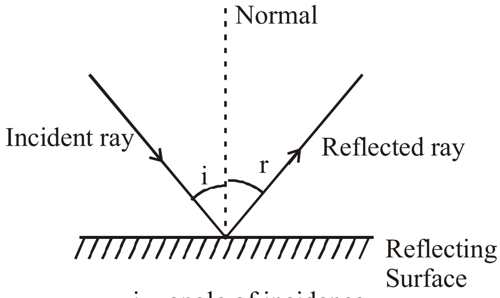
Chapter 24
Ray Optics and Optical Instruments

REFLECTION OF LIGHT

It is the turning back of light in the same medium.



Laws of Reflection

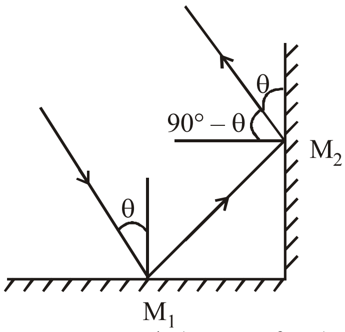
(i) Angle of incidence (i) = angle of reflection (r)

(ii) The incident ray, reflected ray and normal are always in same plane.

REFLECTION FROM PLANE SURFACE

Plane mirror has infinitely large radius of curvature. It produces virtual image of same size but laterally inverted. Image is as much behind the mirror as much is the object in front of it.

(i) If the direction of the incident ray is kept constant and the mirror is rotated through an angle θ about an axis in the plane mirror, then the reflected ray rotates through an angle 2θ.



(ii) If an object moves towards (or away from) a plane mirror at a speed v, the image will also approach (or recede) at the same speed v, i.e. the speed of image relative to object will be v – (–v) = 2v.

(iii) If two plane mirrors are inclined to each other at 90º, the emergent ray is always antiparallel to incident ray if it suffers one reflection from each whatever be the angle of incidence. The same is found to hold good for three-plane mirrors forming the corner of a cube if the incident light suffers one reflection from each of them.

(iv) If there are two plane mirrors inclined to each other at an angle θ, the no. of images of a point object formed are determined as follows :

(a) If $\frac{360°}{\theta}$ is even integer (say m), no. of images formed = (m – 1), for all positions of object.

(b) If $\left(\frac{360°}{\theta}\right)$ is odd integer (say m), no. of images formed, n = m, if the object is not on the bisector of mirrors and n = (m – 1), if the object is on the bisector of mirrors.

(c) If $\left(\frac{360°}{\theta}\right)$ is a fraction, the no. of images formed will be equal to its integral part.

Note : A plane mirror always forms a virtual image if object is real and forms a real image if the object is virtual.

MIRROR FORMULA

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

where, u = distance of the object from the pole of mirror
v = distance of the image from the pole of mirror
f = focal length of the mirror.

Note : Mirror formula is valid only when the following conditions are satisfied :

(a) Object is placed very near to the principal axis.

(b) Object is placed far from the mirror.

Magnification

$$m=\frac{v}{u}=\frac{v-f}{f}=\frac{f}{u-f} \text{ or } m=\frac{I}{O}=-\left[\frac{v}{u}\right]$$

where, I = size of the image and O = size of the object and negative sign implies that image is inverted w.r.t the object.

The above formulae are applicable only for paraxial rays (the rays which makes very small angle with the principal axis).

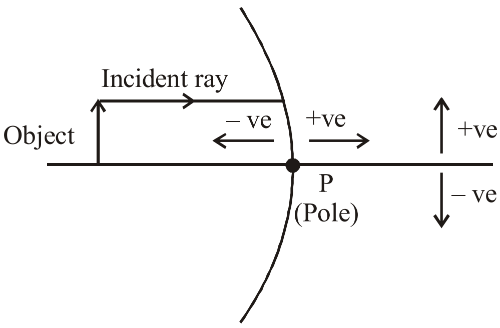
Areal magnification : When a two dimensional object is placed with its plane perpendicular to the principal axis, its magnification called superficial magnification or aerial magnification and is given by

$$M_s = \frac{Area\ of\ image}{Area\ of\ object} = m^2 = \left(\frac{v}{u}\right)^2$$

Sign Conventions for Mirror and Lenses

New cartesian sign conventions :

1. All the distances are measured from pole of spherical mirror and optical centre in case of lenses.
2. The distances measured in a direction opposite to the direction of incident light is taken as negative and vice-versa.
3. The heights measured upward and perpendicular to the principal axis of mirror are taken as positive and vice -versa.
4. Angle measured from the normal in the anticlockwise direction is positive and vice-versa.



Reflecting or refracting surface

IMAGE FORMED BY CONCAVE AND CONVEX MIRROR

Image Formed by Concave Mirror

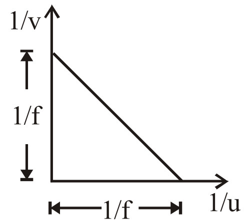
Position of object	Position of image	Magnification	Nature of image
Between P and F	Behind the mirror	+ve, m > 1	Virtual and erect
At F	At infinity	– ve, Highly magnified	Real and inverted
Between F and C	Beyond C	– ve, Magnified	Real and inverted
At C	At C	m = –1	Real and inverted
Beyond C	between F and C	Dismished	Real and inverted
At infinity	At F	Highly diminshed	Real and inverted

Image Formed by Convex Mirror

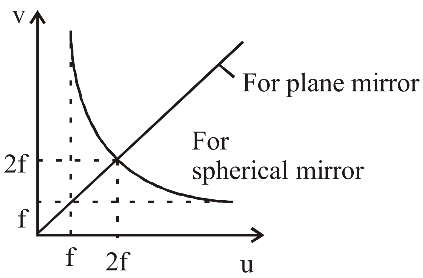
Position of object	Position of image	Magnification	Nature of image
Infront of mirror	Between P and F	m < +1	Virual and erect
At infinity	At F	m < < +1	Virtual and erect

Keep in Memory

1. Rays retrace their path when their direction is reversed.
2. Focal length of a mirror depends only on the curvature of the mirror $\left(f = \frac{R}{2}\right)$. It does not depend on the material of the mirror or on the wavelength of incident light.
3. Focal length of concave mirror is always negative. Focal length of convex mirror is always positive.
4. The graph of $\frac{1}{v}$ versus $\frac{1}{u}$ for a concave mirror, if real image is formed.



5. The graph shows variation of v with change in u for a mirror.



6. A person needs a plane mirror of minimum half of his height to see his full image.
7. A person standing in the middle of room can see complete wall behind him if the mirror in front of him is $\frac{1}{3}$rd of height of wall.
8. A convex mirror is used as a rear view mirror (called driver mirror).
9. If two or more optical components produce magnification, then overall magnification (m) is the product of magnification due to each component,
   i.e., $m = m_1 \times m_2 \times \ldots$
   - If m is negative, the image is inverted
   - If m is positive, the image is erect.
10. When an object moves with constant speed towards a concave mirror from infinity to focus, the image will move away from the mirror slower in the beginning and with the speed of the object when it is at centre of curvature C and faster later on.
11. Concave mirrors are used as reflectors, as objective in reflecting telescope and by doctors (ENT) to examine ears, nose and throat. It is also used as shaving mirrors.
12. The inability of a spherical mirror (or lens) of large aperture to focus the paraxial rays and marginal rays to the same point on the principal axis is called spherical aberration. Due to this defect the image formed is blurred. This defect can be removed by using parabolic mirror.
13. Chromatic aberration is absent in mirrors but present in

lenses. This is because the focal length of mirror is independent of wavelength of light $\left(f=\frac{R}{2}\right)$ but that of lens is dependent on wavelength.

14. Different colour rays travel with different velocity in a medium but velocity of all coloured rays is same in vacuum (and air).

15. If a hole is formed in a mirror, then also we will get full image with no hole in the image. The hole will only reduce the intensity of rays forming the image.

Newton's Formula

In case of spherical mirrors if object distance (x_1) and image distance (x_2) are measured from focus instead of pole, $u=(f+x_1)$ and $v=(f+x_2)$, the mirror formula $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

reduces to $\frac{1}{(f+x_2)}+\frac{1}{(f+x_1)}=\frac{1}{f}$

which on simplification gives $x_1 x_2 = f^2$

Example 1.

The focal length of a concave mirror is 30 cm. Find the position of the object in front of the mirror, so that the image is three times the size of the object.

Solution :

Here image can be real or virtual. If the image is real

$f=-30,\ u=?,\ m=-3$

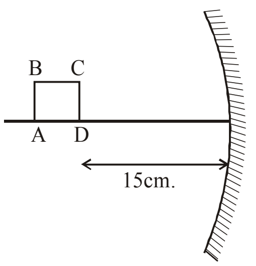
$$m=\frac{f}{f-u} \Rightarrow -3=\frac{-30}{-30-u} \Rightarrow u=-40 \text{ cm.}$$

If the image is virtual

$$m=\frac{f}{f-u} \Rightarrow 3=\frac{-30}{-30-u} \Rightarrow u=-20 \text{ cm.}$$

Example 2.

A square ABCD of side 1mm is kept at distance 15 cm infront of the concave mirror as shown in the figure. The focal length of the mirror is 10 cm. Find the perimeter of its image.



Solution :

$$v=-30,\ m=-\frac{v}{u}=-2$$

$$\therefore\ A'B' = C'D' = 2\times 1 = 2\text{mm}$$

$$\text{Now } \frac{B'C'}{BC}=\frac{A'D'}{AD}=\frac{v^2}{u^2}=4 \Rightarrow B'C' = A'D' = 4 \text{ mm}$$

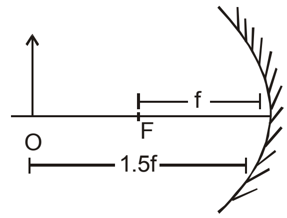
$$\therefore \text{Perimeter} = 2+2+4+4 = 12 \text{ mm}$$

Example 3.

An object of length 2.5 cm is placed at a distance of 1.5 f from a concave mirror where f is the magnitude of the focal length of the mirror. The length of the object is perpendicular to the principal axis. Find the length of the image. Is the image erect or inverted?

Solution :

The given situation is shown in figure.



The focal length $f=-f$ and $u=-1.5f$, we have

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \text{ or } -\frac{1}{1.5f}+\frac{1}{v}=-\frac{1}{f}$$

$$\text{or } \frac{1}{v}=\frac{1}{1.5f}-\frac{1}{f}=\frac{-1}{3f} \text{ or } v=-3f$$

$$\text{Now } m=-\frac{v}{u}=\frac{3f}{-1.5f}=-2 \text{ or } \frac{h_2}{h_1}=-2$$

or $h_2=-2h_1=-5.0$ cm

The image is 5.0 cm long. The minus sign shows that it is inverted.

REFRACTION

Whenever a wave is bounced back into same medium at an interface reflection is said to have occurred. Transmission of a wave into the second medium at an interface is called refraction.

When a ray of light is passing from denser to rarer medium, it bends away from the normal and when passing from rarer to denser medium, it bends towards the normal.

- When a ray of light passing from one medium to another medium frequency and phase do not change while wavelength and velocity changes.
- Twinkling of stars, appearance of sun before actual sunrise and after actual sunset etc. are due to atmospheric refraction.

Laws of Refraction

(i) **Snell's Law :** When a light ray is incident on a surface separating two transparent media, the ray bends at the time of changing the medium.

i.e. $\frac{\sin i}{\sin r}=\frac{v_1}{v_2}=\frac{\mu_2}{\mu_1}={}_1\mu_2,$

where i = angle of incidence

r = angle of refraction

v_1 = vel. of light in 1st medium

v_2 = vel. of light in 2nd medium

${}_2^1\mu$ or ${}_1\mu_2$ = refractive index of 2nd medium w.r.t. the 1st medium.

μ_1 = refractive index of 1st medium w.r.t vacuum (or air)

μ_2 = refractive index of 2nd medium w.r.t vacuum (or air)

(ii) The incident ray, the normal and the refracted ray at the interface all lie in the same plane.

Refractive Index of the Medium

(a) Refractive index of second medium w.r.t. first medium

$${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{c/v_2}{c/v_1} = \frac{v_1}{v_2}$$

$$= \frac{\textit{Velocity of light in first medium}}{\textit{Velocity of light in second medium}}$$

(b) Absolute refractive index of medium (n or μ)

$$\frac{\textit{Velocity of light in vacuum}}{\textit{Velocity of light in medium}} = \frac{c}{v} = \frac{\sin i}{\sin r} = n = \mu$$

Refractive index is the relative property of two media. *If the first medium carrying the incident ray is a vacuum, then the ratio* $\frac{\text{Sin}\, i}{\text{Sin}\, r}$ *is called the 'absolute refractive index of the second medium'*. The relative refractive index of any two media is equal to the ratio of their absolute refractive indices. Therefore, if the absolute refractive index of medium 1 and 2 be n_1 and n_2 respectively, then the refractive index of medium 2 with respect to medium 1 is

$${}_1n_2 = n_{12} = \frac{n_2}{n_1} = \frac{\text{Sin}\, i}{\text{Sin}\, r}$$

$n_1 \sin i = n_2 \sin r$

According to **cauchy's formula**

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

where, A and B are cauchy's constant.

$\lambda_{red} > \lambda_{violet}$

so, $\mu_{red} < \mu_{violet}$

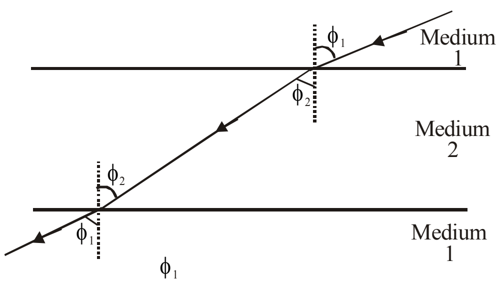
(c) $${}_1n_2 = \frac{1}{{}_2n_1}$$

(d) For three mediums 1, 2 and 3 due to successive refraction.

$${}_1n_2 \times {}_2n_3 \times {}_3n_1 = 1$$

$$\frac{n_2}{n_1} \times \frac{n_3}{n_2} \times \frac{n_1}{n_3} = 1$$

(e) For two mediums, n_1 and n_2 are refractive indices with respect to vacuum, the incident and emergent rays are parallel then $n_1 \sin\phi_1 = n_2 \sin\phi_2$.



Factors affecting refractive index :

(i) Nature of the medium

(ii) Wavelength

(iii) Temperature of the medium-with increase in temperature, refractive index of medium decreases.

Transmission of Wave

(i) The equation of the wave refracted or transmitted to the next medium is given by : $y = A'' \sin\left(\omega t - k_0' x\right)$. This is independent of the nature (rarer/denser) of the medium. The wave is not inverted.

(ii) The amplitude (A'') of the transmitted wave is less than that (A) of the incident wave.

(iii) The angular frequency remains unchanged. However the wave number changes. Note that the phase of the transmitted wave is $\left(\omega t - k_0' x\right)$ and that of the incident wave is $(\omega t - kx)$.

(iv) The compression or rarefaction are transmitted as such and same is the case with the crest or trough.

The wave velocity (v_p), the angular frequency (ω) and the wave number (k) are related as $v_p = \omega/k = n\lambda$. Let the wave velocity in the medium to which the wave is transmitted be $v'_p = \omega/k' = n\lambda'$.

(i) If second medium is denser, in comparison to first medium (i.e. $\mu_2 > \mu_1$), then from Snell's law

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = \frac{v_2}{v_1} \quad \text{here } \mu_2 > \mu_1 \text{ so } v_1 > v_2$$

$\Rightarrow k_1 < k_2$ and $\lambda_1 > \lambda_2$.

It means that *if ray goes from rarer medium to denser medium (i.e. from first medium to second medium), then wave number increases & wavelength decreases.*

(ii) If second medium is rarer in comparison to first medium, then from Snell's law

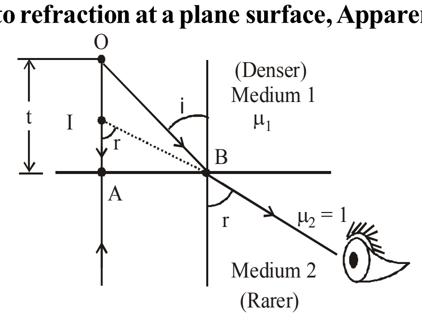
$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} \quad \text{here } \mu_2 < \mu_1 \text{ so } v_1 < v_2$$

$\Rightarrow k_1 > k_2$ and $\lambda_1 < \lambda_2$.

It means that *when ray goes from denser to rarer medium, then wave number decreases & wavelength increases.*

(iii) *No change in wave number k occurs on reflection.*

Image due to refraction at a plane surface, Apparent shift



(a) Here O = position of object

I = position of image

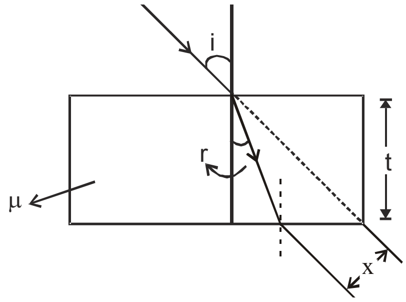
$$\frac{\textit{Apparent depth}}{\textit{Real depth}} = \frac{1}{\mu} = \frac{\mu_2}{\mu_1} \quad \text{i.e.} \quad \frac{AI}{AO} = \frac{1}{\mu} \Rightarrow AI = \frac{t}{\mu}$$

(b) The image shifts closer to eye by an amount OI = AO – AI or $\Delta t = \left(1 - \frac{1}{\mu}\right) t$ where t = thickness of medium over the object and Δt = apparent shift in its position towards the observer.

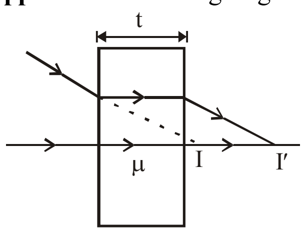
When an object in denser medium is seen through rarer medium, then apparent depth is less than real depth. But when an aeroplane or bird flying is seen by an observers in denser medium, the apparent height is more by $(\mu - 1)t$

Lateral shift by a slab of uniform thickness t, is

$$x = \frac{t}{\cos r}\sin(i - r)$$



The **apparent shift** through a glass slab is in the direction of light

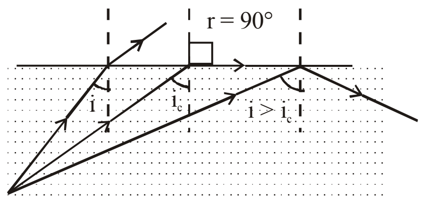


$$II' = S = t\left(1 - \frac{1}{\mu}\right)$$

TOTAL INTERNAL REFLECTION (TIR)

When the object is placed in an optically denser medium and if the incident angle is greater than the critical angle then the ray of light gets reflected back to the originating medium. This phenomenon is called total internal reflection.

Critical angle (i_c) : When a ray passes from an optically denser medium to an optically rarer medium, the angle of refraction r is greater than the corresponding angle of incidence i. From Snell's law



$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

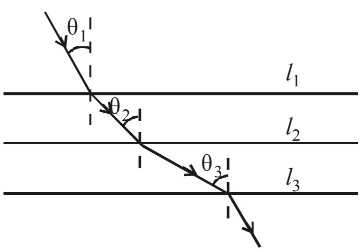
Let $\mu_1 = \mu$ and $\mu_2 = 1$ and let for $i = i_c$, $r = 90°$ then $\sin i_c = 1/\mu$

$\therefore\ i_c = \sin^{-1}\frac{1}{\mu}$; *i_c is called the critical angle*

This phenomenon takes place in shining of air bubble, sparkling of diamond, mirage and looming, in optical communication using optical fibre.

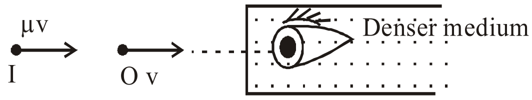
Keep in Memory

1. On travelling through a series of parallel layers, light follows the following formula
   $\mu \sin\theta = \text{constant} = \mu_1 \sin\theta_1 = \mu_2 \sin\theta_2 = \mu_3 \sin\theta_3$

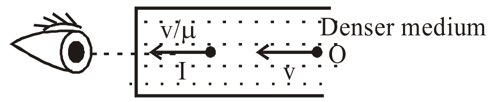


- It is important to note that the above relationship is valid only when boundaries undeviated.

2. In case of refraction, if i = 0 then r = 0. This means that the ray which strikes to a boundary at 90° passes through the boundary undeviated.
3. If an object moves towards a denser medium with a velocity v then the image moves faster with speed of μv as seen by the observer in denser medium.



If an object moves towards a rarer medium with a velocity v then the image moves slower with a speed v/μ as seen by the observer in rarer medium.



