LIGHT

INTRODUCTION

It is an invisible energy which causes sensation of vision in us.

Optics can be classified into two branches:
(i) Ray Optics or Geometrical Optics
(ii) Wave Optics or Physical Optics

Ray or geometrical optics: It concerns itself with the particle nature of light and is based on (i) the rectilinear propagation of light and (ii) the laws of reflection and refraction of light. It explains the formation of images in mirrors and lenses, the aberration of optical images and the working and designing of optical instruments.

Wave or physical optics : It concerns itself with the wave nature of light and is based on the phenomena like: (i) interference (ii) diffraction and (iii) polarization of light.

KEY CONCEPTS

Light is form of energy which, when falls on the objects, makes the objects visible. Light consists of electromagnetic waves, which do not require any material medium to travel. It travels with very high speed in vacuum i.e. about 3×10^8 m/sec.

NATURE OF LIGHT

Various theories about nature of light have been proposed from time to time. Some of the main theories are as follows :

Corpuscular theory of light : Newton, the great among the greatest, proposed in 1675 A.D. According to this theory : Light is of particle nature.

A source of light sends tiny, elastic massless, particles called corpuscles.

These corpuscles travel in all directions in straight lines with same speed.

The speed of corpuscles (light) is more in denser medium than in rarer medium.

Different colours of light are due to difference in the size of corpuscles.

Vision is the result of stimulation of retina by corpuscles.

As corpuscles come out from the source, the mass of source decreases.

DRAW BACKS

The corpuscular theory explained reflection and refraction (some extent), but it could not explain the other phenomena of light.

Decrease in mass of source of light, when it emits corpuscles is not observed.

Focault's Rotating Mirror experiments provide that light travels with high speed in optically rarer medium and with low speed in optically denser medium and contradicts with Newton's assumption.

Wave theory of light :

In 1678, Dutch scientist Christian Huygens, suggested that light travels in the form of waves just as sound propagates through air. He proposed that light waves propagate through an all hypothetical medium, called ether medium. Later on, the existence of such a medium was discarded due to its contradictory properties.

Light propagates in the form of Transverse (Mechanical) Progressive Waves.

For the propagation of these light waves it is assumed that a hypothetical elastic, less dense, invisible medium called Ether medium is required.

Different colours of light are due to difference in the wave length of waves.

Velocity of light is more in optically rarer medium and is less in optically denser medium.

DRAW BACKS

It explained most of the phenomena of light like Reflection, Refraction, Interference and Diffraction, but it could not explain Polarisation, Photo-electric effect etc.

The assumption of existence of Ether medium is proved wrong by Michelson Moreley experiments.

Electromagnetic nature of light waves

In 1873, Maxwell suggested that light propagates as electric and magnetic field oscillators. These are called electromagnetic waves which requires no medium for their propagation. Also, these waves are transverse in nature.

Light is a form of energy which is propagated as electromagnetic waves with a speed 3×10^8 ms^{-1} through vacuum.

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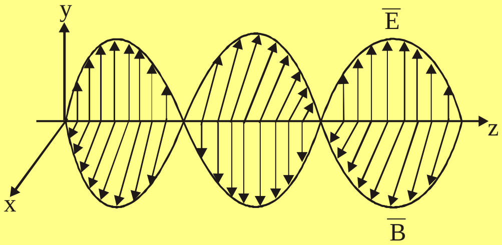
An electromagnetic wave consisting of oscillating electric $\overline{E}$ and magnetic $\overline{B}$ fields which are perpendicular to each other and perpendicular to wave propagation. It is non-mechanical wave, so that it does not require any material medium for its propagation.



Among many electromagnetic radiations, range of radiations called visible region, is named as light (visible)

Electromagnetic radiations are characterised by physical quantities like wavelength and frequency. The systematic or ordered distribution of wavelength is called as spectrum.

The spectrum of visible region is as shown

UV rays	VIOLET	BLUE	GREEN	YELLOW	ORANGE	RED	Infrared rays

4000 Å 4500 Å 5000 Å 5500 Å 6000 Å 6500 Å 7000 Å

Electromagnetic waves exhibit all the phenomena of light. They carry momentum and energy along with them.

DRAW BACKS

It could not explain Photo-electric effect, Compton effect, Raman effect etc.

Planck's Quantum theory of light :

According to max Planck, light travels in the form of small packets of energy. So in we see that in phenomena like interference, diffraction and polarization, light behaves as a wave. While in photoelectric, it behaves as a particle. Later on, **De Broglie** suggested that light has a dual nature. i.e., it can behave as particles as well as waves.

According to this theory, light is discrete in nature, it is not continuous.

Every electromagnetic wave is associated with a discrete energy packet called Quanta or Photon.

Photon is massless energy packet of energy

$E = n\,h\,\upsilon$

where $n = 1, 2, 3$ ....

Where h = planck's constant

($h = 6.63 \times 10^{-34}$ J)

υ = frequency

Photon has no charge, it travels with a speed

$c = 3 \times 10^{8}\ ms^{-1}$

DRAW BACKS

It explained only the phenomena like Photo-electric effect, Raman effect, Compton effect etc. but not the phenomena connected with Wave nature of light.

From the observed facts, experiments and various theories of nature of light, it is concluded that light has dual nature, when it is propagating it takes electromagnetic wave nature while interacting with matter it exhibits particle behaviour (photon)

SOURCES OF LIGHT

(i) Luminous Bodies :

The bodies which give out light energy by themselves are called luminous bodies.

Example

The sun, The stars, burning candle, glowing electric bulb etc.

(ii) Non-Luminous Bodies :

The bodies which do not give light energy on their own, but reflect light energy falling on them are called non-luminous bodies.

Example: Planets, Moon, Rocks, Mirror, etc.

Used in the study of Light :

Optical Medium :

Anything (material or non-material), through which light energy passes wholly or partially, is called optical medium.

Example: Vacuum, air, most of the gases, water, glass, plastics, etc.

- **Homogeneous medium :**

  An optical medium which has uniform composition throughout is called homogeneous medium.

  Example: Vacuum, distilled water, pure alcohol, glass, plastics, diamond etc.

- **Heterogeneous medium :**

  An optical medium, which has different composition at different points is called heterogeneous medium.

  Example: Air, muddy water, fog, mist etc.

- **Transparent medium :**

  A medium which allows most of the light energy to pass through it, is called transparent medium.

  Example: glass

- **Translucent medium :**

  A medium which partially allows the light energy to pass through it is called translucent medium. In such a medium, we cannot see through clearly.

  Example : Butter Paper, oiled paper, tissue paper, grounded glass

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- **Opaque bodies :**

  Those bodies which do not allow the light energy to pass through them are called opaque bodies. We cannot see through opaque bodies. These bodies can either absorb light energy or reflect it.

  Example: Bricks, wood, stones, metals etc.

- **Point source of light :**

  A source of light which is of the size of pin head is called point source of light.

- **Extended source of light :**

  Any source of light, which is bigger than point source of light is called extended source of light.

  Example :

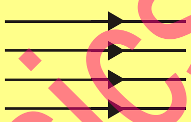
  A bulb, a tubelight, a burning candle, etc.

- **Ray of light :**

  The path along which light energy travels in a given direction is called ray of light. A ray of light is represented as a straight line. The arrowhead on it gives the direction of light.

- **Beam of light :**

  A collection of number of rays of light is called beam of light. Sometimes, if the number of rays are too small then such a collection of rays is called pencil of light.

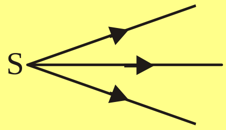


- **Parallel Rays :**

  When the rays of light travel parallel to each other, then the collection of such rays is called parallel rays. Eg. Sun rays entering into a room through a ventilator constitute a parallel beam of light.

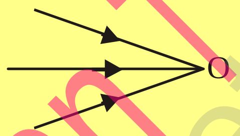
- **Divergent beam :**

  When the rays of light originating from a point, travel in various directions, then the collection of such rays is called divergent beam. Eg. rays originating from a point source of light constitute divergent beam.



- **Convergent beam :**

  When the rays of light coming from different directions, meet at a point, then the collection of such rays is called convergent beam.



GENERAL TERMS

1. **Mirror :**

   Any smooth polished surface which can turn rays of light into the same medium is called the mirror.

2. **Incident Ray :**

   A ray of light which travels from an optical medium towards the mirror is called the incident rays.

3. **Reflected Ray :**

   A ray of light which bounces off the mirror surface, into the same optical medium in which incident ray was travelling, is called the reflected ray.

4. **Normal :** A light perpendicular to the surface of mirror.

5. **Point of Incidence :**

   The point on the mirror surface, where incident ray strikes surface of mirror is called point of incidence.

6. **Angle of Incidence :**

   The angle which the incident ray makes with the normal is called the angle of incidence.

7. **Angle of Reflection :**

   The angle which the reflected ray makes with normal is called angle of reflection.

8. **Rectilinear Propagation of Light :**

   Light travels in straight line. It is called Rectilinear Propagation of Light. The formation of shadows (eclipses) is due to Rectilinear Propagation of Light.

PRINCIPLE OF REVERSIBILITY

If a light ray is reversed, it always retraces its path. It is called the Principle of Reversibility. So that the object and image positions are interchangeable. So they are conjugate points.

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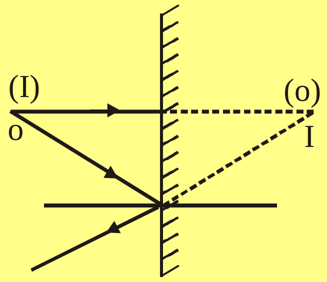


REFLECTION OF LIGHT

The phenomenon due to which a ray of light travelling from one optical medium to another optical medium, a part of the incident light is thrown back into the original medium. This phenomenon is called reflection of light.

Or

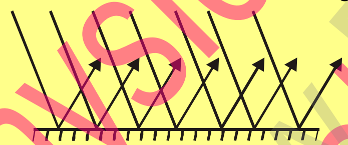
Reflection of light is the phenomenon of bouncing back of light in the same medium on striking the surface of any object.

- **Reflection is of two types :**

1. Regular Reflection
2. Irregular Reflection or diffused reflection

Regular Reflection :

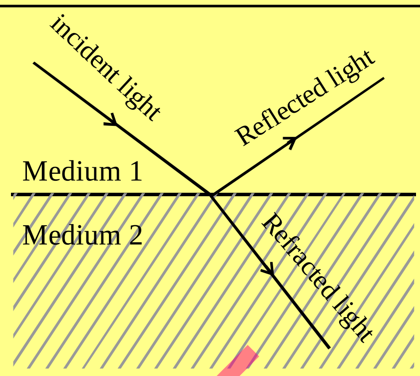
When the reflecting surface is smooth and well polished, the parallel rays falling on it are reflected parallel to one another, as shown in figure, i.e., the reflected light goes in one particular direction. This is regular reflection. The smooth and well polished surface is called a mirror, Silver metal is one of the best reflectors of light.



Irregular reflection : When the reflecting surface is rough, the parallel rays falling on it are reflected in different directions, as shown in figure. Such a reflection is known as diffused reflection or irregular reflection.

BEHAVIOR OF LIGHT AT THE INTERFACE OF TWO MEDIA :

When light travelling in one medium falls on the surface of a second medium, the following three effects may occurs.

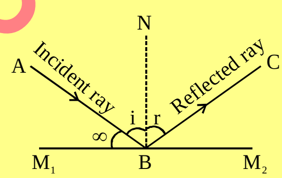


passage of light through two media

- A part of the incident light is turned back into the first medium. This is called reflection of light.
- A part of the incident light is transmitted into the second medium along a changed direction. This is called refraction of light.
- The remaining third part of light energy is absorbed by the second medium. This is called absorption of light.

LAW OF REFLECTION

Consider a reflecting surface (say a plane mirror) M_1M_2. Let a ray of light AB falls on the surface at B which comes back along BC. The ray of light AB is known as incident ray and the ray BC is known as reflected ray.



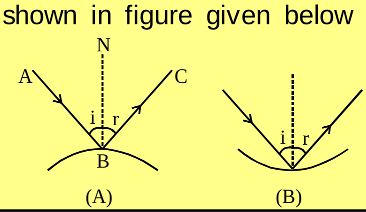
ACCORDING TO LAW OF REFLECTION

Angle of incidence is equal to angle of reflection i.e. $\angle i = \angle r$.

- The incidence ray, reflected ray and normal to the reflecting surface at the point of incidence are coplanar.

Note :-

- Non luminous bodies are visible only when the light reflected from them reaches our eye.
- Laws of reflection are same whether the reflecting surface is plane or curved. Reflection of light from the curved surfaces is shown in figure given below :



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TYPES OF MIRRORS

(a) Plane Mirror

(b) Spherical mirror:

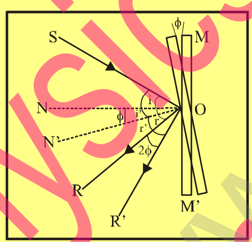
Spherical mirror are of two types :

(i) Concave mirror 

(ii) convex mirror 

Characteristics of the Image formed by a plane Mirror

- The image formed by a plane mirror is virtual.
- The image formed by a plane mirror is erect.
- The image formed by a plane mirror is of the same size as that of an object.
- The image formed by a plane mirror is at the same distance behind the mirror as the object is in front of it.
- The image is laterally inverted i.e. the right side of the object appears as the left side of the image and vice versa.
- For a given incident ray, if the mirror is rotated through an angle θ, then the reflected ray turns through an angle of 2θ.



The new angle of incidence $i' = i + \phi$

The new angle of reflection $r' = r + \phi$

$\angle ROR' = \angle SOR' - \angle SOR$

$\therefore\ i' = r'$

$= (i' + r') - (i + r) \qquad i = r$

$= 2i' - 2i$

$= 2(i + \phi) - 2i$

$= 2\phi$

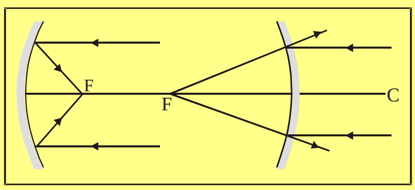
- The length of the plane mirror to have the full length image of a person standing in front of it, is equal to half the height of the person.
- When two plane mirrors are placed at an angle θ to each other, the object is kept between them, then the number of images observed is $n = \dfrac{360}{\theta}$.

  If n is even then it is (n – 1).

  'n' should be always odd number.
- When two plane mirrors are held facing each other and parallel to each other ($\theta = 0°$) and the object is kept between them, then the number of images observed is infinite.

General Terms used in Spherical Mirrors

- **Pole :** Geometric centre of the spherical mirror is called pole. It is denoted by the letter P.
- **Centre of curvature**. The centre of the imaginary sphere to which the mirror belongs is called the centre of curvature. The centre of curvature of a concave mirror is in front of it but the centre of curvature of a convex mirror is behind it.
- **Radius of curvature**. It is radius of the imaginary sphere of which the mirror is a part.
- **Principal axis**. The straight line passing through the pole and centre of curvature is called the principal axis.
- **Principal Focus :** The principal focus of a spherical mirror is a point on the principal axis of the mirror, where all the rays travelling parallel to the principal axis and close to it after reflection from the mirror converge to for concave mirror or diverge from for convex mirror. Thus, a concave mirror has a real focus but a convex mirror has a virtual focus because the rays appear to come from focus because the rays appear to come from focus.
- **Focus :** When a bundle of rays parallel to the principal axis are incident on a spherical mirror, they converge to a point or appear to diverge from a point on the principal axis called the focus. It is represented by figure.



- **Focal length.** It is the distance of the principal focus from the pole of the mirror

  If r is radius of curvature of the mirror of focal length, f, then r = 2f

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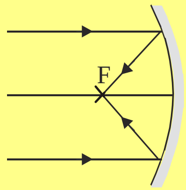
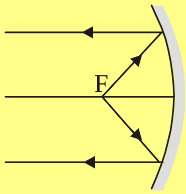
RULES FOR FORMATION OF THE IMAGES

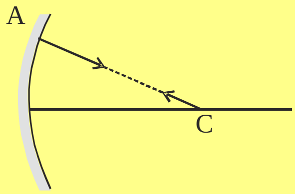
- The ray moving parallel to principal axis will pass through F after reflection.



