**

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

where
u = distance of the object from the optical centre of the lens
v = distance of the image from the optical centre of the lens
f = focal length of a lens
f is positive for converging or convex lens and f is negative for diverging or concave lens.
- **Linear magnification**

$$m = \frac{\text{size of image } (I)}{\text{size of object } (O)} = \frac{v}{u}$$

where m is positive for erect image and m is negative for inverted image.
- **Power of a lens**

$$P = \frac{1}{\text{focal length in metres}}$$

  - The SI unit of power of lens is dioptre (D). $1\text{ D} = 1\text{ m}^{-1}$
  - For a convex lens, P is positive.
  - For a concave lens, P is negative.
    When focal length (f) of lens is in cm, then

$$P = \frac{100}{f \text{ (in cm)}} \text{ dioptre}$$

- **Combination of thin lenses in contact :** When a number of thin lenses of focal length f_1, f_2, ...etc. are placed in contact coaxially, the equivalent focal length F of the combination is given by

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}+....$$

The total power of the combination is given by

$$P = P_1 + P_2 + P_3 + ...$$

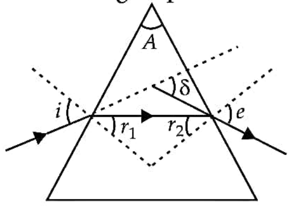
- When two thin lenses of focal lengths f_1 and f_2 are placed coaxially and separated by a distance d, the focal length of a combination is given by

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1 f_2}$$

In terms of power $P = P_1 + P_2 - dP_1P_2$.

Refraction through a prism

- **Prism :** It is a homogeneous, transparent medium enclosed by two plane surfaces inclined at an angle. These surfaces are called the refracting surfaces and angle between them is known as the refracting angle or the angle of prism. The angle between the incident ray and the emergent ray is known as the angle of deviation.
- For refraction through a prism it is found that



$\delta = i + e - A$ where $A = r_1 + r_2$

When A and i are small

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

In a position of minimum deviation

$\delta = \delta_m$, $i = e$ and $r_1 = r_2 = r$

$$\therefore\ i=\left(\frac{A+\delta_m}{2}\right) \text{ and } r=\frac{A}{2}$$

- The refractive index of the material of the prism is

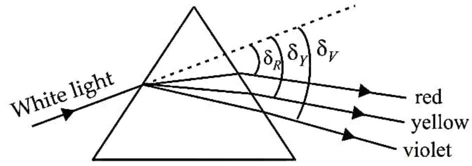
$$\mu=\frac{\sin\left[\frac{(A+\delta_m)}{2}\right]}{\sin\left(\frac{A}{2}\right)}$$

This is known as prism formula where A is the angle of prism and δ_m is the angle of minimum deviation.

Dispersion of light : It is the phenomenon of splitting of white light into its constituent colours on passing through a prism. This is because different colours have different wavelengths ($\lambda_R > \lambda_V$). According to Cauchy's formula

$$\mu = A+\frac{B}{\lambda^2}+\frac{C}{\lambda^4}$$

where A, B, C are arbitrary constants. Therefore, μ of material of prism for different colours is different ($\mu_V > \mu_R$). As $\delta = (\mu - 1) A$, therefore different colours turn through different angles on passing through the prism. This is the cause of dispersion.



- **Angular dispersion :** The difference in deviation between any two colours is known as angular dispersion.
  - Angular dispersion, $\delta_V - \delta_R = (\mu_V - \mu_R)A$ where μ_V and μ_R are the refractive index for violet and red rays.
  - Mean deviation, $\delta=\frac{\delta_V+\delta_R}{2}$.
  - Dispersive power,

$$\omega=\frac{\text{angular dispersion }(\delta_V-\delta_R)}{\text{mean deviation }(\delta)};$$

$$\omega=\frac{\mu_V-\mu_R}{(\mu-1)},$$

where $\mu=\frac{\mu_V+\mu_R}{2}$ = mean refractive index

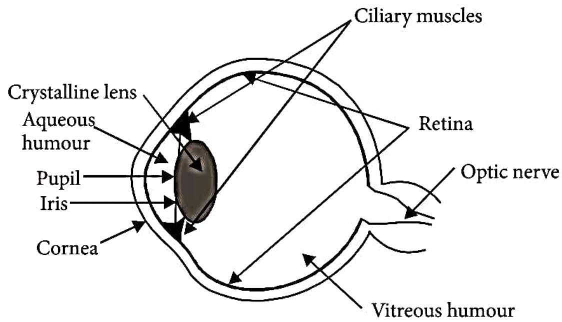
Some natural phenomena due to sunlight

- **Rainbow :** Rainbow is a beautiful arc of seven colours seen in the sky after rainfall. The rainbow is an example of the dispersion of sunlight by the water drops in the atmosphere. This is a phenomenon due to combined effect of dispersion, refraction and reflection of sunlight by spherical water droplets of rain. To observe the rainbow, back of observer must be towards the sun.
- **Scattering of light :** As sunlight travels through the earth's atmosphere, it gets scattered (changes its direction) by the atmospheric particles. Light of shorter wavelengths is scattered much more than light of longer wavelengths. The amount of scattering is inversely proportional to the fourth power of the wavelength. This is known as Rayleigh scattering.

Illustrations of scattering of light

- Blue colour of sky
- White colour clouds
- The sun looks reddish at the time of sun rise and sun set
- Danger signals are red.

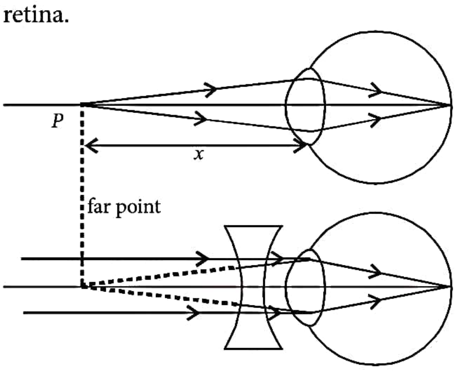
Optical instruments



- **Defects of eye :** Defects of eye are mainly of four types :
  - **Myopia**
  - **Hypermetropia**
  - **Presbyopia**
  - **Astigmatism**

(a) Myopia (near sightedness) : In this defect of eye, the eye lens becomes too thick and cannot focus the image of distance objects on the retina, due to which eye is not able to observe distant objects clearly. In this defect, lens converges incident light of distant object to a point well before the retina and maximum focal length is less than distance between lens and the retinal *i.e.*, less than 25 cm.

This defect is removed by introducing an appropriate concave lens between the eye and the object. Concave lens with right diverging effect focuses the image of distant object on the retina.

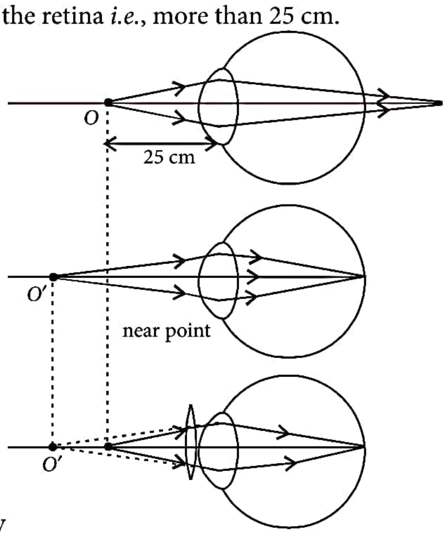


So, for $u = -\infty$, $v = -x$

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}=\frac{1}{-x}-\frac{1}{\infty}=-\frac{1}{x}+0 \text{ or } f=-x\text{ m}$$

This gives the focal length and $P=-\frac{1}{x}\text{D}$ gives the power of the concave lens required to correct the defect of the given myopic eye.

(b) Hypermetropia (far sightedness) : In this defect, the eye lens becomes too thin and cannot focus the image of nearby objects on the retina, due to which eye is not able to observe near by objects clearly. In this defect, eye converges incident light of nearby object to a point behind the retina, and minimum focal length is more than distance between the lens and the retina *i.e.*, more than 25 cm.



v

This defect is removed by interposing an appropriate convex lens between the eye and the object. Convex lens with the right converging effect focuses the image of nearby object on the retina and the ray from the object at the least distance of distinct vision (25 cm), appear to be coming from near point *P* to the eye lens.

So, for $u = -0.25$ m, $v = -y$ m

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}=-\frac{1}{y}+\frac{1}{0.25}=-\frac{1}{y}+4$$

or $f=\dfrac{y}{4y-1}\text{m}$

This gives the focal length and $P=\dfrac{4y-1}{y}\text{D}$ gives the power of the convex lens required to correct the defect of the given hypermetropic eye.

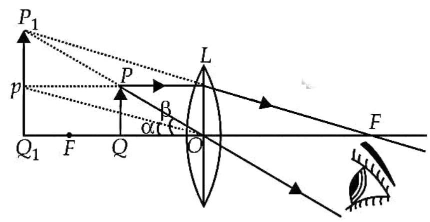
(c) Presbyopia : It is an old age disease. At old age, ciliary muscles loose their elasticity and cannot change the focal length of eye lens effectively. Due to this eye lens looses its power of accommodation, and person can then suffer from both myopia and hypermetropia.

This is overcome either by using two separate spectacles, one for myopia and another for hypermetropia or by using a single spectacle having bifocal lens.

(d) Astigmatism : It is the defect of eye which occurs when the cornea is not spherical in shape. For example, if the cornea have a larger curvature in the vertical plane than in the horizontal plane, then on looking at a horizontal line, focusing in the vertical plane is needed for a sharp image. But due to astigmatism, lines in one direction are well focused, while those in perpendicular direction are not. It is corrected by a lens with one cylindrical surface.

A cylindrical surface focuses rays in one plane but not in a perpendicular plane. By choosing the radius of curvature and axis direction of the cylindrical surface, astigmatism can be corrected. Astigmatism can occur along with myopia or hypermetropia.

- **Simple microscope :** It is also known as magnifying glass or simple magnifier. It consists of a convergent lens with object between its focus and optical centre and eye close to it. The image formed by it is erect, virtual, enlarged and on same side of lens between object and infinity.



- When the image is formed at infinity (far point),

$$M = \frac{D}{f}$$

- When the image is formed at the least distance of distinct vision D (near point),

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

- Magnifying power

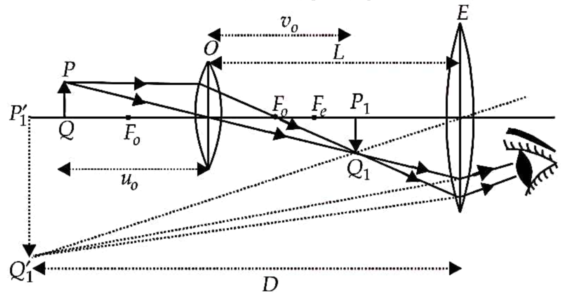
$$M = \frac{\text{angle subtended by image at the eye}}{\text{angle subtended by the object at the eye}}$$

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

where both the object and image are situated at the least distance of distinct vision.

- **Compound microscope :** It consists of two convergent lenses of short focal lengths and apertures arranged co-axially. Lens (of focal length f_o) facing the object is known as objective or field lens while the lens (of focal length f_e) facing the eye, is known as eye-piece or ocular. The objective has a smaller aperture and smaller focal length than eye-piece. Magnifying power of a compound microscope

$$M = m_o \times m_e$$



- When the final image is formed at infinity (normal adjustment),

$$M = \frac{v_o}{u_o}\left(\frac{D}{f_e}\right)$$

Length of tube, $L = v_o + f_e$

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

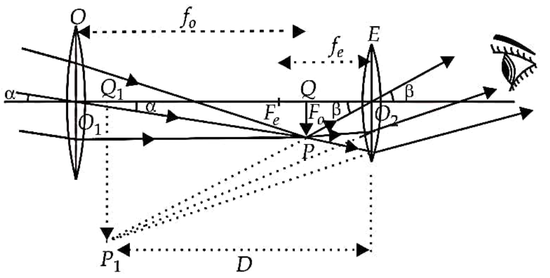
$$M = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right)$$

where u_o and v_o represent the distance of object and image from the objective lens, f_e is the focal length of an eye lens.

Length of the tube, $L = v_o + \left(\frac{f_e D}{f_e + D}\right)$

- **Astronomical telescope (refracting type)**

It consists of two converging lenses. The one facing the object is known as objective or field lens and has large focal length and aperture while the other facing the eye is known as eye-piece or ocular and has small focal length and aperture.



– When the final image is formed at infinity (normal adjustment),

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

Length of tube, $L = f_o + f_e$

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

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

Length of tube, $L = f_o + \dfrac{f_e D}{f_e + D}$

▶ **Terrestrial telescope :** It is used for observing far off objects on the ground. The essential requirement of such a telescope is that final image must be erect w.r.t. the object. To achieve it, an inverting convex lens (of focal length f) is used in between the objective and eye piece of astronomical telescope. This lens is known as erecting lens.

In normal adjustment,

Magnifying power, $M = \dfrac{f_o}{f_e}$

Length of the telescope tube, $L = f_o + 4f + f_e$

▶ **Reflecting type telescope :** Reflecting type telescope was designed by Newton in order to overcome the drawbacks of refracting type telescope. In a reflecting type telescope, a concave mirror of large aperture is used as objective in place of a convex lens. It possesses a large light gathering power and a high resolving power. Due to this, it enables us to see even faint stars and observe their minute details.

– In normal adjustment

Magnifying power, $M = \dfrac{f_o}{f_e} = \dfrac{\left(\frac{R}{2}\right)}{f_e}$

where R is the radius of curvature of concave mirror.

– Reflecting type telescope is free from chromatic aberration because light does not undergo refraction. By using paraboloidal mirror, spherical aberrations can be eliminated in reflecting type telescope.

Previous Years' CBSE Board Questions

9.2 Reflection of Light by Spherical Mirrors

VSA (1 mark)

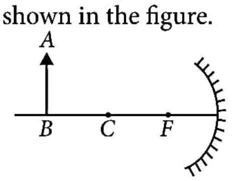
1. A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens? *(Delhi 2014)*

2. When an object is placed between f and $2f$ of a concave mirror, would the image formed be (i) real or virtual and (ii) diminished or magnified?

SA I (2 marks)

3. Use the mirror equation to show that an object placed between f and $2f$ of a concave mirror produces a real image beyond $2f$. *(Delhi 2015)*

4. An object AB is kept in front of a concave mirror as shown in the figure.



(i) Complete the ray diagram showing the image formation of the object.
(ii) How will the position and intensity of the image be affected if the lower half of the mirror's reflecting surface is painted black? *(AI 2012)*

5. (a) Plane and convex mirrors are known to produce virtual images of the objects. Draw a ray diagram to show how, in the case of convex mirrors, virtual objects can produce real images.
(b) Why are convex mirrors used as side view mirrors in vehicles? *(Delhi 2012C)*

6. (a) Draw a ray diagram for a convex mirror showing the image formation of an object placed anywhere in front of the mirror.
(b) Use this ray diagram to obtain the expression for its linear magnification. *(AI 2012C)*

7. Draw a ray diagram showing the formation of the image by a concave mirror of an object placed beyond its centre of curvature. If the lower half of the mirror's reflecting surface is covered, what effect will it have on the image? *(AI 2011C)*

SA II (3 marks)

8. (a) Calculate the distance of an object of height h from a concave mirror of radius of curvature 20 cm, so as to obtain a real image of magnification 2. Find the location of image also.
(b) Using mirror formula, explain why does a convex mirror always produce a virtual image. *(Delhi 2016)*

9. (a) A mobile phone lies along the principal axis of a concave mirror. Show, with the help of a suitable diagram, the formation of its image. Explain why magnification is not uniform.
(b) Suppose the lower half of the concave mirror's reflecting surface is covered with an opaque material. What effect this will have on the image of the object? Explain. *(Delhi 2014)*

10. Use the mirror equation to show that
(a) an object placed between f and $2f$ 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. *(AI 2011)*

11. (a) How is the focal length of a spherical mirror affected when the wavelength of the light used is increased?
(b) A convex lens has 20 cm focal length in air. What is its focal length in water? (Refractive index of air-water = 1.33, refractive index of air-glass = 1.5). *(Foreign 2010)*

12. An object of 3 cm height is placed at a distance of 60 cm from a convex mirror of focal length 30 cm. Find the nature, position and size of the image formed. *(AI 2010C)*

LA (5 marks)

13. Draw a ray diagram to show the image formation by a concave mirror when the object is kept between its focus and the pole. Using this diagram, derive the magnification formula for the image formed. *(Delhi 2011)*

14. Derive the 'mirror equation' using the ray diagram for the formation of a real image by a concave mirror. *(Delhi 2010C)*

9.3 Refraction

VSA (1 mark)

15. 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 media would the velocity of light be minimum? *(AI 2012)*

16. When monochromatic light travels from one medium to another its wavelength changes but frequency remains the same. Explain.