4. Denser the medium, smaller is the wavelength.
5. When light travels from one medium to another the wavelength and velocity changes proportionally but frequency of rays remains the same
6. ${}_2^1\mu = \frac{\mu_2}{\mu_1}$ and ${}_c^b\mu = \frac{{}^a\mu_c}{{}^a\mu_b}$ ('a' for air/vacuum)
7. When a parallel compound slab consists of two media of equal thickness and refractive indices μ_1 and μ_2 then the equivalent refractive index $\mu = \frac{2\mu_1\mu_2}{\mu_1 + \mu_2}$

COMMON DEFAULT

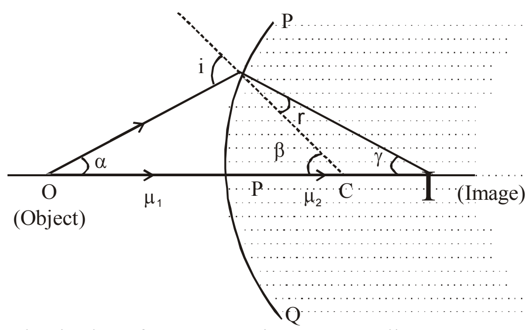
✗ ***Incorrect :*** If a mirror or a lens is painted black on one half, then half of image will be formed.

✓ ***Correct :*** If half of the mirror or lens is blackened, we get full image but with half the intensity.

REFRACTION AT A SPHERICAL SURFACE

For any curved spherical surfaces. Relation between u and v in terms of refractive indices of the mediums and the radius of curvature of the curved spherical surface.

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



Spherical surface separating two media

(i) The **lateral magnification** in case of refraction from curved surfaces $m = \frac{\mu_1}{\mu_2}\left(\frac{v}{u}\right)$

(ii) **Longitudinal magnification** $m' = \frac{\mu_2}{\mu_1}m^2$

Note : μ_1 is refractive index of medium 1 through which light passes first before meeting the interface and μ_2 is the refractive index of medium 2 to which light encounters after it passes through the interface.

REFRACTION BY A LENS

The **focus point** of a lens is the point where image of an object placed at infinity is formed. And its distance from optical centre of the lens is called **focal length**.

Focal length of convex lens is +ve, and of concave lens is –ve.

(i) **Lens formula or thin lens formula**

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

(ii) **Lens maker's formula,**

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

where ${}_2^1\mu=\frac{\mu_2}{\mu_1}$

In the above formula μ_2 is refractive index of lens whereas μ_1 is the refractive index of surrounding medium.

R_1 is the radius of curvature of the lens reached first by light and R_2 is the radius of curvature of the other surface.

Magnification : m = v/u

This relation holds for both convex and concave lenses for real as well as virtual images.

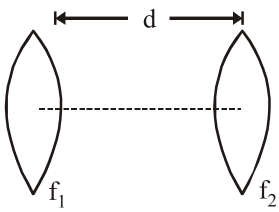
Power of a lens, P = reciprocal of focal length expressed in metres.

$i.e.,\ P=\frac{1}{f\,(\text{in metre})}$. Its **unit :** dioptre(D).

Note : To solve numerical problems use sign conventions while substituting values in above equations.

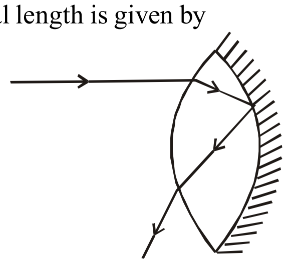
Equivalent focal length of two lenses separated by distance d

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1f_2}$$



Equivalent focal length of lens - mirror combination :

In such a case, the ray of light suffers two refraction from the lens and one reflection from the mirror. The combination behaves as a mirror whose focal length is given by



$$\frac{1}{F}=\frac{2}{f_1}+\frac{1}{f_m}$$

f_1 = focal length of lens, f_m = focal length of mirror

It is important that in the above formula, we cannot apply the sign conventions of cartesian system rather **following sign conventions are followed**.

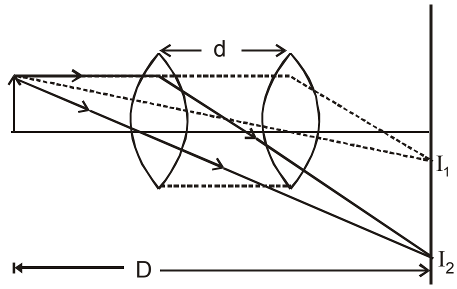
Focal length of a converging lens / mirror is taken as positive and focal length of diverging lens/mirror is taken as negative.

Focal Length by Displacement Method

$$f=\frac{D^2-d^2}{4D}$$

where D = distance between an object and screen

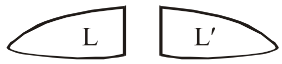
and d = distance between two positions of lens.



Aperture of a lens : With reference to a lens, aperture means the effective diameter of its light transmitting area. So the brightness i.e. intensity of image formed by a lens which depends on the light passing through the lens will depend on the square of aperture i.e. I ∝ (aperture)^2

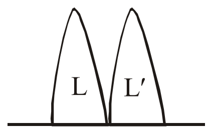
COMBINATION OF LENSES

(i) If a lens of focal length f is cut in two equal parts as shown in figure, each part will have focal length = f



(ii) If the above parts of lens are put in contact as shown then the resultant focal length will be,

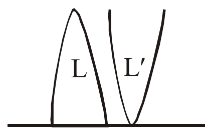
$$\frac{1}{F}=\frac{1}{f}+\frac{1}{f}=\frac{2}{f}\ i.e.\ F=\frac{f}{2}$$



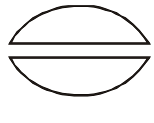
(iii) If the two parts are put as shown, then L will behave as convergent lens of focal length f while the other (L′) divergent of same focal length,

$$\therefore\ \frac{1}{F}=\frac{1}{+f}+\frac{1}{-f}\quad or\quad F=\infty$$

$$\therefore\ P=0$$



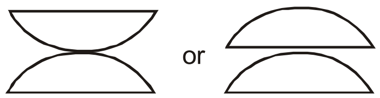
(iv) If a lens of focal length f is divided into equal parts as shown, then each part will have focal length f′,



i.e. $\frac{1}{f}=\frac{1}{f'}+\frac{1}{f'}\quad or\quad f'=2f$

i.e., each part will have focal length 2f.

(v) If these parts are put as shown, then the resultant focal length of the combination will be

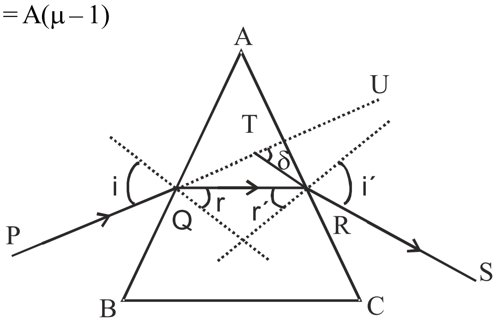


$$\frac{1}{F}=\frac{1}{2f}+\frac{1}{2f} \quad or \quad F=f$$ i.e. initial value.

REFRACTION THROUGH A PRISM

Prism is a transparent medium whose refracting surfaces are inclined to each other.

(i) The angle of deviation is given by $\delta = i + i' - A$
where A= angle of prism. For δ to be minimum, $i = i'$ and $r = r'$
$\delta_m = A(\mu - 1)$

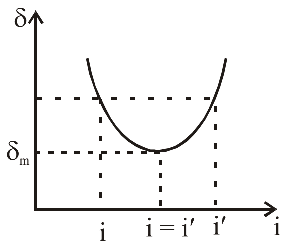


Refractive index of prism, $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$

where δ_m = minimum angle of deviation
If angle of prism A is small, than δ_m is also small.

$\therefore \quad \mu = \dfrac{(A+\delta_m)/2}{A/2}$

Plot of angle of deviation (δ) versus angle of incidence (i) for a triangular prism.



Dispersion

It is the breaking up of white ray of light into its constituents colours VIBGYOR. The band of seven constituents colours is called **spectrum.**

Angular dispersion : It is defined as the difference of deviations suffered by the extreme colours.

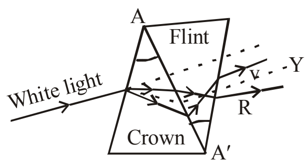
i.e., $\theta = \delta_v - \delta_r = (\mu_v - \mu_r)A$ [For thin prism]

Dispersive power : It is defined as the ratio of angular dispersion to the mean deviation produced by the prism.

i.e., $\omega = \dfrac{\delta_v - \delta_r}{\delta} = \dfrac{\mu_v - \mu_r}{\mu}$ [For thin prism]

Keep in Memory

1. A ray entering a prism of angle A will not emerge out of prism if $A > 2\theta_c$ where θ_c = critical angle
2. Maximum deviation through a prism will occur when angle of incidence is 90°.
For this prism $\delta = (\mu - 1)A$
This shows that for a small angled prism, deviation is independent of angle of incidence.
3. Angle of emergence of a prism is 90° (called grazing emergence) when angle of incidence
$i = \sin^{-1}[\sqrt{(\mu^2-1)}\sin A - \cos A]$
4. A single prism produces deviation and dispersion simultaneously.
5. **Dispersion without deviation :** When white light is incident on a combination of two prisms of different materials and of suitable angles placed opposite to each other, the emergent light may have only dispersion without any deviation (of mean colour yellow).



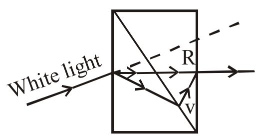
For this to happen the conditions is

$\dfrac{A}{A'} = -\dfrac{(\mu'-1)}{(\mu-1)}$ (For thin lenses)

The net angular dispersion produced

$\theta = (\omega - \omega')\delta$ (For thin lenses)

6. **Deviation without dispersion**



For this to happen $\dfrac{A'}{A} = \dfrac{-(\mu_v - \mu_r)}{(\mu_v' - \mu_r')}$ .... (1)

Net deviation $\delta_{net} = \delta\left(1 - \dfrac{\omega}{\omega'}\right)$

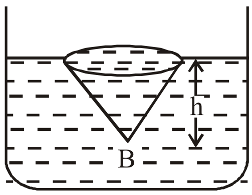
Equation (1) is said to be the **condition of achromatism** for combination of two prisms.

7. Variation of refractive index of a medium with wavelength causing incident light to split into constituent colours is dispersion.
Cauchy's equation : $\mu = a + \dfrac{b}{\lambda^2} + \dfrac{c}{\lambda^4}$, where *a*, *b* and *c* are constants.
8. Rayleigh scattering law explains blue colour of sky. Intensity of scattered light is proportional to $1/\lambda^4$. Hence the red light having highest value of λ_R scatters less.

9. Rainbow can be observed if light source is behind and the droplets are in front of the observer, i.e. when the back of a person is towards the sun.
It is a consequence of dispersion of sunlight by water droplets due to a combinations of refraction and total internal reflection. If the rainbow is formed after one internal reflection in the droplets, it is called a **primary rainbow**. In this the violet ray emerges at an angle of 40.8° and red rays at an angle of 42.8°. If the rainbow is formed after two internal reflections, it is called a **secondary rainbow.** In this the violet rays emerge at 54° and red at 51°, i.e. the order of colours is reversed. The primary rainbow is brighter than the secondary.

10. When a point source of light is placed at a depth h below the surface of water of refractive index m , then radius of bright circular patch on the surface of water is given by

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



11. When a lens made up of glass is immersed in water, its focal length changes.

$$\frac{1}{f} = \left({}^{a}_{g}\mu - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \frac{1}{f'} = \left({}^{w}_{g}\mu - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{f'}{f} = \frac{{}^{a}_{g}\mu - 1}{{}^{\omega}_{g}\mu - 1} = \frac{{}_{g}\mu / \mu_a - 1}{{}_{g}\mu / \mu_\omega - 1} = \frac{({}_{g}\mu - {}_{a}\mu)\mu_\omega}{({}_{g}\mu - {}_{\omega}\mu)\mu_a}$$

12. For achromatic combination of these lenses in contact, the necessary condition is $\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$

13. For two lenses separated by distance d, spherical aberration is minimum when $d = f_1 - f_2$.

14. A convex lens forms a real image when the object is placed beyond focus. When the object is placed between optical centre and focus, convex lens forms a virtual image.

15. A concave lens always form a virtual image for a real object.

16. A lens is called thin when the thickness of the lens is small compared to the object distance, image distance, radii of curvatures of the lens.
In the case of thick lens, the problem has to be solved using formula for each interface one by one.

17.

Real image (inverted)	Virtual image (erect)
Real image is formed by intersection of rays.	Virtual image is formed by actual extending the rays in the back direction.
This image can be brought on a screen.	This image cannot be brought on screen.

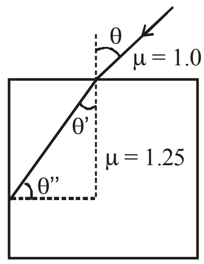
COMMON DEFAULT

✗ ***Incorrect :*** Using thin lens formula while the lens given in the numerical problem is thick.

✓ ***Correct :*** The lens formula $\left(\frac{1}{v} - \frac{1}{u} = \frac{1}{f}\right)$ and lens maker's formula $\left[\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)\right]$ are valid only for thin lenses.

Example 4.

Consider the situation shown in figure. Find maximum angle for which the light suffers total internal reflection at the vertical surface.



Solution :

The critical angle for this case is

$$\theta'' = \sin^{-1}\frac{1}{1.25} = \sin^{-1}\frac{4}{5} \quad \text{or} \quad \sin\theta'' = \frac{4}{5}$$

Since $\theta'' = \frac{\pi}{2} - \theta'$, we have $\sin\theta' = \cos\theta'' = \frac{3}{5}$

From Snell's law,

$$\frac{\sin\theta}{\sin\theta'} = 1.25 \quad \text{or} \quad \sin\theta = 1.25 \times \sin\theta' = 1.25 \times \frac{3}{5} = \frac{3}{4}$$

$$\text{or} \quad \theta = \sin^{-1}\frac{3}{4}$$

If θ″ is greater than the critical angle, θ will be smaller than this value. Thus, the maximum value of θ′ for which total internal reflection takes place at the vertical surface is $\sin^{-1}(3/4)$.

$$\frac{BO_1}{BI} = \mu \quad \text{or,} \quad \frac{AB + AO_1}{BI} = \mu \quad \text{or} \quad \frac{t + \mu x}{BI} = \mu$$

$$\text{or} \quad BI = x + \frac{t}{\mu}$$

The net shift is

$$OI = OB - BI = (x + t) - \left(x + \frac{t}{\mu}\right) = t\left(1 - \frac{1}{\mu}\right)$$

which is independent of x.

Example 5.

A tank is filled with water to a height of 12.5 cm. The apparent depth of a needle lying at the bottom of full tank is measured by a microscope to be 9.4 cm. What is the refractive index of water? If water is replaced by a liquid of refractive index 1.63 upto the same height, by what distance would the microscope have to be moved to focus *the needle again?*

Solution :

Here real depth =12.5 cm : apparent depth = 9.4 cm; μ = ?

$$\mu = \frac{\text{real depth}}{\text{Apparent depth}} = \frac{12.5}{9.4} = 1.33$$

Now in second case, μ = 1.63, real depth = 12.5 cm , apparent depth = ?

$$1.63 = \frac{12.5}{y} \text{ or } y = \frac{12.5}{1.63} = 7.67\,\text{cm}.$$

Distance through which microscope has to be moved up = 9.4 – 7.67 = 1.73 cm.

Example 6.

A converging lens has a focal length of 20 cm in air. It is made of a material of refractive index 1.6. If the lens is immersed in a liquid of refractive index 1.3. What will be the new focal length of the lens?

Solution :

$$\frac{1}{f_1} = (\mu_1 - 1)\frac{2}{R} \qquad \mu_1 = 1.6,\ f_1 = 20$$

$$\frac{1}{f_1} = (1.6 - 1)\frac{2}{R}$$

$$\text{or } \frac{1}{20} = \frac{0.6\times 2}{R} \therefore R = \frac{0.6\times 2\times 20}{10} = 24\text{cm}$$

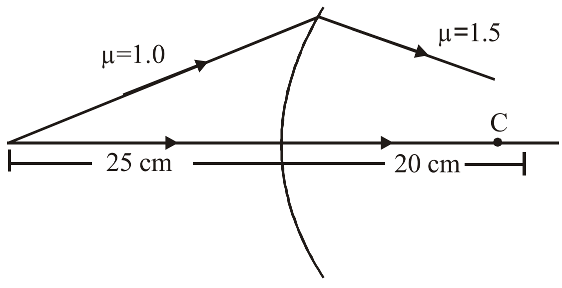
$$\frac{1}{f_2} = (\mu_1 - 1)\times\frac{2}{R} \quad \therefore \frac{1}{f_2} = (\frac{1.6}{1.3} - 1) = \frac{2}{R}$$

$$\frac{1}{f_2} = (\frac{1.6 - 1.3}{1.3})\frac{2}{24} = \frac{0.3}{1.3}\times\frac{1}{12} = \frac{1}{52}$$

f_2 = 52 cm.

Example 7.

Locate the image formed by refraction in the situation shown in figure. The point C is the centre of curvature.



Solution :

$$\text{We have, } \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \text{ ....(1)}$$

Here u = –25 cm, R = 20 cm, μ_1 = 1.0 and μ_2 = 1.5

Putting the values in (1),

$$\frac{1.5}{v} + \frac{1.0}{25\text{ cm}} = \frac{1.5 - 1.0}{20\text{ cm}} \quad \text{or, } \frac{1.5}{v} = \frac{1}{40\text{ cm}} - \frac{1}{25\text{ cm}}$$

or, v = –100 cm.

As v is negative, the image is formed to the left of the separating surface at a distance of 100 cm from it.

Example 8.

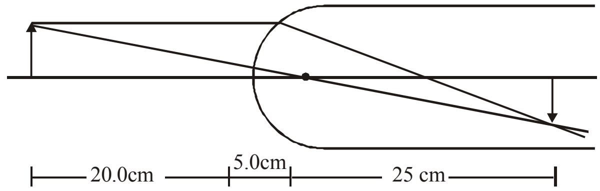
One end of a horizontal cylindrical glass rod (μ = 1.5) of radius 5.0 cm is rounded in the shape of a hemisphere. An object 0.5 mm high is placed perpendicular to the axis of the rod at a distance of 20.0 cm from the rounded edge. Locate the image of the object and find its height.

Solution :

Taking the origin at the vertex, u = –20.0 cm and R = 5.0 cm.

$$\text{We have, } \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\text{or } \frac{1.5}{v} = \frac{1}{-20.0\text{ cm}} + \frac{0.5}{5.0\text{ cm}} = \frac{1}{20\text{ cm}} \text{ or } v = 30\text{ cm}$$



The image is formed inside the rod at a distance of 30 cm from the vertex.

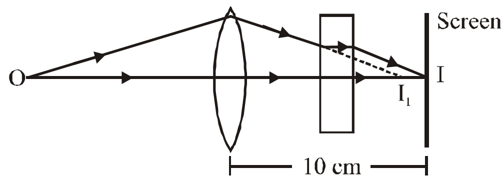
$$\text{The magnification is } m = \frac{\mu_1 v}{\mu_2 u} = \frac{30\text{ cm}}{-1.5\times 20\text{ cm}} = -1$$

Thus, the image will be of same height (0.5 mm) as the object but it will be inverted.

Example 9.

A convex lens focuses a distant object on a screen placed 10 cm away from it. A glass plate (μ = 1.5) of thickness 1.5 cm is inserted between the lens and the screen. Where should the object be placed so that its image is again focused on the screen.

Solution :



The focal length of the lens is 10 cm. The situation with the glass plate inserted is shown in figure. The object is placed at O. The lens would form the image at I_1 but the glass plate intercepts the rays and forms the image at I on the screen. The shift

$$I_1 I = t\left(1 - \frac{1}{\mu}\right) = (1.5\text{ cm})\left(1 - \frac{1}{1.5}\right) = 0.5\text{ cm}.$$

Thus, the lens forms the image at a distance of 9.5 cm from itself. Using

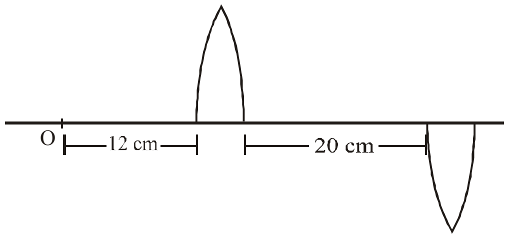
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{u} = \frac{1}{v} - \frac{1}{f} = \frac{1}{9.5\text{ cm}} - \frac{1}{10\text{ cm}}$$

$\Rightarrow$ u = 190 cm

Thus, the object should be placed at a distance of 190 cm from the lens.

Example 10.