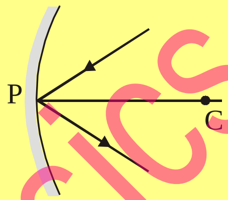
- The ray passing through F will become parallel to principal axis after reflection.



- A ray passing through C center of curvature will retrace its path as it is incidental normally.



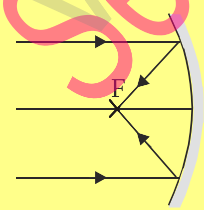
- A ray falling at pole making some angle with the principle axis will make the same angle with the principal axis after reflection.



NATURE, POSITION AND SIZE OF IMAGE FORMED BY A CONCAVE MIRROR

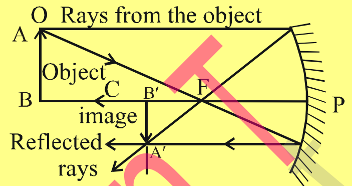
Let us start with the object at infinity and gradually bring it nearer to the mirror. The following cases arise :

- **When the object lies at infinity :** We have real, inverted & diminished image formed at focus.



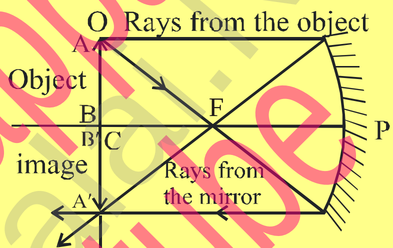
Use : E.N.T. specialist use a concave mirror as a 'head mirror' to concentrate light on the body parts like eye, ear, nose, throat etc. to be examined. The image is real, inverted, very much diminished and on the focus.

- **When the object lies beyond the centre** of curvature : Let AB be an object, placed beyond C, the centre of curvature of the mirror. A' B' is the image of AB formed by the mirror and as is clear from the figure, it is between the focus and the centre curvature, and it is real, inverted and diminished.



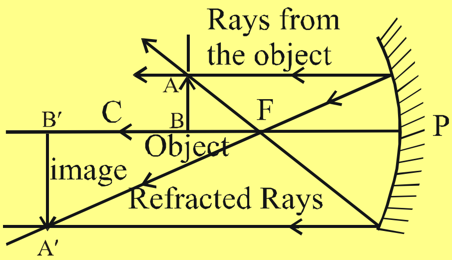
Use : Reflecting telescope

- **When the object lies at the centre of curvature :**



Let the object AB, lie at C, the centre of curvature of the mirror. We get the image of A'B', of the object AB. Which also lie at the centre of curvature. Image is real, inverted and of hte same size as the object.

- **When the object lies in between the centre of curvature and the focus :** Let the object A'B' be now placed between C and F in Figure. We have its real inverted and magnified image A'B', formed beyond C, the centre of the curvature of the mirror.



Use : Floodlight have the light source between the center and the focus of a concave mirror in order to spread the rays.

- **When the object lies at the focus :** Here, we consider a point object (O) at the focus F, rays from it, incident on the mirror are rendered parallel to the principal axis. And thus the image is formed at infinity, and is real, inverted and highly magnified.

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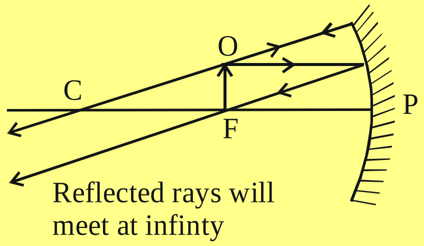
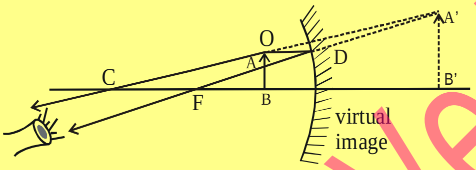


Use : Search light, car head lights, and flush lights have the light source near the focus of a concave mirror to use this property.

- **When the object lies in between the focus and the pole of the mirror :** Let an object AB be placed on the axis of the mirror, between F and P (pole of the mirror). Then proceeding exactly as in case (v) above, we find that the two reflected rays DF and OC appear to meet at A', when produced backwards, and thus we get a virtual magnified and erect image A' B' of the object AB, behind the mirror.

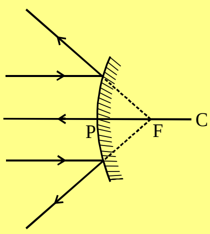


Use : Shaving mirrors, dental mirrors, make up mirrors for ladies use this arrangement to get virtual, magnified image.

- **When the object lies very near to the pole of mirror :** If we have a small or a point object placed right on the pole of the concave mirror, then since a small portion of it would just behave like a plane mirror, we shall have an image of the object, in accordance with the ordinary laws of reflection at plane surfaces. Image will also lie at the pole of the mirror and will be virtual, erect and of the same size, but laterally inverted.

NATURE, POSITION AND SIZE OF IMAGE FORMED BY A CONVEX MIRROR

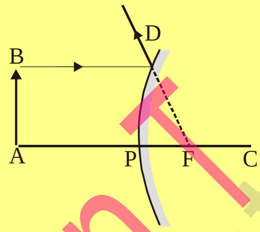
In the case of a convex mirror only two positions of the object, are possible (i) at infinity and (ii) between infinity and the pole of the mirror.



In either case, the image lies behind the mirror and is virtual erect and extremely diminished.

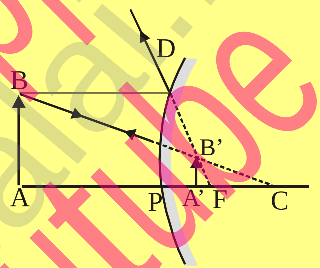
Case-1

When object is at infinity : Image position will be at focus F. Nature of image is virtual and point sized.



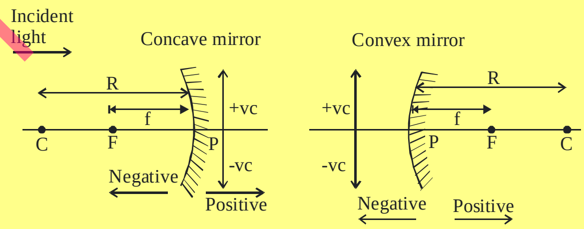
Case-2

When object is between infinity and the pole : Image position will be between the focus and the pole. Nature of image is virtual, smaller and erect.



NEW SIGN CONVENTION

Number of sign conventions are in use. New Cartesian sign conventions used herein, are explained as under :



- All the distances are measured from the pole of the spherical mirror.
- Distances measured in the direction of incident light are taken as positive where as the distances measured in the direction opposite to that of the incident light are taken as negative.
- The upward distances perpendicular to the principal axis are taken as positive, while the downward distances perpendicular to the principal axis are taken as negative. Clearly, focal length f and radius of curvature are negative for a concave mirror and positive for a convex mirror.

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MIRROR FORMULA

$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ Where u is the object distance, v is the image distance & f the focal length of the mirror.

Caution : Always use the formulae with proper sign convention.

LINEAR MAGNFICATION

- It is defined as the ratio of the size or height of the image to the size of the object, it is denoted by m,
- if h_i = size of the image [or height of the image] and h_o = size of the object [or height of the object] $m = \frac{h_i}{h_o} = -\frac{v}{u}$
- If, m > 1, i.e., linear magnification is greater than one, then image is magnified or enlarged, size of image is greater than the size of the object.

  If m = 1, i.e., linear magnification is equal to one, then image is of the same size as that of the object. $h_o = h_i$

  If m < 1, i.e., linear magnification is less than one, then image is smaller than the object.

APPLICATIONS OF SPHERICAL MIRRORS

CONCAVE MIRROR :

- Concave mirrors have a variety of applications in science as well as in our daily life, they are as follows :
- Concave paraboloid mirrors are used in search light, motor head light, torch etc.
- Concave paraboloid mirrors are used as dish antennas to receive and send radio signals.
- Concave mirrors are preferred over plane mirror for shaving and make up. When a man keeps his face between the pole and the focus of the concave mirror, virtual, erect and highly magnified image of his face is formed. It helps him to have a better shave, similarly, a lady can see her face better with the help of a concave mirror while doing make up.
- Concave mirrors are used as reflectors in cinema projectors.
- Concave mirrors are used by dentists and ENT specialists to focus light on teeth, an eye or in the ear or a nose to examine these organs.
- It is preferred in solar cookers to focus the sun light.

CONVEX MIRROR

- Convex mirror is used as a rear view mirror because it produces erect and diminished images, since the image is small in size, so the field view is increased, this mirror is also known as driver's mirror.
- It is used as a reflector for street lighting purpose.

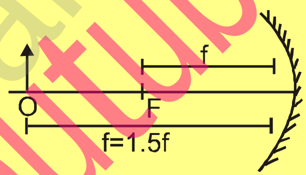
Illustration:

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



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

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

$$\text{now } m=-\frac{v}{u}=\frac{3f}{-1.5f}=-2$$

$$\text{or } \frac{h_2}{h_1} = -2 \text{ or } h_2 = -2h_1 = -5.0 \text{ cm}$$

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

Illustration:

If the magnification of a body of size 1 m is 2, what is the size of image?

Solution :

Given magnification, m = 2; Size of object, h_1 = 1 m

Size of image, h_2 = ? Using $m = \frac{h_2}{h_1}$

$$2 = \frac{h_2}{1}$$

$\Rightarrow$ h_2 = 2 m; so, size of image is 2 m.

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Illustration:

A concave and convex mirror of focal length 10 cm and 15 cm are placed at a distance 70 cm. An object AB of height 2 cm is placed at a distance 30 cm from concave mirror. First ray is incident on concave mirror then on convex mirror. Find size, position and nature of image.

Solution:

For concave mirror,

u = –30 cm, f = – 10 cm

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

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

$\Rightarrow$ v = – 15 cm

Now, $\frac{A'B'}{AB}=\frac{-v}{u}=\frac{-15}{-30}$

$\Rightarrow \quad A'B' = -1\ \text{cm}$

Image formed by first reflection will be real inverted and diminished

For convex mirror

u′ = – 55 cm, f′ = + 15 cm

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

$\Rightarrow \quad \frac{1}{v'}-\frac{1}{55}=\frac{1}{15}$

$\Rightarrow$ v′ = 165/14 cm

Now, $\frac{A''B''}{A'B'}=-\frac{v'}{u'}=-\frac{\left(\frac{165}{14}\right)}{(-55)}$

$\Rightarrow$ A″B″ = $\left(-\frac{3}{14}\right)(-1)=$ 0.02 cm

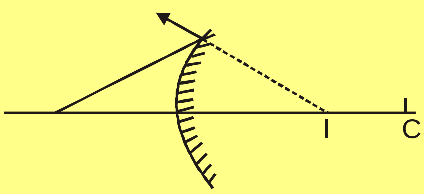
Final image will be virtual and diminished.

Illustration

A convex mirror has its radius of curvature 20 cm. Find the position of the image of object placed at a distance of 12 cm from the mirror.

Solution :

The situation is shown in figure.



Here u = –12 cm and R = +20 cm. We have

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

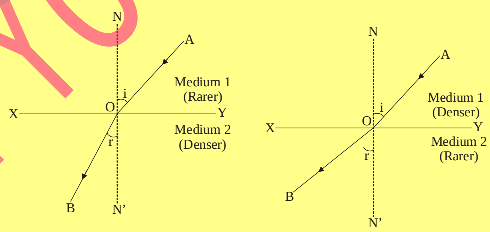
$\Rightarrow \frac{2}{20}-\frac{1}{12}\text{cm}=\frac{11}{60}\text{cm}$

$v=\frac{60}{11}\text{cm}$

REFRACTION

When a ray of light travels from one medium to another, it undergoes a change in its direction. When a ray of light goes from an optically rarer medium to a denser medium, it bends towards the normal. On the other hand, a ray of light going from an optically denser medium to a rarer medium, will bend away from the normal. The bending of a ray of light on passing from one medium to another is called refraction.

The rays of light while going from air (rarer) to glass (denser) will bend towards the normal. The rays of light going from denser to rarer, say from glass or water to air, will bend away from the normal.



LAWS OF REFRACTION.

There are two laws of refraction:

The ratio of the sine of the angle of incidence to the sine of the angle of refraction for a given pair of media is constant i.e.

$$\frac{\sin i}{\sin r}=\text{constant}$$

Where i and r stand for angle of incidence and angle of refraction respectively.

This constant is called the refractive index of the medium

$$\mu=\frac{\sin i}{\sin r}$$

This relation is called Snell's law.

The incident ray, the refracted ray and the normal at the point of incidence, all lie in the same plane.

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REFRACTIVE INDEX OF A MEDIUM

Refractive index of a medium is the ratio of velocity of light in air or vacuum to its velocity in a given medium. This is known as the absolute refractive index.

$$\therefore \quad \mu = \frac{\text{velocity in air or vacuum (c)}}{\text{velocity in give medium (v)}} \Rightarrow \mu = \frac{c}{v}$$

Where μ is absolute refractive index. If μ_1 and μ_2 are the refractive indices of two media and v_1 and v_2 are the velocity of light in the medium one and medium two respectively.

then

$$\mu_1 = \frac{c}{v_1} \quad \text{......... (1) and}$$

$$\mu_2 = \frac{c}{v_2} \quad \text{......... (2)}$$

Dividing (2) by (1), we get

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

$$\frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} = {}^1\mu_2$$

${}^1\mu_2$ is the relative refractive index of medium 2 with respect to medium 1.

$$\therefore \ {}^1\mu_2 \text{ or } {}^1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2}$$

Medium

Absolute	**refractive index**
Air	1.00
Water	1.33
Glass	1.5
Diamond	2.42

Illustration

If refractive index of medium 1 is 4/3 and that of medium 2 is 3/2, find refractive index of medium 2 with respect to medium 1.

Solution :

Given,

Refractive index of medium 1, $\mu_1 = 4/3$

Refractive index of medium 2, $\mu_2 = 3/2$

Refractive index of medium 2 w.r.t. 1 = ${}^1\mu_2$ = ?

$$\text{Using } {}^1\mu_2 = \frac{n_2}{n_1} \Rightarrow {}^1\mu_2 = \frac{3/2}{4/3} \Rightarrow {}^1\mu_2 = \frac{9}{8}$$

Illustration

The refractive index of water is 4/3 and for glass it is 3/2, with respect to air. What is the refractive index of water with respect to glass?

Solution :

Given,

Refractive index of glass, $\mu_g = 3/2$

Refractive index of water, $\mu_w = 4/3$

R.I. of water w.r.t. glass, ${}^g\mu_w$ = ?

$$\text{Using} \quad {}^g\mu_w = \frac{\mu_w}{\mu_g} = \frac{4/3}{3/2}$$

$${}^g\mu_w = \frac{8}{9}$$

COMPOUND SLAB

A compound slab is made of two or two more media (say water glass) bounded by parallel faces and is placed in air. A compound slab can be made by placing a glass tray completely filled with water on a glass slab.

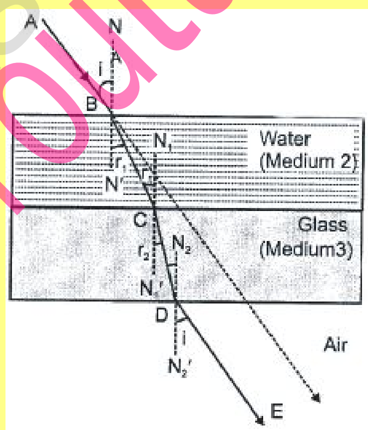

Figure: Lateral shifting of light in compound slab

When an incident ray AB travelling in air (medium 1) strikes the water surface (medium 2) at B, it is refracted along BC. In figure $\angle ABN = i_1$ (incident angle) and $\angle N'BC = r_1$(angle of refraction).