SA I (2 marks)

17. How does the refractive index of a transparent medium depend on the wavelength of incident light used? Velocity of light in glass is 2×10^8 m/s and in air is 3×10^8 m/s. If the ray of light passes from glass to air, calculate the value of critical angle. *(Foreign 2015)*

SA II (3 marks)

18. Do the frequency and wavelength change when light passes from a rarer to a denser medium? *(Delhi 2012C)*

9.4 Total Internal Reflection

VSA (1 mark)

19. State the criteria for the phenomenon of total internal reflection of light to take place. *(Delhi 2011C, Delhi 2010)*

SA I (2 marks)

20. (a) Write the necessary conditions for the phenomenon of total internal reflection to occur.
(b) Write the relation between the refractive index and critical angle for a given pair of optical media. *(Delhi 2013)*

21. 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'. *(Delhi 2012C)*

SA II (3 marks)

22. Define the term 'critical angle' for a pair of media.
A point source of monochromatic light 'S' is kept at the centre of the bottom of a cylinder of radius 15.0 cm. The cylinder contains water (refractive index 4/3) to a height of 7.0 cm. Draw the ray diagram and calculate the area of water surface through which the light emerges in air. *(Delhi 2013C)*

23. A small bulb (assumed to be a point source) is placed at the bottom of a tank containing water to a depth of 80 cm. Find out the area of the surface of water through which light from the bulb can emerge. Take the value of the refractive index of water to be 4/3. *(Delhi 2013C)*

24. State the necessary conditions for producing total internal reflection of light. Draw ray diagrams to show how specially designed prisms make use of total internal reflection to obtain inverted image of the object by deviating rays (i) through 90° and (ii) through 180°. *(AI 2011C)*

25. Define total internal reflection. State its essential conditions. *(Delhi 2010)*

VBQ (4 marks)

26. One day Chetan's mother developed a severe stomach ache all of a sudden. She was rushed to the doctor who suggested for an immediate endoscopy test and gave an estimate of expenditure for the same. Chetan immediately contacted his class teacher and shared the information with her. The class teacher arranged for the money and rushed to the hospital. On realising that Chetan belonged to a below average income group family, even the doctor offered concession for the test fee. The test was conducted successfully.

Answer the following questions based on the given information:
(a) Which principle in optics is made use of endoscopy?
(b) Briefly explain the values reflected in the action taken by the teacher.
(c) In what way do you appreciate the response of the doctor on the given situation? *(AI 2013)*

LA (5 marks)

27. Explain briefly how the phenomenon of total internal reflection is used in fibre optics. *(2/5, Delhi 2011)*

28. Explain with the help of a diagram, how the total internal reflection is used for transmission of video signals using optical fibres. *(Delhi 2008)*

29. For a ray of light travelling from a denser medium of refractive index n_1 to a rarer medium of refractive index n_2, prove that $\frac{n_2}{n_1} = \sin i_c$, where i_c is the critical angle of incidence for the media. *(Delhi 2008)*

9.5 Refraction at Spherical Surfaces and by Lenses

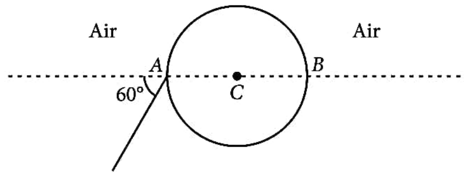
VSA (1 mark)

30. A concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65. What is the nature of the lens? *(Delhi 2015)*

31. A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason. *(AI 2014)*

32. A biconcave lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason. *(AI 2014)*

33. A ray of light falls on a transparent sphere with centre C as shown in the figure. The ray emerges from the sphere parallel to the line AB. Find the angle of refraction at A if refractive index of the material of the sphere is $\sqrt{3}$.



(Foreign 2014)

34. When red light passing through a convex lens is replaced by light of blue colour, how will the focal length of the lens change? *(AI 2013C)*

35. 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)*

36. 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)*

37. Two thin lenses of power –4 D and 2 D are placed in contact coaxially. Find the focal length of the combination. *(AI 2012C)*

38. 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)*

39. 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? *(AI 2010)*

40. Two thin lenses of power + 6 D and –2 D are in contact. What is the focal length of the combination? *(AI 2009)*

41. A glass lens of refractive index 1.5 is placed in a trough of liquid. What must be the refractive index of the liquid in order to make the lens disappear? *(Delhi 2008)*

SA I (2 marks)

42. An equiconvex lens of focal length 'f' is cut into two identical plane convex lenses. How will the power of each part be related to the focal length of the original lens?
A double convex lens of +5 D is made of glass of refractive index 1.55 with both faces of equal radii of curvature. Find the value of its radius of curvature. *(Foreign 2015)*

43. 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)*

44. A convex lens of focal length f_1 is kept in contact with a concave lens of focal length f_2. Find the focal length of the combination. *(AI 2013)*

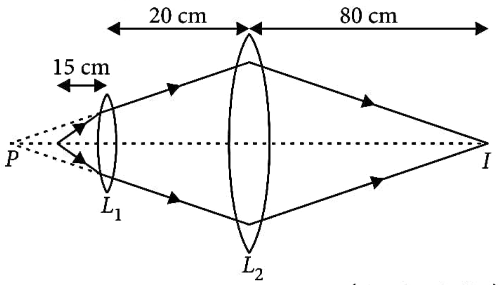
45. A beam of light converges at a point *P*. A concave lens of focal length 16 cm is placed in the path of this beam 12 cm from *P*. Draw a ray diagram and find the location of the point at which the beam would now converge. *(Delhi 2011C)*

46. 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. *(Delhi 2010)*

47. A convex lens of refractive index 1.5 has a focal length of 18 cm in air. Calculate the change in its focal length when it is immersed in water of refractive index $\frac{4}{3}$.

SA II (3 marks)

48. In the following diagram, an object '*O*' is placed 15 cm in front of a convex lens L_1 of focal length 20 cm and the final image is formed at *I* at a distance of 80 cm from the second lens L_2. Find the focal length of the lens L_2.



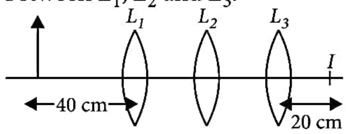
(Foreign 2016)

49. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept at 15 cm from each other. A point object lies 60 cm in front of the convex lens. Draw a ray diagram to show the formation of the image by the combination. Determine the nature and position of the image formed. *(AI 2014)*

50. A convex lens of focal length 20 cm is placed coaxially with a concave mirror of focal length 10 cm at a distance of 50 cm apart from each other. A beam of light coming parallel to the principal axis is incident on the convex lens. Find the position of the final image formed by this combination. Draw the ray diagram showing the formation of the image. *(AI 2014)*

51. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept 15 cm apart. A point object is placed 40 cm in front of the convex lens. Find the position of the image formed by this combination. Draw the ray diagram showing the image formation. *(AI 2014)*

52. 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 '*I*' of L_3. Find the separations between L_1, L_2 and L_3.



(AI 2012)

53. Define power of a lens. Write its units. Deduce the relation $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ for two thin lenses kept in contact coaxially. *(Foreign 2012)*

54. 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 $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$, where *u* and *v* represent respectively the distance of the object and the image formed. *(Delhi 2012C)*

55. 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? *(AI 2011)*

56. With the help of suitable ray diagram, derive a relation between the object distance (u), image distance (v) and radius of curvature (R) for a convex spherical surface, when a ray of light travels from rarer to denser medium. *(Delhi 2011C)*

57. A convex lens of refractive index 1.5 has a focal length of 20 cm in air. Calculate the change in its focal length when it is immersed in water of refractive index 4/3. *(Delhi 2008)*

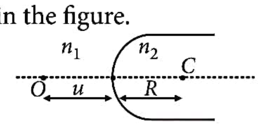
58. A double convex lens of glass of refractive index 1.6 has its both surface of equal radii of curvature of 30 cm each. An object of height 5 cm is placed at a distance of 12.5 cm from the lens. Calculate the size of the image formed. *(AI 2007)*

59. 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.

LA (5 marks)

60. (a) Derive the mathematical relation between refractive indices n_1 and n_2 of two media and radius of curvature R for refraction at a convex spherical surface. Consider the object to be a point source lying on the principle axis in rarer medium of refractive index n_1 and a real image formed in the denser medium of refractive index n_2. Hence, derive lens maker's formula.
(b) Light from a point source in air falls on a convex spherical glass surface of refractive index 1.5 and radius of curvature 20 cm. The distance of light source from the glass surface is 100 cm. At what position is the image formed ? *(AI 2016)*

61. (a) A point object 'O' is kept in a medium of refractive index n_1 in front of a convex spherical surface of radius of curvature R which separates the second medium of refractive index n_2 from the first one, as shown in the figure.
Draw the ray diagram showing the image formation and deduce



the relationship between the object distance and the image distance in terms of n_1, n_2 and R.
(b) (i) When the image formed above acts as a virtual object for a concave spherical surface separating the medium n_2 from n_1 ($n_2 > n_1$), draw this ray diagram and write the similar (similar to (a)) relation.
(ii) Hence obtain the expression for the lens maker's formula. *(Delhi 2015)*

62. Draw a ray diagram showing the formation of the image by a point object on the principal axis of a spherical convex surface separating two media of refractive indices n_1 and n_2, when a point source is kept in rarer medium of refractive index n_1. Derive the relation between object and image distance in terms of refractive index of the medium and radius of curvature of the surface.
Hence obtain the expression for lens-maker's formula in the case of thin convex lens. *(Delhi 2014C)*

63. (a) A point object is placed in front of a double convex lens (of refractive index $n = n_2/n_1$ with respect to air) with its spherical faces of radii of curvature R_1 and R_2. Show the path of rays due to refraction at first and subsequently at the second surface to obtain the formation of the real image of the object.
Hence obtain the lens-maker's formula for a thin lens.
(b) A double convex lens having both faces of the same radius of curvature has refractive index 1.55. Find out the radius of curvature of the lens required to get the focal length of 20 cm. *(AI 2014C)*

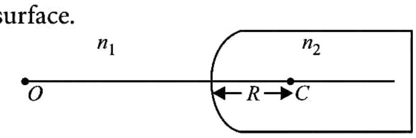
64. (a) Obtain lens makers formula using the expression

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$$

Here the ray of light propagating from a rarer medium of refractive index (n_1) to a denser medium of refractive index (n_2) is incident on the convex side of spherical refracting surface of radius of curvature R. *(Delhi 2011)*

65. Figure shows a convex spherical surface with centre of curvature C, separating the two media of refractive indices n_1 and n_2. Draw a ray diagram showing the formation of the image of a point object O lying on the principal axis.

Derive the relationship between the object and image distance in terms of refractive indices of the media and the radius of curvature R of the surface.



(3/5, Delhi 2010C)

66. Trace the rays of light showing the formation of an image due to a point object placed on the axis of a spherical surface separating the two media of refractive indices n_1 and n_2. Establish the relation between the distances of the object, the image and the radius of curvature from the central point of the spherical surface.
Hence derive the expression of the lens maker's formula. *(Delhi 2009)*

67. Derive the lens formula, $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ for a concave lens, using the necessary ray diagram.
Two lenses of powers 10 D and –5 D are placed in contact.
(i) Calculate the power of the new lens.
(ii) Where should an object be held from the lens, so as to obtain a virtual image of magnification 2? *(AI 2008)*

9.6 Refraction through a Prism

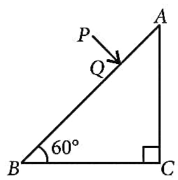
VSA (1 mark)

68. Write the relationship between angle of incidence 'i', angle of prism 'A' and angle of minimum deviation δ_m for a triangular prism. *(Delhi 2013)*

69. How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced with red light? *(AI 2008)*

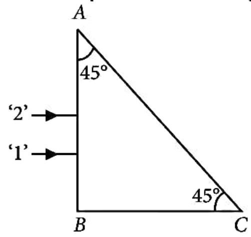
SA I (2 marks)

70. A ray PQ incident normally on the refracting face BA is refracted in the prism BAC made of material of refractive index 1.5. Complete the path of ray through the prism.



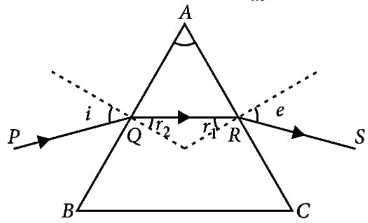
From which face will the ray emerge? Justify your answer. *(AI 2016)*

71. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.33 and 1.45. Trace the path of these rays after entering the prism.



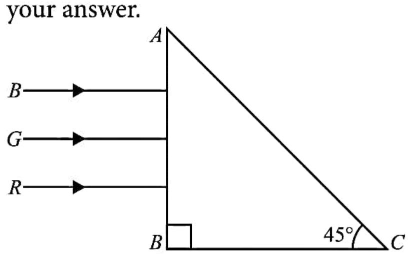
(AI 2014)

72. Figure shows a ray of light passing through a prism. If the refracted ray QR is parallel to the base BC, show that (i) $r_1 = r_2 = A/2$, (ii) angle of minimum deviation, $D_m = 2i - A$.



(Foreign 2014)

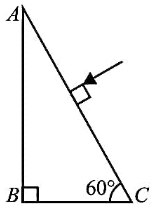
73. Three rays of light, red (R), green (G) and blue (B), are incident on the face AB of a right angled prism, as shown in the figure. The refractive indices of the material of the prism for red, green and blue are 1.39, 1.44 and 1.47 respectively. Which one of the three rays will emerge out of the prism? Give reason to support your answer.



(Foreign 2013, Delhi 2009)

74. A ray of light, incident on an equilateral glass prism ($\mu_g = \sqrt{3}$) moves parallel to the base line of the prism inside it. Find the angle of incidence for this ray. *(Delhi 2012)*

75. Trace the path of a ray of light passing through a glass prism (*ABC*) as shown in the figure. If the refractive index of glass is $\sqrt{3}$, find out of the value of the angle of emergence from the prism.



(Foreign 2012)

76. The following table gives the values of the angle of deviation, for different values of the angle of incidence, for a triangular prism :

Angle of Incidence	33°	38°	42°	52°	60°	71°
Angle of Deviation	60°	50°	46°	40°	43°	50°

(a) For what value of the angle of incidence, is the angle of emergence likely to be equal to the angle of incidence itself?