A lens is cut into two equal pieces and they are placed as shown in figure. An object is placed at a distance of 12 cm left from the first half lens. The focal length of original lens was 30 cm. Find the position of final image.



Solution :

Focal length of each lens is 30 cm

For first lens u = – 12, f = 30 cm

$$\frac{1}{v_1}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{v_1}=\frac{1}{u}+\frac{1}{f}=-\frac{1}{12}+\frac{1}{30}$$

or, $v_1 = -20$ cm.

For the second half lens image formed at v_1 acts as object. Therefore object distance from second lens is = 20 + 20 = 40 cm or $v_1' = -40$ cm

f of this lens = 30 cm

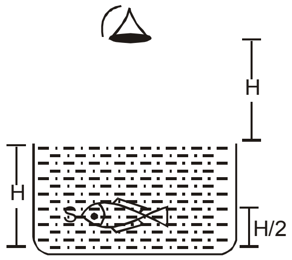
$$\therefore\ \frac{1}{v}-\frac{1}{v'_1}=\frac{1}{f}\Rightarrow\frac{1}{v}=\frac{1}{v'_1}+\frac{1}{f}\Rightarrow\frac{1}{v}=-\frac{1}{40}+\frac{1}{30}=\frac{1}{120}$$

or v = 120 cm.

Final image is 120 cm right from second lens.

Example 11.

Consider the situation in figure. The bottom of the plot is a reflecting plane mirror. S is a small fish and T is a human eye, refractive index of water is μ (a) At what distance (s) from itself, will the fish see the image (s) of the eye (b) At what distance (s) from itself will the eye see the image (s) of the fish.



Solution :

(a) We have the formula

$$\frac{h_{app}}{h_{real}}=\frac{\mu}{1}=h_{app}=\mu H \text{ (from the surface of water)}$$

Now distance of fish from surface is H/2

∴ Image of eye as seen by fish is = H(μ + ½) above the fish.

also the apparent image of eye, again makes an image with the plane mirror, the apparent distance of eye is μH + H from the plane mirror

∴ Now image formed is μH + H below the plane mirror. Distance of fish from the mirror is H/2

∴ Distance of image from the fish is μH + H + H/2 = H (μ + 3/2) below the fish.

(b) Here we have to find the images of fish as seen by the eye.

Let $h_{apparent}$ be the apparent distance of the fish from the surface

$$\therefore\ \frac{h_{app.}}{h_{real}}=\frac{1}{\mu}\ ;\ h_{app}=\frac{\mu H}{2\mu}$$

∴ Image formed is (H + H/2μ) below the, eye,

i.e, $H\left(1+\frac{1}{2\mu}\right)$ below the eye.

Also image of fish, formed by plane mirror is H/2 below the mirror.

$\therefore h_{real} = H + H/2 = 3H/2$

(∵ h_{real} is distance of fish image formed by the mirror from the surface)

$$\text{Now } \frac{h_{app}}{h_{real.}}=\frac{1}{\mu}\Rightarrow h_{app}=\frac{3H}{2\mu}$$

∴ Image formed is $\left(H+\frac{3H}{2\mu}\right)$ below the eye i.e,

$H\left(1+\frac{3}{2\mu}\right)$ below the eye.

Example 12.

A lens has a power of +5 diopter in air. What will be its power if completely immersed in water ?

Given $\mu_g=\frac{3}{2};\ \mu_w=\frac{4}{3}$

Solution :

Let f_a and f_w be the focal lengths of the lens in air water respectively, then

$$P_a=\frac{1}{f_a} \text{ and } P_w=\frac{\mu_w}{f_w}\ ;\ f_a = 0.2 \text{ m} = 20 \text{ cm}$$

Using lens maker's formula

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

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

$$\Rightarrow P_w=\frac{\mu_w}{f_w}=(\mu_g-\mu_w)\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \quad \text{...(ii)}$$

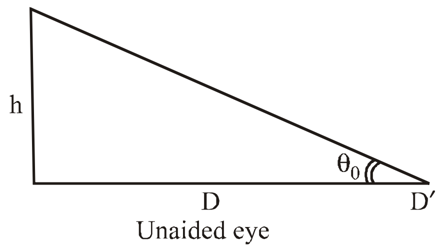
Dividing equation (ii) by equation (i), we get,

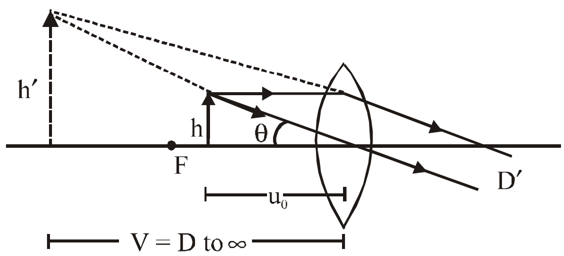
$$\frac{P_w}{P_a}=\frac{(\mu_g-\mu_w)}{(\mu_g-1)}=\frac{1}{3} \text{ or } P_w=\frac{P_a}{3}+\frac{+5}{3}=\frac{10}{3}D$$

OPTICAL INSTRUMENTS

(i) Simple Microscope

It is known as simple magnifier & consist of a convergent lens with object between its focus & optical centre & eye close to it.





The magnifying power of a simple microscope (M.P.) is

$$M.P. = \frac{\textit{visual angle with instrument}}{\textit{max visual angle for unaided eye}} = \frac{\theta}{\theta_0}$$

Here $\theta_0 = \frac{h}{D}, \theta = \frac{h_1}{v} = \frac{h}{u}$ so $M.P. = \frac{\theta}{\theta_0} = \frac{h}{v} \times \frac{D}{h} = \frac{D}{u}$

(a) If image is at infinity [far point] then from lens formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{\alpha} - \frac{1}{-u} = \frac{1}{f} \text{ i.e., } u = f \;\; \& \;\; M.P. = \frac{D}{f}$$

In this case M.P. is minimum if eye is least strained.

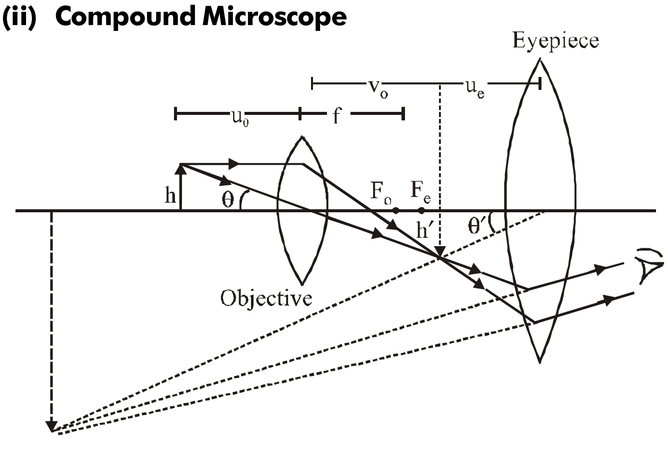
(b) If image is at D [near point] then u = –D

and from lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

we get $\frac{D}{u} = (1 + \frac{D}{f})$ so, $M.P = \left(1 + \frac{D}{f}\right)$

In this case M.P. is maximum and as final image is close to eye, eye is under maximum strain.

(ii) Compound Microscope



M.P. of compound microscope is defined as

$$M.P = \frac{\textit{visual angle with the instrument}}{\textit{max. visual angle for unaided eye}} = \frac{\theta}{\theta_0}$$

where $\theta_0 = \frac{h}{D}, \; \theta = \frac{h_1}{u_e}$

so $M.P. = \frac{h_1}{u_e} \times \frac{D}{h} = \left(\frac{h_1}{h}\right)\left(\frac{D}{u_e}\right)$

(since for objective $m = \frac{T}{o} = \frac{v}{u} \Rightarrow \frac{h^1}{h} = -\frac{v}{u}$, as u is –ive)

so $M.P. = \frac{-v}{u}\left(\frac{D}{u_e}\right)$

(a) **When image is formed at least distance of distinct vision,** $M = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right) = M_0 \times M_e$

(b) **When the final image is formed at infinity**

$$M = \frac{-v_0}{u_0}\left(\frac{D}{f_e}\right)$$

(iii) Astronomical Telescope

(a) **If the final image is formed at a distance D,**

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

and **length of tube** is $L = f_0 + \frac{f_e D}{f_e + D}$

(b) **If the final image is formed at infinity** then

$M = \frac{f_0}{f_e}$ and the **length of tube** is $\ell = f_0 + f_e$

(iv) Galilean Telescope

$M = \frac{f_0}{f_e}$; **Length of tube** $L = f_o - f_e$

(v) Terrestrial Telescope

$M = \frac{f_0}{f_e}$;

Length of tube $L = f_o + f_e + 4f$, where f is the focal length of erecting lens, which is used in this telescope.

Resolving Power of Microscope and Telescope

(i) The **resolving power of microscope** is $R = \frac{2\mu \sin\theta}{\lambda}$
where μ = refractive index of medium between object and objective of microscope and θ = angle subtended by a radius of the objective on one of the objects. (When both objects are not self illuminous).

(ii) The **resolving power of a telescope** is $R = \frac{a}{1.22\lambda}$ where a = diameter of objective of telescope.

Keep in Memory

1.

	Refracting type telescope (use of lenses)		Reflecting type telescope (use of mirrors)
1	It suffers from spherical aberration and chromatic aberration.	1	It is almost free from spherical aberration and asbolutely free from chromatic aberration.
2	The lenses used have small aperature and therefore light gathering power is small.	2	The aperature of mirrors used is large and therefore light gathering power is large.

2.

	Simple microscope		Compound microscope
1	Use of single lens of small focal length.	1	Use of two lenses $f_0 < f_e$.
2	Magnifying power $M = \left(1 + \frac{D}{f}\right)$ When image formed at D $M = \frac{D}{f}$ When Image formed at infinite.	2	Magnifying power $M = -\frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$ When image formed at D $M = -\frac{v_0}{u_0}\frac{D}{f_e}$ When image formed at infinite.
3	Object is placed between optical centre and focus.	3	Object is placed just outside the principle focus.

3.

	Astronomical telescope		Galilean telescope
1	Both lenses are convex lens.	1	Objective is convex lens and eye piece is concave lens
2	Magnifying power $M = -\frac{f_0}{f_e}$ for normal adjustment.	2	Magnifying power $M = +\frac{f_0}{f_e}$ for normal adjustment.
3	Length of telescope $L = f_0 + f_e$	3	Length of telescope $L = f_0 - f_e$

4. Some common eye defects are myopia, hypermetropia, astigmatism and presbyopia.

5.

	Myopia (or short sightedness)		Hypermetropia (or long - sightedness)
1	Eye can see near objects clearly but cannot see far objects clearly because the light from the for off object arriving the eye lens may get converged in front of retina.	1	Eye can see far off objects clearly but cannot see near objects clearly because the light from the near by object arriving the eye lens may get converged at a point behind the retina.
2	It can be corrected by concave lens (power of concave lens is –ve).	2	It can be corrected by convex lens (Power of convex lens is +ve).

6. **Astigmatism :** It is due to different curvature of cornea in horizontal and vertical plane. It is corrected by using **cylindrical lens.**
7. **Presbyopia :** The eye with this defect cannot see near objects as well as far off objects clearly.

Example 13.

A small telescope has an objective of focal length 140cm and an eye piece of focal length 5.0cm. What is the magnifying power of the telescope for viewing distant objects when
(a) the telescope is in normal adjustment?
(b) the final image is formed at the least distance of distinct vision?

Solution :

Here, $f_0 = 140$ cm, $f_e = 5.0$ cm

(a) The magnifying power in normal adjustment is given by $m = \frac{f_0}{f_e} = \frac{140}{5} = 28$

(b) When image is formed at least distance of distinct vision

$$m = \frac{f_0}{f_e}\left[1 + \frac{f_e}{D}\right] = 28\left[1 + \frac{5}{25}\right] = 25 \times \frac{6}{5} = 33.6$$

where D = 25cm

Example 14.

A compound microscope has an objective of focal length 1 cm and an eyepiece of focal length 2.5 cm. An object has to be placed at a distance of 1.2 cm away from the objective, for normal adjustment. Find (a) the angular magnification and (b) the length of the microscope tube.

Solution :

(a) If the first image is formed at a distance v from the objective, then we have

$$\frac{1}{v} - \frac{1}{(-1.2\text{ cm})} = \frac{1}{1\text{ cm}} \text{ or } v = 6\text{ cm}.$$

The angular magnification in normal adjustment is,

$$m = \frac{v}{u}\frac{D}{f_e} = -\frac{6\text{ cm}}{1.2\text{ cm}}.\frac{25\text{ cm}}{2.5\text{ cm}} = -50.$$

(b) For normal adjustment, the first image must be in the focal plane of the eyepiece.
The length of the tube is, therefore,

$$L = v + f_e = 6\text{ cm} + 2.5\text{ cm} = 8.5\text{ cm}$$

Example 15.

A person cannot see objects in nearer than 500 cm from the eye. Determine the focal length and the power of glasses which enable him to read a book 25 cm from his eye.

Solution :

Let f be the focal length of the glass. Then for the glass,
$u = 25$ cm, $v = -500$ cm

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

$$\text{or, } \frac{1}{f} = \frac{1}{25} - \frac{1}{500} = \frac{20-1}{500}$$

$$\text{or, } f = \frac{500}{19} = 26.3\text{ cm} = 0.263\text{ m}$$

$$P(\text{power}) = \frac{1}{f} = \frac{1}{0.263} = 3.8\text{ dioptre}$$

Example 16.

What is the power of the spectacles required (a) by a hypermetropic eye whose near point is 125 cm (b) by a myopic eye whose far point is 50 cm ?

Solution :

(a) u = 25 cm, v = –125 cm

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

$$\text{or, } \frac{1}{f} = \frac{1}{25} - \frac{1}{125} = \frac{5-1}{125}$$

$$\text{or, } f = \frac{125}{4} = 31.25\text{ cm} = 0.3125\text{ m}$$

$$P = \frac{1}{f} = \frac{1}{0.3125} = 3.2 \text{ dioptre}$$

(b) u = ∞, v = –50 cm

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

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

$$\text{or, } \frac{1}{f} = \frac{1}{\infty} - \frac{1}{50} = -\frac{1}{50}$$

$\Rightarrow$ f = –50 cm = – 0.5 m

$$P = \frac{1}{f} = -\frac{1}{0.5} = -2 \text{ dioptre}$$

Example 17.

A person with normal vision has a range of accommodation from 25 cm to infinity. Over what range would he be able to see objects distinctly when wearing the spectacles of a friend whose correction is +4 dioptres.

Solution :

$$P = 4 \text{ dioptres}, \therefore f = \frac{1}{4}\text{m} = 25 \text{ cm}$$

For near point, v = –25 cm,

$$u = \frac{vf}{v-f} = \frac{-25 \times 25}{-25 - 25} = 12.5\text{ cm}$$

For far point, v = ∞

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

$$\frac{1}{u} + \frac{1}{\infty} = \frac{1}{25}$$

or u = 25 cm

Hence, the range of distinct vision is from 12.5 cm to 25 cm.

Example 18.

Where is the near point of an eye for which a spectacle lens of +1 dioptre is prescribed ?

Solution :

P = +1 dioptre.

$$\therefore f = \frac{1}{P} = \frac{1}{1} = 1\text{ m} = 100 \text{ cm}$$

For the spectacle lens,

u = 25 cm, f = 100 cm, v = ?

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

$$\text{or } \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{u-f}{uf}$$

$$\text{or } v = \frac{uf}{u-f} = \frac{25 \times 100}{25 - 100} = -33.33\text{ cm}$$

i.e., the near point is 33.33 cm from the eye.

Example 19.

A certain person can see clearly at distance between 20 cm and 200 cm from his eye. What sepctacles are required to enable him to see distant objects clearly and what will be his least distance of distinct vision when he is wearing them?

Solution :

For seeing distant objects

u = ∞, v = –200 cm, f = ?

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

$$\text{or, } \frac{1}{f} = \frac{1}{\infty} - \frac{1}{200} = -\frac{1}{200} \text{ or } f = -200\text{cm}$$

For finding the least distance of distinct vision

u = ?, v = –20 cm, f = –200cm.

$$u = \frac{vf}{v-f} = \frac{-20(-200)}{-20-(-200)} = \frac{(20 \times 200)}{180} = 22.2\text{ cm}$$

i.e., his least distance of distinct vision is 22.2 cm when he is wearing spectacles.

Example 20.

An elderly person cannot see clearly, without the use of spectacles, objects nearer than 200 cm. What spectacles will he need to reduce this distance to 25 cm ? If his eyes can focus rays which are converging to points not less than 150 cm behind them, calculate his range of distinct vision when using the spectacles.

Solution :

Here u = 25 cm, v = – 200 cm

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

$$\text{or, } \frac{1}{f} = \frac{1}{25} - \frac{1}{200} = \frac{8-1}{200}$$

$$\Rightarrow f = \frac{200}{7} = 28.6 \text{ cm}$$

i.e., he should use the converging lens of focal length 28.6 cm.

Let x be the object distance for v = 150 cm, then

$$\frac{1}{x} + \frac{1}{150} = \frac{1}{f} = \frac{7}{200}$$

$$\Rightarrow \frac{1}{x} = \frac{7}{200} - \frac{1}{150} = \frac{21-4}{600}$$

$$\Rightarrow x = \frac{600}{17} = 35.3\text{ cm}$$

$\therefore$ Range of distinct vision is 25 cm to 35.3 cm.

Example 21.

An angular magnification (magnifying power) of 30 × is desired using an objective of focal length 1.25 cm. and an eyepiece of focal length 5 cm. in a compound microscope. What is the separation between objective and the eyepiece ?

Solution :

Let final image be formed at lease distance of distinct vision

For eyepiece, $M_e = \left(1+\frac{25}{f_e}\right) = \left(1+\frac{25}{5}\right) = 6$

Now, $M = M_0 \times M_e$

For objective, $M_0 = \frac{M}{M_e} = \frac{-30}{6} = -5$,

For objective, if $u_0 = -x$ cm, $v_0 = 5x$ cm.

Again, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ or $\frac{1}{5x} - \frac{1}{-x} = \frac{1}{1.25}$

On simplification, $x = 1.5$

$\therefore$ $u_0 = -1.5$ cm, $v_0 = 7.5$ cm.

For eyepiece, $M_e = \frac{v_e}{u_e}$

or $u_e = \frac{v_e}{M_e} = \frac{-25}{6} = -4.17$ cm.

Distance between objective and eyepiece

$= v_{objective} + |u_{eyepiece}| = 7.5 + 4.17 = 11.67$ cm.

Example 22.

A small telescope has an objective lens of focal length 144 cm. and eye-piece of focal length 6.0 cm. What is the magnifying power of the telescope ? What is the separation between objective and eye-piece ? Assume normal adjustment.

Solution :

$M = \frac{f_0}{f_e} = \frac{144}{6} = 24$

$L = f_0 + f_e = (144 + 6)$ cm. $= 150$ cm.

PHOTOMETRY

Ray optics is based on the assumption that light travels along straight line.

(i) **Luminous flux** (ϕ) of a source of light = amount of visible light energy emitted per second from the source.
The **SI unit** of luminous fulx (ϕ) is lumen.

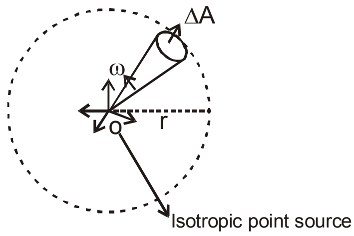
(ii) **Luminous intensity** (I) of a light source = luminous flux emitted per unit solid angle in any direction.
Its **SI unit** is candela.

Luminous intensity, $I = \frac{\Delta\phi}{\Delta\omega}$

For isotropic point source,
Solid angle,

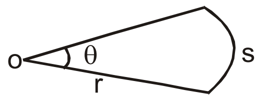
$$\omega = \frac{\Delta A(\text{surface area})}{r^2} = \frac{4\pi r^2}{r^2} = 4\pi \text{ steradian}$$

(where $\Delta A = 4\pi r^2$ = total surface area of sphere of radius r)



so $I = \frac{\phi}{4\pi}$ or $\phi = 4\pi . I$

Solid angle : We know that arc of a circle subtends an angle θ on the centre of circle O

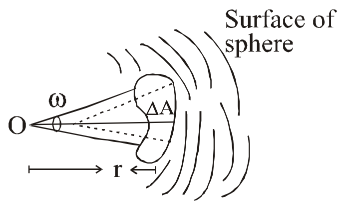


i.e., $\theta = \frac{S}{r} = \frac{\text{Arc of circle}}{\text{Radius of circle}}$ ...(i)

(a) The unit of θ (plane angle) is radian.
Similarly in the case of a sphere, the surface area of sphere subtends an angle on the centre of sphere O, which is called solid angle & is denoted by ω.
Let radius of sphere is r and a small area ΔA on its surface subtends a solid angle ω at the centre then

$\omega = \frac{\Delta A}{r^2}$ = constant ..(ii)

(b)



The unit of solid angle is steradian. If in eq (ii)
$\Delta A = r^2$, then $\omega = 1$ steradian
If $\Delta A = 4\pi r^2$ (total surface area of sphere)
then $\omega = 4\pi$ steradian.