- Now the ray BC acts as an incident ray for the surface separating glass slab and water. So the incident ray BC after striking this surface at C is refracted along CD in glass (medium 3). $\angle BCN_1 = r_1$, which is equal to angle of refraction, now acts as angle of incidence.

$\angle DCN_1 = r_2$ =angle of refraction

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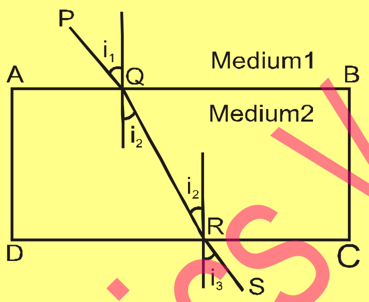
- The ray CD acts as an incident ray for the surface separating glass slab and air. So the incident ray CD after striking this surface at D is refracted along DE in air. The rays DE and AB are parallel, so $\angle N_2'DE = \angle ABN = i$. In this case, $\angle CDN_2 = r_2$, incident angle and $\angle N_2'DE = i$, angle of refraction.

***NOTE*: Incident ray AB and emergent ray DE will be parallel**

REFRACTION THROUGH GLASS SLAB

Consider a glass slab ABCD placed in air. A ray PQ incident from air to glass at an angle i_1 is refracted along QR at an angle i_2. The ray QR is incident along glass - air interface, hence it undergoes refraction along RS at an angle i_3 (RS is called as an emergent ray)

From Snell's law



$$\frac{\mu_2}{\mu_1} = \frac{\sin i_1}{\sin i_2} \qquad ....(1)$$

Where μ_2 is refractive index of glass and μ_1 is refractive index of air.

From equation (1)

$\mu_1 \sin i_1 = \mu_2 \sin i_2$ ......(2)

At glass air interface

$$\frac{\mu_1}{\mu_2} = \frac{\sin i_2}{\sin i_3}$$

$\mu_1 \sin i_3 = \mu_2 \sin i_2$ ......(3)

Comparing (2) and (3)

$\mu_1 \sin i_1 = \mu_1 \sin i_3$

Since $\mu_1 = 1$ (refractibe index of air)

$\sin i_1 = \sin i_3$

Thus the emergent ray is parallel to the incident ray.

CRITICAL ANGLE

When a light ray passing from denser medium to rarer medium, at a point on the boundary or surface (which is separating two mediums) for a certain angle of incidence, the refracted ray confines to the boundary by making an angle of refraction 90º. Such angle of incidence is called critical angle.

$\mu_1 \sin i = \mu_2 \sin 90^o$

$(\because r = 90^o, \mu_2 = 1)$

$\mu_1 \sin c = 1 \cdot 1$

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

TOTAL INTERNAL REFLECTION

The phenomenon of reflection when a ray of light travelling from a denser to rare medium is sent back to the same denser medium, provided when it strikes the interface of the denser and the rarer media at an angle greater than the critical angle, is called total internal reflection.

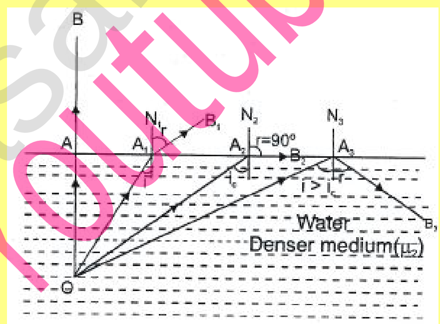


Figure : Ray diagram showing total internal reflection

When a ray of light falls on the interface separating denser and rarer medium, it is refracted as shown in figure. As the angle of incidence increases, the refracted ray bends towards the interface. At a particular angle of incidence, the, refracted light travels along the interface and the angle of refraction becomes 90°. The angle of incidence for which angle of refraction becomes 90° is called critical angle i_c.

When the angle of incidence becomes greater than the critical angle, there is no refracted light and all the light is reflected in the denser medium. This phenomenon is known as total internal reflection.

CONDITIONS FOR TOTAL INTERNAL REFLECTION

- The light should travel from denser to rarer medium.
- The angle of incidence must be greater than the critical angle for the given pair of media.

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IMPORTANT NOTE

During total internal reflection of light, the whole incident light energy is reflected back to the parent optically denser medium.

- Critical angle of a medium depends upon the wavelength of light.

CRITICAL ANGLE WAVELENGTH

Greater the wavelength greater will be the critical angle thus angle of a medium will be maximum for red colour and minimum for violet colour.

- Critical angle depends upon the nature of the pair of media, Greater the refractive index, lesser will be the critical angle.
- Image formed due to total internal reflection is much brighter because total light is reflected back into the same medium and there is no loss in intensity of light.

SOME PHENOMENA

WORKING OF PORRO PRISM

A right angled isosceles prism called Porro-Prism can be used in periscope or binocular.

The refractive index of glass is 1.5 and the critical angle is equal to 41.8°. When the ray of light falls on the face of a right angled prism at angle greater than 41.8°, it will suffer total internal reflection.

Right angle prisms used to bend the light through 90° and 180° are shown in figure (a) and (b) respectively. A right angled prism used to invert the image of an object without changing its size as shown in figure below :

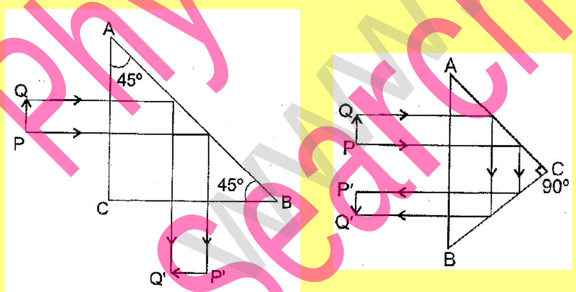

Figure : Working of porro prism additional information

Mirrors can also be used for bending the rays of light. But the intensity of the beam reflected by mirrors is low because even a highly polished mirror does not reflect whole light. On the other hand, in Porro-prism the whole light is reflected. Therefore, there is no loss in intensity of light and hence image is bright.

SPARKLING OR BRILLIANCE OF A DIAMOND

The refractive index of diamond is 2.5 which gives, the critical angle as 24°. The faces of the diamond are cut is such a way that whenever light falls on any of the faces, the angle of incidence is greater than the critical angle i.e. 24°. So when light falls on the diamond, it suffers repeated total internal reflections. The light which finally emerges out form few places in certain directions makes the diamond sparkling.

SHINING OF AIR BUBBLE IN WATER

The critical angle for water-air interface is 48°45'. When light propagating from water (denser medium) is incident on the surface of air bubble (rarer medium) at an angle greater than 48°45', the total internal reflection takes place. Hence the air bubble in water shines brilliantly.

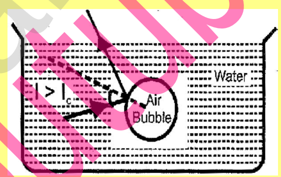

Figure: Shining of air bubble in water

MIRAGE

Mirage is an optical illusion of water observed generally in deserts when the inverted image of an object (e.g. a tree) is observed along with the object itself on a hot day.

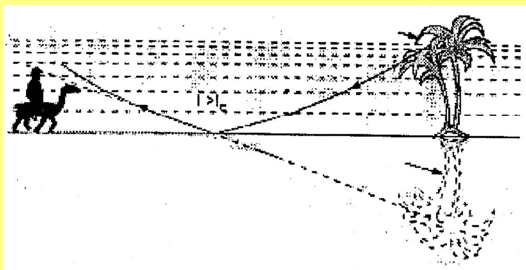

Fig. : A image formation in deserts

Due to the heating of the surface of earth on a hot day, the density and hence the refractive index of the layers of air close to the surface of earth becomes less. The temperature of the atmosphere decreases with height from the surface of earth, so the value of density and hence the refractive index of the layers of air at higher altitude is more. The rays of light from distant

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objects (say a tree) reaches the surface of earth with an angle of incidence greater than the critical angle. Hence the incident light suffers total internal reflection as shown in the figure. When an observer sees the object as well as the image he gets the impression of water pool near the object.

(a) The mirage formed in hot regions is called inferior mirage.

(b) Superior mirage is formed in cold regions. This type of mirage is called looming.

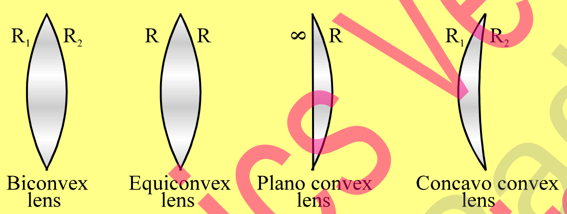
LENSES

Lens : A lens is a transparent medium bounded by two refracting surfaces such that at least one of the refracting surfaces is curved.

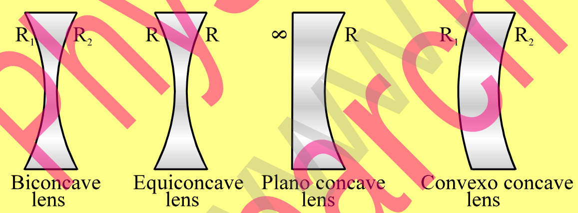
If the thickness of the lens is negligibly small in comparison to the object distance or the image distance, the lens is called thin. Here we shall limit ourself to thin lenses.

TYPES OF LENSES

Spherical lenses are of the following types :



Convex Lenses

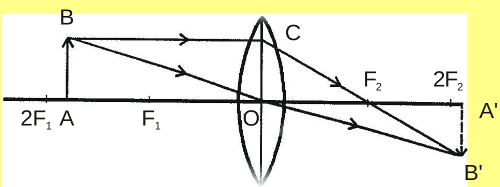


CONCAVE LENSES

- **Lens Formula :**

Relation between object distance u, image distance v and focal length f for lens is :

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



PROOF

Let object AB be kept on one side of lens (between F_1 and $2F_1$) then image A' B' is formed on other side of **lens** (beyond $2F_2$). Now obeying sign **conventions,** the object distance OA= –u, the image distance $OA' = +v$. and the focal length $OF_2 = f$.

Since $\Delta OA'B'$ and ΔOAB are similar

$$\therefore \frac{A'B'}{AB}=\frac{OA'}{OA} \quad \text{........(i)}$$

Again ΔCOF_2 and $\Delta B'A'F_2$ are similar

$$\therefore \frac{A'B'}{OC}=\frac{F_2A'}{OF_2}$$

But OC = AB. $\therefore \frac{A'B'}{AB}=\frac{F_2A'}{OF_2}$ ....(ii)

Hence from equation (i) and (ii)

$$\frac{OA'}{OA}=\frac{F_2A'}{OF_2}=\frac{OA'-OF_2}{OF_2}$$

$$\Rightarrow \frac{v}{-u}=\frac{v-f}{f} \Rightarrow vf=-uv+uf$$

on dividing each term by u v f, we get

$$\frac{uf}{uvf}=\frac{uv}{uvf}+\frac{uf}{uvf}$$

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

NOTE: Lens maker formula:

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

(where μ is absolute refractive index of lens material)

Illustration:

A 2.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the nature, position and size of the image. Also, find its magnification.

Solution :

Here, object size, h_1 = 2.0 cm

focal length of convex lens, f = 10 cm

object distance, u = –15 cm

Image distance, v = ?

Image size, h_2 = ?

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

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$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} - \frac{1}{15} = \frac{1}{30}$$

v = 30 cm.

As v is positive, the image formed is on the right side of the lens. It must be real and inverted. Now,

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

$$m = \frac{h_2}{2.0} = \frac{30}{-15}$$

$h_2 = -2$

and $m = -1$

Negative sign of m and h_2 show that the image is inverted.

Thus a real, inverted image enlarged 2 times (i.e. 4.0 cm tall) is formed at a distance of 30 cm on the right side of the lens.

POWER OF LENS

It may be defined as the reciprocal of its focal length in metres

Power of a lens,

$$P = \frac{1}{\text{focal length of the lens (f) in metres}}$$

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

The power of a lens is inversely proportional to its focal length, hence the lens of short focal length has more power and the lens of long focal length has less power.

- SI unit of power of lens is dioptre. It is denoted by D.
- **One dioptre.** It is the power of a lens whose focal length is 1 meter. A convex lens has a positive focal length, hence its power is also positive (+D)

  A concave lens has a negative focal length hence its power is also negative (–D).
- Magnification formula for the lens

$$m = \frac{h_i}{h_0} = \frac{v}{u}$$

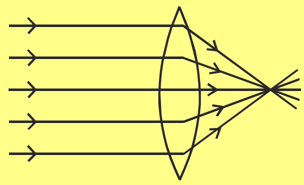
where h_i = height of image,

h_0 = height of the object

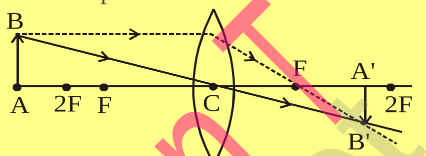
v = distance of image from the lens, and

u = distance of the object from the lens

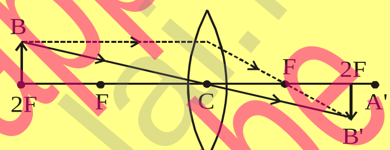
IMAGE FORMED BY CONVEX LENS



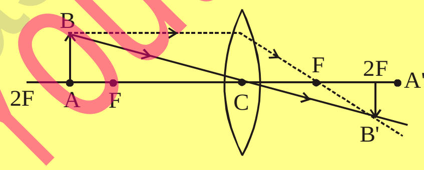
(a) If object is at infinity then image is at focus. The image is real inverted and point in size



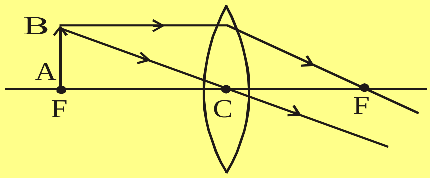
(b) If object lies beyond 2F, then the image is formed between F and 2F. The image is real inverted and smaller in size.



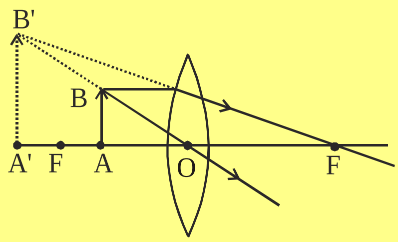
(c) If object is at 2F, the image is formed on other side at 2F. The image is real, inverted and of same size.



(d) If object is between F and 2F, the image is beyond 2F. The image is real inverted and bigger in size.



(e) If the object is at F, then image is formed at infinity. The image is real, inverted and highly magnified.



(f) If object lies between O and F, the image is on the same side as is the object. The image is virtual, erect and bigger in size.

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IMAGE FORMED BY CONCAVE LENS

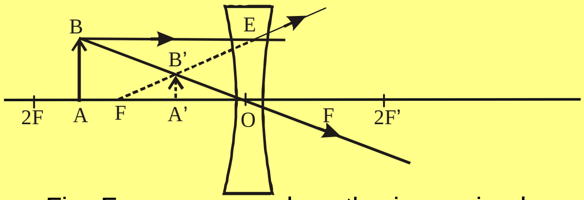


Fig. For a concave lens the image is always on the same side, Lies between O and F. The image is virtual, erect and smaller in size.

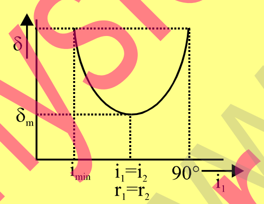
Position of object	Position of image	Nuture of image	Size of image	Ray Diagram
		Convex		
At infinity	At focus	Real inverted	Point Size	Figure. (a)
Beyond 2F	Between F and 2F	Real inverted	Smaller in size	Figure. (b)
At 2F	At 2F	Real inverted	Same size	Figure. (c)
Between 2F and 2F	Beyond 2F	Real inverted	Bigger in size	Figure. (d)
At 2F	At infinity	Real inverted	Bigger in size	Figure. (e)
Between Optical Centre O and F	On the same side as the objecte	Real inverted	Bigger in size	Figure. (f)
		Concave		
Anywhere	On the same side between optical centre O and F	Real inverted	Smaller in size	Figure. (g)

PRISM

REFRACTION THROUGH PRISM

A homogeneous transparent and refracting medium bounded by two plane surfaces inclined at an angle is called a prism. AB and AC are refracting surfaces. $\angle BAC = \angle A$ Is called refracting angle or the angle of prism. (Also called Apex angle).