(b) Draw a ray diagram, showing the passage of a ray of light through this prism when the angle of incidence has the above value.

(Delhi 2010C)

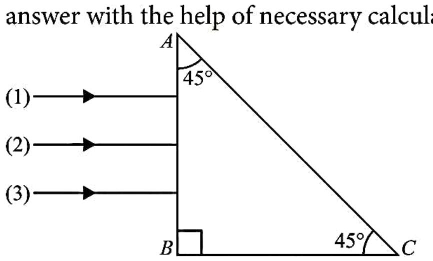
77. Define refractive index of a transparent medium.

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.

(AI 2009)

SA II (3 marks)

78. Three rays (1, 2, 3) of different colours fall normally on one of the sides of an isosceles right angled prism as shown. The refractive index of prism for these rays is 1.39, 1.47 and 1.52 respectively. Find which of these rays get internally reflected and which get only refracted from *AC*. Trace the paths of rays. Justify your answer with the help of necessary calculations.



(Foreign 2016)

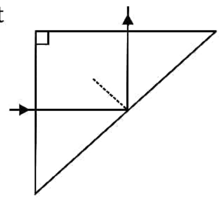
79. Draw a ray diagram showing the path of a ray of light entering through a triangular glass prism. Deduce the expression for the refractive index of glass prism in terms of the angle of minimum deviation and angle of the prism. *(AI 2012C)*

80. A ray of light passing through an equilateral triangular glass prism from air undergoes minimum deviation when angle of incidence is $3/4^{th}$ of the angle of prism. Calculate the speed of light in the prism.

LA (5 marks)

81. (i) Plot a graph to show variation of the angle of deviation as a function of angle of incidence for light passing through a prism. Derive an expression for refractive index of the prism in terms of angle of minimum deviation and angle of prism.

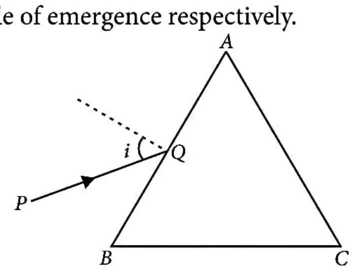
(ii) A ray of light incident normally on one face of a right isosceles prism is totally reflected as shown in figure. What must be the minimum value of refractive index of glass ? Give relevant calculations. *(3/5, Delhi 2016)*



82. **(a)** A ray *PQ* of light is incident on the face *AB* of a glass prism *ABC* (as shown in the figure) and emerges out of the face *AC*. Trace the path of the ray. Show that

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

where δ and *e* denote the angle of deviation and angle of emergence respectively.

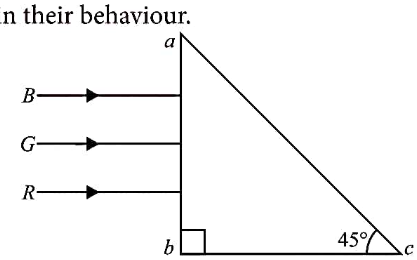


Plot a graph showing the variation of the angle of deviation as a function of angle of incidence. State the condition under which $\angle\delta$ is minimum.

(b) Find out the relation between the refractive index (μ) of the glass prism and $\angle A$ for the case when the angle of prism (A) is equal to the angle of minimum deviation (δ_m). Hence obtain the value of the refractive index for angle of prism $A = 60°$. *(AI 2015)*

83. (a) 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. *(3/5, Delhi 2011)*

84. (i) A ray of monochromatic light is incident on one of the faces of an equilateral triangular prism of refracting angle A. Trace the path of ray passing through the prism. Hence, derive an expression for the refractive index of the material of the prism in terms of the angle of minimum deviation and its refracting angle.
(ii) Three light rays red (R), green (G) and blue (B) are incident on the right angled prism abc at face ab. The refractive indices of the material of the prism for red, green and blue wavelengths are respectively 1.39, 1.44 and 1.47. Trace the paths of these rays reasoning out the difference in their behaviour.



(Foreign 2011)

9.7 Dispersion by a Prism

SA I (2 marks)

85. (a) Why does white light disperse when passed through a glass prism?
(b) Using lens maker's formula, show how the focal length of a given lens depends upon the colour of light incident on it. *(AI 2015C)*

86. Violet colour is seen at the bottom of the spectrum when white light is dispersed by a prism.
State reasons to explain these observations. *(Delhi 2010)*

LA (5 marks)

87. What is dispersion of light ? What is its cause ? *(2/5, Delhi 2016)*

9.8 Some Natural Phenomena due to Sunlight

VSA (1 mark)

88. Why does sun appear red at sunrise and sunset? *(AI 2016, Foreign 2015)*

89. Why does bluish colour predominate in a clear sky? *(AI 2015, AI 2008)*

90. Why does the sky appear blue? *(Foreign 2010)*

91. Under what condition does a rainbow is observed? *(AI 2010C)*

SA I (2 marks)

92. Write the conditions for observing a rainbow. Show by drawing suitable diagrams, how one understands the formation of a rainbow. *(AI 2014C)*

93. The bluish colour predominantes in clear sky why? *(Delhi 2010)*

9.9 Optical Instruments

VSA (1 mark)

94. 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 (A)
L_1	3 D	8 cm
L_2	6 D	1 cm
L_3	10 D	1 cm

(Delhi 2009)

SA I (2 marks)

95. You are given two converging lenses of focal lengths 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, find out the separation between the objective and the eyepiece. *(AI 2015)*

96. A small telescope has an objective lens of focal length 150 cm and eyepiece of focal length 5 cm. What is the magnifying power of the telescope for viewing distant objects in normal adjustment?
If this telescope is used to view a 100 m tall tower 3 km away, what is the height of the image of the tower formed by the objective lens? *(AI 2015)*

97. Draw a schematic arrangement of a reflecting telescope (Cassegrain) showing how rays coming from a distant object are received at the eye-piece. Write its two important advantages over a refracting telescope. *(Delhi 2013C)*

98. Draw a labelled ray diagram of a reflecting telescope. Mention its two advantages over the refracting telescope. *(AI 2012)*

99. Draw a ray diagram to show the formation of the image in a myopic eye. Show with the help of a ray diagram how this defect is corrected. *(Foreign 2010)*

100. Draw a labelled ray diagram of an astronomical telescope in the near point position. Write the expression for its magnifying power. *(AI 2008)*

SA II (3 marks)

101. Draw a schematic ray diagram of reflecting telescope showing how rays coming from a distant object are received at the eye-piece. Write its two important advantages over a refracting telescope. *(Delhi 2016)*

102. (i) A giant refracting telescope has an objective lens of focal length 15 m. If an eye piece of focal length 1.0 cm is used, what is the angular magnification of the telescope?
(ii) 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 3.48×10^6 m and the radius of lunar orbit is 3.8×10^8 m. *(Delhi 2015, AI 2011)*

103. Which two of the following lenses L_1, L_2, and L_3 will you select as objective and eyepiece for constructing best possible (i) telescope (ii) microscope? Give reason to support your answer.

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

(Delhi 2015C)

104. (a) Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision.
(b) The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece 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 eye piece. *(Delhi 2014)*

105. (i) Draw a schematic labelled ray diagram of a reflecting type telescope.
(ii) Write two important advantage justifying why reflecting type telescopes are preferred over refracting telescopes.
(iii) The objective of a telescope is of larger focal length and of larger aperture (compared to the eyepiece). Why? Give reasons. *(Foreign 2013)*

106. (a) A small telescope has an objective lens of focal length 140 cm and an eyepiece of focal length 5.0 cm. Find the magnifying power of the telescope for viewing distant objects when
(i) the telescope is in normal adjustment,
(ii) the final image is formed at the least distance of distinct vision.
(b) Also find the separation between the objective lens and the eye piece in normal adjustment. *(AI 2013C)*

107. Draw a ray diagram showing the image formation by a compound microscope when the final image is formed at the near point. *(AI 2012C)*

108. Two convex lenses of focal length 10 cm and 1 cm constitute a telescope. The telescope is focussed on a point which is 1m away from the objective. Calculate the magnification produced and the length of the tube, if the final image is formed at a distance of 25 cm from the eyepiece. *(Delhi 2011C)*

109. (i) (a) Draw a neat labelled ray diagram of an astronomical telescope in normal adjustment.
(b) 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? *(AI 2010)*

110 (i) Draw a neat labelled 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? *(AI 2010)*

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

112. 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 20. If the length of the telescope is 105 cm in this adjustment, find the focal lengths of the two lenses.

VBQ (4 marks)

113. Amit's uncle was finding great difficulty in reading a book placed at normal place. He was not going to the doctor because he could not afford the cost. When Amit came to know of it, he took his uncle to the doctor. After thoroughly checking his eyes, the doctor prescribed the proper lenses for him. Amit bought the spectacles for his uncle from his pocket money. By using spectacles he could now read with great ease. For this, he expressed his gratitude to his nephew.
Based on the above paragraph, answer the following :
(a) (i) Why does least distance of distinct vision increase with age?
(ii) What type of lens is required to correct this defect?
(b) What, according to you, are the two values displayed by Amit towards his uncle?
(Delhi 2013C)

LA (5 mark)

114. (i) Draw a labelled ray diagram to obtain the real image formed by an astronomical telescope in normal adjustment position. Define its magnifying power.
(ii) You are given three lenses of power 0.5 D, 4 D and 10 D to design a telescope.
(a) Which lenses should he use as objective and eyepiece ? Justify your answer.
(b) Why is the aperture of the objective preferred to be large ? *(AI 2016)*

115. (i) Draw a labelled schematic ray diagram of astronomical telescope in normal adjustment.
(ii) Which two aberrations do objectives of refracting telescope suffer from? How are these overcome in reflecting telescope?
(Foreign 2016)

116. Draw a ray diagram showing the image formation of a distant object by a refracting telescope. Define its magnifying power and write the two important factors considered to increase the magnifying power.
Describe briefly the two main limitations and explain how far these can be minimized in a reflecting telescope. *(Foreign 2015)*

117. (a) Draw a ray diagram showing image formation in a compound microscope. Define the term 'limit of resolution' and name the factors on which it depends. How is it related to resolving power of a microscope?
(b) Suggest two ways by which the resolving power of a microscope can be increased.
(c) 'A telescope resolves whereas a microscope magnifies.' Justify this statement. *(Foreign 2015)*

118. Draw a ray diagram showing the image formation by a compound microscope. Obtain expression for total magnification when the image is formed at infinity. *(3/5, AI 2015C)*

119. (a) Draw a labelled ray diagram of an astronomical telescope to show the image formation of a distant object. Write the main considerations required in selecting the objective and eyepiece lenses in order to have large magnifying power and high resolution of the telescope.
(b) A compound microscope has an objective of focal length 1.25 cm and eyepiece of focal length 5 cm. A small object is kept at 2.5 cm from the objective. If the final image formed is at infinity, find the distance between the objective and the eyepiece. *(Foreign 2014)*

120. (a) Draw a ray diagram showing the image formation by a compound microscope. Hence obtain expression for total magnification when the image is formed at infinity.
(b) Distinguish between myopia and hypermetropia. Show diagrammatically how these defects can be corrected. *(Delhi 2013)*

121. 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. *(AI 2013)*

122. Define magnifying power of a telescope. Write its expression.
A small telescope has an objective lens of focal length 150 cm and an eye piece 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 eye piece. *(Delhi 2012)*

123. 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)*

124. 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 eye piece 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)*

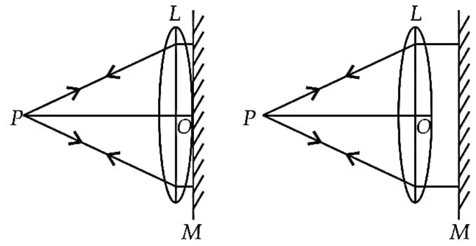
125. Define the magnifying power of a compound microscope. Why should both the objective and the eyepiece have small focal lengths in a microscope? *(2/5, Delhi 2010C)*

126. Write any two advantages of a reflecting telescope over a refracting telescope. *(2/5, Delhi 2010C)*

127. (a) Draw the labelled ray diagram for the formation of image by a compound microscope.
(b) Derive the expression for the total magnification of a compound microscope.
(c) Explain why both the objective and the eyepiece of a compound microscope must have short focal lengths. *(Delhi 2009)*

Detailed Solutions

1.



(a) (b)

From figure, focal length of lens = OP = 20 cm

2. When an object is placed between f and $2f$ of a concave mirror, the image formed is real and magnified.

3. From mirror formula, $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}$

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

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

or $\quad -\frac{1}{2f} < -\frac{1}{u} < -\frac{1}{f}$

or $\quad \frac{1}{f}-\frac{1}{2f} < \frac{1}{f}-\frac{1}{u} < \frac{1}{f}-\frac{1}{f}$

or $\quad \frac{1}{2f} < \frac{1}{v} < 0$

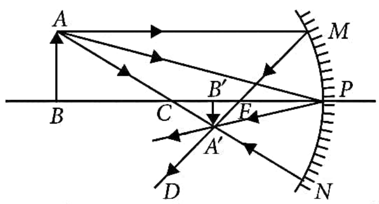
This implies that $v < 0$ so that image is formed on left. Also the above inequality implies

$2f > v$

or $\quad |2f| < |v|$ $\quad$ [$\because$ $2f$ and v are negative]

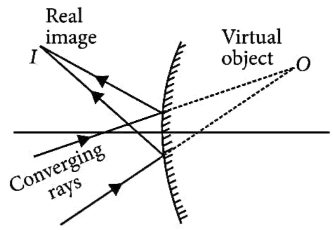
i.e., the real image is formed beyond $2f$.

4. (i)



(ii) Position of image will remain same/unchanged and intensity of image will decrease.

5. (a) If a plane or a convex mirror is placed in the path of rays converging to a point, the rays get reflected to a point in front of the mirror. Real image can be obtained on a screen.



(b) The convex mirror is used as side view mirrors in vehicles as it gives a wide field of view of the traffic.

6. (a)

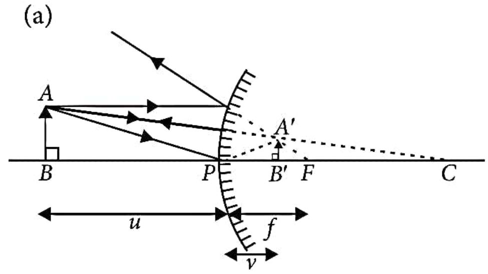


Figure shows the formation of image $A'B'$ of a finite object AB by a convex mirror.

(b) Now, $\Delta ABP \sim \Delta A'B'P$

$\therefore \quad \frac{A'B'}{AB}=\frac{PB'}{PB}$

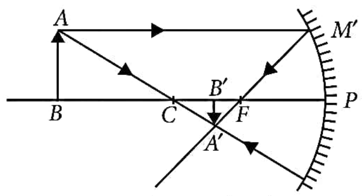
Applying the new Cartesian sign convention,

$A'B' = h_2, AB = h_1, PB' = v, PB = -u$

$\therefore \quad \frac{h_2}{h_1}=\frac{v}{-u}$

Linear magnification, $m=\frac{h_2}{h_1}=-\frac{v}{u}$

7. (i)



(ii) One would naturally think that image will be half of the object, but taking the laws of reflection to be true for all points of the mirror, the image will be of the whole object. However, as the area of the reflecting surface has reduced, the intensity of the image will be dim.