(iii) **Illuminance** (E) of a surface is the luminous flux incident normally on unit area of the surface.
Its unit is lux.

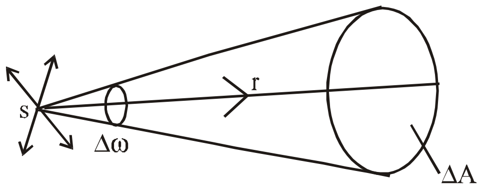
$$E = \frac{\Delta\phi}{\Delta A}$$

For point source, the total normal area will be $4\pi r^2$,

so $E = \frac{\phi}{A} = \frac{\phi}{4\pi r^2} \Rightarrow E \propto \frac{1}{r^2}$

(iv) **Luminance or brightness** of a surface is the luminous flux reflected into our eyes from unit area of the surface.
The unit of Brightness is lambert.

(v) **Inverse square law for illuminance :** Let S is a unidirectional point source, whose luminous intensity is I. It has some surface ΔA at distance r from source S.



Let central ray of source s falls perpendicularly on surface ΔA, then luminous flux Δϕ is given by

$\Delta\phi = I \times \Delta\omega$ ...(i)

where $\Delta\omega = \dfrac{\Delta A}{r^2}$

$\Rightarrow \Delta\phi = I \times \dfrac{\Delta A}{r^2}$ ...(ii)

or $\dfrac{\Delta\phi}{\Delta A} = \dfrac{I}{r^2}$ or $E = \dfrac{I}{r^2}$ ...(iii)

where E is called illuminance or intensity of illumination.

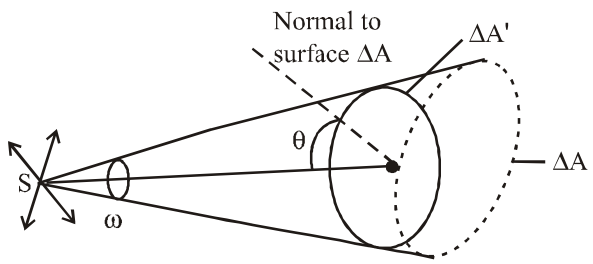
If in eq. (iii) I is constant for a given source then $E \propto \dfrac{I}{r^2}$.

So intensity of illumination of any source is inversely proportional to square of the distance between light source & surface. This is called inverse square law.

Lambert's Cosine Law for Illuminance

Let S is unidirectional point source & its luminous intensity is I. There is a surface of area ΔA at distance r from S, which is kept in such a way that light from S falls obliquely on it and central ray makes an angle θ with normal to ΔA.

Then by fig. $\Delta A' = \Delta A \cos\theta$



According to definition of luminous intensity :

$\Delta\phi = I \times \Delta\omega$

where $\Delta\omega = \dfrac{\Delta A'}{r^2} = \dfrac{\Delta A \cos\theta}{r^2} \Rightarrow \Delta\phi = \dfrac{I \times \Delta A \cos\theta}{r^2}$

or $E = \dfrac{\Delta\phi}{\Delta A} = \dfrac{I\cos\theta}{r^2}$

For any given source (I constant) & at a fixed distance (r constant) $E \propto \cos\theta$

i.e., the, intensity of illumination of a surface is proportional to the cosine of angle of the inclination of the surface. This is called Lambert's cosine law. As θ increases, cos θ decreases & consequently E decreases.

θ is the angle between normal to the area and direction of light propagation.

Example 23.

What is the effect on the intensity of illumination on a table if a lamp hanging 2 m directly above it is lowered by 0.5 m?

Solution :

$E_1 = \dfrac{I}{r_1^2}$ and $E_2 = \dfrac{I}{r_2^2}$

$\therefore \dfrac{E_2}{E_1} = \left(\dfrac{r_1}{r_2}\right)^2 = \left(\dfrac{2}{1.5}\right)^2 = \left(\dfrac{4}{2.25}\right)$

Fractional increase in the intensity

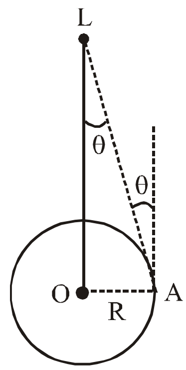
$= \dfrac{E_2 - E_1}{E_1} = \left(\dfrac{E_2}{E_1} - 1\right) = \left(\dfrac{4}{2.25} - 1\right) \times 100 = 78\%$

Example 24.

A lamp of power P is suspended at the centre of a circular table of radius r. What should be the height of the lamp above the table so that maximum intensity is produced at the edge?

Solution :

See figure, the intensity of illumination at edge (i.e., at point A)



$E = \dfrac{I\cos\theta}{(LA)^2} = \dfrac{I_1\cos\theta}{(h^2 + r^2)}$

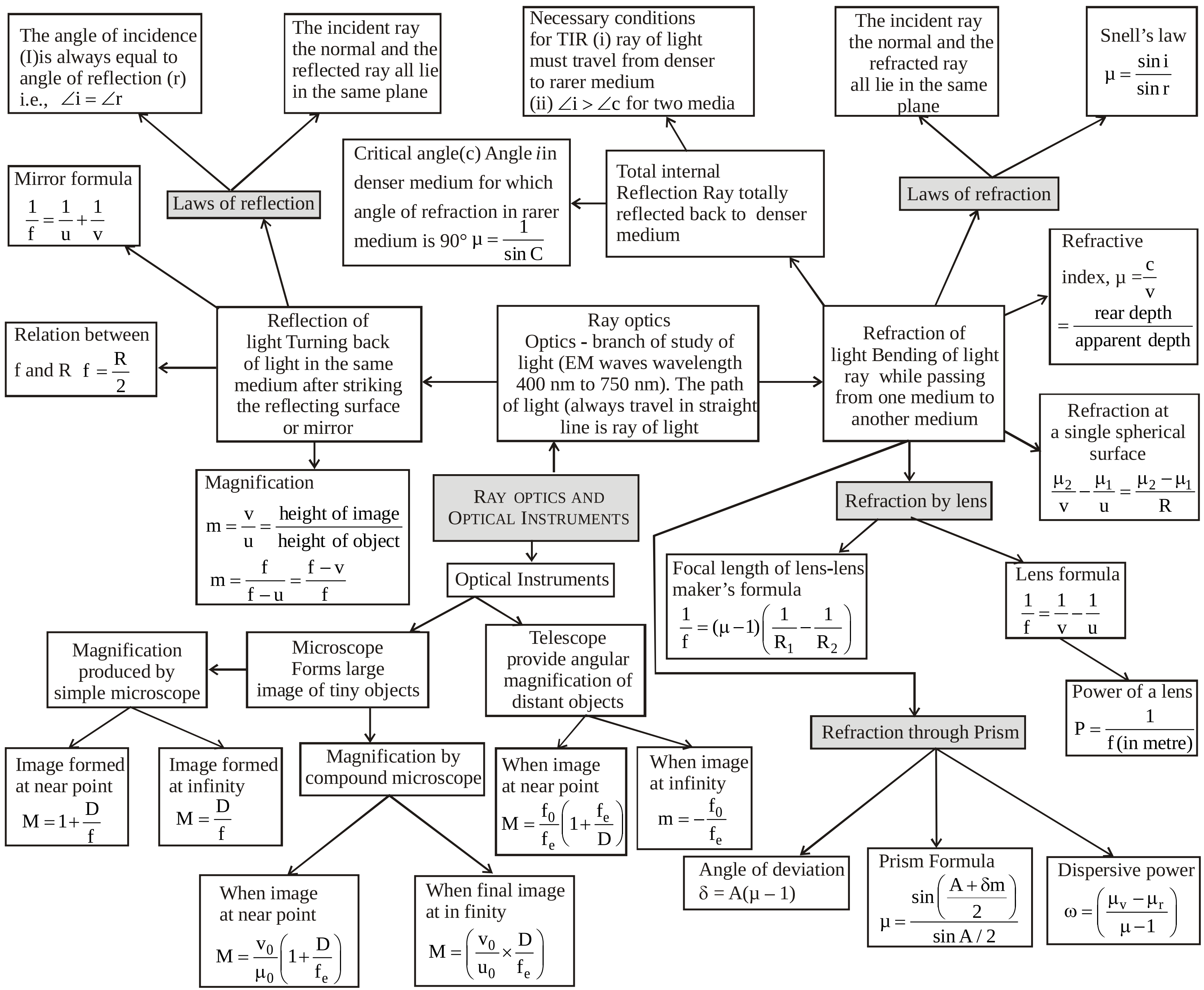
From figure. $\cos\theta = \dfrac{h}{\sqrt{(h^2 + r^2)}}$

$\therefore E = \dfrac{I h}{\sqrt{(h^2 + r^2)^3}}$

For maximum intensity, dE/dh = 0

Applying this condition, we get $h = r\sqrt{2}$

CONCEPT MAP


RAY OPTICS AND OPTICAL INSTRUMENTS
Ray optics
Optics - branch of study of light (EM waves wavelength 400 nm to 750 nm). The path of light (always travel in straight line is ray of light
Reflection of light Turning back of light in the same medium after striking the reflecting surface or mirror
Laws of reflection
The angle of incidence (I)is always equal to angle of reflection (r) i.e., $\angle i = \angle r$
The incident ray the normal and the reflected ray all lie in the same plane
Mirror formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$
Relation between f and R $f = \frac{R}{2}$
Magnification $m = \frac{v}{u} = \frac{\text{height of image}}{\text{height of object}}$
$m = \frac{f}{f-u} = \frac{f-v}{f}$
Refraction of light Bending of light ray while passing from one medium to another medium
Total internal Reflection Ray totally reflected back to denser medium
Necessary conditions for TIR (i) ray of light must travel from denser to rarer medium (ii) $\angle i > \angle c$ for two media
Critical angle(c) Angle i in denser medium for which angle of refraction in rarer medium is 90° $\mu = \frac{1}{\sin C}$
Laws of refraction
The incident ray the normal and the refracted ray all lie in the same plane
Snell's law $\mu = \frac{\sin i}{\sin r}$
Refractive index, $\mu = \frac{c}{v} = \frac{\text{rear depth}}{\text{apparent depth}}$
Refraction at a single spherical surface $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$
Refraction by lens
Focal length of lens-lens maker's formula $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
Lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$
Power of a lens $P = \frac{1}{f\,(\text{in metre})}$
Refraction through Prism
Angle of deviation $\delta = A(\mu - 1)$
Prism Formula $\mu = \frac{\sin\left(\frac{A + \delta m}{2}\right)}{\sin A/2}$
Dispersive power $\omega = \left(\frac{\mu_v - \mu_r}{\mu - 1}\right)$
Optical Instruments
Microscope Forms large image of tiny objects
Magnification produced by simple microscope
Image formed at near point $M = 1 + \frac{D}{f}$
Image formed at infinity $M = \frac{D}{f}$
Magnification by compound microscope
When image at near point $M = \frac{v_0}{\mu_0}\left(1 + \frac{D}{f_e}\right)$
When final image at in finity $M = \left(\frac{v_0}{u_0} \times \frac{D}{f_e}\right)$
Telescope provide angular magnification of distant objects
When image at near point $M = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$
When image at infinity $m = -\frac{f_0}{f_e}$

EXERCISE - 1
Conceptual Questions

1. What will be the colour of the sky as seen from the earth if there were no atmosphere?
(a) Black (b) Blue
(c) Orange (d) Red

2. Monochromatic light of wavelength λ_1 travelling in a medium of refractive index μ_1 enters a denser medium of refractive index μ_2. The wavelength in the second medium is
(a) $\lambda_1 (\mu_1/\mu_2)$ (b) $\lambda_1 (\mu_2/\mu_1)$
(c) $\lambda_1 (\mu_2 - \mu_1)/\mu_2$ (d) $\lambda_1 (\mu_2 - \mu_1)/\mu_1$

3. A vessel of depth 2d cm is half filled with a liquid of refractive index μ_1 and the upper half with a liquid of refractive index μ_2. The apparent depth of the vessel seen perpendicularly is
(a) $\left(\frac{\mu_1 \mu_2}{\mu_1 + \mu_2}\right)d$ (b) $\left(\frac{1}{\mu_1} + \frac{1}{\mu_2}\right)d$
(c) $\left(\frac{1}{\mu_1} + \frac{1}{\mu_2}\right)2d$ (d) $\left(\frac{1}{\mu_1 \mu_2}\right)2d$

4. In a room containing smoke particles, the intensity due to a source of light will
(a) obey the inverse square law
(b) be constant at all distances
(c) increase with distance from the source than the inverse fourth power law
(d) fall faster with distance from the source than the inverse fourth power law

5. What causes chromatic aberration?
(a) Non - paraxial rays
(b) Paraxial rays
(c) Variation of focal length with colour
(d) Difference in radii of curvature of the bounding surfaces of the lens

6. Which of the following is not the case with the image formed by a concave lens?
(a) It may be erect or inverted
(b) It may be magnified or diminished
(c) It may be real or virtual
(d) Real image may be between the pole and focus or beyond focus

7. Critical angle of light passing from glass to water is minimum for
(a) red colour (b) green colour
(c) yellow colour (d) violet colour

8. A normal eye is not able to see objects closer than 25 cm because
(a) the focal length of the eye is 25 cm
(b) the distance of the retina from the eye-lens is 25 cm
(c) the eye is not able to decrease the distance between the eye-lens and the retina beyond a limit
(d) the eye is not able to decrease the focal length beyond a limit

9. The one parameter that determines the brightness of a light source sensed by an eye is
(a) energy of light entering the eye per second
(b) wavelength of the light
(c) total radiant flux entering the eye
(d) total luminous flux entering the eye

10. In vacuum the speed of light depends upon
(a) frequency
(b) wavelength
(c) velocity of light sources
(d) None of these

11. The intensity produced by a long cylindrical light source at a small distance r from the source is proportional to
(a) $\frac{1}{r^2}$ (b) $\frac{1}{r^3}$
(c) $\frac{1}{r}$ (d) None of these

12. The refractive index of a piece of transparent quartz is the greatest for
(a) violet light (b) red light
(c) green light (d) yellow light

13. Light travels through a glass plate of thickness t and having refractive index μ. If c be the velocity of light in vacuum, the time taken by the light to travel this thickness of glass is
(a) $\frac{t}{\mu c}$ (b) $t\mu c$ (c) $\frac{\mu t}{c}$ (d) $\frac{tc}{\mu}$

14. A convex mirror of focal length f produces an image (1/n)th of the size of the object. The distance of the object from the mirror is
(a) $(n - 1) f$ (b) f/n
(c) $(n + 1) f$ (d) nf

15. Amount of light entering into the camera depends upon.
(a) focal length of objective lens
(b) product of focal length and diameter of the objective lens
(c) distance of object from camera
(d) aperture setting of the camera

16. In optical fibres, propagation of light is due to
(a) diffraction (b) total internal reflection
(c) reflection (d) refraction

17. Rectilinear motion of light in a medium is caused due to
(a) high frequency
(b) short wavelength
(c) velocity of light
(d) uniform refractive index of the medium

18. Resolving power of a telescope increases with
(a) increase in focal length of eye-piece
(b) increase in focal length of objective
(c) increase in aperture of eye piece
(d) increase in apeture of objective

19. The distance between an object and its real image formed by a convex lens cannot be
(a) greater than 2 f (b) less than 2 f
(c) greater than 4 f (d) less than 4 f

20. An electromagnetic radiation of frequency n, wavelength λ, travelling with velocity v in air enters in a glass slab of refractive index (μ). The frequency, wavelength and velocity of light in the glass slab will be respectively
(a) $n, \frac{\lambda}{\mu}$ and $\frac{v}{\mu}$ (b) $n, 2\lambda$ and $\frac{v}{\mu}$
(c) $\frac{n}{\mu}, \frac{\lambda}{\mu}$ and $\frac{v}{\mu}$ (d) $\frac{2\pi}{\mu}, \frac{\lambda}{\mu}$ and v

21. A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will
(a) remain unchanged
(b) become zero
(c) become infinite
(d) become small, but non-zero

22. Two thin lenses of focal lengths f_1 and f_2 are in contact and coaxial. Its power is same as power of a single lens given by
(a) $\frac{f_1+f_2}{f_1f_2}$ (b) $\sqrt{\left(\frac{f_1}{f_2}\right)}$ (c) $\sqrt{\left(\frac{f_2}{f_1}\right)}$ (d) $\frac{f_1+f_2}{2}$

23. For the angle of minimum deviation of a prism to be equal to its refracting angle, the prism must be made of a material whose refractive index
(a) lies between $\sqrt{2}$ and 1
(b) lies between 2 and $\sqrt{2}$
(c) is less than 1
(d) is greater than 2

24. Which of the following is not due to total internal reflection?
(a) Working of optical fibre
(b) Difference between apparent and real depth of pond
(c) Mirage on hot summer days
(d) Brilliance of diamond

25. An astronomical telescope has a large aperture to
(a) reduce spherical aberration
(b) have high resolution
(c) increase span of observation
(d) have low dispersion

EXERCISE - 2
Applied Questions

1. A lamp of 250 candle power is hanging at a distance of 6 m from a wall. The illuminance at a point on the wall at a minimum distance from lamp will be
(a) 9.64 lux (b) 4.69 lux
(c) 6.94 lux (d) None of these

2. An electric bulb illuminates a plane surface. The intensity of illumination on the surface at a point 2 m away from the bulb is 5×10^{-4} phot (lumen/cm^2). The line joining the bulb to the point makes an angle of 60º with the normal to the surface. The luminous intensity of the bulb in candela (candle power) is
(a) $40\sqrt{3}$ (b) 40
(c) 20 (d) 40×10^{-4}

3. If two mirrors are kept at 60º to each other, then the number of images formed by them is
(a) 5 (b) 6 (c) 7 (d) 8

4. Wavelength of light used in an optical instrument are λ_1 = 4000Å and λ_2 = 5000 Å, then ratio of their respective resolving powers (corresponding to λ_1 and λ_2) is
(a) 16 : 25 (b) 9 : 1 (c) 4 : 5 (d) 5 : 4

5. The critical angle for light going from medium X into medium Y is θ. The speed of light in medium X is v, then speed of light in medium Y is
(a) v(1 – cos θ) (b) v/sin θ
(c) v/cos θ (d) v cos θ

6. A man wants to see two poles, separately, situated at 11 km. The minimum distance (approximately) between these poles will be
(a) 5m (b) 0.5m
(c) 1m (d) 3m

7. The index of refraction of diamond is 2.0. The velocity of light in diamond is approximately
(a) 1.5×10^{10} cm/sec (b) 2×10^{10} cm/sec
(c) 3.0×10^{10} cm/sec (d) 6×10^{10} cm/sec

8. The luminous intensity of 100 W unidirectional bulb is 100 candela. The total luminous flux emitted from bulb will be
(a) 100 π lumen (b) 200 π lumen
(c) 300 π lumen (d) 400 π lumen

9. The refractive index of water is 1.33. What will be speed of light in water ?

(a) 3×10^8 m/s (b) 2.25×10^8 m/s
(c) 4×10^8 m/s (d) 1.33×10^8 m/s

10. A concave mirror of focal length f produces an image n times the size of object. If image is real, then distance of object from mirror, is

(a) $(n-1)$ f (b) $\{(n-1)/n\}$ f
(c) $\{(n+1)/n\}$ f (d) $(n+1)$ f

11. In a concave mirror, an object is placed at a distance x_1 from focus, and image is formed at a distance x_2 from focus. Then focal length of mirror is

(a) $\sqrt{x_1 x_2}$ (b) $\frac{x_1 - x_2}{2}$
(c) $\frac{x_1 + x_2}{2}$ (d) $\sqrt{\frac{x_1}{x_2}}$

12. A convex lens of focal length f_1 and a concave lens of focal length f_2 are placed in contact. The focal length of the combination is

(a) $(f_1 + f_2)$ (b) $(f_1 - f_2)$
(c) $\frac{f_1 f_2}{f_2 - f_1}$ (d) $\frac{f_1 f_2}{f_1 + f_2}$

13. A lens of power + 2 diopter is placed in contact with a lens of power – 1 diopter. The combination will behave like

(a) a convergent lens of focal length 50 cm
(b) a divergent lens of focal length 100 cm
(c) a convergent lens of focal length 100 cm
(d) a convergent lens of focal length 200 cm

14. Light takes t_1 sec to travel a distance x in vacuum and the same light takes t_2 sec to travel 10 cm in a medium. Critical angle for corresponding medium will be

(a) $\sin^{-1}\left(\frac{10\,t_2}{t_1 x}\right)$ (b) $\sin^{-1}\left(\frac{t_2 x}{10\,t_1}\right)$
(c) $\sin^{-1}\left(\frac{10\,t_1}{t_2 x}\right)$ (d) $\sin^{-1}\left(\frac{t_1 x}{10\,t_2}\right)$

15. A double convex lens of focal length 6 cm is made of glass of refractive index 1.5. The radius of curvature of one surface is double that of other surface. The value of small radius of curvature is

(a) 6 cm (b) 4.5 cm (c) 9 cm (d) 4 cm

16. A prism has a refracting angle of 60º. When placed in the position of minimum deviation, it produces a deviation of 30º. The angle of incidence is

(a) 30º (b) 45º (c) 15º (d) 60º

17. A ray of light passes through an equilateral prism such that the angle of incidence is equal to the angle of emergence and the latter is equal to 3/4th of the angle of prism. The angle of deviation is

(a) 45º (b) 39º (c) 20º (d) 30º

18. An achromatic convergent doublet of two lenses in contact has a power of + 2D. The convex lens has power + 5D. What is the ratio of dispersive powers of convergent and divergent lenses ?