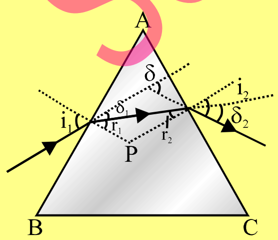
δ = angle of deviation. [$\delta = \delta_1 + \delta_2$]



For refraction of a monochromatic (single wave length) ray of light through a prism;

$\delta = (i_1 + i_2) - (r_1 + r_2)$ and $r_1 + r_2 = A$

Variation of δ versus i (shown in diagram)



There is one and only one angle of incidence for which the angle of deviation is minimum. When $\delta = \delta_m$, $i_1 = i_2$ and $r_1 = r_2$, the ray passes symmetrically about the prism, and then

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

μ = absolute R. I. of glass.

Note : When the prism is dipped in a medium then μ = R. I. of glass w.r.t. medium.

DISPERSION OF LIGHT

The angular splitting of a ray of white light into a number of components when it is refracted in a medium other than air is called **Dispersion of Light**.

- Angle of Dispersion : Angle between the rays of the extreme colours in the refracted (dispersed) light is called angle of dispersion. $\theta = \delta_v - \delta_r$. (figure a)

(ii) Successive Refraction, (figure b, c)

Figure (a) Figure (b) Figure (c)

- Dispersive power (ω) of the medium of the material of prism.

$$\omega = \frac{\text{Angular dispersion}}{\text{Deviation of mean ray(yellow)}}$$

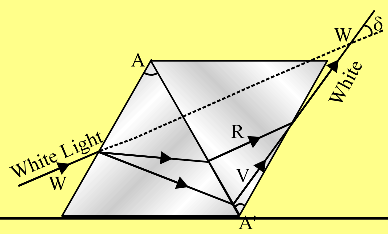
For small angled prism ($A \le 10°$)

$$\omega = \frac{\delta_v - \delta_R}{\delta_y} = \frac{\mu_V - \mu_R}{\mu - 1} \; ; \; \mu = \frac{\mu_V + \mu_R}{2}$$

μ_v, μ_R and μ are R. I. of material for violet, red and yellow colours respectively.

COMBINATION OF PRISMS

As the dispersive powers of the different materials are different, two or more prisms of different materials can be combined such that the rays of composite light on passing through the combination may suffer either dispersion without deviation or deviation without dispersion.



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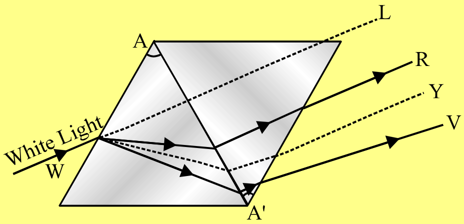
- Achromatic combination (or deviation without dispersion) :
  Condition for achromatic combination :
  $\theta_1 + \theta_2 = 0$
  $(\mu_v - \mu_r)A = -(\mu'_v - \mu'_r)A'$
  Net mean deviation =
  $$\left[\frac{\mu_v + \mu_R}{2} - 1\right]A - \left[\frac{\mu'_v + \mu'_R}{2} - 1\right]A'$$
  or $\omega\delta + \omega'\delta' = 0$
  where ω, ω' are dispersive powers for the two prisms and δ, δ' are the mean deviation.
- Dispersion without deviation (Direct vision combination)
  This combination is used for dispersion without deviation



Condition $\delta = 0$

i.e. $$\left[\frac{\mu_v + \mu_R}{2} - 1\right]A + \left[\frac{\mu'_v + \mu'_R}{2} - 1\right]A' = 0$$

Net angle of dispersion

$$\theta = (\mu_v - \mu_r)A + (\mu'_v - \mu'_r)A'$$

COLOURS

Colour of Objects in White and Coloured Light :

We known that white light is a mixture of several colours, Light can be of different colours. Let us understand that why different objects appear to have different colours. A rose appears red because when white light falls on rose, it reflects only the red component and absorbs the other components. We conclude that the colour of an object depends upon the colour of light it reflects.

NOTE:

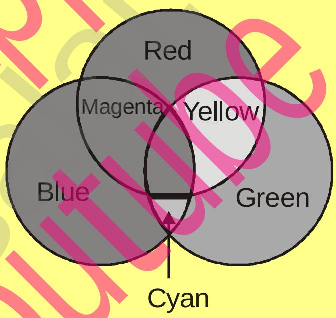
- If an object absorbs lights of all colours and reflects none it appears black.
- If an object reflects light of all colour, it appears white when seen in white light.
- When we talk of colour of an object we refer to its colour as seen in white light.
- A rose will appear black in green light because there is no red component in the light and it will not reflect any light. Hence no light will come from rose to the eye. Similarly if a green leaf seen in red light it appears black.
- If a white flower is seen in red light it appear red because a white object reflects light of all colours falling on it So it reflects the red light falling on it which then enters the eye.

PRIMARY COLOURS OF LIGHT

Red, green and blue are primary colours of light and they produce white light when added in equal proportions. All colours can be obtained by mixing these three colours in different proportions.

Secondary Colours or Composite Colours of Light:

The Colours of light produced by adding any of primary colours are called secondary colours. Cyan, magenta and yellow are secondary colours of light.

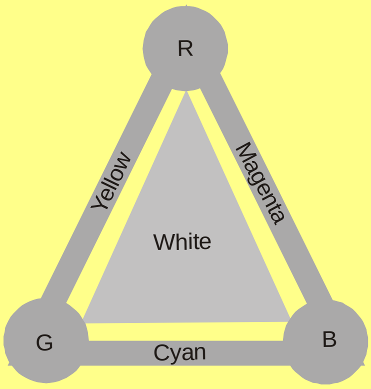


Red + Green = Yellow
Green + Blue = Cyan
Red + Blue = Magenta

The method of producing different colours of light adding the primary colours is called colour addition.

Complementary Colours of Light:

The light of two colours which when added in equal proportions produce white light are called complementary colours of light and the two colours are called complements of each other.



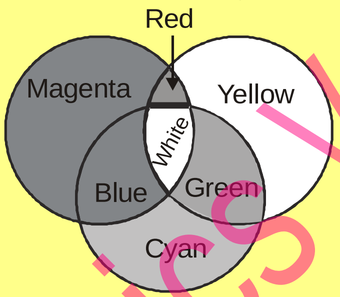
For example, yellow and blue light are complementary colours of light because when they are mixed in equal proportions, they produce white light. We can also find the pairs of complimetary colours of light as follows.

(Red + Green) + Blue = Yellow + Blue = White
Red + (Green + Blue) = Red + Cyan = White
(Red + Blue) + Green = Magenta + Green = White

The above result can be diagrammatically represented in the form of a tringle as shown in figure below. The outer limbs of the figure show the results of the addition of primary colours red, green and blue. The complementary colour pairs such as red and cyan are opposite to each other.

Primary Colours of Pigment:

Pigments are those substances that give colour to an object. The colour of a pigment as seen by us depends on what components of light it absorb or subtract from white before reflecting the rest to our eyes. A primary colour (cyan, magenta, yellow) of a pigment is due to a primary colour of light being subtracted from white light.

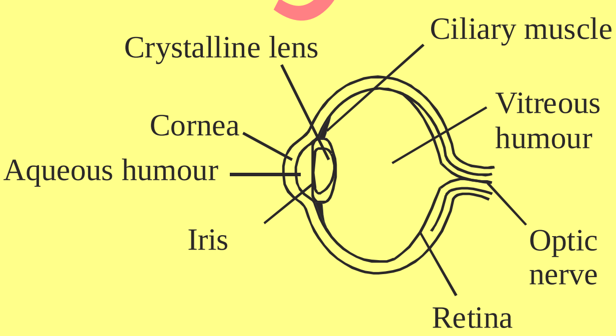


White - Red = Blue + Green = Cyan
White - Green = Red + Blue = Magenta
White - Blue = Red + Green = Yellow

Mixing CMY (cyan, magenta, yellow) pigment in the correct proportions can produce millions of colour. If equal amount of pure CMY pigments are mixed, we should get black pigment.

However, printers use black ink in addition to CMY inks to get good results.

THE HUMAN EYE



WORKING OF THE EYE

When we look at an object, light rays begin from the object and enter the pupil of the eye and fall on the eye lens, due to which an image is formed on the retina. Since object is real and the eye lens is a converging lens, an inverted and real image is formed on the retina. As retina contains millions of receptors in the form of rods and cones, light signal is converted into electrical signal and transmitted to the brain through optic nerves. Our brain processes this signal and we are able to see the object.

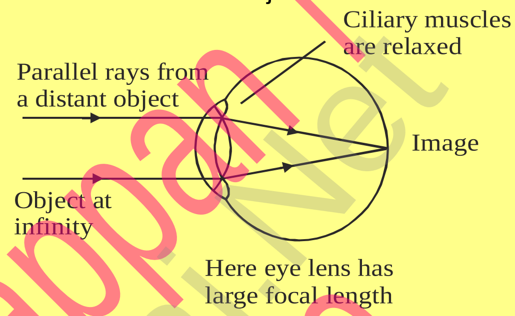


Fig. (b)

- When the eye is focussed on a distant object, focal length of the lens becomes maximum, as the cillary muscles are completely relaxed. In this situation parallel rays coming from a distant object are focussed on the retina and the object is seen clearly as shown in fig. (b).
- When the eye is focussed on a nearby object, the cillary muscles contract, such that focal length of the eye lens is adjusted in such a way that the image is formed on the retina. Image formed by the eye lens of a nearby object is shown in Fig. (c)

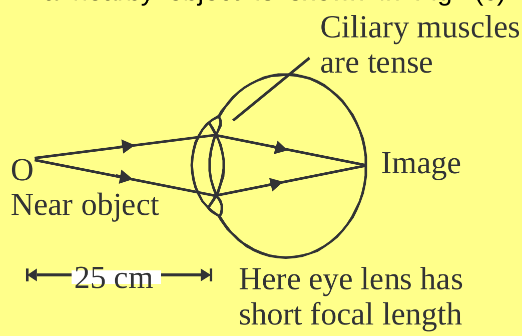


Fig. (c)

- Thus, the eye lens adjusts its focal length according to the distance of object from the eye, which is called accomodation.

Accommodation

It is the property by virtue of which the eye lens adjusts its focal length. What if an object is held very close to the eye? Then, object will not be seen clearly and eyes will also be

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• strained. So, there is a minimum distance from lens lesser than that our eye cannot see clearly. Near point is the minimum distance at which objects can be seen clearly. For normal person, least distance of distinct vision is 25 cm i.e. if an object is at distance less than 25cm, it will not be visible clearly and the eyes will be strained. So, if an object is placed at a distance of 25 cm from eye, the eye will accommodate in such a way that the image is formed on the retina as shown in Fig. (d)

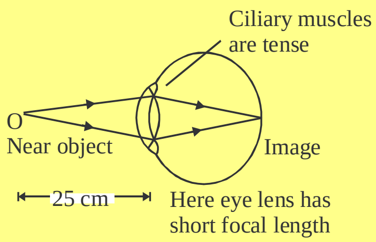

Fig. (d)

FAR POINT

It is the longest point from the eye upto which an object can be seen clearly. For normal vision it is at infinity i. e. if object is placed at infinity, the eye will accommodate in such a way that its image is formed at the retina as shown in Figure (e).

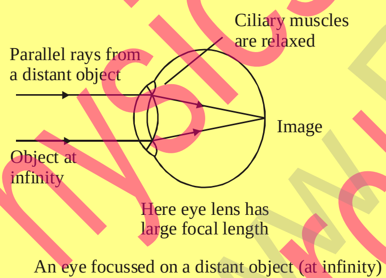

Figure. (e)

RANGE OF NORMAL VISION

It is minimum to maximum distance of an object from the eye, such that the object can be seen clearly.For normal vision range is 25 cm to infinity.

PERSISTENCE OF VISION

When we see an object, its impression lasts for about $\frac{1}{16}$ of a second on the retina even if object is removed. The continuance of the impression of the object on the eye is known as persistence of vision.

POWER OF ACCOMMODATION

It is the maximum variation of power of the eye. For a young person, it is about 4 Dioptres and with age, it decreases.

The maximum power of accommodation of the eye for a person having normal vision (d = 25 cm)

is $P = \frac{100}{f} = \frac{100}{d} = \frac{100}{25}$ = 4 dioptre.

CATARACT

With ageing, an opaque membrane is formed on the eye, due to which vision decreases sharply, this is called cataract. Normal vision can be restored after cataract surgery.

COLOUR BLINDNESS

Inability to distinguish different colours is called colour blindness. A colour blind person can see very well otherwise.

COLOUR PERCEPTION BY ANIMALS

In different animals, structure of rods and cones are different, due to which their colour perception is also different.

(a) Bees can see objects in ultraviolet light also.

(b) In chicks, cones are sensitive to bright light only, as a result they wake up at sunrise and sleep by sunset.

DEFECTS OF VISION

We have already studied that eye accommodates its focal length, according to the distance at which object is placed. If object is far off, its focal length is maximum and when object is at distance of distinct vision (25 cm), muscles compress the lens so that focal length is decreased. But sometime, the eye loses its power of accommodation, due to which object cannot be seen clearly, i.e., vision becomes blurred.

There are four main defects of vision, namely:

1. Myopia or near-sightedness,
2. Hypermetropia or far-sightedness,
3. Presbyopia and
4. Astigmatism.

Let us discuss each one of them and also their remedial measures by using suitable lenses.

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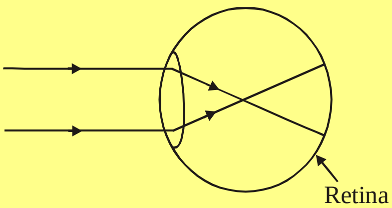
MYOPIA OR SHORT-SIGHTEDNESS

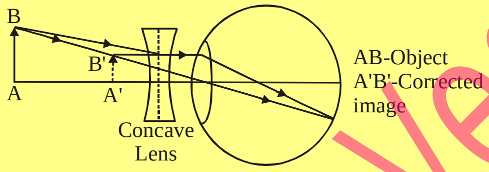
Inability of the eye in viewing long distance objects.The image in this case falls before the retina. For every myopic eye, there exists a far point beyond which clear image cannot be seen. Short-sightedness is caused due to

(i) excessive curvature in cornea (or)

(ii) elongation of eye- ball

The short-sightedness is corrected by using a concave lens, which diverges and shifts the image to the retina.





DERIVATION

Here, $u = -\infty$

$v = -x$

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

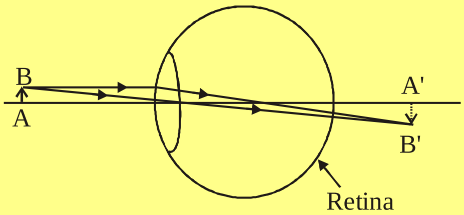
$= -\frac{1}{x} + \frac{1}{\infty} = \frac{1}{f}$

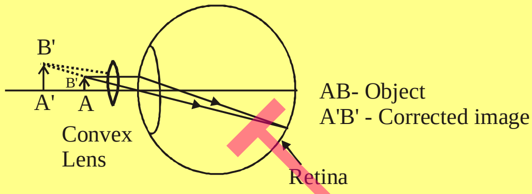
$= \frac{1}{f} = -\frac{1}{x}$

So, $f = -x$

HYPERMETROPIA OR LONG-SIGHTEDNES.

The inability of the eye in viewing the nearby objects. The image in this case falls beyond the retina. For hypermetropic eye, there exists a near point. Long-sightedness is caused due to(i) Greater focal length of the lens or (ii) eye-ball becoming smaller. It is corrected by using a convex lens, which converges and shifts the image to the retina from beyond.