8. (a) Here, $R = -20$ cm, $f = R/2 = -10$ cm

$m = -2$ (image is real)

u = object distance, v = image distance

$m = -\frac{v}{u} \Rightarrow v = 2u$

Using mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

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

$\therefore \quad u = -15$ cm

Hence, $v = 2u = -30$ cm

(b) For convex mirror : $f > 0$, $u < 0$

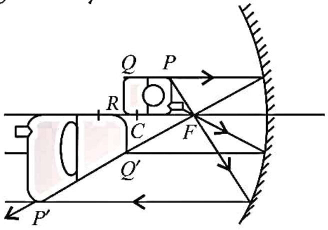
Using mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{f}-\frac{1}{(-u)} \Rightarrow \frac{1}{v}=\frac{1}{f}+\frac{1}{u} \Rightarrow v=\frac{f \times u}{f+u}$

$\therefore \quad v > 0$

This implies that image of object placed in front of a convex mirror is always formed behind the mirror which is virtual in nature.

9. (a) The formation of the image of the cell phone is shown in figure. The part which is at R will be imaged at R and will be of the same size, *i.e.*, $Q'R = QR$. The other end P of the mobile phone is highly magnified by the concave mirror.



Thus the different parts of the mobile phone are magnified in different proportions because of their different locations from the concave mirror.

(b) *Refer to answer 7(ii).*

10. (a) *Refer to answer 3.*

(b) *Refer to answer 8(b).*

(c) From mirror formula,

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

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

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

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

Also, $\frac{1}{v}<\frac{1}{|u|}$ or $v>|u|$ $\therefore$ $|m|=\frac{v}{|u|}>1$

i.e., image is enlarged.

11. (a) Wavelength of light has no effect on focal length of a spherical mirror.

(b) Given, $f_a = 20$ cm, $n_g = 1.5$, $n_w = 1.33$

$$f_w = \frac{n_g - 1}{\frac{n_g}{n_w}-1} \times f_a = \frac{1.5-1}{\left(\frac{1.5}{1.33}-1\right)} \times 20 \text{ cm} \approx 80 \text{ cm}$$

12. Here, height of object $h = 3$ cm

$u = -60$ cm, $f = +30$ cm

Using the mirror formula, we have

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

$\frac{1}{v}+\frac{1}{-60}=\frac{1}{30} \Rightarrow \frac{1}{v}=\frac{1}{30}+\frac{1}{60}$

$\frac{1}{v}=\frac{2+1}{60} \Rightarrow \frac{1}{v}=\frac{3}{60} \quad \therefore \; v = 20$ cm

(i) The image is virtual and erect.

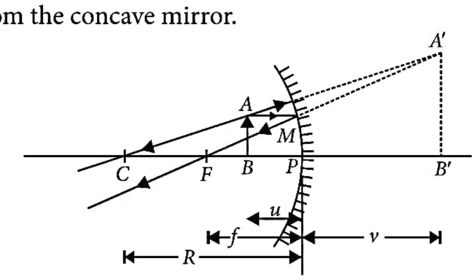
(ii) The image is at a distance of 20 cm from the mirror on the opposite side of the object.

(iii) $\frac{h'}{h}=-\frac{v}{u} \Rightarrow \frac{h'}{3}=-\left(\frac{20}{-60}\right) \Rightarrow \frac{h'}{3}=\frac{1}{3}$

$\Rightarrow \; h' = 1$ cm

$\therefore$ Image is diminished and its size is 1 cm.

13. Consider an object AB placed on the principal axis of a concave mirror between its pole P and focus F. As shown in figure, a virtual and erect image $A'\,B'$ is formed behind the mirror, after reflection from the concave mirror.



Using the cartesian sign convention, we find that

Object distance, $BP = -u$

Image distance, $PB' = v$

Focal length, $FP = -f$

Radius of curvature, $CP = -R = -2f$

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

$$\therefore \quad \frac{AB}{A'B'} = \frac{CB}{CB'} = \frac{CP - BP}{CP + PB'} = \frac{-2f + u}{-2f + v} \quad \text{... (i)}$$

Also $\Delta MPF \sim \Delta A'B'F$

$$\therefore \quad \frac{MP}{A'B'} = \frac{FP}{FB'} = \frac{FP}{FP + PB'}$$

$$\text{or} \quad \frac{AB}{A'B'} = \frac{-f}{-f + v} \quad \text{... (ii)}$$

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

$$\frac{-2f + u}{-2f + v} = \frac{-f}{-f + v}$$

or $2f^2 - fu - 2fv + uv = 2f^2 - fv$

or $-fv - fu + uv = 0$

or $uv = fv + fu$

Dividing both sides by uvf, we get

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

This proves the mirror equation for a concave mirror when it forms a virtual image.

Now $\Delta MPF \sim \Delta A'B'F$

$$\therefore \quad \frac{A'B'}{MP} = \frac{FB'}{FP} \text{ or } \frac{A'B'}{AB} = \frac{FP + PB'}{FP}$$

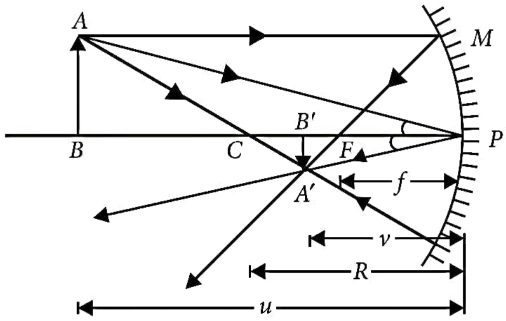
Applying the new cartesian sign convention,

$A'B' = h_2$, $AB = h_1$, $FP = -f$, $PB' = v$

$$\therefore \quad \frac{h_2}{h_1} = \frac{-f + v}{-f}$$

$$\text{or} \quad m = \frac{h_2}{h_1} = \frac{f - v}{f} = -\frac{v}{u}$$

14.



Consider an object AB placed on the principal axis beyond the centre of curvature C of a concave mirror of small aperture.

Using Cartesian sign convention, we find

Object distance, $BP = -u$

Image distance, $B'P = -v$

Focal length, $FP = -f$

Radius of curvature, $CP = -R = -2f$

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

$$\therefore \quad \frac{A'B'}{AB} = \frac{CB'}{CB} = \frac{CP - PB'}{BP - CP} = \frac{-R + v}{-u + R} \quad \text{... (i)}$$

As $\angle A'PB' = \angle APB$

$\therefore \quad \Delta A'B'P \sim \Delta ABP$

Consequently,

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

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

$$\frac{-R + v}{-u + R} = \frac{v}{u}$$

or $-uR + uv = -uv + vR$

or $vR + uR = 2uv$

Dividing both sides by uvR, we get

$$\frac{1}{u} + \frac{1}{v} = \frac{2}{R}$$

But $R = 2f$

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

This proves the mirror equation for a concave mirror when it forms a real image.

15. Refractive index, $\mu = \frac{c}{v} = \frac{\sin i}{\sin r}$

As $\sin 15° < \sin 25° < \sin 35°$

So, $v_A < v_B < v_C$

Hence in medium A, velocity of light is minimum.

16. Frequency being a characteristic of source of light, does not change with change of medium.

Refractive index μ of medium is defined as,

$$\mu = \frac{c}{v} = \frac{\text{(speed of light in vacuum)}}{\text{(speed of light in medium)}}$$

As, $v = \upsilon\lambda$

$\therefore \quad \mu \propto \frac{1}{\lambda} \quad (\because \upsilon \text{ is same in different media})$

Hence, wavelength of light is different in different media.

17. (i) The refractive index of a transparent medium is inversely proportional to the wavelength of incident light. The relationship between the two is given by

$$\mu = \frac{\lambda_0}{\lambda}$$

where

μ = Refractive index of medium

λ_0 = Wavelength of incident light in vacuum
λ = Wavelength of incident light in medium
(ii) Given :
Velocity of light in air, $v_a = 3 \times 10^8$ m/s
Velocity of light in glass, $v_g = 2 \times 10^8$ m/s

The refractive index of glass is given by, $\mu_g = \frac{c}{v_g}$
where c is speed of light in vacuum.
The refractive index of air is given by, $\mu_a = \frac{c}{v_a}$

$\therefore$ The refractive index of glass w.r.t. air will be

$${}^a\mu_g = \frac{\mu_g}{\mu_a} \Rightarrow {}^a\mu_g = \frac{v_a}{v_g} = \frac{3\times10^8}{2\times10^8} = 1.5$$

We know

$${}^a\mu_g = \frac{1}{\sin C}$$

where C is the critical angle for the interface

$$\therefore \quad \frac{1}{\sin C} = 1.5 \Rightarrow \sin C = \frac{1}{1.5}$$

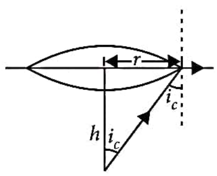
$\Rightarrow$ $C = \sin^{-1}(0.66) \Rightarrow C = 41.3°$
$\therefore$ Critical angle, $C = 41.3°$

18. When the light travels from a rarer to a denser medium, its frequency remains unchanged but wavelength decreases. It is because, frequency is an inherent property of light. Since energy of a photon of light is $h\upsilon$, its energy will remain the same.

19. Essential conditions for total internal reflection :
(i) Light should travel from a denser medium to a rarer medium.
(ii) Angle of incidence in denser medium should be greater than the critical angle for the pair of media in contact.

20. (a) *Refer to answer 19.*
(b) ${}^a\mu_b = \frac{1}{\sin C}$, where a and b are the rarer and denser media respectively and C is the critical angle for the given pair of optical media.

21. Radius,



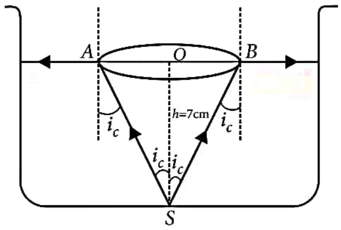
$$r = h\tan i_c = h\frac{\sin i_c}{\cos i_c}$$

$$r = h\frac{1/\mu}{\sqrt{1-\frac{1}{\mu^2}}} = \frac{h}{\sqrt{\mu^2-1}}$$

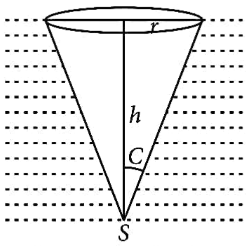
22. The angle of incidence in denser medium for which the angle of refraction in rarer medium is 90° is called the critical angle (i_c) for the pair of media. The light rays emerge through a circle of radius r.

Area of water surface = $\frac{\pi h^2}{\mu^2-1}$

$$= \frac{22}{7}\times\frac{(7)^2}{(1.33)^2-1} = 200.28 \text{ cm}^2$$



23. The light rays starting from bulb can pass through the surface if angle of incidence at surface is less than or equal to critical angle (C) for water air interface. If h is the depth of bulb from the surface,

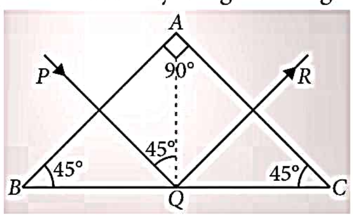


the light will emerge only through a circle of radius r given by $r = \frac{h}{\sqrt{\mu^2-1}}$

Area of water surface = $\frac{\pi h^2}{\mu^2-1}$

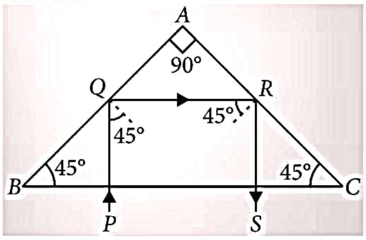
$$= \frac{22}{7}\times\frac{(0.80)^2}{(1.33)^2-1} = 2.6 \text{ m}^2$$

24. (a) *Refer to answer 19.*
(b) (i) To deviate a ray of light through 90° :



A totally reflecting prism is used to deviate the path of the ray of light through 90°, when it is inconvenient to view the direct light. In Michelson's method to find velocity of light, the direct light from the octagonal mirror is avoided from direct viewing by making use of totally reflecting prism.
(ii) To deviate a ray of light through 180° : When the ray of light comes to meet the hypotenuse face

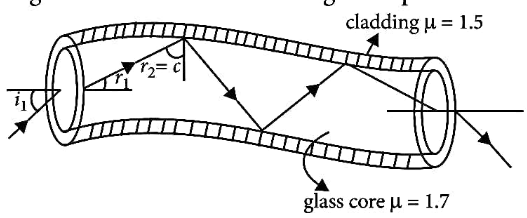
BC at right angles to it, it is refracted out of prism as such along the path RS. The path of the ray of light has been turned through 180° due to two total internal reflections.



25. (i) When light passes from an optically denser medium to a rarer medium at the interface, under certain conditions the incident light can be made to be reflected back into the same medium without any loss of intensity. This phenomenon is called total internal reflection.
(ii) *Refer to answer 19.*

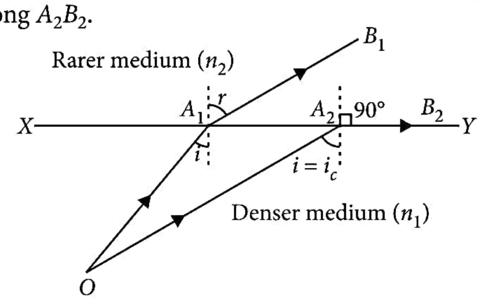
26. (a) Total internal reflection
(b) Knowing the financial status of the family, the class teacher immediately arranged the money required to be paid as test fee. Her caring and helping attitude towards others resulted in timely help to the family and treatment to Chetan's mother. Such helping actions on the part of the individual make it a better world to live in.
(c) Doctor's sympathetic view of the situation resulting in reduction in fee is highly appreciable. Such professional ethics can be of immense help to the individual belonging to below average income groups of the society.

27. (i) Optical fibre is made up of very fine quality glass or quartz of refractive index about 1.7. A light beam incident on one end of an optical fibre at appropriate angle refracts into the fibre and undergoes repeated total internal reflection. This is because the angle of incidence is greater than critical angle. The beam of light is received at other end of fibre with nearly no loss in intensity. To send a complete image, the image of different portion is send through separate fibres and thus a complete image can be transmitted through an optical fibre.



28. *Refer to answer 27.*

29. Let O be a point object in the denser medium of refractive index (n_1). A ray incident along OA_1 deviates away from normal and is refracted along A_1B_1 in the rarer medium of refractive index (n_2). Angle of refraction increases with increase in the angle of incidence.
For particular value of $i = i_c$, the critical angle, the incident ray OA_2 is refracted at r = 90° and goes along A_2B_2.



Applying Snell's law at A_2, when $i = i_c$, r = 90°

$n_1 \sin i_c = n_2 \sin 90° \Rightarrow n_1 \sin i_c = n_2 \times 1$

$\therefore \quad \frac{n_2}{n_1} = \sin i_c$

30. Focal length of a concave lens is negative.
Using lens maker's formula,

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

Here, $\mu_l = 1.5$, $\mu_m = 1.65$

Also, $\frac{\mu_l}{\mu_m} < 1$, so $\left(\frac{\mu_l}{\mu_m} - 1\right)$ is negative and focal length of the given lens becomes positive. Hence, it behaves as a convex lens.

31. The lens will act as a diverging lens as the refractive index of water is greater than that of lens.

32. The lens will act as a converging lens as the refractive index of water is greater than that of biconcave lens.

33. From Snell's law, we have : $\frac{\sin(i)}{\sin(r)} = \mu$

At A, $i = 60°$; $\mu = \sqrt{3}$

Now, $\sin(r) = \frac{\sin(i)}{\mu}$

$\Rightarrow \quad \sin(r) = \frac{\sin(60°)}{\sqrt{3}} = \frac{1}{2}$

$\Rightarrow \quad r = \sin^{-1}\left(\frac{1}{2}\right)$

$\therefore \quad r = 30°$

34. Focal length of the lens decrease when red light is replaced by blue light.

35. When the refractive index of the biconvex lens is equal to the refractive index of the liquid in which lens is immersed then the biconvex lens behaves as a plane glass sheet. In this case, $\frac{1}{f} = 0$ or $f \to \infty$.