(a) 2 : 5 (b) 3 : 5 (c) 5 : 2 (d) 5 : 3

19. The dispersive power of material of a lens of focal length 20 cm is 0.08. What is the longitudinal chromatic aberration of the lens ?

(a) 0.08 cm (b) 0.08/20 cm
(c) 1.6 cm (d) 0.16 cm

20. The magnifying power of a telescope is 9. When it is adjusted for parallel rays, the distance between the objective and the eye piece is found to be 20 cm. The focal length of lenses are

(a) 18 cm, 2 cm (b) 11 cm, 9 cm
(c) 10 cm, 10 cm (d) 15 cm, 5 cm

21. The focal length of the objective of a telescope is 60 cm. To obtain a magnification of 20, the focal length of the eye piece should be

(a) 2 cm (b) 3 cm (c) 4 cm (d) 5 cm

22. The focal lengths of objective and eye lens of an astronomical telelscope are respectively 2 meter and 5 cm. Final image is formed at (i) least distance of distinct vision (ii) infinity Magnifying power in two cases will be

(a) – 48, – 40 (b) – 40, – 48
(c) – 40, + 48 (d) – 48, + 40

23. We wish to see inside an atom. Assume the atom to have a diameter of 100 pm. This means that one must be able to resolve a width of say 10 pm. If an electron microscope is used the energy required should be

(a) 1.5 keV (b) 50 keV
(c) 150 keV (d) 1.5 MeV

24. Which of the following is false ?

(a) Convex lens always forms image with $m < 1$
(b) A simple mirror produces virtual, erect and same-sized image
(c) A concave mirror produces virtual, erect and magnified image
(d) A convex lens can produce real and same-sized image

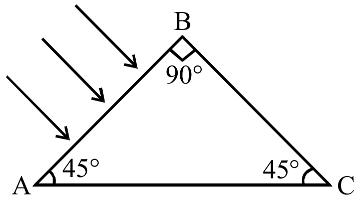
25. A plane mirror reflects a beam of light to form a real image. The incident beam is

(a) parallel (b) convergent
(c) divergent (d) any one of the above

26. An object is placed at a distance 2f from the pole of a convex mirror of focal length f. The linear magnification is

(a) $\frac{1}{3}$ (b) $\frac{2}{3}$ (c) $\frac{3}{4}$ (d) 1

27. A beam of light consisting of red, green and blue colours is incident on a right-angled prism as shown. The refractive index of the material of the prism for the above red, green and blue wavelengths are 1.39, 1.44 and 1.47 respectively. The prism will



(a) separate part of the red colour from the green and blue colours.
(b) separate part of the blue colour from the red and green colours.
(c) separate all the three colours from one another.
(d) not separate even partially any colour from the other two colours.

28. A concave mirror of focal length f. in vacuum is placed in a medium of refractive index 2. Its focal length in the medium is
(a) $\frac{f}{2}$ (b) f (c) 2 f (d) 4 f

29. The maximum and minimum distance between a convex lens and an object, for the magnification of a real image to be greater than one are
(a) 2f and f (b) f and zero
(c) ∞ and 2f (d) 4f and 2f

30. A plane convex lens of focal length 16 cm, is to be made of glass of refractive index 1.5. The radius of curvature of the curved surface should be
(a) 8 cm (b) 12 cm (c) 16 cm (d) 24 cm

31. A real image is formed by a convex lens. If we put a concave lens in contact with it, the combination again forms a real image. The new image
(a) is closer to the lens system.
(b) is farther form the lens system.
(c) is at the original position.
(d) may be anywhere depending on the focal length of the concave lens.

32. A plano-convex lens of focal length 30 cm has its plane surface silvered. An object is placed 40 cm from the lens on the convex side. The distance of the image from the lens is
(a) 18 cm (b) 24 cm (c) 30 cm (d) 40 cm

33. Two convex lenses of focal lengths f_1 and f_2 are mounted coaxially separated by a distance. If the power of the combination is zero, the distance between the lenses is
(a) $|f_1 - f_2|$ (b) $f_1 + f_2$
(c) $\frac{f_1 f_2}{|f_1 - f_2|}$ (d) $\frac{f_1 f_2}{f_1 + f_2}$

34. If D is the deviation of a normally falling light beam on a thin prism of angle A and δ is the dispersive power of the same prism then
(a) D is independent of A.
(b) D is independent of refractive Index.
(c) δ is independent of refractive index.
(d) δ is independent of A.

35. Why is refractive index in a transparent medium greater than one ?
(a) Because the speed of light in vaccum is always less than speed in a transparent medium
(b) Because the speed of light in vaccum is always greater than speed in a transparent medium
(c) Frequency of wave changes when it crosses medium
(d) None of these

36. Two convex lenses of focal lengths 0.3 m and 0.05 m are used to make a telescope. The distance kept between the two in order to obtain an image at infinity is
(a) 0.35m (b) 0.25m (c) 0.175m (d) 0.15m

37. The refractive indices of glass and water with respect to air are 3/2 and 4/3 respectively. Then the refractive index of glass with respect to water is
(a) 8/9 (b) 9/8 (c) 7/6 (d) 2

38. The wavelength of a monochromatic light in vacuum is λ. It travels from vacuum to a medium of absolute refractive index μ. The ratio of wavelength of the incident and refracted wave is
(a) $\mu^2 : 1$ (b) 1 : 1 (c) $\mu : 1$ (d) $1 : \mu$

39. An object is placed at a distance of 40 cm in front of a concave mirror of focal length 20 cm. The image produced is
(a) real, inverted and smaller in size
(b) real, inverted and of same size
(c) real and erect
(d) virtual and inverted

40. The frequency of a light wave in a material is 2×10^{14} Hz and wavelength is 5000 Å. The refractive index of material will be
(a) 1.50 (b) 3.00 (c) 1.33 (d) 1.40

41. A ray incident at 15° on one refracting surface of a prism of angle 60° suffers a deviation of 55°. What is the angle of emergence ?
(a) 95° (b) 45°
(c) 30° (d) None of these

42. A man's near point is 0.5 m and far point is 3 m. Power of spectacle lenses required for (i) reading purposes, (ii) seeing distant objects, respectively, are
(a) –2 D and + 3 D (b) +2 D and –3 D
(c) +2 D and –0.33 D (d) –2 D and + 0.33 D

43. Two light sources with equal luminous intensity are lying at a distance of 1.2 m from each other. Where should a screen be placed between them such that illuminance on one of its faces is four times that on another face ?
(a) 0.2m (b) 0.4m (c) 0.8m (d) 1.6m

44. A lamp is hanging along the axis of a circular table of radius r. At what height should the lamp be placed above the table, so that the illuminance at the edge of the table is $\frac{1}{8}$ of that at its centre?
(a) r/2 (b) $r/\sqrt{2}$ (c) r/3 (d) $r/\sqrt{3}$

45. A rectangular block of glass is placed on a mark made on the surface of the table and it is viewed from the vertical position of eye. If refractive index of glass be μ and its thickness d, then the mark will appear to be raised up by

(a) $\frac{(\mu+1)d}{\mu}$ (b) $\frac{(\mu-1)d}{\mu}$

(c) $\frac{(\mu+1)}{\mu d}$ (d) $\frac{(\mu-1)\mu}{d}$

46. Light passes through a glass plate of thickness d and refractive index μ. For small angle of incidence i, the lateral displacement is

(a) id (b) $id(\mu-1)$

(c) $\frac{id(\mu-1)}{\mu}$ (d) $\frac{id\mu}{\mu-1}$

47. A glass slab of thickness 4 cm contains the same number of waves as 5 cm of water when both are traversed by the same monochromatic light. If the refractive index of water is 4/3, what is that of glass?

(a) 5/3 (b) 5/4 (c) 16/15 (d) 1.5

48. An air bubble in glass slab (μ = 1.5) from one side is 6 cm and from other side is 4 cm. The thickness of glass slab is

(a) 10 cm (b) 6.67 cm

(c) 15 cm (d) None of these

49. A vessel is half filled with a liquid of refractive index μ. The other half of the vessel is filled with an immiscible liquid of refrative index 1.5 μ. The apparent depth of the vessel is 50% of the actual depth. Then μ is

(a) 1.4 (b) 1.5 (c) 1.6 (d) 1.67

50. A man 160 cm high stands in front of a plane mirror. His eyes are at a height of 150 cm from the floor. Then the minimum length of the plane mirror for him to see his full length image is

(a) 85 cm (b) 170 cm (c) 80 cm (d) 340 cm

51. It is desired to photograph the image of an object placed at a distance of 3 m from plane mirror. The camera, which is at a distance of 4.5 m from mirror should be focussed for a distance of

(a) 3m (b) 4.5m (c) 6m (d) 7.5m

52. Two thin lenses are in contact and the focal length of the combination is 80 cm. If the focal length of one lens is 20 cm, then the power of the other lens will be

(a) 1.66D (b) 4.00D

(c) – 100 D (d) – 3.75 D

53. A thin convergent glass lens (μ_g = 1.5) has a power of + 5.0 D. When this lens is immersed in a liquid of refractive index μ, it acts as a divergent lens of focal length 100 cm. The value of μ must be

(a) 4/3 (b) 5/3 (c) 5/4 (d) 6/5

54. A ray of light passes through an equilateral prism (μ = 1.5). The angle of minimum deviation is

(a) 45° (b) 37° 12' (c) 20° (d) 30°

55. Two lenses in contact form an achromatic lens. Their focal lengths are in the ratio 2 : 3. Their dispersive powers must be in the ratio of

(a) 1 : 3 (b) 2 : 3 (c) 3 : 2 (d) 3 : 1

56. A combination is made of two lenses of focal length f and f' in contact, the dispersive powers of the materials of the lenses are ω and ω'. The combination is achromatic, when

(a) $\omega = \omega_0, \omega' = 2\omega_0 \quad f' = 2f$

(b) $\omega = \omega_0, \omega' = 2\omega_0 \quad f' = f/2$

(c) $\omega = \omega_0, \omega' = 2\omega_0 \quad f' = -f/2$

(d) $\omega = \omega_0, \omega' = 2\omega_0 \quad f' = -2f$

57. An achromatic convergent lens of focal length 20 cms is made of two lenses (in contact) of materials having dispersive powers in the ratio of 1 : 2 and having focal lengths f_1 and f_2. Which of the following is true ?

(a) $f_1 = 10$ cms, $f_2 = -20$ cms

(b) $f_1 = 20$ cms, $f_2 = 10$cms

(c) $f_1 = -10$ cms, $f_2 = -20$ cms

(d) $f_1 = 20$ cms, $f_2 = -20$ cms

58. A simple telescope, consisting of an objective of focal length 60 cm and a single eye lens of focal length 5 cm is focussed on a distant object in such a way that parallel rays emerge from the eye lens. If the object subtends an angle of 2° at the objective, the angular width of the image is

(a) 10° (b) 24° (c) 50° (d) (1/6)°

59. An astronomical telescope has an angular magnification of magnitude 5 for distant objects. The separation between the objective and the eye-piece is 36 cms and the final image is formed at infinity. The focal length f_0 of the objective and f_e of the eye piece are

(a) $f_0 = 45$ cm and $f_2 = -9$ cm

(b) $f_0 = 50$ cm and $f_e = 10$ cm

(c) $f_0 = 7.2$ cm and $f_e = 5$ cm

(d) $f_0 = 30$ cm and $f_e = 6$ cm

60. Two lens of focal length f_1 and f_2 are kept in contact coaxially. The resultant power of combination will be

(a) $\frac{f_1 f_2}{f_1 - f_2}$ (b) $\frac{f_1 + f_2}{f_1 f_2}$

(c) $f_1 + f_2$ (d) $\frac{f_1}{f_2} + \frac{f_2}{f_1}$

61. When white light enters a prism, its gets split into its constituent colours. This is due to

(a) high density of prism material

(b) because μ is different for different wavelength

(c) diffraction of light

(d) velocity changes for different frequency

62. A pencil of light rays falls on a plane mirror and form a real image, so the incident rays are

(a) parallel (b) diverging

(c) converging (d) statement is false

63. Astronauts look down on earth surface from a space ship parked at an altitude of 500 km. They can resolve objects of the earth of the size (It can be assumed that the pupils diameter is 5mm and wavelength of light is 500 nm)

(a) 0.5m (b) 5m (c) 50m (d) 500m

64. Spherical aberration in a thin lens can be reduced by

(a) using a monochromatic light
(b) using a doublet combination
(c) using a circular annular mark over the lens
(d) increasing the size of the lens

65. A lens produces an image of an object on a screen. If a slab of refractive index *n* is placed in between lens and screen, the screen has to be moved by distance *d* behind. The thickness of slab is

(a) nd (b) $\frac{n-1}{nd}$ (c) $\frac{(n-1)d}{n}$ (d) $\frac{nd}{n-1}$

66. An object is moved along the principal axis of a converging lens from a position 5 focal lengths from the lens to a position that is 2 focal lengths from the lens. Which statement about the resulting image is most accurate?

(a) The image increases in size and decreases in distance from the lens
(b) The image increases in size and increases in distance from the lens
(c) The image decreases in size and decreases in distance from the lens
(d) The image decreases in size and increases in distance from the lens

67. An object is placed upright on the axis of a thin convex lens at a distance of four focal lengths (4f) from the center of the lens. An inverted image appears at a distance of 4/3 f on the other side of the lens. What is the ratio of the height of he image of the height of the object?

(a) 1/3 (b) 3/4 (c) 4/3 (d) 3/1

68. A paper, with two marks having separation d, is held normal to the line of sight of an observer at a distance of 50m. The diameter of the eye-lens of the observer is 2 mm. Which of the following is the least value of d, so that the marks can be seen as separate ? (The mean wavelength of visible light may be taken as 5000 Å)

(a) 1.25m (b) 12.5 cm (c) 1.25 cm (d) 2.5mm

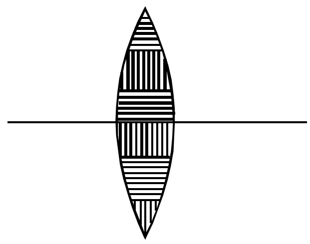
69. A diver inside water sees the setting sun at

(a) 41° to the horizon (b) 49° to the horizon
(c) 0° to the horizon (d) 45° to the horizon

70. A concave mirror forms the image of an object on a screen. If the lower half of the mirror is covered with an opaque card, the effect would be to make the

(a) image less bright.
(b) lower half of the image disappear.
(c) upper half of the image disappear.
(d) image blurred.

71. The layered lens as shown is made of two types of transparent materials-one indicated by horizontal lines and the other by vertical lines. The number of images formed of an object will be



(a) 1 (b) 2 (c) 3 (d) 6

72. In the displacement method, a concave lens is placed in between an object and a screen. If the magnification in the two positions are m_1 and m_2 ($m_1 > m_2$), and the distance between the two positions of the lens is x, the focal length of the lens is

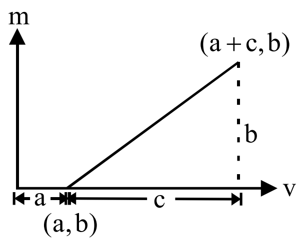
(a) $\frac{x}{m_1 + m_2}$ (b) $\frac{x}{m_1 - m_2}$

(c) $\frac{x}{(m_1 + m_2)^2}$ (d) $\frac{x}{(m_1 - m_2)^2}$

73. A thin lens has focal length f, and its aperture has diameter D. It forms an image of intensity I. If the central part of the aperture, of diameter $\frac{D}{2}$, is blocked by an opaque paper, the focal length of the lens and the intensity of image will become

(a) $\frac{f}{2}, \frac{I}{2}$ (b) f, $\frac{I}{4}$ (c) $\frac{3f}{4}, \frac{I}{2}$ (d) f, $\frac{3I}{4}$

74. The graph shows the variation of magnification m produced by a convex lens with the image distance v. The focal length of the lens is



(a) $\frac{b}{c}$ (b) $\frac{c}{b}$ (c) b (d) $\frac{ab}{c}$

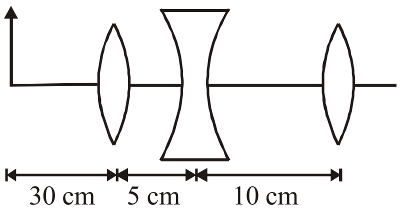
75. A ray of light traveling in water is incident on its surface open to air. The angle of incidence is θ, which is less than the critical angle. Then there will be

(a) only a reflected ray and no refracted ray
(b) only a refracted ray and no reflected ray
(c) a reflected ray and a refracted ray and the angle between them would be less than 180°–2θ
(d) a reflected ray and a refracted ray and the angle between them would be greater than 180°–2θ

76. Air has refractive index 1.0003. The thickness of air column, which will have one more wavelength of yellow light (6000 Å) than in the same thickness of vacuum is

(a) 2mm (b) 2 cm (c) 2m (d) 2km.

77. The position of final image formed by the given lens combination from the third lens will be at a distance of ($f_1 = +10$ cm, $f_2 = -10$ cm and $f_3 = +30$ cm).



(a) 15 cm (b) infinity (c) 45 cm (d) 30 cm

78. A ray of light is travelling from glass to air. (Refractive index of glass = 1.5). The angle of incidence is 50°.
The deviation of the ray is

(a) 0° (b) 80°

(c) $50° - \sin^{-1}\left[\frac{\sin 50°}{1.5}\right]$ (d) $\sin^{-1}\left[\frac{\sin 50°}{1.5}\right] - 50°$

79. If f_V and f_R are the focal lengths of a convex lens for violet and red light respectively and F_V and F_R are the focal lengths of concave lens for violet and red light respectively, then we have

(a) $f_V < f_R$ and $F_V > F_R$ (b) $f_V < f_R$ and $F_V < F_R$

(c) $f_V > f_R$ and $F_V > F_R$ (d) $f_V > f_R$ and $F_V < F_R$

80. A ray is incident at an angle of incidence *i* on one surface of a prism of small angle A and emerges normally from the opposite surface. If the refractive index of the material of prism is μ, the angle of incidence *i* is nearly equal to

(a) $\frac{A}{\mu}$ (b) $\frac{A}{2\mu}$

(c) μA (d) $\frac{\mu A}{2}$

81. One face of a rectangular glass plate 6 cm thick is silvered. An object held 8 cm in front of the first face, forms an image 12 cm behind the silvered face. The refractive index of the glass is

(a) 0.4 (b) 0.8 (c) 1.2 (d) 1.6

82. A convex lens of focal length 80 cm and a concave lens of focal length 50 cm are combined together. What will be their resulting power?

(a) +6.5 D (b) –6.5 D (c) +7.5 D (d) –0.75 D

83. A luminous object is placed at a distance of 30 cm from the convex lens of focal length 20 cm. On the other side of the lens, at what distance from the lens a convex mirror of radius of curvature 10 cm be placed in order to have an upright image of the object coincident with it?

(a) 12 cm (b) 30 cm (c) 50 cm (d) 60 cm

84. Light enters at an angle of incidence in a transparent rod of refractive index ***n***. For what value of the refractive index of the material of the rod the light once entered into it will not leave it through its lateral face whatsoever be the value of angle of incidence?