- Suppose x' = distance of near point N' of defective eye,

d = distance of near point N of normal eye

= least distance of distinct vision of normal eye.

f = focal length of convex lens to be used.

For the correcting lens, object is at N, i.e., u = –d, image is at N', i.e., v = –x'

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

$\therefore \frac{1}{f} = \frac{1}{-x'} + \frac{1}{d} = \frac{-d + x'}{x'd}$

$$f = \frac{x'd}{x' - d}$$

As x' > d, f is positive. Therefore, correcting lens must be convex.

Illustration

The near point of ahypermetropic eye is at 75 cm from the eye. What is the power of the lens required to enable him to read clearly a book held at 25 cm from the eye?

Sol.

Here, distance of near point, x' = 75 cm., distance of book, d = 25 cm

power, P = ?, focal length, f = ?

As $f = \frac{x'd}{x' - d}$

$$\therefore f = \frac{75 \times 25}{75 - 25} = \frac{75 \times 25}{50} = 37.5\text{cm}$$

$$P = \frac{100}{f} = \frac{100}{37.5} = 2.66\text{D}$$

As 'f ' is positive, the corrective lens is convex.

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PRESBYOPIA

In human eye, with age, the near point recedes and the far point gets reduced. The eye becomes both myopic and hypermetropic. This is caused due to

- weakening of cillary muscles and
- reducing ability of the lens to change the curvature. It can be corrected by using bi-focal lens.

ASTIGMATISM

The inability of the eye in focussing objects in both horizontal and vertical lines clearly is called astigmatism. This is caused due to varying curvature in lens in horizontal and vertical lines. It is corrected by using cylindrical lenses.

SCATTERING OF LIGHT

The phenomena of change in the direction of propagation of light caused by the large number of molecules such as smoke, tiny water droplets, suspended particules of dust and molecules of air present in the earth's atmosphere is called scattering of light.

The colour of the scattered light perceived by us depends on the size of the particles.

- Very fine particles scatter mainly blue colour.
- Large sized particles scatter light, of longer wavelengths.
- Enough larger particles scatter the light which may appear white.

RAYLEIGH SCATTERING

According to Rayleigh "The amount of scattering is inversely proportional to the fourth power of the wavelength." Therefore the light of shorter wavelength is scattered much more than the light of longer wavelenght. There is no change in the vavelength of light rays during scattering.

The most beautiful phenomena of nature such as 'Blue colour of sky', 'White colour of clouds', 'Red hues of sunrise and sunset', can be explained in terms of scattering of light.

BLUE COLOUR OF SKY

Blue colour has a shorter wavelength than red. So according to ralyeigh scattering law, blue colour of sunlight scattered much more strongly by the large no. Of molecules present in the earth's atmosphere. Hence the sky appears blue.

On the surface of moon, there is no atmosphere. Therefore the scattering phenomena does not occur on the moon. Hence the sky of the moon appears dark.

WHITE COLOUR OF CLOUDS

Large particles like rain drops, dust or ice particles present in the atmosphere scattered all the wavelengths of light almost equally. Hence the clouds which have droplets of water scattered all colours equally to give the white appearance. So clouds generally appear white.

AT SUNSET OR SUNRISE, THE SUN LOOKS ALMOST REDDISH

The sun rays have to travel through a larger atmospheric distance. As $\lambda_b \leq \lambda_r$, most of the blue which is least scattered is received by our eye and appears to come from sun. Hence the appearance of sun at sunset or sunrise, full moon near the horizon may look almost reddish.

DANGER SIGNALS ARE RED

The wavelength of red colour is longer among the other colours of visible spectrum of sunlight. According to Rayleigh scattering law (scattering $\propto \frac{1}{\lambda^4}$), red colour is least scattered while passing through the atmosphere and therefore travels large distance, i.e., red colour can be seen through a large distance. Hence the danger signals make use of red light.

TYNDALL EFFECT

The phenomenon of scattering of light by the colloidal particles is known as Tyndall effect. This effect can be observed when

(a) A fine beam of sunlight enters a room containing suspended particles of dust, the path of the beam of light is visible. It is due to the scattering of light.

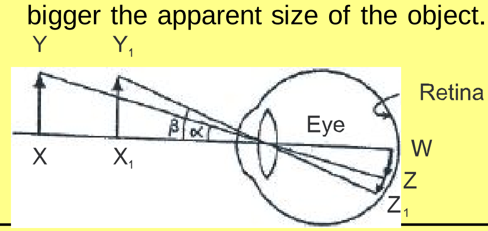
(b) Sunlight passes through a canopy of dense forest. In the forest, mist containing tiny droplets of water, which act as particles of colloid dispersed in air.

OPTICAL INSTRUMENTS

(a) Visual Angle, Magnifying Power, Optical instruments:

VISUAL ANGLE

The **angle** which an object subtends at our eye is called the 'visual angle'. The apparent size of an object as seen by our eye depends upon the visual angle. Larger the visual angle, bigger the apparent size of the object.



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MAGNIFYING POWER

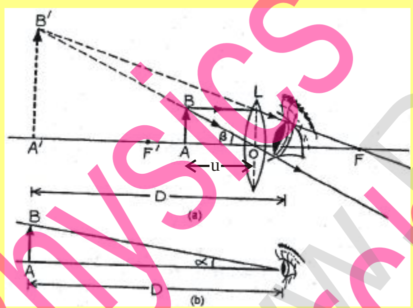
The purpose of microscopes and telescopes is to increase the visual angle. Therefore, the power of these instruments is measured by their power of increasing the visual angle. This is the ratio of the visual angle subtended by the image formed by the instrument at the eye to the visual angle subtended by the object at the unaided eye.

MICROSCOPE

A microscope is an optical instrument which forms large image of a close and tiny object. This image subtends a large visual angle at the eye so that the object looks large. There are mainly two types of microscopes:

(i) SIMPLE MICROSCOPE

In the simplest form, a simple microscope or magnifying glass, is just a thin, short-focus convex lens carrying a handle. The object to be seen is placed between the lens and its focus and the eye is placed just behind the lens. Then, the eye sees a magnified, erect and virtual image on the same side as the object. The position of the object between the lens and its focus is so adjusted that the image is formed at the least distance of distinct vision (d) from the eye. The image is then seen most distinctly.



AB is small object placed between a lens L and its first focus F'. Its magnified virtual image A'B' is formed at distance D form the lens. Since the eye is just behind the lens, so the eye is also at D.

Magnifying Power: Let β be the angle subtended by the image A'B' at the eye {figure (a)} and α be the angle subtended by the object AB at the eye when placed directly at a distance D from the eye {Figure (b)}. Then, the magnifying power of the simple microscope is given by-

m =

$$\frac{\text{angle subtended by the eye, distinct vision } (\beta)}{\text{angle subtended by the object at the eye, distinct vision } (\alpha)}$$

Since the object AB is small, the angle β and α are also small and we may write $\beta = \tan\beta$ and $\alpha = \tan\alpha$. Thus

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

From the geometry of the figure,

$\tan\beta$ = AB/OA and $\tan\alpha$ =AB/D.

$$\therefore M = \frac{D}{u}$$

The image A' B' is being formed at a distance D in front of the lens. Hence, in the lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we shall put v = -D and u = -u (with proper sign). Thus,

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

or $$\frac{1}{u} = \frac{1}{D} + \frac{1}{f}$$

or $$\frac{D}{u} = 1 + \frac{D}{f}$$

Putting this value of D/u is equation (i), we get

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

We shall substitute only numerical values of D and f, thus M is positive which means that an erect image is formed. It is also clear that shorter the focal length of the lens, larger is the magnifying power. If the eye is kept at distance d from the lens, then v = -(D - d) and the magnifying power will be

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

Thus, magnifying power is reduced. Hence to obtain maximum magnifying power, the eye must be very close to the lens.

To see with relaxed eye, the image A'B' should be formed at infinity. In this case the object AB will be at the focus of the lens, that if, u = f. Then, from equation (i), we have

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

The magnifying glass (simple microscope) is used by watch makers and jewellers to have magnified view of tiny components of watches and fine work on jewelry. It is also used to examine finger prints and palm lines and by the students to read vernier scales, etc.

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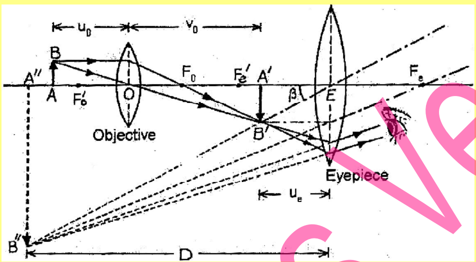
(ii) COMPOUND MICROSCOPE

A simple magnifier provides only assistance with inspection of the minute details of an object. Greater magnification can be achieved by combining two lenses in a device called a compound microscope, a diagram of which is shown in figure.

Construction: It consists of a long cylindrical metallic tube carrying at one end an achromatic convex lens O of small focal length and small aperture (see figure). This lens is called the 'objective lens'. At the other end of the tube is fitted a smaller tube. At the outer end of this smaller tube is fitted and achromatic convex lens E whose focal length and aperture are larger than that of the objective lens. The lens E is towards the eye and is called the 'eyepiece'. Cross-wires are mounted at the focus of the eyepiece. The entire tube can be moved forward and backward by rack and pinion arrangement.



WORKING

Suppose AB is a small object placed slightly away from the first focus F_0 of the objective lens O (figure) which forms a real inverted and magnified image A'B'. This image lies between the eyepiece E and its first focus F_e and acts as an object for the eyepiece which forms a magnified, virtual final image A"B", To find the position of B", two dotted rays (-. -. -.) are taken from B'. One ray, which is parallel to the principal axis passes, after refraction, through the second focus F_e of E. The other ray which passes through the optical centre of E travels straight. Both the refracted rays when produced backward meet at B". The image A"B" is generally formed at the least distance of distinct vision although it can be formed anywhere between this position and infinity. The rays by which the eye sees the image are clearly shown in the figure.

MAGNIFYING POWER

Suppose the final image A" B" subtends an angle β at the eyepiece E. Since eye is very near to the eyepiece, the angle β can also be taken as subtended by A" B" at the eye. Suppose when the object AB is at the least distance of distinct vision D, then it subtends an angle α at the eye. The magnifying power of the microscope is

$$M = \frac{A''B''}{AB} = \frac{A''B''}{A'B'} \times \frac{A'B'}{AB} \quad ....(i)$$

Here $\frac{A'B'}{AB}$ is magnifying power of objective lens, i.e. $\frac{A'B'}{AB} = -\frac{v_0}{u_0}$

$\frac{A''B''}{A'B'}$ is the magnifying power of eyepiece so there are two possibilities:

(a) The final image is formed at the least distance of distinct vision (d): If the distance of the final image A"B" from the eyepiece be D, then by applying the len's formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ for the eyepiece, we shall have

$v = -D$, $u = -u_e$ and $f = +f_e$

where f_e is the focal length of the eyepiece. Now, we get

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

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

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

$$\frac{A''B''}{A'B'} = \frac{D}{u_e}$$

Substituting this value of D / u_e in equation (i), we get

$$M = -\frac{v_0}{u_0} = \left[1 + \frac{D}{f_e}\right] ....(ii)$$

In this position, the length of the microscope will be $v_0 + u_e$

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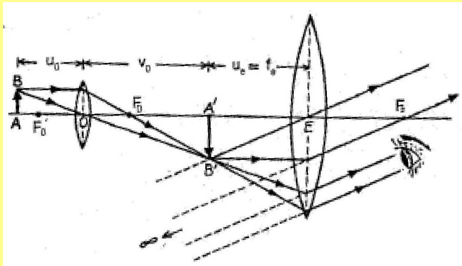
THE FINAL IMAGE IS FORMED AT INFINITY

To see with relaxed eye, the final image A"B" should be formed at infinity (figure). In this case the image A' B' will be at the focus F'_e of the eyepiece E i.e. $u_e = f_e$ Substituting this value in equation (i), we get the magnifying power of the relaxed eye, which is given by



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

In this position, the length of the microscope will be $v_0 + f_e$. It is clear from these formulae that in order to increase the magnifying power of microscope:

u_0 should be small i.e. the object AB should be placed quite close to the objective O. But, to obtain a real and magnified image of the object, the object should be placed beyond the focal length f_0 of the objective. Hence, for greater magnifying power of the microscope, the focal length of the objective should be small.

The distance v_0 of the image A'B' from the objective O should be large. For this, the object should be placed near the first focus of the objective.

The focal length f_e of the eyepiece should be small.

Illustration:

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. (a) Find the angular magnification. (b) Find the length of the micro-scope tube.

Sol.

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

we have $\frac{1}{v} - \frac{1}{(-1.2cm)} = \frac{1}{1cm}$ or

v = 6 cm.

The angular magnification in normal adjustment is,

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

(b) For normal adjustment, the first image must be in the focal plane of the eyepiece.

The length of the tube is, therefore,

$L = v + f_e = 6$ cm + 2.5 cm = 8.5 cm.

(c) **Telescope:** A telescope is an optical device which enables us to see distant object clearly. It provides angular magnification of the distant objects.

DIFFERENT TYPES OF TELESCOPE

Broadly, the telescopes can be divided into two categories:

(i) **Refracting telescopes:**

These make use of lenses to view distant objects. These are of two types:

(a) **Astronomical telescope:** It is used to see heavenly objects like the sun, stars, planets, etc. The final image formed is inverted one which is immaterial in the case of heavenly bodies because of their round shape.

(b) **Terrestrial telescope:** It is used to see distant objects on the surface of the earth. The final image formed is erect one. This is an essential condition for viewing the objects on earth's surface correctly.

(ii) **Reflecting telescopes:**

These make use of converging mirrors to view the distant objects. For example, Newtonian telescope.

(a) **Astronomical Telescope (Refracting Type):** An astronomical telescope is an optical instrument used to see heavenly objects like stars, planets, etc. The image of such a distant object formed by the telescope subtends a large visual angle at the eye, so that the object appears quite big to the eye.

Construction: It consists of a long cylindrical metallic tube carrying at one end an achromatic convex lens of large focal length and large

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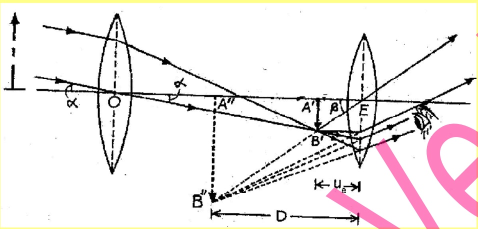
aperture which is called the objective lens. At the other end of the tube is fitted a smaller tube which can be moved in and out in the bigger tube by a rack and pinion arrangement. At the other end of the smaller tube is fitted an achromatic convex lens of small focal length and small aperture which is called the eyepiece. Cross-wires are mounted in the smaller tube at the focus of the eyepiece.

WORKING:

In figure are shown the objective lens O and the eyepiece E of a telescope. AB is a distant object whose end A is on the axis of the telescope. The lens O forms a small, real and inverted image A'B' at its second focus F_e . This image lies inside the first focus F_e of the eyepiece E and acts as an object for the eyepiece which forms a virtual, erect (with respect to A'B') and magnified final image A"B"



To find the position of B", two dotted rays (................) are taken from B'. One ray, which passes through the optical centre E, goes straight and the second ray which is taken parallel to the principal axis goes, after refraction, through the second focus F_e of E. The two refracted rays when produced backward meet at B".