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

$f \propto \frac{1}{(\mu - 1)}$ and $\mu_V > \mu_R$

The increase in refractive index would result in decrease of focal length of lens. Hence, we can say that replacing red light with violet light, decreases the focal length of the lens used.

37. Net power $P = P_1 + P_2 = -4 + 2 = -2$ D

Focal length $f = \frac{1}{P} = \frac{1}{-2}\text{m} = -0.5\text{ m} = -50\text{ cm}$

38. The value of refractive index of the liquid is 1.45.

39. $f_1 = f$ (for converging lens),
$f_2 = -f$ (for diverging lens)
$\therefore$ Focal length of their combination is

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f} - \frac{1}{f} = 0 \quad \Rightarrow \quad F = \frac{1}{0} = \infty$$

40. Power $P = +6\text{ D} - 2\text{ D} = 4$ D

Focal length $f = \frac{1}{P} = \frac{1}{4} = 0.25\text{ m} = 25\text{ cm}$

41. The refractive index of the liquid must be equal to 1.5.

42. (i) The focal length of original equiconvex lens is f.
Let the focal length of each part after cutting be F.

Here, $\frac{1}{f} = \frac{1}{F} + \frac{1}{F} \Rightarrow \frac{1}{f} = \frac{2}{F}$

$\Rightarrow f = \frac{F}{2} \Rightarrow F = 2f$

Power of each part will be given by

$P = \frac{1}{F} \Rightarrow P = \frac{1}{2f}$

(ii) From lens maker formula, we have

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

where
P = Power of lens = +5 D
μ = Refractive index of the lens = 1.55
R_1 = Radius of curvature of first face (+ve)
R_2 = Radius of curvature of second face (–ve)
Given : $R_1 = R_2 = R$

$$\Rightarrow \quad 5 = (1.55 - 1)\left(\frac{1}{R} - \frac{1}{-R}\right) \Rightarrow 5 = (1.55 - 1)\left(\frac{2}{R}\right)$$

$$\Rightarrow \quad 5 = 0.55\left(\frac{2}{R}\right) \Rightarrow R = \frac{0.55 \times 2}{5} \Rightarrow R = 0.22\text{ m}$$

The radius of curvature of the lens is 22 cm.

43. Given that focal length of convex lens, $f_1 = +25$ cm and focal length of concave lens, $f_2 = -20$ cm
Equivalent focal length,

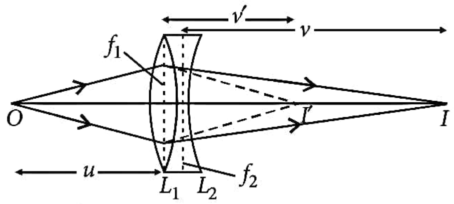
$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{25} + \frac{1}{-20} = -\frac{1}{100}$$

$\therefore \quad F = -100$ cm

Power of the combination, $P = \frac{1}{F(\text{m})} = \frac{1}{-1\text{m}} = -1\text{D}$

The focal length of the combination= 1 m = 100 cm. The system will be diverging in nature as the focal length is negative.

44.



For convex lens

$$\frac{1}{f_1} = \frac{1}{v'} - \frac{1}{u} \quad \text{...(i)}$$

For concave lens (f_2 = –ve)

$$-\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v'} \quad \text{...(ii)}$$

Adding equations (i) and (ii)

$$\frac{1}{f_1} - \frac{1}{f_2} = -\frac{1}{u} + \frac{1}{v}$$

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

where f = focal length of combination

$$\therefore \quad \frac{1}{f_1} - \frac{1}{f_2} = \frac{1}{f}$$

So, $f = \frac{f_1 f_2}{f_2 - f_1}$

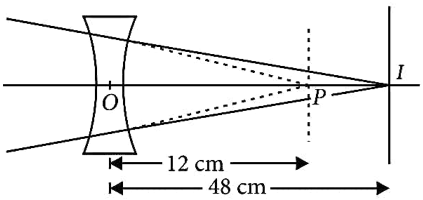
45. Given, in the absence of the lens the rays converge at *P*. If the lens is place at *O*, then the distance *OP* is the object distance of virtual object at *P*.

$\therefore \quad u = 12$ cm, $f = -16$ cm

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

$$\therefore \quad \frac{1}{v} - \frac{1}{12} = \frac{1}{16} \Rightarrow v = 48 \text{ cm}$$

Thus, the beam converges at a distance 48 cm from the lens or 48 – 12 = 36 cm after *P*.



46. Here $R_1 = 10$ cm, $R_2 = -15$ cm, $f = 12$ cm, $\mu = ?$

Using lens formula, we have

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

$$\frac{1}{12} = (\mu - 1)\left(\frac{1}{10} - \frac{1}{-15}\right) = (\mu - 1)\left(\frac{3+2}{30}\right) = (\mu - 1)\left(\frac{5}{30}\right)$$

$$\Rightarrow \quad (\mu - 1) = \frac{1}{12} \times \frac{30}{5}$$

$\Rightarrow \quad \mu - 1 = 0.5 \Rightarrow \mu = 1 + 0.5 \quad \therefore \quad \mu = 1.5$

47. ${}^a\mu_g = 1.5 = 3/2$; $f = +18$ cm

$$\frac{1}{f} = ({}^a\mu_g - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{...(i)}$$

$$\frac{1}{f'} = ({}^w\mu_g - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{...(ii)}$$

From (i) and (ii)

$$\frac{f'}{f} = \frac{{}^a\mu_g - 1}{{}^w\mu_g - 1} = \frac{1.5 - 1}{1.125 - 1} = \frac{0.5}{0.125} = 4$$

$$\left({}^w\mu_g = \frac{{}^a\mu_g}{{}^a\mu_w} = \frac{3/2}{4/3} = 1.125\right)$$

or $f' = 4f$

$f' = 4 \times 18 = 72$ cm

Change in focal length, $3f = 54$ cm

48. As per the figure,

The image formed by lens L_1 is at *P*. Therefore, using lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

As per the parameters given in the question

$u = -15$ cm, $f_{L_1} = 20$ cm

So, the image distance will be

$$\frac{1}{v} - \frac{1}{(-15)} = \frac{1}{20}$$

$v = -60$ cm

Now, this image is acting as an object for the lens L_2. We can again use the lens formula and other parameters given in the question and question figure to find the focal length of lens L_2.

$$\frac{1}{v_{L_2}} - \frac{1}{u_{L_2}} = \frac{1}{f_{L_2}}$$

Here, $u_{L_2} = v + (-20) = -60 - 20 = -80$ cm

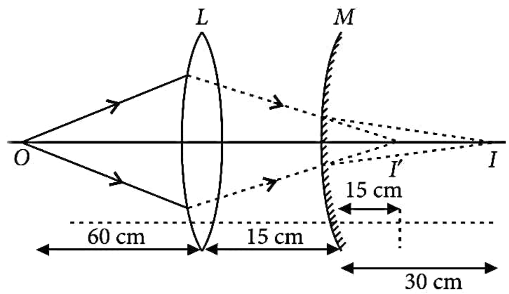
$v_{L_2} = 80$ cm

$$\frac{1}{80} - \frac{1}{(-80)} = \frac{1}{f_{L_2}}$$

$f_{L_2} = 40$ cm

So, the focal length of the lens $L_2 = 40$ cm.

49.



For the convex lens,

$u = -60$ cm, $f = +20$ cm

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ gives $v = +30$ cm

For the convex mirror

$u = +(30 - 15)$ cm $= 15$ cm, $f = +\frac{20}{2}$ cm $= 10$ cm

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ gives $v = +30$ cm

Final image is formed at the distance of 30 cm from the convex mirror (or 45 cm from the convex lens) to the right of the convex mirror.

The final image formed is a virtual image.

50. Let us first locate the image of the point object *S* formed by the convex lens. Here

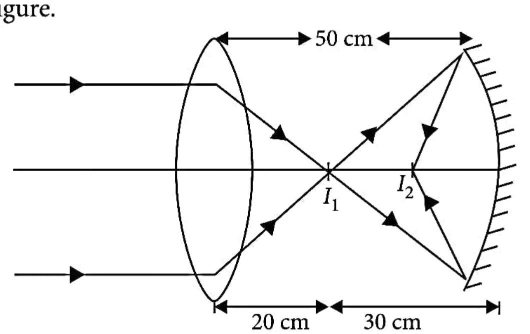
$u = -\infty$ cm and $f = 20$ cm

From the lens formula, we have: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{20}$$

$\therefore \quad v = +\,20$ cm

The positive sign shows that the image is formed to the right of the lens, as shown in the following figure.



The image I_1 is formed in front of the mirror and hence, acts as a real source for the mirror. The concave mirror forms the image I_2. For the concave mirror, $u = -\,30$ cm and $f = -10$ cm

Using mirror formula,

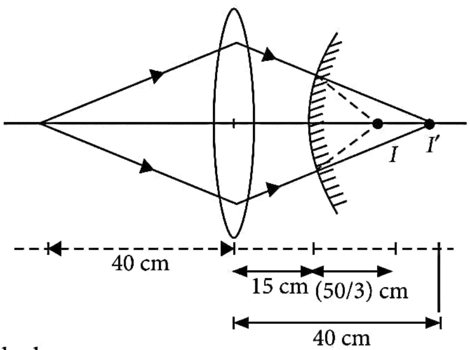
$$\frac{1}{v'} + \frac{1}{-30} = \frac{1}{-10}$$

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

$v' = -15$ cm

Hence, the final image is formed at I_2 at a distance of 15 cm from the concave mirror.

51.



For the lens

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

$u = -\,40$ cm, $f = +\,20$ cm. This gives $v = +\,40$ cm

This image acts as a (virtual) object for the convex mirror

$\therefore \quad u = (+\,40 - 15)$ cm $= 25$ cm

Also $f = +\dfrac{20}{2}$ cm $= +10$ cm

From $\quad \dfrac{1}{f} = \dfrac{1}{v} + \dfrac{1}{u}$

We get $v = \dfrac{50}{3}$cm $\simeq 16.67$ cm

The final image is, therefore formed at a distance of 16.67 cm $\left(= \dfrac{50}{3}\text{ cm}\right)$ to the right of the convex mirror.

(at a distance of 31.67 cm $\left(= \dfrac{95}{3}\text{ cm}\right)$ to the right of the convex lens.

52. For lens L_1

$$\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1}$$

$$\frac{1}{20} = \frac{1}{v_1} - \frac{1}{-40} \Rightarrow v_1 = 40 \text{ cm}$$

For L_3

$$\frac{1}{f_3} = \frac{1}{v_3} - \frac{1}{u_3}$$

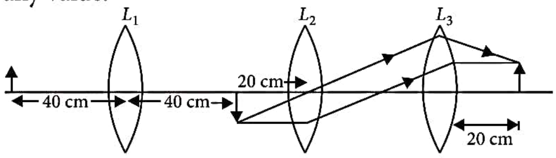
$u_3 = ?, f_3 = +\,20$ cm, $v_3 = 20$ cm

$$\frac{1}{20} = \frac{1}{20} + \frac{1}{u_3}$$

$u_3 = \infty$

It shows that L_2 must render the rays parallel to the common axis. It means that the image (I_1), formed by L_1, must be at a distance of 20 cm from L_2 (at the focus of L_2)

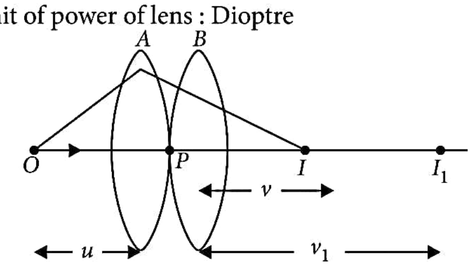
Therefore, distance between L_1 and L_2 (= 40 + 20) = 60 cm and distance between L_2 and L_3 can have any value.



53. Power of lens : It is the reciprocal of focal length of a lens.

$P = \dfrac{1}{f}$ (f is in metre)

Unit of power of lens : Dioptre



An object is placed at point O. The lens A produces an image at I_1 which serves as a virtual object for lens

B which produces final image at I.

Given, the lenses are thin. The optical centres (P) of the lenses A and B coincide with each other.

For lens A, we have

$$\frac{1}{v_1}-\frac{1}{u}=\frac{1}{f_1} \quad \ldots\text{(i)}$$

For lens B, we have $\frac{1}{v}-\frac{1}{v_1}=\frac{1}{f_2}$ ...(ii)

Adding equations (i) and (ii),

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f_1}+\frac{1}{f_2} \quad \ldots\text{(iii)}$$

If two lenses are considered as equivalent to a single lens of focal length f, then

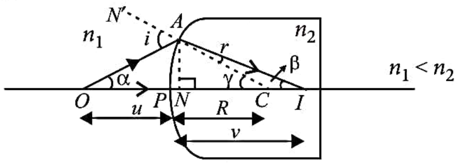
$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \quad \ldots\text{(iv)}$$

From equation (iii) and equation (iv), we can write

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$$

54. Refraction at convex spherical surface

When object is in rarer medium and image formed is real.



In ΔOAC, $i = \alpha + \gamma$

and in ΔAIC, $\gamma = r + \beta$ or $r = \gamma - \beta$

$\therefore$ By Snell's law $^1n_2 = \frac{\sin i}{\sin r} \approx \frac{i}{r} = \frac{\alpha+\gamma}{\gamma-\beta}$

or $\frac{n_2}{n_1}=\frac{\alpha+\gamma}{\gamma-\beta}$ or $n_2\gamma - n_2\beta = n_1\alpha + n_1\gamma$

or $(n_2 - n_1)\gamma = n_1\alpha + n_2\beta$ ...(i)

As α, β and γ are small and P and N lie close to each other,

So, $\alpha \approx \tan\alpha = \frac{AN}{NO} \approx \frac{AN}{PO}$

$\beta \approx \tan\beta = \frac{AN}{NI} \approx \frac{AN}{PI}$

$\gamma \approx \tan\gamma = \frac{AN}{NC} \approx \frac{AN}{PC}$

On using them in equation (i), we get

$$(n_2 - n_1)\frac{AN}{PC} = n_1\frac{AN}{PO} + n_2\frac{AN}{PI}$$

or $\frac{n_2-n_1}{PC}=\frac{n_1}{PO}+\frac{n_2}{PI}$ ...(ii)

where, $PC = + R$, radius of curvature

$PO = - u$, object distance

$PI = + v$, image distance

So $\frac{n_2-n_1}{R}=\frac{n_1}{-u}+\frac{n_2}{v}$ or $\frac{n_2-n_1}{R}=\frac{n_2}{v}-\frac{n_1}{u}$

This gives formula for refraction at spherical surface when object is in rarer medium.

55. Here, $^a\mu_g = 1.5$

Let f_{air} be the focal length of the lens in air,

Then,

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

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

or $\left(\frac{1}{R_1}-\frac{1}{R_2}\right)=\frac{2}{f_{air}}$ ... (i)

(i) When lens is dipped in medium A

Here, $^a\mu_A = 1.65$

Let f_A be the focal length of the lens, when dipped in medium A. Then,

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

Using the equation (i), we have

$$\frac{1}{f_A}=\left(\frac{1.5}{1.65}-1\right)\times\frac{2}{f_{air}}=-\frac{1}{5.5f_{air}}$$

or $f_A = -5.5\,f_{air}$

As the sign of f_A is opposite to that of f_{air} the lens will behave as a diverging lens.