(a) $n > \sqrt{2}$ (b) n = 1 (c) n = 1.1 (d) n = 1.3

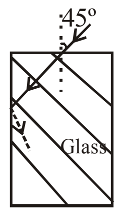
85. The radius of curvature of a thin plano-convex lens is 10 cm (of curved surface) and the refractive index is 1.5. If the plane surface is silvered, then it behaves like a concave mirror of focal length

(a) 10 cm (b) 15 cm (c) 20 cm (d) 5 cm

86. An air bubble in a glass slab (μ = 1.5) is 5 cm deep when viewed from one face and 2 cm deep when viewed from the opposite face. The thickness of the slab is

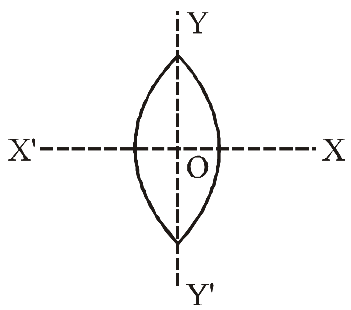
(a) 7.5 cm (b) 10.5 cm (c) 7 cm (d) 10 cm

87. A light ray falls on a rectangular glass slab as shown. The index of refraction of the glass, if total internal reflection is to occur at the vertical face, is



(a) $\sqrt{3/2}$ (b) $\frac{(\sqrt{3}+1)}{2}$ (c) $\frac{(\sqrt{2}+1)}{2}$ (d) $\sqrt{5}/2$

88. An equiconvex lens is cut into two halves along (i) XOX' and (ii) YOY' as shown in the figure. Let f, f', f'' be the focal lengths of the complete lens, of each half in case (i), and of each half in case (ii), respectively



Choose the correct statement from the following

(a) f' = 2f, f'' = 2f (b) f' = f, f'' = 2f

(c) f' = 2f, f'' = f (d) f' = f, f'' = f

89. A plano-convex lens is made of material of refractive index 1.6. The radius of curvature of the curved surface is 60 cm. The focal length of the lens is

(a) 50 cm (b) 100 cm (c) 200 cm (d) 400 cm

90. The refractive index of the material of a prism is $\sqrt{2}$ and its refracting angle is 30º. One of the refracting surfaces of the prism is made a mirror inwards. A beam of monochromatic light enters the prism from the mirrored surface if its angle of incidence of the prism is

(a) 30º (b) 45º (c) 60º (d) 0º

91. A telescope has an objective lens of 10 cm diameter and is situated at a distance of one kilometer from two objects. The minimum distance between these two objects, which can be resolved by the telescope, when the mean wavelength of light is 5000 Å, is of the order of

(a) 5 cm (b) 0.5 m (c) 5 m (d) 5 mm

92. The refractive index of the material of the prism is $\sqrt{3}$; then the angle of minimum deviation of the prism is

(a) 30º (b) 45º (c) 60º (d) 75º

93. A ray of light travelling in a transparent medium of refractive index μ , falls on a surface separating the medium from air at an angle of incidence of 45°. For which of the following value of μ the ray can undergo total internal reflection?

(a) $\mu = 1.33$ (b) $\mu = 1.40$ (c) $\mu = 1.50$ (d) $\mu = 1.25$

94. A biconvex lens has a radius of curvature of magnitude 20 cm. Which one of the following options best describe the image formed of an object of height 2 cm placed 30 cm from the lens?

(a) Virtual, upright, height = 1 cm
(b) Virtual, upright, height = 0.5 cm
(c) Real, inverted, height = 4 cm
(d) Real, inverted, height = 1cm

95. A thin prism of angle 15º made of glass of refractive index $\mu_1 = 1.5$ is combined with another prism of glass of refractive index $\mu_2 = 1.75$. The combination of the prism produces dispersion without deviation. The angle of the second prism should be

(a) 7º (b) 10º (c) 12º (d) 5º

96. A person is six feet tall. How tall must a vertical mirror be if he is able to see his entire length?

(a) 3 ft (b) 4.5 ft (c) 7.5 ft (d) 6 ft

Directions for Qs. (97 to 100) : Each question contains STATEMENT-1 and STATEMENT-2. Choose the correct answer (ONLY ONE option is correct) from the following-

(a) Statement -1 is false, Statement-2 is true
(b) Statement -1 is true, Statement-2 is true; Statement -2 is a correct explanation for Statement-1
(c) Statement -1 is true, Statement-2 is true; Statement -2 is not a correct explanation for Statement-1
(d) Statement -1 is true, Statement-2 is false

97. **Statement 1:** Two convex lenses joined together cannot produce an achromatic combination.

Statement 2 : The condition for achromatism is $\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$ where symbols have their usual meaning.

98. **Statement 1:** Critical angle is minimum for violet colour.

Statement 2 : Because critical angle $\theta_c = \sin^{-1}\left(\frac{1}{\mu}\right)$ and $\mu \propto \frac{1}{\lambda}$.

99. **Statement 1:** Optical fibres are used to transmit light without any appreciable loss in its intensity over distance of several kilometers.

Statement 2 : Optical fibres are very thick and all the light is passed through it without any loss.

100. **Statement 1 :** If P_1 and P_2 be the powers of two thin lenses located coaxially in a medium of refractive index μ at a distance d, then the power P of the combination is $P = P_1 + P_2 - P_1P_2d/\mu$

Statement 2 : Because for above given system equivalent focal length is given by $F = \frac{f_1f_2}{f_1 + f_2 - d/\mu}$ and $P = \frac{1}{F}$.

EXERCISE - 3
Exemplar & Past Years NEET/AIPMT Questions

Exemplar Questions

1. A ray of light incident at an angle θ on a refracting face of a prism emerges from the other face normally. If the angle of the prism is 5° and the prism is made of a material of refractive index 1.5, the angle of incidence is

(a) 7.5° (b) 5°
(c) 15° (d) 2.5°

2. A short pulse of white light is incident from air to a glass slab at normal incidence. After travelling through the slab, the first colour to emerge is

(a) blue (b) green
(c) violet (d) red

3. An object approaches a convergent lens from the left of the lens with a uniform speed 5 m/s and stops at the focus. The image

(a) moves away from the lens with an uniform speed 5 m/s
(b) moves away from the lens with an uniform acceleration
(c) moves away from the lens with a non-uniform acceleration
(d) moves towards the lens with a non-uniform acceleration

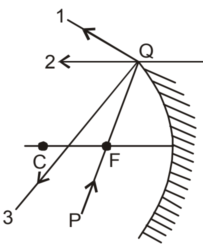
4. A passenger in an aeroplane shall
(a) never see a rainbow
(b) may see a primary and a secondary rainbow as concentric circles
(c) may see a primary and a secondary rainbow as concentric arcs
(d) shall never see a secondary rainbow

5. You are given four sources of light each one providing a light of a single colour - red, blue, green and yellow. Suppose the angle of refraction for a beam of yellow light corresponding to a particular angle of incidence at the interface of two media is 90°. Which of the following statements is correct if the source of yellow light is replaced with that of other lights without changing the angle of incidence?
(a) The beam of red light would undergo total internal reflection
(b) The beam of red light would bend towards normal while it gets refracted through the second medium
(c) The beam of blue light would undergo total internal reflection
(d) The beam of green light would bend away from the normal as it gets refracted through the second medium

6. The radius of curvature of the curved surface of a plano-convex lens is 20 cm. If the refractive index of the material of the lens be 1.5, it will
(a) act as a convex lens only for the objects that lie on its curved side
(b) act as a concave lens for the objects that lie on its curved side
(c) act as a convex lens irrespective of the side on which the object lies
(d) act as a concave lens irrespective of side on which the object lies

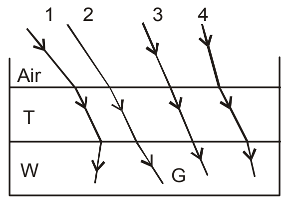
7. The phenomena involved in the reflection of radiowaves by ionosphere is similar to
(a) reflection of light by a plane mirror
(b) total internal reflection of light in air during a mirage
(c) dispersion of light by water molecules during the formation of a rainbow
(d) scattering of light by the particles of air

8. The direction of ray of light incident on a concave mirror is shown by PQ while directions in which the ray would travel after reflection is shown by four rays marked 1, 2, 3 and 4 (figure). Which of the four rays correctly shows the direction of reflected ray?



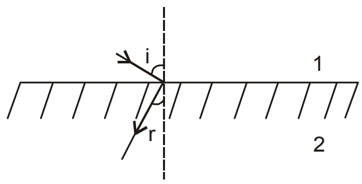
(a) 1 (b) 2 (c) 3 (d) 4

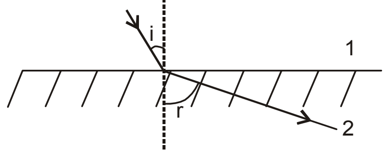
9. The optical density of turpentine is higher than tnat of water while its mass density is lower. Figure shows a layer of turpentine floating over water in a container. For which one of the four rays incident on turpentine in figure, the path shown is correct?
(a) 1 (b) 2 (c) 3 (d) 4

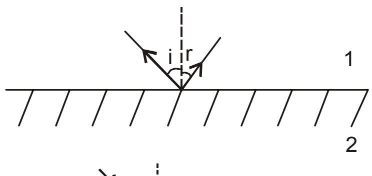


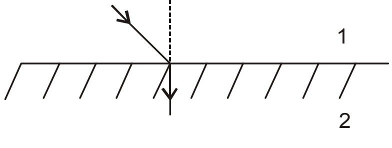
10. A car is moving with at a constant speed of 60 km h^{-1} on a straight road. Looking at the rear view mirror, the driver finds that the car following him is at a distance of 100 m and is approaching with a speed of 5 kmh^{-1}.
In order to keep track of the car in the rear, the driver begins to glance alternatively at the rear and side mirror of his car after every 2 s till the other car overtakes. If the two cars were maintaining their speeds, which of the following statement (s) is/are correct?
(a) The speed of the car in the rear is 65 km h^{-1}
(b) In the side mirror, the car in the rear would appear to approach with a speed of 5 kmh^{-1} to the driver of the leading car
(c) In the rear view mirror, the speed of the approaching car would appear to decrease as the distance between the cars decreases
(d) In the side mirror, the speed of the approaching car would appear to increase as the distance between the cars decreases

11. There are certain material developed in laboratories which have a negative refractive index figure. A ray incident from air (Medium 1) into such a medium (Medium 2) shall follow a path given by

(a)


(b)


(c)


(d)


NEET/AIPMT (2013-2017) Questions

12. A plano convex lens fits exactly into a plano concave lens. Their plane surfaces are parallel to each other. If lenses are made of different materials of refractive indices μ_1 and μ_2 and R is the radius of curvature of the curved surface of the lenses, then the focal length of the combination is ***[2013]***

(a) $\frac{R}{2(\mu_1 - \mu_2)}$ (b) $\frac{R}{(\mu_1 - \mu_2)}$

(c) $\frac{2R}{(\mu_2 - \mu_1)}$ (d) $\frac{R}{2(\mu_1 + \mu_2)}$

13. For a normal eye, the cornea of eye provides a converging power of 40D and the least converging power of the eye lens behind the cornea is 20D. Using this information, the distance between the retina and the eye lens of the eye can be estimated to be ***[2013]***

(a) 2.5 cm (b) 1.67 cm
(c) 1.5 cm (d) 5 cm

14. Two plane mirrors are inclined at 70°. A ray incident on one mirror at angle θ after reflection falls on second mirror and is reflected from there parallel to first mirror. The value of θ is ***[NEET Kar. 2013]***

(a) 50° (b) 45°
(c) 30° (d) 55°

15. The reddish appearance of the sun at sunrise and sunset is due to ***[NEET Kar. 2013]***

(a) the colour of the sky
(b) the scattering of light
(c) the polarisation of light
(d) the colour of the sun

16. If the focal length of objective lens is increased then magnifying power of : ***[2014]***

(a) microscope will increase but that of telescope decrease.
(b) microscope and telescope both will increase.
(c) microscope and telescope both will decrease
(d) microscope will decrease but that of telescope increase.

17. The angle of a prism is 'A'. One of its refracting surfaces is silvered. Light rays falling at an angle of incidence 2A on the first surface returns back through the same path after suffering reflection at the silvered surface. The refractive index μ, of the prism is : ***[2014]***

(a) 2 sin A (b) 2 cos A

(c) $\frac{1}{2}\cos A$ (d) tan A

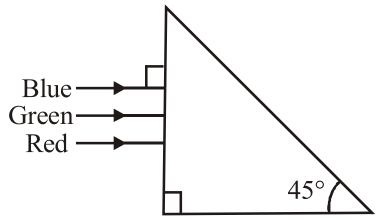
18. The refracting angle of a prism is 'A', and refractive index of the material of the prism is cot(A/2). The angle of minimum deviation is : ***[2015]***

(a) 180° – 2A (b) 90° – A
(c) 180° + 2A (d) 180° – 3A

19. Two identical thin plano-convex glass lenses (refractive index 1.5) each having radius of curvature of 20 cm are placed with their convex surfaces in contact at the centre. The intervening space is filled with oil of refractive index 1.7. The focal length of the combination is ***[2015]***

(a) –25 cm (b) –50 cm
(c) 50 cm (d) –20 cm

20. A beam of light consisting of red, green and blue colours is incident on a right angled prism. The refractive index of the material of the prism for the above red, green and blue wavelengths are 1.39, 1.44 and 1.47, respectively. ***[2015 RS]***



The prism will:

(a) separate all the three colours from one another
(b) not separate the three colours at all
(c) separate the red colour part from the green and blue colours
(d) separate the blue colour part from the red and green colours

21. In an astronomical telescope in normal adjustment a straight black line of lenght L is drawn on inside part of objective lens. The eye-piece forms a real image of this line. The length of this image is *l*. The magnification of the telescope is :

(a) $\frac{L}{I} - 1$ (b) $\frac{L + I}{L - I}$ ***[2015 RS]***

(c) $\frac{L}{I}$ (d) $\frac{L}{I} + 1$

22. The angle of incidence for a ray of light at a refracting surface of a prism is 45°. The angle of prism is 60°. If the ray suffers minimum deviation through the prism, the angle of minimum deviation and refractive index of the material of the prism respectively, are : ***[2016]***

(a) $45°, \frac{1}{\sqrt{2}}$ (b) $30°, \sqrt{2}$

(c) $45°, \sqrt{2}$ (d) $30°, \frac{1}{\sqrt{2}}$

23. A astronomical telescope has objective and eyepiece of focal lengths 40 cm and 4 cm respectively. To view an object 200 cm away from the objective, the lenses must be separated by a distance : ***[2016]***

(a) 37.3 cm (b) 46.0 cm
(c) 50.0 cm (d) 54.0 cm

24. Match the corresponding entries of column-1 with column-2 (Where m is the magnification produced by the mirror): ***[2016]***

Column-1	**Column-2**
(A) m = –2	(a) Convex mirror
(B) $m = -\frac{1}{2}$	(b) Concave mirror
(C) m = +2	(c) Real image
(D) $m = +\frac{1}{2}$	(d) Virtual image

(a) A $\rightarrow$ b and c, B $\rightarrow$b and c, C $\rightarrow$ b and d, D $\rightarrow$ a and d.
(b) A $\rightarrow$ a and c, B $\rightarrow$ a and d, C $\rightarrow$ a and b, D $\rightarrow$ c and d
(c) A $\rightarrow$ a and d, B $\rightarrow$ b and c, C $\rightarrow$ b and d, D $\rightarrow$ b and c
(d) A $\rightarrow$ c and d, B $\rightarrow$ b and d, C $\rightarrow$ b and c, D $\rightarrow$ a and d

25. A beam of light from a source L is incident normally on a plane mirror fixed at a certain distance x from the source. The beam is reflected back as a spot on a scale placed just above the source I. When the mirror is rotated through a small angle θ, the spot of the light is found to move through a distance y on the scale. The angle θ is given by ***[2017]***

(a) $\frac{y}{x}$ (b) $\frac{x}{2y}$
(c) $\frac{x}{y}$ (d) $\frac{y}{2x}$

26. A thin prism having refracting angle 10° is made of glass of refractive index 1.42. This prism is combined with another thin prism of glass of refractive index 1.7. This combination produces dispersion without deviation. The refracting angle of second prism should be ***[2017]***

(a) 6° (b) 8°
(c) 10° (d) 4°

Hints & Solutions

EXERCISE - 1

1. (a) As no scattering of light occurs, sky appears dark.

2. (a) $\lambda_a = \frac{c}{\nu}$ or $\lambda_m = \frac{v}{\nu} = \frac{c}{\mu_m \nu}$ $\quad (\because \mu_m = \frac{c}{v})$

$\therefore \quad \lambda_1 = \frac{c}{\mu_1 \nu}$ and $\lambda_2 = \frac{c}{\mu_2 \nu}$

or $\quad \lambda_1 \mu_1 = \lambda_2 \mu_2$ or $\lambda_2 = \lambda_1 (\mu_1 / \mu_2)$

3. (b) Apparent depth = $d/\mu_1 + d/\mu_2$

4. (d) 5. (c) 6. (d) 7. (d)

8. (d) Because, the focal length of eye lens can not decrease beyond a certain limit.

9. (d) It is the total luminous flux.

10. (d)

11. (c) The intensity of cylindrical source at small distance r is inversely proportional to r.

$I \propto \frac{1}{r}$ (since $A \propto \frac{1}{\sqrt{r}}$ & $I \propto A^2$)

12. (a) $\mu \propto \frac{1}{\lambda}$, $\lambda_{red} > \lambda_{violet}$

13. (c) $\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in glass plate}}$

or $\mu = \frac{c}{c'}$ or $c' = \frac{c}{\mu}$

Time taken = distance/velocity = $t/(c/\mu) = \frac{\mu t}{c}$

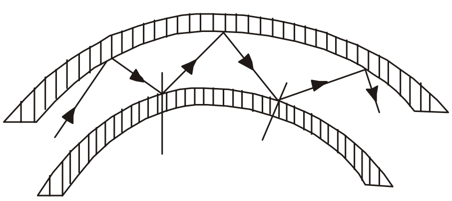
14. (a) $m = \frac{1}{n} = \frac{-v}{(-u)} \Rightarrow v = \frac{u}{n}$

As $\quad \frac{1}{v} + \frac{1}{u} = \frac{1}{f} \qquad \therefore \frac{n}{u} - \frac{1}{u} = \frac{1}{f}$

$u = (n - 1) f$

15. (d) Amount of light entering into the camera depends upon aperture setting the camera.

16. (b) Optical fibre is a device which transmits light introduced at one end to the opposite end, with little loss of the light through the sides of the fibre. It is possible with the help of total internal reflection.



17. (d) If the medium is heterogeneous having a gradient of refractive index. Then light rays will not follow a rectilinear (straight line path).

18. (d) Resolving power $= \frac{\lambda}{d\lambda}$ plane transmission grating

Resolving power for telescope

$= \frac{1}{\text{limit of resolution}} = \frac{d}{1.22\lambda} = \frac{d_0}{d_1}$

by increasing the aperture of objective resolving power can be increased.

19. (d) Least distance is 4f when object is at radius of curvature, and greatest is infinity.

20. (a) When electromagnetic wave enters in other medium, frequency reamains unchanged while wavelength and velocity become $\frac{1}{\mu}$ times.

so, e.m. entering from air to glass slab (μ), frequency remains n, wavelength $\lambda' = \frac{\lambda}{\mu}$

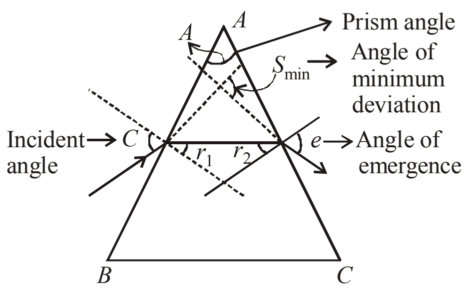
velocity of light in medium $v' = \frac{v}{\mu}$

21. (c) $\frac{1}{f} = ({}_{\ell}\mu_g - 1)\left(\frac{1}{R} - \frac{1}{R_2}\right)$ where ${}_{\ell}\mu_g = 1$ is given, we get

$\Rightarrow \frac{1}{f} = (1-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = 0$ or $\Rightarrow f = \infty$

22. (a) $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{f_2 + f_1}{f_1 f_2}$; $\quad P = \frac{1}{F} = \frac{f_1 + f_2}{f_1 f_2}$

23. (b)



The angle of minimum deviation is given as

$\delta_{min} = i + e - A$

for minimum deviation

$\delta_{min} = A$ then

$2A = i + e$

in case of δ_{min} $i = e$

$2A = 2i \quad r_1 = r_2 = \frac{A}{2}$

$i = A = 90°$

from smell's law

$1 \sin i = n \sin r_1$

$\sin A = n \sin \frac{A}{2}$

$$2\sin\frac{}{2}\cos\frac{}{2}=n\sin\frac{}{2}$$

$$2\cos\frac{A}{2}=n$$

when $A=90°=i_{min}$

then $n_{min}=\sqrt{2}$

$i=A=0\ \ n_{max}=2$

24. (b) Difference between apparent and real depth of a pond is due to the refraction of light, not due to the total internal reflection. Other three phenomena are due to the total internal reflection.
25. (b) Large aperture increases the amount of light gathered by the telescope increasing the resolution.