- Magnifying Power: The magnifying power (angular magnification) of a telescope is defined by,

$$M = \frac{\text{angle by the final image at the eye}}{\text{angle by the object at the eye when seen directly}}$$

Since eye is near the eyepiece E, the angle β subtended by the final image A"B" at the eyepiece may be taken as the angle subtended at the eye. In the same way, since the object AB is very far from the telescope, the angle α subtended by the object at the objective may be taken as the angle subtended at the eye. Then

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

Since angle β and α are very small, we may write β = tan β and α = tan α thus

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

Now, from the geometry of the figure, we have, tan β = A'B' / EA' and tan α = A'B'/OA'.

$$\therefore M = \frac{A'B'/EA'}{A'B'/OA'} = \frac{OA'}{EA'}$$

If the focal length of the objective O be f_o and the distance of A'B' from the eyepiece E be u_o then, with proper sign, OA' = + f_o and EA' = $-u_e$ Thus, by the above equation, we have

$$M = -\frac{f_0}{u_e}$$

This is the general formula of magnifying power. Now there are two possibilities:

(i) The final image is formed at the least distance D of distinct vision: If the distance of the final image A"B" from the eyepiece be D, then in applying the lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ for the eyepiece, w e shall have

v = -D, u = $-u_e$ and f = + f_e

Where f_e is the focal length of the eyepiece, We get

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

or

$$\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} = \frac{1}{f_e}\left[1 + \frac{f_e}{D}\right]$$

Substituting this value of $1/u_e$ in eq. (i) we have

$$M = \frac{f_0}{f_e} = \left[1 + \frac{f_e}{D}\right] \quad \text{...............(ii)}$$

We shall substitute only the numerical values of f_o, f_e and D in this formula. In this position the length of the telescope will be f_o + u_e.

(ii) The final Image is formed at infinity: To see with relaxed eye, the final image should be formed at infinity (figure). For this, the distance between the objective and the eyepiece is adjusted so that the image A'B' formed by the objective O is at the focus F'_e of the eyepiece (u_e=f_e). This adjustment of the telescope is called 'normal adjustment'. Substituting u_e = f_e in eq. (i) we get

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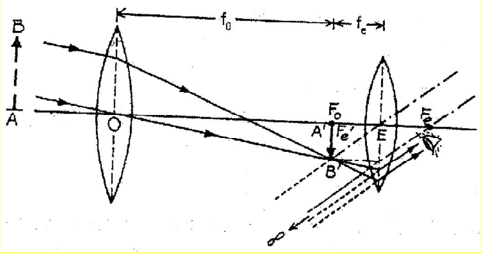


$$M = -\frac{f_o}{f_e} \qquad ....(iii)$$

In this position the length of the telescope will be $\mathbf{f_o + f_e}$.

It is clear from eq. (ii) and (iii) that for large magnifying power of a telescope the focal length f_e of the objective lens should be large and the focal length f_e of the eyepiece should be small. Negative sign indicates that the final image is inverted.

Illustration:

A small telescope has an objective of focal length 140 cm and an eye piece of focal length 5.0 cm. 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_o = 140 cm, f_e = 5.0 cm

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

(b) when image is formed at the distance of distinct vision

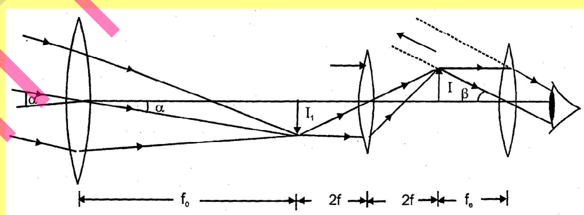
$$m = \frac{f_o}{f_e}\left[1 + \frac{f_e}{D}\right] = 28\left[1 + \frac{5}{25}\right] = 25 \times \frac{6}{5} = 33.6$$

where D = 25 cm

(b) Terrestrial Telescope :

An astronomical telescope produces an inverted image of the distant object. Therefore, it is suitable for astronomy because it makes a little difference if the image of a star, for example, is inverted. However, it is useless for viewing objects on the earth (e.g. distant trees, building, etc.) in which an erect image is required.

A terrestrial telescope provides an erect image of the distance object. An astronomical telescope can be converted into terrestrial by introducing one more convex lens (called erecting lens) of focal length f between the objective lens and the eyepiece as shown in figure. The erecting lens is placed at a distance 2f in front of the inverted real image, I_1 of the object formed by the objective lens. The image of I_1 in the erecting lens is I; the image I being real, inverted w.r.t I_1 of the same size as I_1 and also at a distance 2f from the erecting lens. Note that image I is erect w.r.t the object. The eyepiece is so adjusted that the image I lies at the focus of the eyepiece. Therefore, the eyepiece forms the final image at infinity which is virtual, erect w.r.t object and highly magnified. Figure shows the ray diagram of image formation inside a terrestrial telescope.



Ray diagram of terrestrial telescope

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EXERCISE - I (FOUNDATION CORNER)

1. A light ray is made to incident on a glass plate with angle of incidence 15ºand then reflected. Then the angle of deviation is
(A) 45º (B) 130°
(C) 150° (D) 90°

2. The angle between incident ray and reflected ray is 70º. What is the angle of incidence ?
(A) 45º (B) 30º
(C) 55º (D) 35º

3. How will you arrange the two mirrors so that whatever may be the angle of incidence, the incident ray and the reflected ray from the two mirrors will be parallel to each other ?
(A) 90º (B) 45º
(C) 60º (D) 180º

4. Two plane mirrors are inclined to each other at an angle . . A ray of light is reflected first at one mirror and then at the other.
(A) the total deviation of ray is 360º
(B) the total deviation produced by system of mirrors is independent of the angle of incidence on the first mirror
(C) the total deviation produced by system of mirrors depends upon the angle which the two mirror are inclined to each other.
(D) the total deviation of ray is always 90º.

5. Light is focused on the compound wall of a building with the help of vertical plane mirror. A small boy came and rotate the plane mirror with an angle of o 30 clock wise then what happens to the reflected beam when a mirror is rotated by 30º ?
(A) remains fixed (B) rotates by 15º
(C) rotates by 60º (D) rotates by 90º

6. In question no. 5 above, what happens to the normal when a mirror is rotated by 40º ?
(A) remains fixed (B) rotates by 15º
(C) rotates by 60º (D) rotates by 40º

7. In question no. 5 above, what happens to the incident angle when a mirror is rotated by 15º ?
(A) remains fixed (B) increases by 15º
(C) rotates by 60º (D) rotates by 40º

8. The diameter of spherical mirror in which reflection takes place is called
(A) radius of curvature
(B) centre of curvature
(C) linear aperture.
(D) focal length.

9. The image formed by a convex mirror of real object is larger than the object.
(A) When u < 2f (B) When u > 2f
(C) for all values of u (D) for no value of u

10. When object is placed between principal focus and pole for a concave mirror the image is formed at
(A) pole (B) principal focus
(C) centre of curvature (D) behind the mirror

11. Which of the following forms a virtual and erect image for all positions of a real object with a greater field of view
(A) plane mirror (B) convex mirror.
(C) concave mirror (D) all the above

12. The point on the mirror at middle of spherical surface is
(A) pole
(B) principal axis
(C) center of curvature
(D) radius of curvature.

13. For a concave mirror, whenever the distance of object is less than the focal length, the image is virtual. That is called virtual image, because
(A) the image is formed behind the mirror
(B) the image is not inverted
(C) the image cannot be obtained on a screen
(D) the image can be located by virtue of parallax.

14. In case of concave mirror, the minimum distance between a real object and its real image is
(A) f (B) 2f
(C) 4f (D) zero.

15. For a spherical mirror, the paraxial ray is the ray which
(A) coincides with the principal axis
(B) is near the principal axis
(C) is far away from the principal axis
(D) is normal to the principal axis.

16. A virtual image larger than a real object can be produced by
(A) convex mirror (B) concave mirror
(C) plane mirror (D) none of these.

17. The focal length and magnification of a plane mirror are
(A) $f = \infty$, m = 0 (B) f = 0, m = 1
(C) $f = \infty$, m = 1 (D) f = 0, m = 0.

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18. The velocity of light in air is 3×10 ms^{-1} and in glass is 2×10 ms^{-1}. The refractive index of glass w.r.t air is

(A) 2/3 (B) 3/2
(C) 4/3 (D) 9/4.

19. The refractive index of glass and water w.r.t air are 3/2 and 4/3. The refractive index of glass w.r.t water is

(A) 3/2 (B) 2/3
(C) 3/4 (D) 9/8

20. When light travels from rarer medium to denser medium

(A) Refracted ray bends towards normal
(B) Refracted ray bends away from normal
(C) Ray undeviated from path
(D) We cannot identified the ray.

21. When light ray travels from denser medium to rarer medium

(A) Refracted ray bends towards normal
(B) Refracted ray bends away from normal
(C) Ray undeviated from path
(D) We cannot identified the ray.

22. An object in a denser medium appears nearer as seen from rarer medium. Then the refractive index of denser medium is

(A) $\frac{\sin r}{\sin i}$ (B) $\frac{\tan r}{\tan i}$
(C) $\frac{\text{real depth}}{\text{apparent depth}}$ (D) $\frac{\text{apparent depth}}{\text{real depth}}$.

23. If the temperature of the medium increases, then the critical angle is

(A) Increases
(B) Decreases
(C) Remains same
(D) First increases then decreases

24. The critical angle for a ray of light suffering total internal reflection will be smallest for light travelling from

(A) water to air (B) glass to air
(C) glass to water (D) water to glass

25. The phenomenon of total internal reflection does play the role in the

(A) formation of rainbow
(B) sparkling of diamond
(C) phenomenon of mirage
(D) all the above

26. Total Internal reflection is the reason of

(A) Brilliancy of a diamond
(B) Shining of small air bubble in water
(C) Formation of looming in cold countries
(D) all of the above.

27. Ratio of wavelengths of light passing from one medium to another is 4 : 5. Then the ratio of the speeds of the light in two media is:

(A) 4 : 5 (B) 5 : 4
(C) $\sqrt{5}$: 2 (D) 2 : $\sqrt{5}$

28. In the case of equilateral glass prism, refractive index of the material of the prism is $\sqrt{2}$. The angle of minimum deviation is

(A) 60º (B) 30º
(C) 45º (D) $\sin^{-1}(\sqrt{2})$

29. A ray of light passes through an equilateral glass prism, such that the angle of incidence is equal to the angle of emergence. If the angle of emergence is $\frac{3}{4}$ times the angle of the prism. The refractive index of the glass prism is

(A) 1.71 (B) 1.61
(C) 1.41 (D) 1.21

30. The maximum value of index of refraction of a material of prism which allows the passage of light through it when the refracting angle of prism A is

(A) $\sqrt{1+\tan^2\frac{A}{2}}$ (B) $\sqrt{1+\cot^2\frac{A}{2}}$
(C) $\sqrt{1+\cos^2\frac{A}{2}}$ (D) $\sqrt{1+\sin^2\frac{A}{2}}$.

31. A prism with less than ___________ degrees is called small angled prism.

(A) 10º (B) 20º
(C) 15º (D) 30º.

32. In the case of equilateral glass prism, refractive index of the material of the prism is $\sqrt{2}$. The angle of minimum deviation is

(A) 60º (B) 30º
(C) 45º (D) $\sin^{-1}\left(\sqrt{2}\right)$.

33. A double convex air bubble in water would behave as a

(A) convergent lens (B) circle
(C) divergent lens (D) plane mirror.

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34. The distance between the optical centre and the principal focus is

(A) focal length (B) object distance

(C) image distance (D) foci

35. The graph drawn with object distance along x-coordinate and image (real) distance as y-coordinate for a convex is a

(A) straight line

(B) circle

(C) parabola

(D) rectangular hyperbola

36. A lens behaves as a converging lens in air and as a diverging lens in water. The refractive index of the material of the lens is

(A) equal to unity

(B) equal to 1.33

(C) between unit and 1.33

(D) greater than 1.33

37. When the lens is thin and radii of cunvature of two refracting surface are equal then the geometric centre of the lens becomes.

(A) principal focus (B) optical center

(C) front vertex (D) back vertex

38. Lens makers formula is valid only for

(A) Paraxial rays & thin lens

(B) Paraxial rays & thick lens

(C) marginal rays & thin lens

(D) marginal rays & thick lens

39. A biconvex lens has radii of curvature 20cm each. If the refractive index of the material of the lens is 1.5. Its focal length is

(A) 20cm (B) 10cm

(C) 30cm (D) 15cm

40. A convex lens of focal length 24cm (μ =1.5) is totally immerged in water (μ =1.33) then its focal length in water.

(A) 100cm (B) 96cm

(C) 92cm (D) 120cm

41. Decreasing the radii of the two surfaces of a double convex or double concave lens

(A) increases its focal length

(B) decreases its focal length

(C) neither increases nor decreases the focal length

(D) increases or decreases

42. A diverging meniscus lens of radii of curvatures 25cm and 50cm has a refractive index 1.5. It focal length is (in cm)

(A) –50 (B) -100

(C) 100 (D) 50

43. When light ray passes rarer medium (μ_1) into denser medium (μ_2), the object distance (u) and image distance (v) then the radius of curvature (R) of the concave refracting surface

(A) $\frac{(\mu_2-\mu_1)uv}{\mu_2 u - v\mu_1}$ (B) $\frac{\mu_2 u - v\mu_1}{(\mu_2-\mu_1)uv}$

(C) $\frac{(\mu_1-\mu_2)uv}{v\mu_1 - u\mu_2}$ (D) $\frac{vu_1 - u\mu_2}{(\mu_1-\mu_2)uv}$.

44. A denser medium of refractive index 1.5 has a concave surface of radius of curvature 12 cm. An object is situated in the denser medium at a distance of 9 cm from the pole. Locate the image due to refraction in air.

(A) A real image at 8 cm

(B) A virtual image at 8 cm

(C) A real image at 4.8 cm

(D) A virtual image at 4.8 cm

45. In a medium of refractive index 1.6 and having a convex surface has a point object in it at a distance of 12 cm from the pole. The radius of curvature is 6 cm. Locate the image as seen from air.

(A) A real image at 30 cm

(B) A virtual image at 30 cm

(C) A real image at 4.28 cm

(D) A virtual image at 4.28 cm

46. A sunshine recorder globe of 20 cm diameter is made of glass of μ = 1.5. A ray enters the globe parallel to the axis. Find the position from the centre of the sphere where the ray crosses the axis.

(A) 15 cm (B) 17 cm

(C) 16 cm (D) 10 cm.

47. A convex refracting surface of radius of curvature 20 cm separates two media of refractive indices 4/3 and 1.60. An object is placed in the first medium (μ = 4/3) at a distance of 200 cm from the refracting surface. Calculate the position of image formed.

(A) at 234.15 cm in rarer media

(B) at 234.15 cm in denser media

(C) at 238.15 cm in rarer media

(D) at 238.20 cm in rarer media.

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48. Far sighted people who have lost their spectacles can still read a book by looking through a small hole in a street of paper, this is because

(A) in doing so the focal length of the eye is effectively increased

(B) in doing so the focal length of the eye effectively increased

(C) in doing so the distance of the object increased

(D) the pin hole produces an image of letters at a longer distance

49. A myopic person cannot see objects lying beyond 2m. The focal length and power of the lens required to remove this defect will be

(A) 1m and 0.5D (B) "2m and "0.5D

(C) 0.5m and 0.5D (D) "0.5 and 0.5D

50. The power of the lens, a short sighted person uses is 2 dioptre. The maximum distance of an object which he can see without spectacle is

(A) 25 cm (B) 50 cm

(C) 100 cm (D) 10 cm

51. For a person suffering from a combination of astigmatism and myopia the type of glasses, that must be used to correct vision is

(A) Plano convex

(B) Plano concave

(C) Plano spherical

(D) Sphero cylindrical

52. Colour blindness can be cured by using

(A) cancave lesn

(B) canvex lens

(C) spherical lens

(D) not curable at all

53. To obtain maximum magnification with a simple microscope where should the eye be placed.

(A) close to lens

(B) half way between focus and optical centre

(C) close to the focus

(D) away from lens

54. To obtain a magnified image at distance of distinct vision with a simple microscope where should the object be placed

(A) away from focus

(B) at focus

(C) between focus and optical centre

(D) Both (A) and (B)

55. In simple microscope the magnifying power (MP) is

(A) MP=0

(B) $MP = \frac{\text{visual angle with instrument}}{\text{maximum visual angle for unaided eye}}$

(C) $MP = \frac{\text{maximum visual angle for unaided eye}}{\text{visual angle with instrument}}$

(D) Both (A) and (C)

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

(A) 4.125 (B) 3.125

(C) 2.125 (D) 5.125

57. The focal length of a magnifier is 5 cm then the magnifying power of a lens relaxed eye (far point) is

(A) 20 (B) 25

(C) 5 (D) 10

58. Atmospheric refraction is due to

(A) changing pressure in the atmosphere

(B) varying density of atmosphere

(C) varying temperature of the atmosphere

(D) both (B) and (C).