(ii) When lens is dipped in medium B

Here, $^a\mu_B = 1.33$

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

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

Using the equation (i), we have

$$\frac{1}{f_B}=\left(\frac{1.5}{1.33}-1\right)\times\frac{2}{f_{air}}=\frac{0.34}{1.33f_{air}}$$

or $f_B = 3.91\,f_{air}$

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

56. *Refer to answer 54.*

57. For the lens in air,

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

$\Rightarrow \quad \frac{1}{20} = (1.5 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\Rightarrow \quad \frac{1}{R_1} - \frac{1}{R_2} = \frac{1}{10}$

When the lens is immersed in water,

Since, $\frac{1}{f_w} = \left(\frac{\mu_g}{\mu_w} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

$\Rightarrow \quad \frac{1}{f_w} = \left(\frac{1.5}{4/3} - 1\right) \times \frac{1}{10}$

or $\quad \frac{1}{f_w} = \frac{1}{8} \times \frac{1}{10} = \frac{1}{80}$

$f_w = 80$ cm

58. Given : $\mu_g = 1.6; R_1 = -R_2 = R = 30$ cm; $h_0 = 5$ cm; $u = -12.5$ cm; $h_1 = ?$

$$\frac{1}{v} - \frac{1}{u} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{v} = (\mu - 1)\left(\frac{2}{R}\right) + \frac{1}{u} = (1.6 - 1)\left(\frac{2}{30}\right) - \frac{1}{12.5}$$

$$\frac{1}{v} = 0.04 - \frac{1}{12.5} = -0.04$$

$v = -25$ cm

$$\frac{h_1}{h_0} = \frac{v}{u}$$

$$h_1 = \frac{25}{12.5} \times 5 = 10 \text{ cm}$$

59. As the image of the object is formed by the lens on the screen, therefore the image is real.

Let the object is placed at a distance x from the lens. As the distance between the object and the screen is 90 cm. Therefore the distance of the image from the lens is $(90 - x)$

According to new Cartesian sign conventions,

$u = -x, v = +(90 - x)$

Magnification $m = \frac{v}{u}$

$\therefore \quad -2 = \frac{(90 - x)}{-x} \Rightarrow x = 30$ cm

$\therefore \quad u = -30$ cm, $v = 60$ cm

Let f be focal length of the lens.

According to thin lens formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}; \frac{1}{60} - \frac{1}{-(30)} = \frac{1}{f}$$

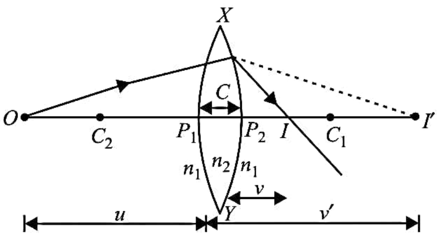
$$\frac{1}{60} + \frac{1}{30} = \frac{1}{f}$$

$f = +20$ cm

A convex lens of focal length 20 cm is required.

60. (a) (i) *Refer to answer 54.*

(ii)



For refraction at spherical surface XP_1Y, object is at O and image is at I'.

So, object distance is u and image distance is v'. Also, ray of light is travelling from rarer medium (n_1) to denser medium (n_2).

$$\text{So,} \quad \frac{n_2 - n_1}{R_1} = \frac{n_2}{v'} - \frac{n_1}{u} \quad \text{...(i)}$$

For refraction at spherical surface XP_2Y, point I' behaves as virtual object and image is formed at I. Also, ray of light is travelling from denser medium (n_2) to rarer medium (n_1)

$$\frac{n_2 - n_1}{R_2} = \frac{n_2}{v'} - \frac{n_1}{v} \quad \text{...(ii)}$$

Subtracting equation (ii) from (i), we get

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2 - n_1}{n_1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...(iii)}$$

When the object is at infinity, light rays incident on lens are parallel and are converged at common point on principal axis known as principal focus F of lens.

So, when $u = -\infty$ then $v = +f$ (focal length)

$$\frac{1}{f} = \left(\frac{n_2 - n_1}{n_1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...(iv)}$$

This gives the "Lens maker's formula" when the lens of glass of refractive index n_2 is placed in any medium of refractive index n_1.

(b) $R = 20$ cm, $n_2 = 1.5$, $n_1 = 1$, $u = -100$ cm

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R} \quad \text{or} \quad \frac{1.5}{v} + \frac{1}{100} = \frac{1.5-1}{20}$$

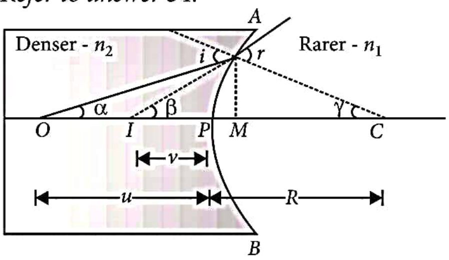
or $\dfrac{1.5}{v} = \dfrac{0.5}{20} - \dfrac{1}{100} = \dfrac{1}{40} - \dfrac{1}{100} = \dfrac{3}{200}$

or $v = \dfrac{200}{3} \times 1.5 = 100$ cm

$\Rightarrow$ So, a real image is formed on the other side, 100 cm away from the surface.

61. (a) *Refer to answer 54.*

(b) (i)



Relationship between the object distance and image distance in terms of n_1, n_2 and R for a concave spherical surface.

$$\frac{n_1}{v} - \frac{n_2}{u} = \frac{n_1 - n_2}{R}$$

(ii) *Refer to answer 60 a(ii).*

62. (a) *Refer to answer 54.*

(b) *Refer to answer 60 a(ii).*

From (iii) and (iv), we have

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

Hence, this is the required expression for lens-marker's formula for the thin lens.

63. (a) *Refer to answer 60 a(ii).*

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

Here $f = 20$ cm, $\mu = 1.55$, $R_1 = -R_2 = R$

$\therefore \quad \dfrac{1}{20} = (1.55-1)\left(\dfrac{1}{R} + \dfrac{1}{R}\right)$ or $\dfrac{1}{20} = 0.55 \times \dfrac{2}{R}$

or $\quad R = 0.55 \times 2 \times 20 = 22$ cm.

64. *Refer to answer 60 a(ii).*

65. *Refer to answer 54.*

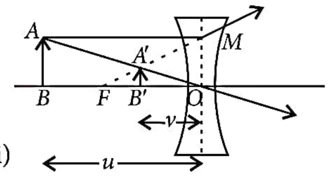
66. *Refer to answer 60(a).*

67. Derivation of lens formula : In the figure, AB is the object kept beyond F perpendicular to the principal of a concave lens. $A'B'$ is the erect, virtual and diminished image.

As, ΔABO and $\Delta A'B'O$ are similar

$$\therefore \quad \frac{AB}{A'B'} = \frac{BO}{B'O} \qquad \ldots(i)$$

Also, ΔMOF and $\Delta A'B'F$ are similar



$$\therefore \quad \frac{MO}{A'B'} = \frac{FO}{FB'}$$

But $MO = AB$

$$\therefore \quad \frac{AB}{A'B'} = \frac{FO}{FB'} \quad \ldots(ii)$$

From equations (i) and (ii)

$$\frac{BO}{B'O} = \frac{FO}{FB'} \quad \text{or} \quad \frac{BO}{B'O} = \frac{FO}{FO - B'O}$$

Using new Cartesian sign convention,

$BO = -u$, $B'O = -v$, $FO = -f$

$$\therefore \quad \frac{-u}{-v} = \frac{-f}{-f+v}$$

or $uf - uv = vf$

or $uv = uf - vf$

Dividing both sides by uvf, we get

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

This is the required lens formula for a concave lens.

(i) Power of new lens, $P = P_1 + P_2$

$\therefore \quad P = 10 - 5 = +5$ D

(ii) Here, $f = \dfrac{1}{P} = \dfrac{100}{5} = 20$ cm, $u = ?$

$$m = \frac{v}{u} \Rightarrow 2 = \frac{-v}{-u} \quad \therefore \quad v = 2u$$

Using lens formula

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

$$\frac{1}{20} = \frac{1}{2u} - \frac{1}{u}$$

$$\frac{1}{20} = \frac{1-2}{2u} \Rightarrow \frac{1}{20} = \frac{-1}{2u} \quad \therefore \quad u = -10 \text{ cm}$$

$\therefore \quad$ Object distance = 10 cm

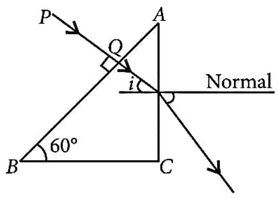
68. The relation between the angle of incidence i, angle of prism A, and the angle of minimum deviation δ_m, for a triangular prism is given by,

$$i = \frac{A + \delta_m}{2}$$

69. $\because$ $\delta_{violet} > \delta_{red}$

When incident violet light is replaced with red light, the angle of minimum deviation of a glass decreases.

70.



Ray will emerge from the face AC

As $\sin i_c = 1/\mu$

Here $\sin i_c = 1/1.5 = 0.67$, $i_c = 42°$

$\angle i$ on face AC is 30° which is less than $\angle i_c$. Hence the ray will get refracted at the face AC.

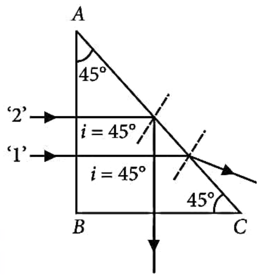
71. Critical angle for ray '1' : $\mu_1 = \dfrac{1}{\sin C_1}$

$$\sin C_1 = \frac{1}{\mu_1} = \frac{1}{1.33} = 0.75 \Rightarrow C_1 \approx 48°$$

Critical angle for ray '2' : $\mu_2 = \dfrac{1}{\sin C_2}$

$$\sin C_2 = \frac{1}{\mu_2} = \frac{1}{1.45} = 0.69 \Rightarrow C_2 \approx 43°$$

Both the rays will fall on the side AC with angle of incidence, i equal to 45°. Critical angle of ray '1' is greater than i. Hence, it will emerge from the prism as shown in the figure. Critical angle of ray '2' is less than i. Hence, it will be internally reflected as shown in the figure.



72. (i) When QR is parallel to the base BC, we have

$i = e \Rightarrow r_1 = r_2 = r$

We know that

$r_1 + r_2 = A \Rightarrow r + r = A$

$\therefore$ $r = A/2$

(ii) Also, we have

$A + D = i + e$

Substituting, $D = D_m$ and $i = e$

$A + D_m = i + i$

$\therefore$ $D_m = 2i - A$

73. Critical angle for

(i) Red light is $\sin c_r = \dfrac{1}{1.39} = 0.7194$

or $c_r = 46°$

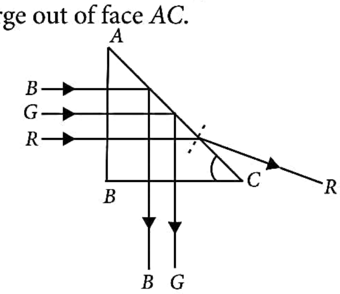
(ii) Green light is $\sin c_g = \dfrac{1}{1.44} = 0.6944$

or $c_g = 44°$

(iii) Blue light is $\sin c_b = \dfrac{1}{1.47} = 0.6802$

or $c_b = 43°$

As angle of incidence $i = 45°$ of red light ray on face AC is less that its critical angle of 46°, so red light ray will emerge out of face AC.



74. Here, $\mu_g = \sqrt{3}$

Angle of prism, $A = 60°$

Since inside the prism the light moves parallel to the base of the prism, therefore the prism is under the minimum deviation.

$\therefore$ $r = \dfrac{A}{2} = \dfrac{60°}{2} = 30°$

According to the Snell's law.

$\mu_a \sin i = \mu_g \sin r$

$(1) \times \sin i = \sqrt{3} \sin 30°$

$\sin i = \sqrt{3} \times \dfrac{1}{2} = \dfrac{\sqrt{3}}{2}$

$i = \sin^{-1}\left(\dfrac{\sqrt{3}}{2}\right)$ or $i = 60°$

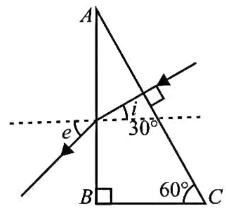
75. Given $n_g = \sqrt{3}$

$i = 0$

At the interface AC,

By Snell's law

$$\frac{\sin i}{\sin r} = \frac{n_a}{n_g}$$



But $\sin i = \sin 0° = 0$, hence $r = 0$

At the interface AB, $i = 30°$

Applying Snell's law

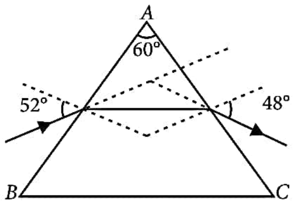
$$\frac{\sin 30°}{\sin e} = \frac{n_a}{n_g} = \frac{1}{\sqrt{3}} \Rightarrow \sin e = \sqrt{3} \sin 30°$$

$\Rightarrow$ $e = 60°$

76. (a) Since $\delta = i + e - A$

$\therefore$ The angle of incidence is likely to be equal to 52°.

(b)

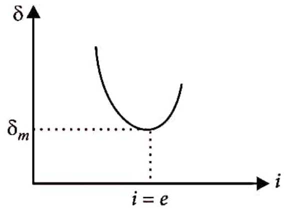


Using the equation $\delta = i + e - A$

$40° = 52° + e - 60° \Rightarrow e = 48°$

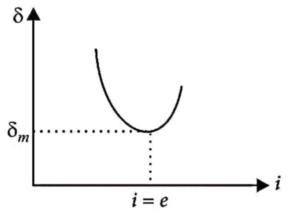
77. Refractive index of a medium is defined as the ratio of speed of light in vacuum to the speed of light in that medium *i.e.* $\mu = \frac{c}{v}$.

Graph showing the variation of the angle of deviation with angle of incidence

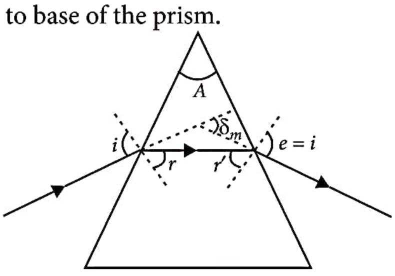


78. *Refer to answer 73.*

79. If graph is plotted between angle of incidence i and angle of deviation δ, it is found that the angle of deviation δ first decreases with increase in angle of incidence i and then becomes minimum 'δ_m' when $i = e$ and then increases with increase in angle of incidence i. Figure shows the path of a ray of light suffering refraction through a prism of refracting angle 'A'.



At minimum deviation, the inside beam travels parallel to base of the prism.



$i = e$

$r = r'$

$\delta_m = (i + e) - (r + r')$

$\delta_m = 2i - 2r$ ...(i)

Also $r + r' = A = 2r$ ...(ii)

So, angle of incidence using equation (i)

$$i = \frac{A + \delta_m}{2}, \text{ angle of refraction } r = \frac{A}{2}$$

Now refractive index of the material of prism

$${}^a\mu_g = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin \frac{A}{2}}$$

where A is the "refracting angle" of the prism and $A = 60°$ for an equiangular prism.