EXERCISE - 2

1. (c) At minimum distance, incidence is normal. Therefore,

$$E=\frac{I}{r^2}=\frac{250}{6^2}=6.94\text{ lux}$$

2. (b) $r=2\text{ m}=200\text{ cm}$
$E=5\times10^{-4}$ phot, $\theta=60^o$
From,

$$E=\frac{I\cos\theta}{r^2},\ I=\frac{Er^2}{\cos\theta}=\frac{5\times10^{-4}(200)^2}{\cos 60}=40\text{ C.P}$$

3. (a) Number of images $(n_1)=\frac{360^o}{\theta}-1$
where θ = angle between mirrors
Here, $\theta=60^o$

So, number of images $n_1=\frac{360^o}{60^o}-1=5$

4. (d) Resolving power of an optical instrument $\propto\frac{1}{\lambda}$

$$\frac{\text{Resolving power at }\lambda_1}{\text{Resolving power at }\lambda_2}=\frac{\lambda_2}{\lambda_1}$$

$$\left(\text{Limit of resolution}\propto\frac{1}{\text{resolving power}}\right)$$

$\therefore$ Ratio of resolving power $=\frac{5000}{4000}=\frac{5}{4}=5:4$

5. (b)
6 (d) 7. (a)
8. (d) $\phi=4\pi I=4\pi(100)=400\pi$ lumen.
9. (b) $\frac{v_2}{v_1}=\frac{\mu_1}{\mu_2}=\frac{1}{1.33}$ or $v_2=\frac{v_1}{1.33}=2.25\times10^8\text{ m/s}$
10. (c) Given $v=nu$ As $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$$\therefore\ \frac{1}{nu}+\frac{1}{u}=\frac{1}{f}\text{ or }u=\frac{(n+1)f}{n}$$

11. (a) Here, $u=f+x_1$, $v=f+x_2$

use $f=\frac{uv}{u+v}$ and solve to get $f=\sqrt{x_1x_2}$

12. (c) $\frac{1}{f}=\frac{1}{f_1}+\frac{1}{-f_2}=\frac{f_2-f_1}{f_1f_2}$; $f=\frac{f_1f_2}{f_2-f_1}$
13. (c) $P=P_1+P_2=+2-1=+1$ dioptre, lens behaves as convergent

$$F=\frac{1}{P}=\frac{1}{1}=1\text{ m}=100\text{ cm}$$

14. (c) $c=\frac{x}{t_1},\ v=\frac{10}{t_2}$

$$\sin i_c=\frac{1}{\mu}=\frac{v}{c}=\frac{10}{t_2}\times\frac{t_1}{x};\ i_c=\sin^{-1}\left(\frac{10t_1}{t_2x}\right)$$

15. (b) If $R_1=R$, $R_2=-2R$

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

$$\frac{1}{6}=(1.5-1)\left(\frac{1}{R}+\frac{1}{2R}\right)=\frac{0.5\times3}{2R}$$

$R=4.5$ cm

16. (b) $i=\frac{A+\delta_m}{2}=\frac{60+30}{2}=45^o$
17. (d) $i_1=i_2=\frac{3}{4}A$
As $A+\delta=i_1+i_2$

$$\therefore\ \delta=i_1+i_2-A=\frac{3}{4}A+\frac{3}{4}A-A=\frac{A}{2}=\frac{60^o}{2}=30^o$$

18. (b) Here, $P_1=5$ D
$P_2=P-P_1=2-5=-3$ D

$$\frac{\omega_1}{\omega_2}=-\frac{f_1}{f_2}=\frac{-P_2}{P_1}=\frac{3}{5}$$

19. (c) Longitudinal chromatic aberration $=\omega f$
$=0.08\times20=1.6$ cm
20. (a) $\frac{f_0}{f_e}=9$, $\therefore\ f_0=9f_e$
Also $f_0+f_e=20$ ($\because$ final image is at infinity)
$9f_e+f_e=20$, $f_e=2$ cm, $\therefore\ f_0=18$ cm
21. (b) In normal adjustment,

$$M=\frac{f_0}{f_e}=20,\ f_e=\frac{f_0}{20}=\frac{60}{20}=3\text{ cm}$$

22. (a) (i) $M=-\frac{f_0}{f_e}\left(1+\frac{f_e}{d}\right)=-\frac{200}{5}\left(1+\frac{5}{25}\right)=-48$
(since least distance d = 25cm)

(ii) $M=-\frac{f_0}{f_e}=-\frac{200}{5}=-40$

23. (b)
24. (a) Convex lens can form image with m < 1, m > 1 and m = 1 depending upon the position of the object. Convex lens forms magnified image (m > 1) when the

object is pole and 2f, same size as the object (m = 1) when the object is at 2f and smaller image (m < 1), when the object is beyond 2f.

25. (b) Virtual object forms real image on a plane mirror, so rays convergent.

26. (a) $\frac{1}{v}-\frac{1}{2f}=\frac{1}{f}\Rightarrow\frac{1}{v}=\frac{3}{2f}\Rightarrow v=\frac{2}{3}f$

$\therefore m=\frac{v}{u}=\frac{2}{3}\frac{f}{2f}=\frac{1}{3}$

27. (a) Difference in refractive indices of blue and green colour are less so they are seen together and red is seen separate because deviation depends on refractive index.

28. (b) Medium doesn't effect focal length of a mirror.

29. (a)

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

$\frac{1}{16}=(1.5-1)\left(\frac{1}{R}-\frac{1}{\infty}\right)$

$\Rightarrow\frac{1}{16}=0.5\times\frac{1}{R}\Rightarrow R=8\text{ cm}$

31. (b) When we bring in contact a concave lens the effective focal length of the combination decreases.

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

according to above relation as f reduces, v increases.

32. (b) 33. (b) 34. (d) 35. (b)

36. (a) In a telescope, to obtain an image at infinity or in normal adjustment, the distance between two convex lenses one called objective (greater focal length) and the other called eye piece (shorter focal length) is L.

$L=f_0+f_e=0.3+0.05=0.35$ m.

37. (b) given : ${}^a\mu_g=\frac{3}{2},{}^a\mu_w=\frac{4}{3}$

$\because\ {}^a\mu_w\times{}^w\mu_g={}^a\mu_g$

$\therefore\ {}^w\mu_g=\frac{{}^a\mu_g}{{}^a\mu_w}=\frac{3/2}{4/3}=\frac{9}{8}.$

38. (c)

39. (b) Object distance u = – 40 cm

Focal length f = – 20 cm

According to mirror formula

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

or $\frac{1}{v}+\frac{1}{-20}-\frac{1}{(-40)}=\frac{1}{-20}+\frac{1}{40}$

$\frac{1}{v}=\frac{-2+1}{40}=-\frac{1}{40}$ or $v=-40$ cm.

Negative sign shows that image is infront of concave mirror. The image is real.

Magnification, $m=\frac{-v}{u}=-\frac{(-40)}{(-40)}=-1$

The image is of the same size and inverted.

40. (b) $\mu=\frac{\text{velocity of light in vacuum (c)}}{\text{velocity of light in medium (v)}}$

But $v=\upsilon\lambda=2\times10^{14}\times5000\times10^{-10}$

In the medium, $v=10^8$ m/s.

$\therefore\ \mu=\frac{v_{vac}}{v_{med}}=\frac{3\times10^8}{10^8}=3.$

41. (d) Here, $i_1=15°, A=60°, \delta=55°, i_2=e=?$

As $i_1+i_2=A+\delta$

$i_2=A+\delta-i_1=60°+55°-15°=100°.$

42. (c) For reading purposes :

u = – 25 cm, v = – 50 cm, f = ?

$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}=-\frac{1}{50}+\frac{1}{25}=\frac{1}{50}$; $P=\frac{100}{f}=+2\text{ D}$

For distant vision, f' = distance of far point = –3 m

$P=\frac{1}{f'}=-\frac{1}{3}\text{D}=-0.33\text{ D}$

43. (c) $E_2=4E_1$. If x is distance from 1st source,

then, $\frac{I}{(1.2-x)^2}=\frac{4I}{x^2}$ or $\frac{1}{1.2-x}=\frac{2}{x}$

$3x=2.4, x=0.8$ m

44. (d) $E_2=\frac{1}{8}E_1$ or, $\frac{1}{(r^2+h^2)}\times\frac{h}{\sqrt{r^2+h^2}}=\frac{1}{8}\frac{1}{h^2}$

(by Lambert's cosine law)

or, $(r^2+h^2)^{3/2}=(2h)^3$ or, $(r^2+h^2)^{1/2}=2h$

or, $r^2+h^2=4h^2$

$h=r/\sqrt{3}$

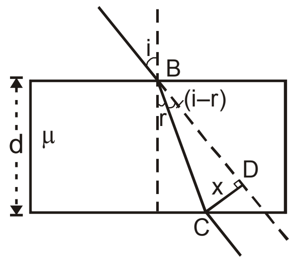
45. (b) Since $\frac{\text{Apparent depth}}{\text{Real depth}}=\frac{1}{\mu}$

$\Rightarrow$ Apparent depth = d/μ

So mark raised up = Real depth – Apparent depth

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

46. (c) From figure



$\frac{x}{BC}=\sin(i-r)\approx(i-r)$ ...(1)

Further, $\frac{d}{BC}=\cos r\approx1$

(When i is small r is small)

$\therefore$ BC ≈ d

From eq. (1), $\frac{x}{d}\approx(i-r)$ or $x\approx d(i-r)$

or $x \approx i\,d\left(1-\frac{r}{i}\right)$

Now $\frac{\sin i}{\sin r} = \frac{i}{r} = \mu$ $\qquad \therefore\ x \approx i\,d\left(1-\frac{1}{\mu}\right)$

47. (a) Given that ${}_w\mu_g = \frac{5}{4}$ and ${}_a\mu_w = \frac{4}{3}$

$\therefore\ {}_a\mu_g = {}_w\mu_g \times {}_a\mu_w = \frac{5}{4} \times \frac{4}{3} = \frac{5}{3}$

48. (c) We know that $\mu = \frac{\text{real depth}}{\text{apparent depth}}$

Let the thickness of the slab be t and real depth of the bubble from one side be x. Then

$\mu = \frac{x}{6} = \frac{(t-x)}{4}$ or $1.5 = \frac{x}{6} = \frac{t-x}{4}$.

This gives x = 9 and $1.5 = \frac{t-9}{4}$ or t = 15 cm

49. (d) Let d be the depth of two liquids.
Then apparant depth

$\frac{(d/2)}{\mu} + \frac{(d/2)}{1.5\mu} = \frac{d}{2}$ or $\frac{1}{\mu} + \frac{2}{3\mu} = 1$

Solving we get $\mu = 1.671$

50. (c) The minimum length of the mirror is half the length of the man. This can be proved from the fact that $\angle i = \angle r$.

51. (d) Distance of image from plane mirror = 3 m at the back. To photograph the image, camera must be focussed for a distance of 4.5 + 3 = 7.5 m.

52. (d) $P_2 = P - P_1 = \frac{100}{80} - \frac{100}{20} = -3.75\ D$

53. (b) $\frac{P_a}{P_1} = \frac{\left(\frac{\mu_g}{\mu_a} - 1\right)}{\left(\frac{\mu_g}{\mu_1} - 1\right)} = \frac{+5}{-100/100} = -5$

$-5\left(\frac{\mu_g}{\mu_1} - 1\right) = \frac{\mu_g}{\mu_a} - 1$

$\frac{1.5}{\mu_1} - 1 = \frac{-1}{5}(1.5-1) = -0.1$; $\mu_1 = \frac{1.5}{0.9} = \frac{5}{3}$

54. (b) $\mu = \frac{\sin(A+\delta_m)/2}{\sin A/2}$

$\Rightarrow \frac{\sin(A+\delta_m)}{2} = \mu \sin A/2` = 1.5 \times \sin 30^\circ = 0.75$

$\frac{A+\delta_m}{2} = \sin^{-1}(0.75) = 48^\circ 36'$ $\therefore\ \delta_m = 37^\circ 12'$

55. (b) Condition for achromatism is $\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$

$\therefore\ \frac{f_1}{f_2} = -\frac{\omega_1}{\omega_2} = \frac{2}{3}$ (leaving sign)

56. (d) The necessary condition is

$\frac{\omega}{\omega'} = -\frac{f}{f'}$ which is satisfied by (d)

57. (a) $\frac{f_1}{f_2} = -\frac{\omega_1}{\omega_2} = -\frac{1}{2}$ $\quad \therefore\ f_2 = -2 f_1$

As $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

$\therefore\ \frac{1}{20} = \frac{1}{f_1} - \frac{1}{2f_1} = \frac{1}{2f_1}$ $\therefore\ f_1 = 10$ cm

$f_2 = -20$ cm

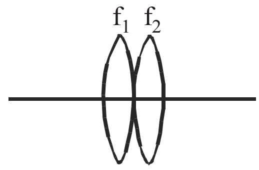
58. (b) $M = \frac{\beta}{\propto} = \frac{f_0}{f_e}$ $\quad \therefore\ \beta = \frac{f_0}{f_e}\propto = \frac{60}{5} \times 2^\circ = 24^\circ$

59. (d) $M = \frac{f_0}{f_e} = 5$, $L = f_0 + f_e = 36$

$\therefore\ f_e = 6$ cm, $f_0 = 30$ cm

60. (b) When two lenses are placed coaxially then their equivalent focal length F is given as

$\frac{1}{F_1} = \frac{1}{f_1} + \frac{1}{f_2} \Rightarrow F = \frac{f_1 f_2}{f_1 + f_2}$



Now power $= \frac{1}{\text{focal length}} = \frac{f_1 + f_2}{f_1 f_2}$

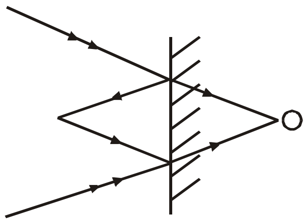
61. (b) Refractive index of medium is given by

$\mu = A + \frac{B}{\lambda^2}$ (where A and B are constant).

Light has seven different colour, so its each colour has different wavelength and so different refractive index. Due to difference in refractive index different refractive angle $\left(\mu = \frac{\sin i}{\sin r}\right)$.

So this is due to dependence on wavelength of refractive index.

62. (c) When a object is real plane mirror form a virtual image and when object is virtual image will be real. Thus in this question object is virtual. Virtual object means object is at infinity. So rays (incident) converge on the mirror.



63. (c) Resolving power of eye $= \lambda / a$

$$= \frac{500 \times 10^{-9}}{5 \times 10^{-3}} = 10^{-4} \text{ radians}$$

Now, arc = angle× radius = $10^{-4} \times (500 \times 10^{3})$m = 50m

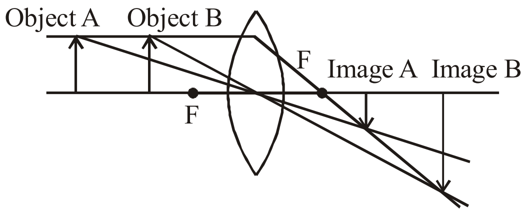
64. (c) Spherical abberation occurs due to the inability of a lens to coverage marginal rays of the same wavelength to the focus as it converges the paraxial rays, This defect can be removed by blocking marginal rays. This can be done by using a circular annular mask over the lens.

65. (d) Shift in the position of image after introducing slab,

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

$$nd = t(n-1) \Rightarrow t = \frac{nd}{(n-1)}$$

66. (b) The easiest way to answer this question is with a fast sketch. For a given object's position, draw two rays from the top of the object. One ray is parallel to the principal axis and passes through the focal point on the opposite side of the lens. The other ray passes through the center of the lens. The top of the image appears where these two rays intersect.



Change the object's position and repeat the process. You will observe that as the object approaches the lens while remaining beyond the focal length, the image produced on the opposite side of the lens moves away from the lens and increases in size. As an aside, the image is real and inverted.

67. (a) The ratio of object to image distance equals the ratio of object to image height. The ratio of image to object height is found by rearranging the ratios to give $4f/(4/3)f = 1/3$. The image is demagnified by a factor of 3. Thus, answer choice A is the best answer.

68. (b) Angular limit of resolution of eye, $\theta = \frac{\lambda}{d}$, where d is diameter of eye lens.

Also if y is the minimum just resolution separation between two objects at distance D from eye then

$$\theta = \frac{y}{D}$$

$$\Rightarrow \frac{y}{D} = \frac{\lambda}{d} \Rightarrow y = \frac{\lambda D}{d} \qquad \text{...............(1)}$$

Here : wavelength $\lambda = 5000\text{Å} = 5 \times 10^{-7}$ m

D = 50m

Diameter of eye lens = 2 mm = 2×10^{-3} m

From eq. (1) minimum separation is

$$y = \frac{5 \times 10^{-7} \times 50}{2 \times 10^{-3}} = 12.5 \times 10^{-3} \text{ m} = 12.5 \text{cm}$$

69. (a)

70. (a) Due to covering the reflection from lower part is not there so it makes the image less bright.

71. (b) Due to difference in refractive indices images obtained will be two. Two mediums will form images at two different points due to difference in focal lengths.

72. (b) 73. (d)

74. (b) $m = \frac{v}{u}$

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

Multiply the equation by v

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

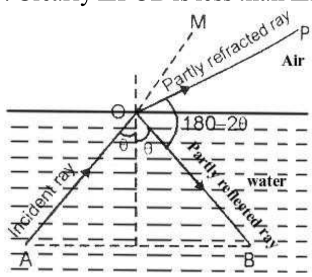
$$\therefore m = 1 - \frac{v}{f}$$

$$\text{Slope} = -\frac{1}{f} = \frac{b}{c} \Rightarrow f = \frac{c}{b}$$

75. (c) The ray is partly reflected and partly refracted.

$\angle MOB = 180 - 2\theta$

But the angle between refracted and reflected ray is $\angle POB$. Clearly $\angle POB$ is less than $\angle MOB$.



76. (a)

77. (d) For 1st lens, $u_1 = -30$, $f_1 = +10$cm,

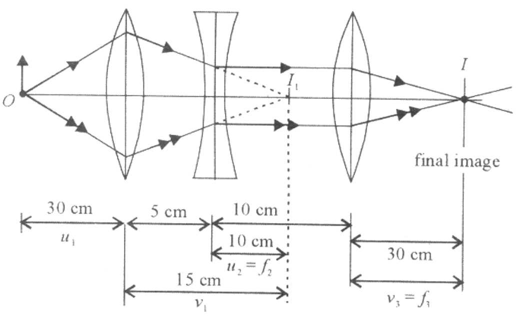
Formula of lens, $\frac{1}{v_1} + \frac{1}{30} = \frac{1}{10}$

or, $v_1 = 15$ cm at I_1 behind the lens.

The images I_1 serves as virtual object for concave lens. For second lens, which is concave, $u_2 = (15 - 5) = 10$ cm. I_1 acts as object. $f_2 = -10$ cm.

The rays will emerge parallel to axis as the virtual object is at focus of concave lens, as shown in the figure. Image of I_1 will be at infinity. These parallel rays are incident on the third lens viz the convex lens, $f_3 = +30$ cm. These parallel rays will be brought to convergence at the focus of the third lens.

$\therefore$ Image distance from third lens = $f_3 = 30$ cm



78. (b) $^a\mu_g = 1.5$

$\therefore$ 1.5 = cosecC or C = 42°. Critical angle for glass = 42°. Hence a ray of light incident at 50° in glass medium undergoes total internal reflection. δ denotes the deviation of the ray.

$\therefore \delta = 180° - (50° + 50°)$ or $\delta = 80°$.

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

According to Cauchy relation $\mu = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4}......$

Hence $f \propto \lambda$.

Hence red light having maximum wavelength has maximum focal length.

$f_V < f_R$ and also $F_V < F_R$

80. (c) As refracted ray emerges normally from oppostite surface, $r_2 = 0$

As $A = r_1 + r_2$ $\therefore r_1 = A$

Now, $\mu = \frac{\sin i_1}{\sin r_1} = \frac{i_1}{r_1} = \frac{i}{A}; i = \mu A$

(where t = thickness of glass plate)

81. (c) Thickness of glass plate (t) = 6 cm;

Distance of the object (u) = 8 cm. and

distance of the image (v) = 12 cm.

Let x = Apparent position of the silvered surface in cm.

Since the image is formed due to relfection at the silvered face and by the property of mirror image distance of object from the mirror = Distance of image from the mirror

or $x + 8 = 12 + 6 - x$ or $x = 5$ cm.