59. The sun appears red during set and rise due to

(A) scattering of light

(B) atmospheric refraction

(C) dispersion

(D) total internal reflection.

60. The sun is seen before it comes to our horizon because

(A) scattering of light

(B) atmospheric refraction

(C) dispersion

(D) total internal reflection.

61. When sunrays enter through window in the early morning the path of the light ray becomes visible when dust or smoke come on its way. This is known as

(A) scattering of light (B) tyndall effect

(C) dispersion (D) refaction of light.

62. The rainbow is formed due to

(A) dispersion and refraction

(B) scattering and refraction

(C) dispersion and scattering

(D) reflection total internal reflection and dispersion of light

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63. Newton has postulated his corpuscular theory on the basis of:
(A) Newton's ring
(B) colour due to thin film
(C) dispersing of light
(D) rectilinear propagation of light.

64. The wavefront is a surface in which:
(A) all points are in the same phase
(B) there are pairs of points in opposite phase.
(C) there are pairs of points with phase difference ($\pi/2$)
(D) there is no relation between the phases.

65. The concept of secondary wavelets from all points on a wavefront was first proposed by:
(A) Newton (B) Huygen
(C) Faraday (D) Raman.

66. Interference proves:
(A) transverse nature of waves
(B) longitudinal nature of waves
(C) wave nature
(D) particle nature.

67. Two waves of equal amplitude and wavelength but differing in phase are superimposed. Amplitude of resultant wave is maximum when phase difference is:
(A) zero (B) $\pi/12$
(C) π (D) $3\pi/2$.

68. In Young's double slit interference experiment if the distance between the slits is made 3- fold, the fringe width becomes.
(A) (1/3) fold (B) 3 fold
(C) (1/9) fold (D) 9 fold.

69. In Young's double slit experiment the separation between the slits is halved and the distance between the slits and screen is doubled. The fringe width is:
(A) unchanged (B) halved
(C) doubled (D) quadrupled.

70. In a certain double slit experimental arrangement, interference fringes of width 1.0 mm each are observed when light of wavelength 5000 Å is used. Keeping the setup unaltered if the source is replaced by another of wavelength 6000 Å, the fringe width will be:
(A) 0.5 mm (B) 1.0 mm
(C) 1.2 mm (D) 1.5 mm.

71. The Young's double slit experiment is performed with blue and with green light of wavelengths 4360 Å and 5460 Å respectively. If x is the distance of 4^{th} maximum from the central one, then:
(A) x(blue) = x(green) (B) x(blue) > x (green)
(C) x(blue) < x (green) (D) $\frac{x(\text{blue})}{x(\text{green})} = \frac{5460}{4360}$

72. In Young's double slit experiment carried out with light of wavelength λ= 5000 Å, the distance between the slits is 0.2 mm and the screen is at 200 cm from the plane of slits. The central maximum is at x = 0. The third maximum will be at x equal to
(A) 1.67 cm (B) 1.5 cm
(C) 0.5 cm (D) 5.0 cm.

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ANSWER KEY

1.	(C)	2.	(D)	3.	(A)	4.	(C)	5.	(C)
6.	(D)	7.	(B)	8.	(C)	9.	(D)	10.	(D)
11.	(B)	12.	(A)	13.	(C)	14.	(D)	15.	(B)
16.	(B)	17.	(C)	18.	(B)	19.	(D)	20.	(A)
21.	(B)	22.	(C)	23.	(B)	24.	(C)	25.	(D)
26.	(D)	27.	(A)	28.	(B)	29.	(C)	30.	(C)
31.	(A)	32.	(A)	33.	(C)	34.	(A)	35.	(D)
36.	(C)	37.	(B)	38.	(D)	39.	(A)	40.	(B)
41.	(B)	42.	(B)	43.	(A)	44.	(D)	45.	(B)
46.	(A)	47.	(A)	48.	(B)	49.	(B)	50.	(B)
51.	(D)	52.	(D)	53.	(A)	54.	(C)	55.	(B)
56.	(A)	57.	(C)	58.	(D)	59.	(A)	60.	(B)
61.	(B)	62.	(D)	63.	(D)	64.	(A)	65.	(B)
66.	(C)	67.	(A)	68.	(A)	69.	(D)	70.	(C)
71.	(C)	72.	(B)						

EXERCISE - II (COMPETITIVE CORNER)

1. A light ray is made to incident on a glass plate with an angle of incidence 30º. Find the angle of reflection is

(A) 60º (B) 30º
(C) 90º (D) 0º

2. The two mirrors are inclined at an angle 90º. If a ray of light is obliquely incident on the first mirror, the deviation after two reflections is

(A) 180º (B) 300º
(C) 90º (D) 60º

3. A ray of light, after reflection from a plane mirror, suffers a deviation of 60º. Find the angle between the incident and reflected rays.

(A) 130º (B) 120º
(C) 145º (D) 60º

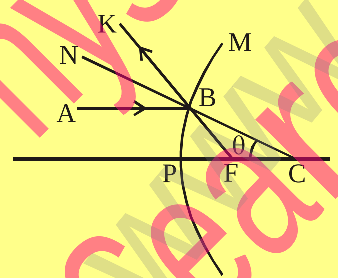
4. The line passing through pole and center of curvature is

(A) pole
(B) principal axis
(C) center of curvature
(D) radius of curvature.

5. The center of the hollow sphere for which the mirror is a part is

(A) pole (B) principal axis
(C) centre of curvature (D) radius of curvature

6. In the Figure, AB and BK represent incident and reflected rays. If angle BCF = 35º. Then ∠BFP. will be equal to ____ degrees.



(A) 70º (B) 35º
(C) 80º (D) 90º

7. A convex mirror has its radius of curvature 30cm. Find the position of the image of an object placed at a distance of 18cm from the mirror

(A) $\frac{50}{11}$ cm (B) $\frac{60}{11}$ cm
(C) $\frac{90}{11}$ cm (D) 90 cm.

8. A ray falls at the pole of convex mirror at an angle 30º with the principal axis. The angle between the reflected ray and principle axis will be

(A) 60º (B) 15º
(C) 30º (D) not predictable.

9. Mark the wrong statement about a virtual image

(A) a virtual image can be photographed
(B) a virtual image can be seen
(C) a virtual image can be photographed by exposing a film at the location of the image
(D) a virtual image may be diminished or enlarged in size in comparison to an object.

10. Which one of the following can produce a parallel beam of light from a point source of light ?

(A) concave mirror (B) convex mirror
(C) plane mirror (D) concave lens.

11. A convex mirror has a focal length f. A real object placed at a distance f in front of it from the pole, produces an image at

(A) ∞ (B) f
(C) f/2 (D) 2f.

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

(A) x_1x_2 (B) $\sqrt{x_1x_2}$
(C) $(x_1 + x_2)/2$ (D) $\sqrt{x_1 / x_2}$.

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

(A) (n – 1) f (B) [(n – 1)/n] f
(C) [(n + 1)/n] f (D) (n + 1) f.

14. Let a ray of light be incident on a parallel glass plate of thickness 8cm at an angle 60º. The refracted angle is o 30º. The emergent ray does not under go deviation and dispersion but shifts laterally and travel parallel to the direction of incident ray. The normal distance between incident and emergent rays is lateral shift. The speed of light is 2×10 ms^{-1} in the glass then the distance AB is

(A) $\frac{8}{\sqrt{3}}$ cm (B) $\frac{16}{\sqrt{3}}$ cm
(C) $\frac{24}{\sqrt{3}}$ cm (D) $\frac{32}{\sqrt{3}}$ cm .

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15. In question no. 6 above, the lateral shift is

(A) $\frac{8}{\sqrt{3}}$ cm (B) $\frac{16}{\sqrt{3}}$ cm

(C) $\frac{24}{\sqrt{3}}$ cm (D) $\frac{32}{\sqrt{3}}$ cm.

16. In question no. 6 above, the time taken to cover the distance AB inside the slab is____ $\times 10^{-8}$ s.

(A) $\frac{8}{\sqrt{3}}$ cm (B) $\frac{16}{\sqrt{3}}$ cm

(C) $\frac{24}{\sqrt{3}}$ cm (D) $\frac{32}{\sqrt{3}}$ cm.

17. A beaker of depth 10cm is filled with a liquid of refractive index 4/3 upto a depth of 6cm and remaining depth is filled with a liquid of refractive index 6/5. The apparent depth of the beaker when observed normally is

(A) 9.8 cm (B) 8.8cm

(C) 7.8cm (D) 6.8 cm

18. A travelling microscope is focussed on to a point on the bottom of a vessel. A liquid whose refractive index is $\frac{6}{5}$ is poured in it. The microscope is lifted to 6cm to focus it again. The depth of the liquid in the vessel is

(A) 18cm (B) 36cm

(C) 9cm (D) 24cm

19. When light travels from one medium to other the refractive index is different then which of the following will change ?

(A) frequency, wavelength and velocity

(B) frequency and wavelength

(C) frequency and velocity

(D) wavelength and velocity.

20. The critical angle of light passing from glass to air is minimum for

(A) red (B) green

(C) yellow (D) violet.

21. Critical angle for a medium is 45º. Its refractive index is

(A) $\sqrt{2}$ (B) $\frac{1}{\sqrt{2}}$

(C) $\sqrt{3}$ (D) $\frac{1}{\sqrt{3}}$.

22. Refractive index of a medium is 2. Its critical angle is

(A) 60º (B) 30º

(C) 40º (D) 50º.

23. Refractive index of a medium is $\frac{2}{\sqrt{3}}$. Its critical angle will be

(A) 45º (B) 60º

(C) 30º (D) 90º.

24. A ray of light is incident on one of the refracting surfaces of an equilateral prism, at an angle of incidence 48º in the minimum deviation position, deviation produced by the prism is

(A) 48º (B) 36º

(C) 24º (D) 18º

25. A ray is incident at an angle of incidence i on one surface of prism of small angle A. The refractive index of the material of the prism is ?. The angle of incidence is nearly equal to

(A) $\frac{A}{2\mu_0}$ (B) $\frac{\mu A}{2}$

(C) $\frac{A}{\mu}$ (D) μA.

26. The deviation of a ray through a prism is related to the angle of prism as

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

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

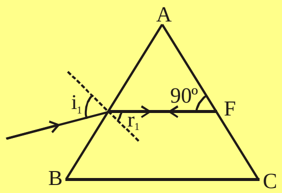
27. The side AC of a glass prism of refractive index 1.5 is silvered. A ray of light falls on the face AB such that it retraces its path. What is the angle of incidence, if the angle of the prism is 35º. (sin 35º = 0.574) $\sin^{-1}(0.86) = 59.4º$

(A) 59.4º

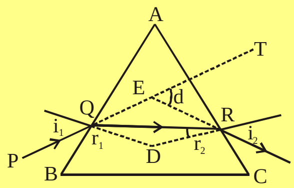
(B) 64.6º

(C) 35º

(D) 72º.



28. When the prism is in the minimum deviation position (Figure). Choose the correct one.



(A) $i_1 = i_2 = I$ and $r_1 = r = r$

(B) Angle of minimum deviation is. Dm =2 (i-A)

(C) Angle of incident $i = \frac{A + D_m}{4}$

(D) Angle of refraction r = A/4

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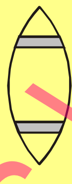
29. The minimum distance between an object and its real image formed by a convex lens is
(A) 1.5f (B) 2f
(C) 2.5f (D) 4f

30. The maximum image distance in the case of a concave lens is
(A) f (B) 4f
(C) infinity (D) 2f

31. A thin lens produces an image of the same size as the object. Then from the optical centre of the lens, the distance of the object is
(A) zero (B) 4f
(C) 2f (D) f/2

32. The focal length of a convex lens is maximum for
(A) ultraviolet rays (B) violet
(C) yellow (D) red rays

33. A layered lens as shown in the figure is made of two materials indicated by different shades. A point object is placed on its axis. The lens will form.



(A) one image
(B) two images
(C) five images
(D) three images

34. Two thin lenses of focal lengths 1 f and 2 f are in contact and coaxial. The combination is equivalent to a single lens of power
(A) $\frac{f_1 f_2}{f_1+f_2}$ (B) $\frac{1}{2}(f_1+f_2)$
(C) $\frac{f_1+f_2}{f_1 f_2}$ (D) $\sqrt{f_1 f_2}$.

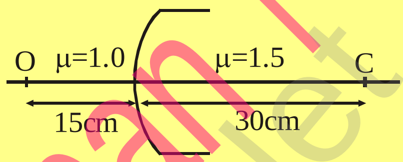
35. Two thin convex lenses of focal length f_1 and f_2 are placed with a distance d between them for the power of the combination to be zero, the separation d is.
(A) f_1-f_2 (B) f_1+f_2
(C) f_1/f_2 (D) $\sqrt{f_1 f_2}$

36. The focal power of a convergent lens of focal length 12.5cm is
(A) +8D (B) +6D
(C) +7D (D) +12.5D

37. Two lenses of power +8 and -3 dioptres are placed in contact, then the power of the combination is
(A) +2D (B) +5D
(C) +4D (D) +6D

38. A convex lens of glass is immersed in water compared to its power in air, its power in water will
(A) increases
(B) decrease
(C) not change
(D) decrease for red light increase for a violet light and power P

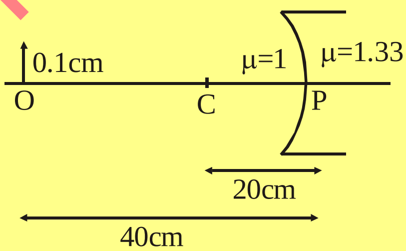
39. Locate the image of the point object O in the situation shown in figure. The point C denotes the centre of curvature of the separating surface.



(A) –30 cm (B) –20 cm
(C) ∞ (D) –40 cm.

40. One end of a horizontal cylindrical glass rod (μ = 1.5) of radius 5 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 cm from the rounded edge. Locate the image of the object and find its height.
(A) 20 cm; 10 mm (B) 30 cm; 0.5 mm
(C) 20 cm; 5 mm (D) 30 cm; 1 mm.

41. Find the size of image formed in the situation shown in figure.



(A) 0.5 cm (B) 0.4 cm
(C) 0.8 cm (D) 0.6 cm.

42. A sphere of glass (μ = 1.5) is of 20 cm diameter. A parallel beam enters it from one side. Where will it get focused on the other side ?
(A) 6 cm (B) 4 cm
(C) 8 cm (D) 5 cm.

43. A glass sphere of 15 cm radius has a small bubble 6 cm from the centre. The bubble is seen along a diameter of the sphere from the side on which it lies. How far from the surface will it appear to be, if refractive index of glass is 1.5 ?
(A) –7.2 cm (B) –7.4 cm
(C) –7.5 cm (D) –7.7 cm.

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44. The near point and the far point of a child are at 10 cm and 100 cm respectively. If the retina is 2 cm behind the eye lens,
The lower range of the power of the eye lens is
(A) 40D (B) 51D
(C) 60D (D) 55D

45. The upper range of the power of the eye lens in the above question no. 6 is
(A) 60D (B) 55D
(C) 40D (D) 31D

46. Range of the power of the eye lens in the above question no. 6 is
(A) 40D “51D (B) 51D “60D
(C) 55D “60D (D) 31D”40D.

47. A person cannot see beyond 100 cm. He should use a glass of power,
(A) –1 D (B) +1 D
(C) –2 D (D) +2 D.

48. The near point of a person is 100 cm. The power of the lens that can be prescribed for him is
(A) 3D (B) 4D
(C) –2D (D) 2D.