80. Here $A = 60°$

and $i = \frac{3}{4}$ of $A \Rightarrow i = \frac{3}{4} \times 60 = 45°$

Using prism formula, we have

$$\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin \frac{A}{2}} = \frac{\sin i}{\sin A/2} \qquad \left[\because\ i = \frac{A + \delta_m}{2}\right]$$

But $\mu = \frac{c}{v}$

$$\therefore \quad \frac{c}{v} = \frac{\sin i}{\sin A/2}$$

$$\frac{3 \times 10^8}{v} = \frac{\sin 45°}{\sin 60°/2}$$

$$\frac{3 \times 10^8}{v} = \frac{\sin 45°}{\sin 30°} \Rightarrow v = \frac{3 \times 10^8 \times \sin 30°}{\sin 45°}$$

$$\therefore \quad v = \frac{3 \times 10^8 \times \frac{1}{2}}{\frac{1}{\sqrt{2}}} \Rightarrow v = 3 \times 10^8 \times \frac{1}{2} \times \sqrt{2}$$

$\therefore$ $v = 1.5 \times 1.41 \times 10^8 = 2.115 \times 10^8$ m/s

81. (i) *Refer to answer 79.*

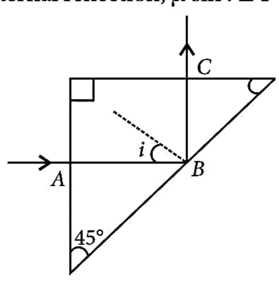
(ii) At point B, for total internal reflection, $\mu \sin i \geq 1$

$$\mu \geq \frac{1}{\sin i}$$

$$\mu \geq \frac{1}{\sin 45°} = \sqrt{2} \qquad (\because i = 45°)$$

$\therefore$ $\mu \geq \sqrt{2}$

$\mu_{min} = \sqrt{2}$



82. *Refer to answer 79.*

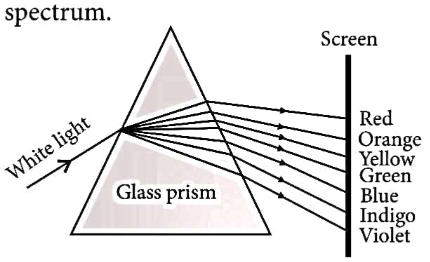
83. *Refer to answer 79.*

84. (a) *Refer to answer 79.*
(b) *Refer to answer 73.*

85. The refractive index of prism-material depends on the wavelength λ of light. It is inversely proportional to square of wavelength *i.e.*, $\mu \propto \frac{1}{\lambda^2}$:
Accordingly refractive index is maximum for violet (λ = 4000 Å) and minimum for red (λ = 7500 Å). So the deviation caused by prism $\delta_m = (\mu - 1) A$ is maximum for violet and minimum for red; hence on passage through the prism; the different colours are separated; thus causing dispersion of white light.

86. When white light is dispersed by a prism, the violet colour deviates through maximum angle. Hence it is seen at the bottom of the spectrum.

87. "Dispersion" of light is the phenomenon of splitting up of white light into its constituent colours. The band of seven colours then obtained on the screen is called "VIBGYOR".
The colour pattern obtained on the screen is also called spectrum.



Cause of dispersion : White light consist of continuous forward wavelength range 400 nm to 700 nm. Refractive index of glass is different for different wavelengths.
Cauchy's formula relating refractive index μ of prism with wavelength λ of light is given by

$$\mu = a + \frac{b}{\lambda^2} + \frac{c}{\lambda^4} + \ldots\ldots\ldots$$

where *a*, *b* and *c* are constants of material of prism.
According to this, refractive index of prism is maximum for violet as its wavelength is minimum and is minimum for red light as its wavelength is maximum.
Hence bending of red light is minimum whereas bending of violet light is maximum.
As, $\delta = A(\mu - 1)$
$\lambda_V < \lambda_R$
i.e. $\mu_V > \mu_R$
so $\delta_V > \delta_R$

Thus red colour deviates least and violet colour deviates maximum.
Hence all colours of white light get deviated at different angles on passing through prism, producing spectrum.

88. 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 atomsphere, red waves of longer wavelength are least scattered and reach the observer. So the sun appears red.

89. The amount of scattering as per Rayleigh's law depends upon wavelength.

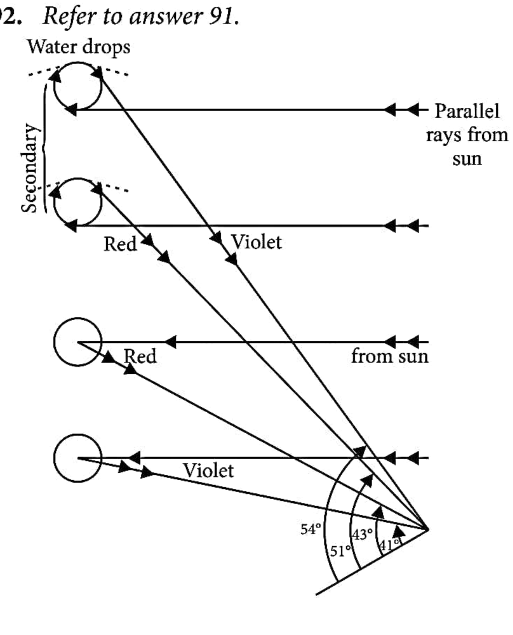
$$\text{Scattering} \propto \frac{1}{\lambda^4}$$

As $\lambda_B < \lambda_R$
Hence blue colour scatters more and also blue colour is most sensitive to our eyes than any colour like violet and indigo. Thus the part of atmosphere which we observe as sky has scattering of blue colour mostly, thus the sky appears to be bluish.

90. *Refer to answer 89.*

91. The conditions for observing a rainbow are :
(i) After the rain, the sky is almost clear and there is bright sunshine, with clouds in the east.
(ii) The sun is at the back of the observer. When a rainbow is seen, the sun, observer's eye and the centre of the arc of the rainbow are all in a straight line. Sometimes, we see a rainbow in the morning. Rainbow is also sometimes seen while using a lawn sprinkler.

92. *Refer to answer 91.*



93. *Refer to answer 89.*

94. For a telescope, lens L_1 is used as objective as its aperture is largest. The lens L_3 is used as eye piece as its focal length is smallest.

95. Maximum magnification of a compound microscope is

$$m = \frac{v_0}{u_0}\left[1 + \frac{D}{f_e}\right]$$

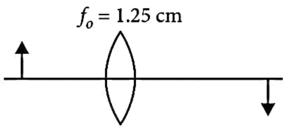
So, for m to be 30,

$$30 = \frac{v_0}{u_0}\left[1 + \frac{25}{5}\right] \quad \text{or} \quad 30 = \frac{v_0}{u_0}[6]$$

$v_0 = 5u_0$ ... (i)

For objective of focal length 1.25 cm,

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



$$\frac{1}{5u_o} - \frac{1}{-u_o} = \frac{1}{1.25}$$

$$\frac{1+5}{5u_o} = \frac{1}{1.25}$$

$5u_o = +7.5$ cm or $u_o = 1.5$ cm. So, $v_o = +7.5$ cm

Now u_e for required magnification

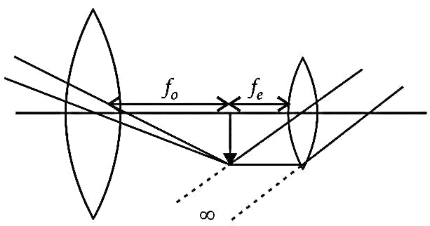
$$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e} \quad \text{or} \quad \frac{1}{-25} - \frac{1}{-u_e} = \frac{1}{5}$$

$$\frac{1}{u_e} = \frac{1}{5} + \frac{1}{25} = \frac{5+1}{25} \quad \text{or} \quad u_e = \frac{25}{6} \text{ cm}$$

Hence, separation between two lenses should be

$$v_o + u_e = 7.5 \text{ cm} + \frac{25}{6} \text{ cm} = 11.67 \text{ cm}$$

96.



Magnifying power of telescope in normal adjustment

$$m = -\frac{f_o}{f_e} = -\frac{150}{5} = -30 \quad \text{... (i)}$$

Height of image for a 100 m tall tower 3 km away, formed by objective lens

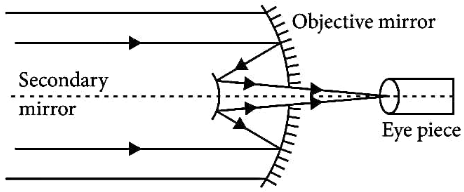
$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o} \Rightarrow \frac{1}{v_o} - \frac{1}{-3000} = \frac{1}{1.5}$$

$$\frac{1}{v_o} = \frac{1}{1.5} - \frac{1}{3000} = \frac{2998.5}{4500} \Rightarrow v_o = \frac{4500}{2998.5} \text{ m}$$

Also, $\frac{h_1}{h_0} = \frac{v_o}{u_o} \Rightarrow \frac{h_1}{100} = \frac{4500}{2998.5} \times \frac{1}{-3000}$

$$h_1 = -\frac{150}{2998.5} \text{ m} = -0.05 \text{ m} = -5 \text{ cm}$$

97. (a)



(b) Advantages :

(i) It is free from chromatic aberration.

(ii) Its resolving power is greater than refracting telescope due to larger aperture of mirror.

98. *Refer to answer 97.*

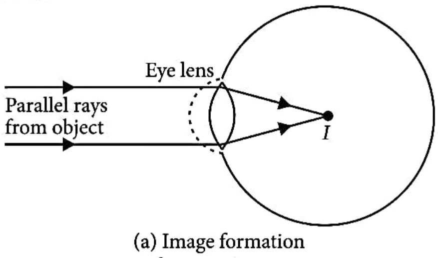
99. Myopia or shortsightedness : Myopia is the defect of eye in which a person can see only nearby objects, but fails to see far away object distinctly.

This defect is due to

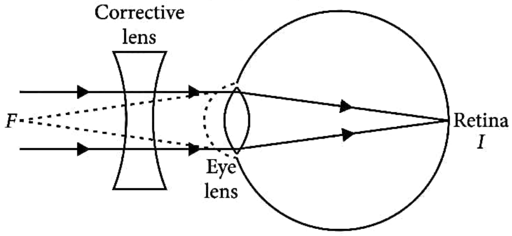
(a) decrease in focal length of the eye lens.

(b) spreading of the eye-sphere.

Due to these reasons the image is formed in front of the retina.

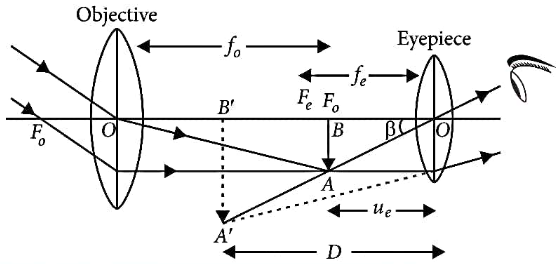


(a) Image formation by myopic eye



(b) Corrected myopia

100. Astronomical telescope in the near point position :



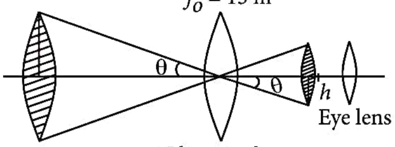
Magnifying power, $m = -\frac{f_o}{f_e}\left(1+\frac{f_e}{D}\right)$

101. *Refer to answer 97.*

102. (i) Here, f_o = 15 m = 1500 cm and f_e = 1.0 cm
Angular magnification by the telescope in normal adjustment

$$m = \frac{f_o}{f_e} = \frac{1500 \text{ cm}}{1.0 \text{ cm}} = 1500$$

(ii) The image of the moon by the objective lens is formed on its focus only as the moon is nearly at infinite distance as compared to focal length.



Height of object

i.e., Radius of moon $R_m = \frac{3.48}{2} \times 10^6$ m

$R_m = 1.74 \times 10^6$ m

Distance of object = Radius of lunar orbit

$R_0 = 3.8 \times 10^8$ cm

Distance of image for objective lens is the focal length of objective lens, f_0 = 15 m

Radius of image of moon by objective lens can be calculated.

$$\tan\theta = \frac{R_m}{R_0} = \frac{h}{f_o}$$

$$h = \frac{R_m \times f_o}{R_0} = \frac{1.74 \times 10^6 \times 15}{3.8 \times 10^8}$$

$h = 6.87 \times 10^{-2}$ m

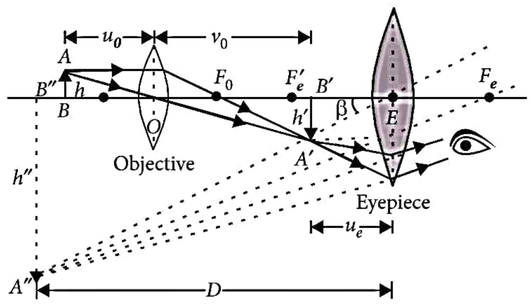
Diameter of the image of moon,

$D_I = 2h = 13.74 \times 10^{-2}$ m = 13.74 cm

103. An astronomical telescope should have an objective of larger aperture and longer focal length while an eye piece of small aperture and small focal length. Therefore, we will use L_2 as an objective and L_3 as an eyepiece.

For constructing microscope, L_3 should be used as objective and L_1 as eyepiece because both the lenses of microscope should have short focal lengths and the focal length of objective should be smaller than the eyepiece.

104. (a)



(b) Separation between eye-piece and the objective, L = 14 cm,

$m = -20$, $m_e = 5$, D = 20 cm, f_o = ?, f_e = ?

Magnification of eye-piece when image is formed at the least distance for clear vision

$$m_e = \left(1+\frac{D}{f_e}\right) \Rightarrow 5 = \left(1+\frac{20}{f_e}\right)$$

$$\Rightarrow 4 = \frac{20}{f_e} \Rightarrow f_e = 5 \text{ cm}$$

Net magnification of the compound microscope when image is formed at the least distance for clear vision

$$m = -\frac{L}{f_o}\left(1+\frac{D}{f_e}\right) \Rightarrow -20 = -\frac{14}{f_o}\left(1+\frac{20}{5}\right)$$

$$\Rightarrow 10 = \frac{7}{f_o}(5) \Rightarrow f_o = \frac{35}{10} = 3.5 \text{ cm}$$

105. (i) *Refer to answer 97(a).*

(ii) *Refer to answer 97(b).*

(iii) (a) The objective of a telescope have a larger focal length to obtain large magnifying power and greater intensity of image.

(b) The aperture of objective lens of a telescope is taken as large because this increases the light gathering capacity of the objective from the distant object. Consequently, a brighter image is formed.

106. (a) (i) Given $f_0 = 140$ cm, $f_e = 5$ cm
When final image is at infinity, magnifying power,

$$m = \frac{-f_0}{f_e} = -\frac{140}{5.0}$$

$m = -28$

Negative sign shows that the image is inverted.

(ii) When final image is at the least distance of distinct vision,

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

$$= \frac{-140}{5.0}\left(1 + \frac{5.0}{25}\right) = -33.6$$

(b) Separation between objective and eye piece when final image is formed at infinity,

$L = f_0 + f_e$

$L = 140$ cm + 5.0 cm

$L = 145$ cm

107. *Refer to answer 104(a).*

108. For objective $u_1 = -100$ cm

$f_1 = 10$ cm, $v_1 = ?$

We know that $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\therefore \quad \frac{1}{v_1} + \frac{1}{100} = \frac{1}{10}$, On simplification,

$$v_1 = \frac{100}{9} \text{ cm}$$

Magnification produced by objective is given by

$$M_0 = \frac{v_1}{u_1} = \frac{100/9}{-100} = -\frac{1}{9}$$

For eyepiece, $u_2 = ?$, $f_2 = 1$ cm, $v_2 = -25$ cm

Again, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ or $-\frac{1}{25} - \frac{1}{u_2} = \frac{1}{1}$,

On simplification, $u_2 = \frac{-25}{26}$ cm. The magnification produced by the eyepiece is given by

$$m_e = \frac{v_2}{u_2} = \frac{-25}{-25/26} = 26$$

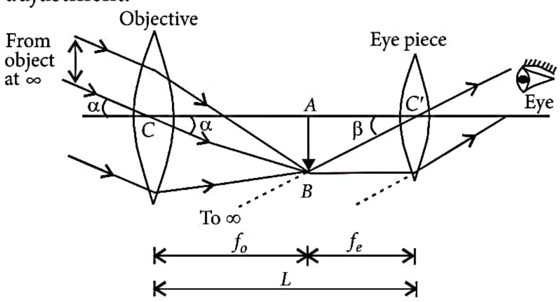
Magnifying power of telescope,

$$m = m_e \times m_0 = -26 \times \frac{1}{9} = -2.89$$

Length of telescope tube

$$= v_1 + |u_2| = \left(\frac{100}{9} + \frac{25}{26}\right) = 12.1 \text{ cm}$$

109. (i) (a) An astronomical telescope in normal adjustment.