Therefore refractive index of glass

$$= \frac{\text{Real depth}}{\text{Apparent depth}} = \frac{6}{5} = 1.2.$$

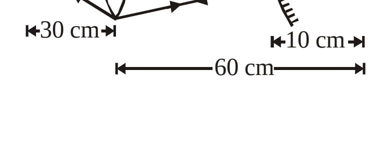
82. (d) We know that $\frac{1}{f} = \sum_{i=1}^{n} \frac{1}{f_i}$

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

$f_1 = 80$ cm, $f_2 = -50$ cm

$\frac{1}{f} = \frac{1}{\frac{80}{100}} - \frac{1}{\frac{50}{100}} \Rightarrow P = \frac{1}{f} = 1.25 - 2 = -0.75D$

83. (c)

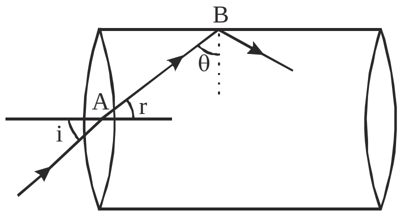


$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$; $\frac{1}{v} - \frac{1}{-30} = \frac{1}{20} \Rightarrow v = 60$ cm

Coincidence is possible when the image is formed at the centre of curvature of the mirror. Only then the rays refracting through the lens will fall normally on the convex mirror and retrace their path to form the image at O. So the distance between lens and mirror = 60 – 10 = 50 cm.

84. (a) Let a ray of light enter at A and refracted beam is AB. This is incident at an angle θ. For no refraction at the lateral face θ > C

$\sin\theta > \sin C$ But $\theta + r = (90°)$



$\therefore \sin(90° - r) > \sin C$ or $\cos r > \sin C$ ..(1)

From Snell's law $n = \frac{\sin i}{\sin r} \Rightarrow \sin r = \frac{\sin i}{n}$

$\therefore \cos r = \sqrt{1 - \sin^2 r} = \sqrt{\left(1 - \frac{\sin^2 i}{n^2}\right)}$

$\therefore$ equation (1) gives, $\sqrt{1 - \frac{\sin^2 i}{n^2}} > \sin C$

$\Rightarrow 1 - \frac{\sin^2 i}{n^2} > \sin^2 C$

Also $\sin C = \frac{1}{n}$

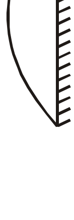
$\therefore 1 - \frac{\sin^2 i}{n^2} > \frac{1}{n^2}$ or $1 > \frac{\sin^2 i}{n^2} + \frac{1}{n^2}$

or $\frac{1}{n^2}(\sin^2 i + 1) < 1$ or $n^2 > \sin^2 i + 1$

Maximum value of sin i = 1

$\therefore$ $n^2 > 2 \Rightarrow n > \sqrt{2}$

85. (c) The silvered plano convex lens behaves as a concave mirror; whose focal length is given by



$\frac{1}{F} = \frac{2}{f_1} + \frac{1}{f_m}$

If plane surface is silvered

$f_m = \frac{R_2}{2} = \frac{\infty}{2} = \infty$

$\therefore \frac{1}{f_1} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$= (\mu - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right) = \frac{\mu - 1}{R}$

$\therefore \quad \frac{1}{F} = \frac{2(\mu-1)}{R} + \frac{1}{\infty} = \frac{2(\mu-1)}{R}$

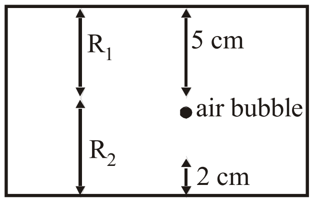
$F = \frac{R}{2(\mu-1)}$

Here $R = 20$ cm, $\mu = 1.5$

$\therefore \quad F = \frac{20}{2(1.5-1)} = 20\text{cm}$

86. (b) $1.5 = \frac{\text{Real depth } (R_1)}{\text{Apparent depth } (5\,\text{cm})}$

$\therefore R_1 = 1.5 \times 5 = 7.5$ cm



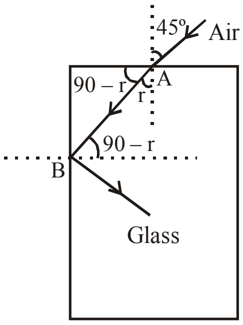
For opposite face, $1.5 = \frac{R_2}{2} \Rightarrow R_2 = 3.0$ cm

$\therefore$ Thickness of the slab $= R_1 + R_2 = 7.5 + 3$
$= 10.5$ cm

87. (a) For point A, ${}_a\mu_g = \frac{\sin 45}{\sin r} \Rightarrow \sin r = \frac{1}{\sqrt{2}\,{}_a\mu_g}$

for point B, $\sin(90 - r) = {}_g\mu_a$

$(90 - r)$ is critical angle.



$\therefore \cos r = {}_g\mu_a = \frac{1}{{}_a\mu_g}$

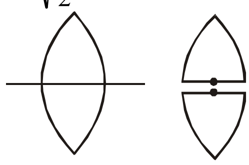
$\Rightarrow {}_a\mu_g = \frac{1}{\cos r}$

$= \frac{1}{\sqrt{1-\sin^2 r}} = \frac{1}{\sqrt{1-\frac{1}{2\,{}_a\mu_g{}^2}}}$

$\Rightarrow {}_a\mu_g{}^2 = \frac{1}{1-\frac{1}{2\,{}_a\mu_g^2}} = \frac{2\,{}_a\mu_g^2}{2\,{}_a\mu_g^2 - 1}$

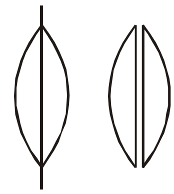
$\Rightarrow 2\,{}_a\mu_g^2 - 1 = 2 \Rightarrow {}_a\mu_g = \sqrt{\frac{3}{2}}$

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



in this case,
R_1 and R_2 are unchanged
So, f will remain unchanged for both pieces of the lens
$\therefore$ f = f'

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



This is combination of two lenses of equal focal length

$\therefore \left[\frac{1}{f} = \frac{1}{f'} + \frac{1}{f'} = \frac{2}{f'}\right] \Rightarrow f'' = 2f$

89. (b) $R_1 = 60$ cm, $R_2 = \infty$, $\mu = 1.6$

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

$\frac{1}{f} = (1.6 - 1)\left(\frac{1}{60}\right) \Rightarrow f = 100$ cm.

90. (b) The angle must be equal to the critical angle,

$C = \sin^{-1}\left(\frac{1}{\mu}\right) = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45^\circ$

91. (d) Here $\frac{x}{1000} = \frac{1.22\lambda}{D}$ or $x = \frac{1.22 \times 5 \times 10^3 \times 10^{-10} \times 10^3}{10 \times 10^{-2}}$

or $x = 1.22 \times 5 \times 10^{-3}$ m = 6.1 m
x is of the order of 5 mm.

92. (c) Angle of minimum deviation

$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} \Rightarrow \sqrt{3} = \frac{\sin\left(\frac{60^\circ+\delta_m}{2}\right)}{\sin\left(\frac{60^\circ}{2}\right)}$

$\Rightarrow \sin\left(30^\circ + \frac{\delta_m}{2}\right) = \frac{\sqrt{3}}{2} \Rightarrow 30^\circ + \frac{\delta_m}{2} = 60^\circ$

$\Rightarrow \delta_m = 60^\circ$.

93. (c) For total internal reflection,

$\mu \geq \frac{1}{\sin C} \geq \sqrt{2} \geq 1.414$

$\Rightarrow \mu = 1.50$

94. (c) $R = 20$ cm, $h_0 = 2$, $u = -30$ cm

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

$= \left(\frac{3}{2} - 1\right)\left[\frac{1}{20} - \left(-\frac{1}{20}\right)\right]$

$\Rightarrow \frac{1}{f} = \left(\frac{3}{2} - 1\right) \times \frac{2}{20}$

$\therefore$ f = 20 cm

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{20} = \frac{1}{v} + \frac{1}{30}$

$\frac{1}{v} = \frac{1}{20} - \frac{1}{30} = \frac{10}{600}$

v = 60 cm

$$m = \frac{h_i}{h_0} = \frac{v}{u} \Rightarrow h_i = \frac{v}{u} \times h_0 = \frac{60}{30} \times 2 = -4 \text{ cm}$$

So, image is inverted.

95. (b) Deviation = zero

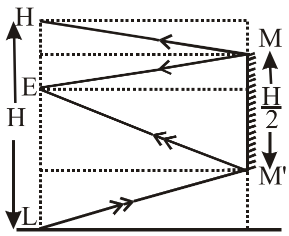
So, $\delta = \delta_1 + \delta_2 = 0 \Rightarrow (\mu_1 - 1)A_1 + (\mu_2 - 1)A_2 = 0$

$\Rightarrow A_2(1.75 - 1) = -(1.5 - 1)\,15°$

$\Rightarrow A_2 = -\frac{0.5}{0.75} \times 15°$ or $A_2 = -10°$.

Negative sign shows that the second prism is inverted with respect to the first.

96. (a) To see his full image in a plane mirror a person requires a mirror of at least half of his height.



97. (b) 98. (b) 99. (d) 100. (b)

EXERCISE - 3

Exemplar Questions

1. (a) As we know that the deviation

$$\delta = (\mu - 1)A \quad \text{..... (i)}$$

By geometry, the angle of refraction by first surface is 5° and given $\mu = 1.5$

So, $\delta = (1.5 - 1) \times 5°$

$= 2.5°$

also, $\delta = \theta - r$, ... (ii)

By putting the value of δ and r in equation (ii)

$2.5° = \theta - 5°$

So, $\theta = 5 + 2.5 = 7.5°$

2. (d) As we know that when light ray goes from one medium to other medium, the frequency of light remains unchanged.

And, $c = \nu\lambda$

So, $c \propto \lambda$ the light of red colour is of highest wavelength and therefore of highest speed. Thus, after travelling through the slab, the red colour emerge first,

3. (c) According to the question, when object is at different position, and if an object approaches towards a convergent lens from the left of the lens with a uniform speed of 5 m/s, the image move away from the lens to infinity with a non-uniform acceleration.

4. (b) When a passenger in an aeroplane then he may see primary and secondary rainbow such as concentric circles.

5. (c) Among all given sources of light, the bule light have smallest wavelength.According to Cauchy relationship, smaller the wavelength higher the refractive index and consequently smaller the critical angle as $\mu = \frac{1}{\sin c}$.

Hence, corresponding to blue colour, the critical angle is least which facilitates total internal reflection for the beam of blue light and the beam of green light would also undergo total internal reflection.

6. (c) Using lens maker's formula for plano-convex lens, so focal length is

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

If object on curved suface

so, $R_2 = \infty$

then, $f = \frac{R_1}{(\mu_2 - \mu_1)}$

Lens placed in air, $\mu_1 = 1$.

(As given that, R = 20cm, $\mu_2 = 1.5$, on substituting the values in)

$$f = \frac{R_1}{\mu - 1}$$

$$= \frac{20}{1.5 - 1}$$

$= 40$ cm

So, f is converging nature, as f > 0. Hence, lens will always act as a convex lens irrespective of the side on which the object lies.

7. (b) The reflection of radiowaves by ionosphere is similar to total internal reflection of light in air during a mirage because angle of incidence is greater than critical angle so that internal reflection of radio wave, take place.

8. (b) The incident PQ ray of light passes through focus F on the concave mirror, after reflection should become parallel to the principal axis, i.e., ray-2.

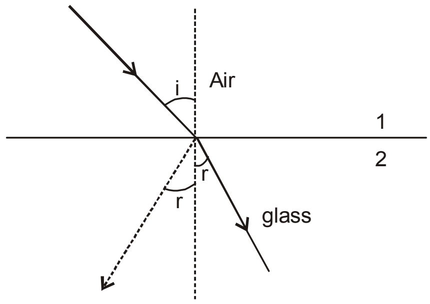
9. (b) As we know, when the ray goes from rarer medium air to optically denser turpentine, then it bends towards the normal i.e., i > r whereas when it goes from optically denser medium turpentine to rarer medium water, then it bends away from normal i.e., i < r.

So, the path of ray 2 is correct.

10. (d) As we know that, the image formed by convex mirror does not depend on the relative position of object w.r.t. mirror.

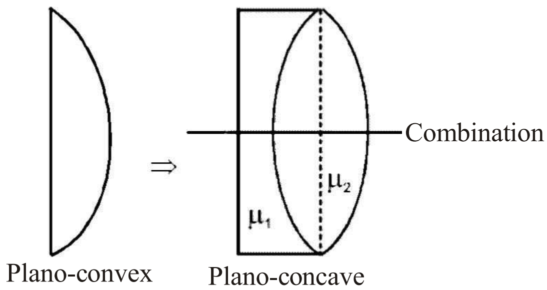
So, when the car approaches in the rear side, initially it appear at rest as images is formed at focus. Hence the speed of the image of the car would appear to increase as the distance between the cars decreases.

11. (a) When the negative refractive index materials are those in which incident ray from air (Medium 1) to them refract or bend differently to that of positive refractive index medium.



NEET/AIPMT (2013-2017) Questions

12. (b)



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

$$= (\mu_1 - 1)\left(\frac{1}{\infty} - \frac{1}{-R}\right) + (\mu_2 - 1)\left(\frac{1}{\infty} - \frac{1}{R}\right)$$

$$= \frac{(\mu_1 - 1)}{R} - \frac{(\mu_2 - 1)}{R} \Rightarrow \frac{1}{f} = \frac{\mu_1 - \mu_2}{R}$$

$$\Rightarrow f = \frac{R}{\mu_1 - \mu_2}$$

Hence, focal length of the combination is $\frac{R}{\mu_1 - \mu_2}$.

13. (b) $P_{cornea} = +40$ D
$P_e = +20$ D
Total power of combination = 40 + 20 = 60 D

Focal length of combination $= \frac{1}{60} \times 100$ cm

$= \frac{5}{3}$ cm

For minimum converging state of eye lens,

$u = -\infty \quad v = ? \quad f = \frac{5}{3}$

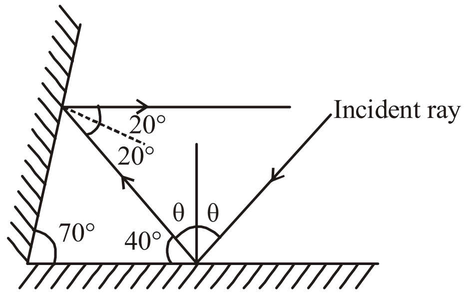
From lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow v = \frac{5}{3} \text{ cm}$$

Distance between retina and cornea-eye lens

$= \frac{5}{3} = 1.67$ m

14. (a)



From fig. $40° + \theta = 90° \therefore \theta = 90° - 40° = 50°$

15. (b) It is due to scattering of light. Scattering $\propto \frac{1}{\lambda^4}$. Hence the light reaches us is rich in red.

16. (d) Magnifying power of microscope

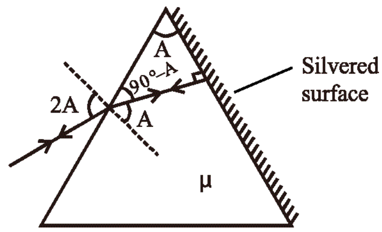
$$= \frac{LD}{f_0 f_e} \propto \frac{1}{f_0}$$

Hence with increase f_0 magnifyig power of microscope decreases.

Magnifying power of telescope $= \frac{f_0}{f_e} \propto f_0$

Hence with increase f_0 magnifying power of telescope increases.

17. (b)



According to Snell's law $\mu = \frac{\sin i}{\sin r}$

$\Rightarrow$ (1) sin 2A = (μ) sin A $\Rightarrow$ $\mu = 2\cos A$

18. (a) As we know, the refractive index of the material of the prism

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

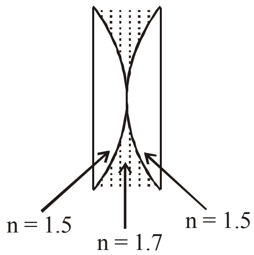
$$\cot A/2 = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin A/2} = \frac{\cos (A/2)}{\sin (A/2)}$$

[$\because \mu = \cot (A/2)$]

$$\Rightarrow \text{Sin}\left(\frac{\delta_m + A}{2}\right) = \sin(90° + A/2)$$

$$\Rightarrow \delta_{min} = 180° - 2A$$

19. (b) Using lens maker's formula,



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

$$\frac{1}{f_1} = \left(\frac{1.5}{1} - 1\right)\left(\frac{1}{\infty} - \frac{1}{-20}\right)$$

$$\Rightarrow f_1 = 40\text{cm}$$

$$\frac{1}{f_2} = \left(\frac{1.7}{1} - 1\right)\left(\frac{1}{-20} - \frac{1}{+20}\right)$$

$$\Rightarrow f_2 = -\frac{100}{7}\text{ cm}$$

and $\frac{1}{f_3} = \left(\frac{1.5}{1} - 1\right)\left(\frac{1}{\infty} - \frac{1}{-20}\right)$

$$\Rightarrow f_3 = 40\text{ cm}$$

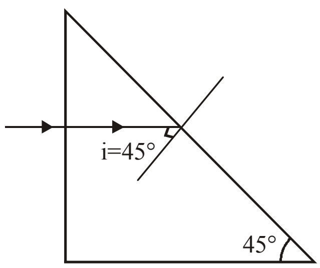
$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$

$$\Rightarrow \frac{1}{f_{eq}} = \frac{1}{40} + \frac{1}{-100/7} + \frac{1}{40}$$

$\therefore \quad f_{eq} = -50$ cm

Therefore, the focal length of the combination is – 50 cm.

20. (c) For total internal reflection, incident angle (i) > critical angle (i_c)

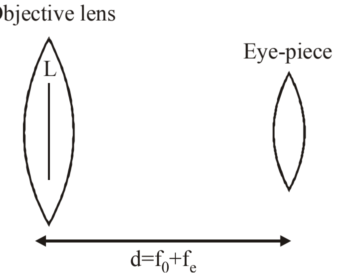


So, $\sin i > \sin i_c$

$$\sin 45° > \frac{1}{\mu} \quad \Rightarrow \mu > \sqrt{2} \Rightarrow 1.414$$

Since refractive index μ of green and voilet are greater than 1.414 so they will total internal reflected. But red colour will be refracted.

21. (c) Objective lens



Magnification by eye piece

$$m = \frac{f}{f+u}$$

$$-\frac{I}{L} = \frac{f_e}{f_e + [-(f_0 + f_e)]} = -\frac{f_e}{f_0} \quad \text{or,} \quad \frac{I}{L} = \frac{f_e}{f_0}$$

Magnification, $M = \frac{f_0}{f_e} = \frac{L}{I}$

22. (b) Given: Angle of incidence
angle of prism,
$i = 45°$;
$A = 60°$;
Angle of minimum deviation,
$\delta_m = 2i - A = 30°$
Refractive index of material of prism.

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

$$= \frac{\sin 45°}{\sin 30°} = \frac{1}{\sqrt{2}} \cdot \frac{2}{1} = \sqrt{2}$$

23. (d) **Given:** Focal length of objective, $f_0 = 40$cm
Focal length of eye – piece $f_e = 4$ cm
image distance, $v_0 = 200$ cm
Using lens formula for objective lens

$$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0} \quad \Rightarrow \quad \frac{1}{v_0} = \frac{1}{f_0} + \frac{1}{u_0}$$

$$\Rightarrow \frac{1}{v_0} = \frac{1}{40} + \frac{1}{-200} = \frac{+5-1}{200}$$

$\Rightarrow v_0 = 50$ cm

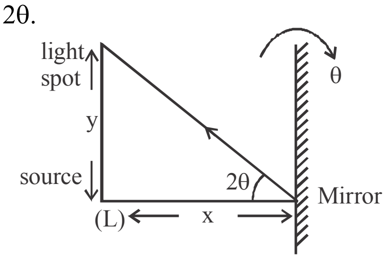
Tube length $\ell = |v_0| + f_e = 50 + 4 = 54$ cm.

24. (a) Magnitude m = +ve ⇒ virtual image
m = –ve ⇒ real image
magnitude of magnification,
$|m| > 1$ ⇒ magnified image
$|m| < 1$ ⇒ diminished image

25. (d) When mirror is rotated by angle θ reflected ray will be rotated by 2θ.

$$\frac{y}{x} = 2\theta$$

$$\Rightarrow \theta = \frac{y}{2x}$$



26. (a) For dispersion without deviation

$$(\mu - 1)A_1 + (\mu' - 1)A_2 = 0$$

$$|(\mu - 1)A_1| = |(\mu' - 1)A_2|$$

$(1.42–1) \times 10° = (1.7–1)A_2$
$4.2 = 0.7A_2$
$A_2 = 6°$