It is used to see distant objects.

It consists of two lenses:

Objective of large aperture and large focal length f_o.

Eyepiece of small aperture and short focal length f_e.

(b) Working : Telescope has an objective and eyepiece. The objective has a large focal length and much larger aperture than the eyepiece. Light from a distant object enters the objective and a real image is formed in the tube at its second focal point. The eye piece magnifies this image and the final inverted image is formed at infinity.

(ii) Here, power of objective lens = 1 D

Power of eye piece = 10 D

In normal adjustment

Magnifying power, $m = -\frac{f_o}{f_e} = -\frac{P_e}{P_o}$

$\Rightarrow \quad m = -10$

110. (i) Compound microscope is used to see extremely small objects. It consists of two lenses.

Objective lens of short aperture and short focal length f_o.

Eye lens of large aperture and short focal length f_e.

For ray diagram of a compound microscope,

Refer to answer 104(a).

Working : A real, inverted and enlarged image $A'B'$ of a tiny object AB, is formed by objective. Eye lens is so adjusted that $A'B'$ lies between its optical centre and principle focus F_e. A virtual and magnified image $A''B''$ (erect w.r.t. $A'B'$) is formed by the eye lens.

(ii) Both, the objective and the eye piece of a compound microscope should have short focal lengths to have greater magnifying power as magnifying power of a compound microscope is given by

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

where
L = length of microscope tube
D = least distance of distinct vision.

111. *Refer to answer 97.*

112. *Refer to answer 109.*
Numerical :
Here $m = 20$, $L = 105$ cm, $f_0 = ?$, $f_e = ?$

$$m = \frac{f_0}{f_e} \Rightarrow 20 = \frac{f_0}{f_e} \therefore f_0 = 20f_e$$

Also $L = 105 \Rightarrow f_0 + f_e = 105$

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

$$\therefore \quad f_e = \frac{105}{21} = 5 \text{ cm}$$

$$\therefore \quad f_0 = 20f_e = 20 \times 5 = 100 \text{ cm}$$

Therefore, focal length of objective f_0 is 100 cm and focal length of eye piece f_e is 5 cm.

113. (a) (i)Hypermetropia is the defect of eye in which a person can see only farther objects but fails to see nearer objects distinctly. This defect is due to increase in focal length of eye lens.
(ii) The equivalent focal length of corrective convex lens and eye lens should be decreased to a value such that the distinct image of nearby objects is formed at the retina.
(b) Presence of mind, alertness, taking initiative, helpful, caring.

114. *Refer to answer 109 (i) (a).*
Magnifying power: It is the ratio of the angle subtended at the eye, by the final image, to the angle which the object subtends at the lens, or the eye.
(ii) (a) For a telescope, power of objective = 0. 5 D
Power of eyepiece = 10 D
This choice would give higher magnification as

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

(b) Aperture of the objective is preferred to be large so as to have high resolving power and larger light gathering power to obtain brighter image.

115. (i) *Refer to answer 109 (i) (a).*
(ii) Refracting telescope suffer from chromatic and spherical aberrations.
Chromatic aberration : The inability of a lens in which image formed by white object is coloured and blurred. This inability of lens to form a clear image is known as chromatic aberration.
Spherical aberration : The inability of a lens to form a point image of an object is called spherical aberration.
In the reflecting-type telescope, the objective lens is replaced by the concave parabolic mirror of a large aperture required for observing fainter objects. The use of parabolic mirror makes the resolving power of the telescope high. The parabolic mirrors are free from chromatic and spherical aberrations.

116. *Refer to answer 100.*
Magnifying power of refracting telescope (M) is defined as the ratio of the angle subtended by the image (β) at the eye to the angle subtended by the distant object at the unaided eye (α).

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

We can increase the magnifying power of telescope by
1. Increasing the focal length of the objective
2. Decreasing the focal length of eyepiece

Two limitations of refractive telescope are:
1. The lenses used in refractive telescope are expensive.
2. The lenses used for making refracting telescope have chromatic aberration and distortions.

They can be minimised by using reflecting type telescope, which use concave mirror rather than a lens for the objective. Reflecting type telescope has the following advantages :
1. They are free from chromatic aberration as mirror is used instead of lens.
2. There is no problem for mechanical support because weight of mirror is much less than the weight of the lens. It can be supported easily.

117. *Refer to answer 104 (a).*
Limit of resolution : The minimum distance between two objects at which they can be seen separately by an optical instrument is known as limit of resolution of the instrument.

Limit of resolution depends upon the wavelength of the light used and the cone angle of light rays entering the microscope from the object.

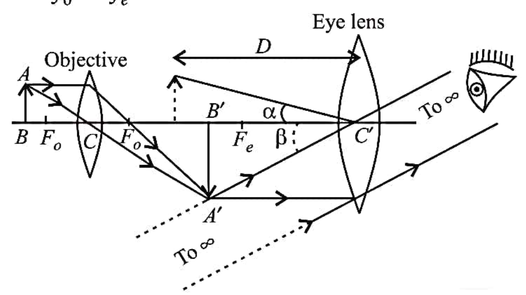
$$d = \frac{1}{\text{RP of the microscope}}$$

where, RP is the resolving power and d is the limit of resolution.

(b) Resolving power of a microscope can be increased by
(i) decreasing the wavelength of light used
(ii) increasing the diameter of objective lens of the microscope.
(c) Through telescope, we see the objects that are at infinite distance from the observer. These objects are already far apart from each other, but due to infinite distance from the observer, they do not appear distinctly. Thus, the telescope resolves these distant objects, so that we can see them distinctly. On the other hand, a microscope magnifies extremely small objects. Thus, one can say that "a telescope resolves whereas a microscope magnifies".

118. When image is formed at infinity the magnifying power of compound microscope is given by

$$M = \frac{-L}{f_0} \times \frac{D}{f_e}$$



Magnification due to objective, $m_0 = \frac{L}{-f_0}$

Angular magnification due to eyepiece, $m_e = \frac{D}{f_e}$

Total magnification when the final image is formed at infinity,

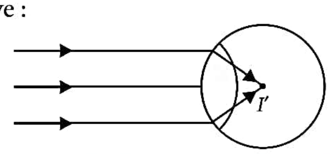
$$m = m_0 \times m_e = -\frac{L}{f_0} \times \frac{D}{f_e}$$

Obviously, magnifying power of the compound microscope is large when both f_0 and f_e are small.

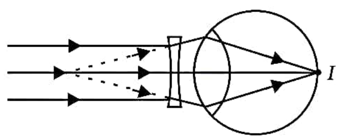
119. (a) *Refer to answer 109 (i).*
In order to have a large magnifying power and high resolution of the telescope, its objective lens should have a large focal length and the eyepiece lens should have a short focal length.
(b) Distance between the objective and the eyepiece,
$L = v_0 + |u_e|$
To find v_0, we have :
$v_0 = \infty$ cm and $f_0 = 1.25$ cm

Now, $\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$
or $v_0 = 2.5$ cm
To find u_e, we have :
$v_e = \infty$ and $f_e = 5$ cm
Calculating using the same formula as above, we get :
$u_e = -5$ cm
$\therefore \quad L = 2.5 + 5 = 7.5$ cm

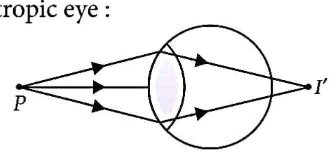
120. (a) *Refer to answer 118.*
(b) Near sightedness or Myopia : A person suffering from myopia can see only nearby objects clearly, but cannot see the objects beyond a certain distance clearly.
Myopic eye :



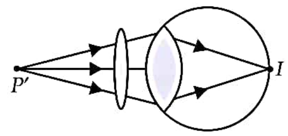
Correction : In order to correct the eye for this defect, a concave lens of suitable focal length is placed close to the eye so that the parallel ray of light from an object at infinity after refraction through the lens appears to come from the far point of the myopic eye.



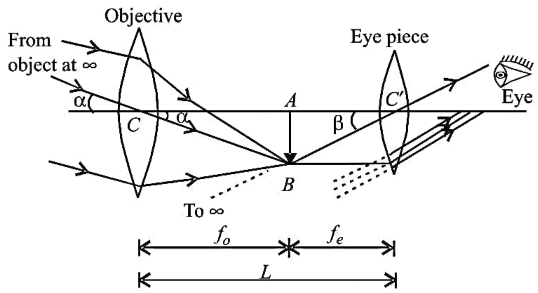
Far sightedness or Hypermetropia : A person suffering from hypermetropia can see distant objects clearly, but cannot see nearby objects.
Hypermetropic eye :



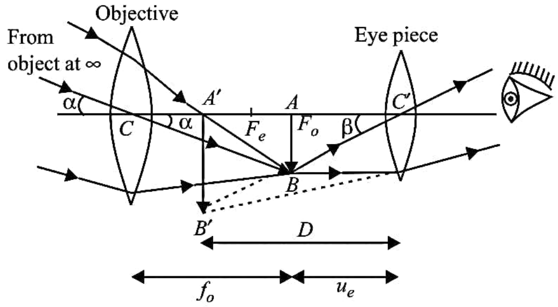
Correction : To correct this defect, a convex lens of suitable focal length is placed close to the eye so that the rays of light from an object placed at the point P after refraction through the lens appear to come from the near point P' of the hypermetropic eye.



121. (a) When final image is formed at infinity :



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



(b) The magnifying power of a telescope is measured by the ratio of angle (β) subtended by the final image on the eye to the angle (α) subtended by object on eye.

$$M = \frac{-f_o}{f_e} \text{ (normal adjustment)}$$

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

where f_o is focal length of the objective and f_e is the focal length of eye piece.

(c) Two limitations of refracting type telescope

(i) Image formed is of lesser intensity.

(ii) Image is not free from chromatic aberration due to refraction.

122. (a) *Refer to answer 121(b).*

(b) Here, f_o = 150 cm, f_e = 5 cm

Angle subtended by 100 m tall tower at 3 km is

$$\alpha = \frac{100}{3\times 1000} = \frac{1}{30} \text{ rad}$$

If h is the height of image formed by the objective, then

$$\alpha = \frac{h}{f_o} = \frac{h}{150}$$

$$\therefore \frac{h}{150} = \frac{1}{30} \quad \text{or} \quad h = \frac{150}{30} \text{ cm} = 5 \text{ cm}$$

Magnification produced by eyepiece

$$m_e = \left(1+\frac{D}{f_e}\right) = \left(1+\frac{25}{5}\right) = 6$$

∴ Height of final image = $h \times m_e = 5 \times 6 = 30$ cm

123. (a)

	Telescope		Microscope
1.	Resolving power should be higher for certain magnification.	1.	Resolving power is not so large but the magnification should be higher.
2.	Focal length of objective should be kept larger while eyepiece focal length should be small for better magnification.	2.	Both objective and eyepiece should have less focal length for better magnification.
3.	Objective should be of large aperture.	3.	Eyepiece should be of large aperture.
4.	Distance between objective and eyepiece is adjusted to focus the object at infinity.	4.	Distance between objective and eyepiece is fixed. For focusing an object distance of objective is changed.

(b) Here, f_o = 1.25 cm, f_e = 5 cm, m = 30

In normal adjustment, image is formed at least distance of distinct vision, D = 25 cm.

Angular magnification of eyepiece

$$m_e = \left(1+\frac{D}{f_e}\right) = \left(1+\frac{25}{5}\right) = 6$$

Total angular magnification, $m = m_o m_e$

∴ Angular magnification of the objective is

$$m_e = \frac{m}{m_o} = \frac{30}{6} = 5$$

As the objective forms the real image

$$\therefore m_o = \frac{v_o}{u_o} = -5 \text{ or } v_o = -5u_o$$

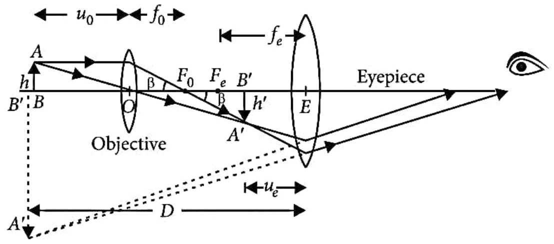
$$\text{As } \frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o} \text{ or } \frac{1}{-5u_o} - \frac{1}{u_o} = \frac{1}{1.25}$$

$$\text{or } \frac{-6}{5u_o} = \frac{1}{1.25}$$

$$u_o = -\frac{1.25\times 6}{5} = -1.5 \text{ cm}$$

Therefore, the object should be held at 1.5 cm in front of the objective lens.

124. Formation of image by a compound microscope : A schematic diagram of a compound microscope is shown in figure :



$$m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha} = \frac{h'/u_e}{h/D} = \frac{h'}{h}\cdot\frac{D}{u_e} = m_0 m_e$$

Here $m_0 = \frac{h'}{h} = \frac{v_0}{u_0}$

As the eyepiece acts as a simple microscope, so

$$m_e = \frac{D}{u_e} = 1 + \frac{D}{f_e} \quad \therefore\ m = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$$

As the object AB is placed close to the focus F_0 of the objective, therefore,

$$u_0 \simeq -f_0$$

Also image $A'B'$ is formed close to the eye lens whose focal length is short, therefore $v_0 \simeq L$ = the length of the microscope tube or the distance between the two lenses.

$$\therefore\quad m_0 = \frac{v_0}{u_0} = \frac{L}{-f_0}$$

$$\therefore\quad m = -\frac{L}{f_0}\left(1 + \frac{D}{f_e}\right) \qquad \text{[for final image at } D\text{]}$$

Numerical : $u_0 = -1.5$ cm, $f_0 = 1.25$ cm, $f_e = 5$ cm, $D = 25$ cm

$$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0} \Rightarrow \frac{1}{v_0} - \frac{1}{-1.5} = \frac{1}{1.25}$$

$$\frac{1}{v_0} = \frac{1}{1.25} - \frac{1}{1.5}$$

$$\text{or}\quad v_0 = \frac{1.25\times 1.5}{0.25} = 5 \times 1.5 = 7.5 \text{ cm}$$

$$\text{Magnifying power, } M = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$$

$$= -\frac{7.5}{1.5}\left(1 + \frac{25}{5}\right)$$

$$= -5(1 + 5) = -30$$

125. (i) The magnifying power of a compound microscope is defined as the ratio of the angle subtended at the eye by the final virtual image to the angle subtended at the eye by the object, when both are at the least distance of distinct vision from the eye.

(ii) *Refer to answer 110 (ii).*

126. *Refer to answer 97 (b).*

127. (a) and (b) *Refer to answer 124.*

(c) *Refer to answer 110(ii).*