49. Magnifying power of a simple microscope increases by
(A) increase in focal length
(B) decrease in focal length
(C) increase the size of object
(D) Both (B) and (C)

50. For which of the following colour, the magnifying power of a microscope will be maximum
(A) green (B) red
(C) violet (D) yellow

51. When the length of a microscope tube increases, its magnifying power
(A) decreases
(B) increases
(C) does not change
(D) may decrease or increase

52. A compound microscope is of magnifying power 100. The magnifying power of its eyepiece is 4. Find the magnification of its objective ?
(A) 4 (B) –25
(C) 0.04 (D) –50

53. The objective of a compound microscope is essentially
(A) concave lens of large focal length and small aperture
(B) convex lens of small focal length and large aperture
(C) convex lens of large focal length and large aperture
(D) convex lens of small focal length and small aperture

54. Twinkling of stars occurs due to
(A) scattering of light
(B) atmospheric refraction
(C) dispersion
(D) total internal reflection.

55. The sky is blue because of,
(A) scattering of light
(B) atmospheric refraction
(C) dispersion
(D) total internal reflection.

56. Sea appears blue because of
(A) scattering of light
(B) atmospheric refraction
(C) dispersion
(D) total internal reflection.

57. The sun appears bigger during rise and set
(A) scattering of light
(B) atmospheric refraction
(C) dispersion
(D) total internal reflection.

58. The scattering of components of light is directly proportional to its
(A) frequency (B) amplitude
(C) velocity (D) colour.

59. The phenomenon of interference of light was first studied and explained by:
(A) Newton (B) Fresnel
(C) Huygens (D) Young.

60. The path difference equivalent to a phase difference of 270º (given wavelength of wave =λ) is:
(A) zero (B) $\lambda/2$
(C) $3\lambda/4$ (D) λ.

61. The light waves from two independent monochromatic light sources are given by:
$y_1 = 2 \sin \omega t$ and $y_2 = 3 \cos \omega t$.
then the correct statement is
(A) Both the waves are coherent
(B) Both the waves are incoherent
(C) Both the waves have different time periods
(D) None of the above.

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62. According to modern theory for nature of light, the light has:
(A) wave nature only
(B) particle nature only
(C) both particle and wave (dual) nature
(D) neither particle nature nor wave nature.

63. When path difference between two points in a wave is λ then their phase difference will be
(A) π (B) 2π
(C) 1.5π (D) 3π.

64. The fringe width in Young's double slit experiment on a screen which is placed at a distance of 1 m from the slits 10^{-3} m apart when the light used has wavelength 6×10^{-7} m, is equal to:
(A) 3×10^{-10} m (B) 3×10^{-4} m
(C) 6×10^{-10} m (D) 6×10^{-4} m.

65. Monochromatic green light of wavelength 5×10^{-7} m illuminates a pair of slits 1 mm apart. The separation of bright lines in the interference pattern formed on a screen 2m away is:
(A) 0.25 mm (B) 0.1 mm
(C) 1.0 mm (D) 0.01 mm.

66. In Young's double slit experiment, the intensity of a bright fringe is:
(A) equal to the intensity of light wave from any one slit
(B) twice the intensity of light wave from any slit
(C) three times the intensity of wave from any slit
(D) four times the intensity of wave from any slit.

67. In Young's double slit experiment. If width (aperture) of the slit S is increased keeping other parameters constant, then the interference fringes will :
(A) remain unchanged
(B) form closer
(C) form further away
(D) gradually disappear.

68. In a Young's double slit experiment, fringe width equal to 1 mm is observed. Then the distance of the nearest bright fringe from the central fringe will be:
(A) 1 mm
(B) 0.5 mm
(C) 2 mm
(D) insufficient data, cannot be determined.

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ANSWER KEY

1.	(B)	2.	(A)	3.	(B)	4.	(B)	5.	(C)
6.	(A)	7.	(C)	8.	(C)	9.	(C)	10.	(A)
11.	(C)	12.	(B)	13.	(C)	14.	(B)	15.	(A)
16.	(A)	17.	(C)	18.	(B)	19.	(D)	20.	(D)
21.	(A)	22.	(B)	23.	(B)	24.	(B)	25.	(A)
26.	(A)	27.	(A)	28.	(A)	29.	(D)	30.	(D)
31.	(C)	32.	(D)	33.	(B)	34.	(C)	35.	(D)
36.	(A)	37.	(B)	38.	(B)	39.	(A)	40.	(B)
41.	(D)	42.	(D)	43.	(C)	44.	(B)	45.	(A)
46.	(B)	47.	(A)	48.	(B)	49.	(B)	50.	(C)
51.	(B)	52.	(B)	53.	(D)	54.	(B)	55.	(A)
56.	(A)	57.	(B)	58.	(A)	59.	(D)	60.	(C)
61.	(B)	62.	(C)	63.	(B)	64.	(D)	65.	(C)
66.	(D)	67.	(D)	68.	(A)				

EXERCISE - III (PREVIOUS YEAR NTSE/OLYMPIAD)

1. When does the total internal reflection take place :-
(A) Refraction from air into any denser medium
(B) Refraction of ray incident from rarer medium
(C) Ray incident from denser medium, with angle of refraction 90°
(D) Ray incident from denser medium with refractive index is [n > 1/(sin of angle of incidence)]

2. Sensitivity of eye is maximum for :-
(A) 4000 Å (B) 8000 Å
(C) 5550 Å (D) 6000 Å

3. A bird in air looks at a fish vertically below it and inside water. x is the height of the bird above the surface of water and y is the depth of the fish below the surface of water. The distance of the fish as observed by the bird is :
(Given m = refractive index of water w.r.t. air) :-
(A) x + y (B) $x + \frac{y}{\mu}$
(C) μx+y (D) μx+μy

4. In the previous question, the distance of the bird as observed by the fish is :-
(A) x + y (B) $x + \frac{y}{\mu}$
(C) μx + y (D) μx+μy

5. An object is placed between two parallel plane mirror. The number of images formed is
(A) four (B) one
(C) two (D) infinite

6. An object is placed between two plane mirrors inclined at some angle to each other. If the number of images formed is 7 then the angle of inclination is
(A) 15° (B) 30°
(C) 45° (D) 60°

7. Which of the following letters do not surface lateral inversion.
(A) HGA (B) HOX
(C) VET (D) YUL

8. A clock hung on a wall has marks instead of numbers on its dial. On the opposite wall there is a mirror, and the image of the clock in the mirror if read, indicates the time as 8.20. What is the time in the clock-
(A) 3.40 (B) 4.40
(C) 5.20 (D) 4.20

9. If you want to see your full image, then minimum size of the mirror
(A) Should be of your height
(B) Should be half of your height
(C) Should be twice of your height
(D) Depends upon distance from the mirror

10. If an object is placed 10 cm in front of a concave mirror of focal length 20 cm, the image will be :–
(A) diminished, upright, virtual
(B) enlarged, upright, virtual
(C) diminished, inverted, real
(D) enlarged, upright, real

11. The magnification m, the image position v and focal length f are related to one another by the relation -
(A) $m = \frac{f-v}{f}$ (B) $m = \frac{f}{f-v}$
(C) $m = \frac{f+v}{f}$ (D) $m = -\frac{f}{f-v}$

12. The relation between magnification m, the object position u and focal length f of the mirror is
(A) $m = \frac{f-u}{f}$ (B) $m = \frac{f}{f-u}$
(C) $m = \frac{f+u}{f}$ (D) $m = \frac{f}{f+u}$

13. v_1 is velocity of light in first medium, v_2 is velocity of light in second medium, then refractive index of second medium with respect to first medium is
(A) v_1/v_2 (B) v_2/v_1
(C) $\sqrt{v_1 / v_2}$ (D) $\sqrt{v_2 / v_1}$

14. The ratio of the refractive index of red light to blue light in air is
(A) Less than unity
(B) Equal to unity
(C) Greater than unity
(D) Less as well as gratert than unity depending upon the experimental arrangement

15. A convex lens of focal length A and a concave lens of focal length B are placed in contact. The focal length of the combination is
(A) A + B (B) (A - B)
(C) $\frac{AB}{(A+B)}$ (D) $\frac{AB}{(B-A)}$

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16. Near and far points of a human eye are
(A) zero and 25 cm (B) 25 cm and 50 cm
(C) 50 cm and 100 cm (D) 25 cm and infinite

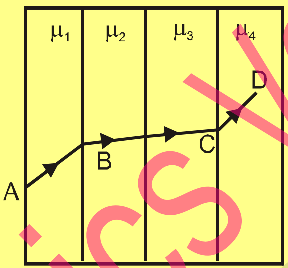
17. The focal length of a concave mirror is f and the distance from the object to the principal focus is x. Then the ratio of the size of the image to the size of the object is-

(A) $\frac{(f+x)}{f}$ (B) $\frac{f}{x}$ (C) $\sqrt{\frac{f}{x}}$ (D) $\frac{f^2}{x^2}$

18. Light travels through a glass plate of thickness t and having refractive index n. If c is the velocity of light in vacuum. the time taken by the light to travel this thickness of glass is :–

(A) $\frac{t}{nc}$ (B) tnc (C) $\frac{nt}{c}$ (D) $\frac{tc}{n}$

19. A ray of light passes through four transparent media with refractive indices m_1, m_2, m_3, and m_4 as shown in the figure. The surfaces of all media are parallel. If the emergent ray CD is parallel to the incident ray AB, we must have:



(A) $m_1 = m_2$ (B) $m_2 = m_3$
(C) $m_3 = m_4$ (D) $m_4 = m_1$

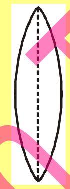
20. Which of the following is used in optical fibres?
(A) Total internal reflection
(B) Scattering
(C) Diffraction
(D) Refraction

21. A convex lens is making full image of an object. if half of lens is covered by an opaque object, then
(A) half image is not seen
(B) full image of same intensity is seen
(C) full image of decreased intensity is seen
(D) half image of same intensity is seen

22. When a thin convex lens is put in contact with a thin concave lens of the same focal length, the resultant combination has a focal length equal to
(A) f/2 (B) 2f (C) 0 (D) ¥

23. Focal length of a convex lens will be maximum for
(A) blue light (B) yellow light
(C) green light (D) red light

24. A convex lens has a focal length f. It is cut into two parts along the dotted line as shown in the figure. The focal length of each part will be

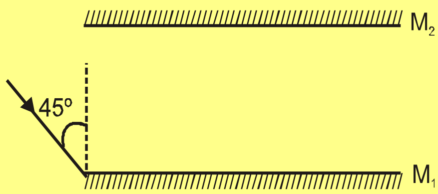


(A) $\frac{f}{2}$ (B) f (C) $\frac{3}{2}$f (D) 2f

25. A normal eye is not able to see objects closer than 25 because
(A) The focal length of the eye is 25 cm
(B) The distance of the retina form 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

26. Myopia can be removed by using a lenses of
(A) concave lens (B) convex lens
(C) cylindrical lens (D) by surgical removal

27. Two plane mirrors M_1 and M_2 each have length 1m and are separated by 1cm. A ray of light is incident on one end of mirror M_1 at angle 45º. How many reflections the ray will have before going at from the other end



(A) 50 (B) 51 (C) 100 (D) 101

28. 'Mirage' is a phenomenon due to :–
(A) relfection of light
(B) reflraction of light
(C) total internal reflection of light
(D) diffraction of light

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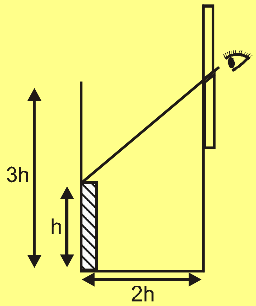
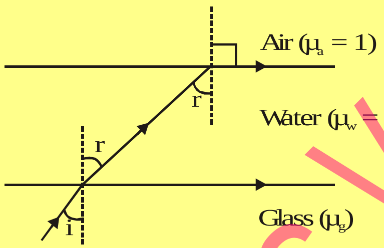
29. An observer can see through a pin-hole the top end of a thin rod of height h, placed as shown in the figure. The beaker height is 3h and its radius h. When the beaker is filled with a liquid up to a height 2h, he can see the lower end of the rod. Then the refractive index of the liquid is–



(A) $\frac{5}{2}$ (B) $\sqrt{\frac{5}{2}}$ (C) $\sqrt{\frac{3}{2}}$ (D) $\frac{3}{2}$

30. A ray of light is incident at the glass-water interface at an angle i. It emerges finally parallel to the surface of water as shown in fig. The value of μ_g would be –

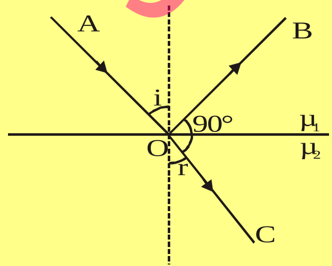


(A) $\left(\frac{4}{3}\right)\sin i$ (B) $\frac{1}{\sin i}$ (C) $\frac{2}{\sqrt{3}\sin i}$ (D) 1.5

31. Two objects A and B when placed in turn in front of a concave mirror of focal length 7.5 cm, give images of equal size. If A is three times the size of B and is placed 30 cm from the mirror, what is the distance of B from the mirror –

(A) 10 cm (B) 12.5 cm
(C) 15 cm (D) 17.5 cm

32. A ray of light in medium of refractive index μ_1 is partly reflected and refracted at the boundary of a medium of refractive index μ_2 as shown fig. If ÐBOC = 90°. The value of angle i is given by –



(A) $\tan^{-1}(\mu_1/\mu_2)$ (B) $\tan^{-1}(\mu_2/\mu_1)$
(C) $\sin^{-1}(\mu_2/\mu_1)$ (D) $\cos^{-1}(\mu_1/\mu_2)$

33. Two transparent media A and B separated by a plane boundary. The speed of light in medium A is 2.0 × 10^8 ms^{-1} and in medium B 2.5 × 10^8 m s^{-1}. The critical angle for which a ray of light going from A to B it totally internally reflected is –

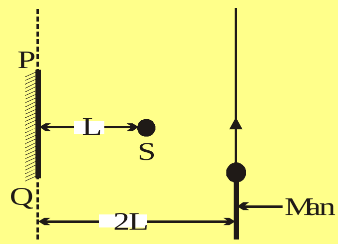
(A) $\sin^{-1}\left(\frac{1}{2}\right)$ (B) $\sin^{-1}\left(\frac{2}{5}\right)$

(C) $\sin^{-1}\left(\frac{4}{5}\right)$ (D) None of these

34. An air bubble in a glass slab (μ = 1.5) is 6 cm deep when viewed through one face and 4 cm deep when viewed through the opposite face. What is the thickness of the slab?

(A) 7.0 cm (B) 7.5 cm (C) 15 cm (D) 10.5 cm

35. A point source of light S is placed at a distance L in front of the centre of a plane mirror PQ of width d hung vertically on a wall as shown in fig. A man walks in front of the mirror along a line parallel to the mirror at a distance 2L from it as shown. The greatest distance over which he can see the image of the light source in the mirror is –



(A) $\frac{d}{2}$ (B) d (C) 2d (D) 3d

36. Two plane mirros, each 1.6 m long, are held parallel and facing each other at a separation of $20\sqrt{3}$ cm. A ray of light is incident at the end of one mirror at an angle of incidence of 30°. The total number of reflections the ray suffers before emerging from the system of mirrors is –

(A) 10 (B) 12 (C) 14 (D) 16

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37. Which of the following statements is/are correct?

(A) The laws of reflection of light hold for plane as well as curved reflecting surfaces.

(B) The size of a virtual image can be measured by receiving it on a screen.

(C) A dentist uses a convex mirror to examine a small cavity.

(D) The focal length of a spherical mirror is half the radius of curvature for all rays.

38. Choose the correct statement(s) from the following:

(A) To a fish under water looking obliquely at a man standing on the bank of lake, the man looks taller than his actual height.

(B) The apparent depth of a tank of water is more for oblique viewing than for normal viewing.

(C) The focal length of a concave mirror will not change if it is immersed in water.

(D) In no situation will a converging lens behave like a diverging lens.

39. An air bubble under water shines brightly because of the phenomenon of –

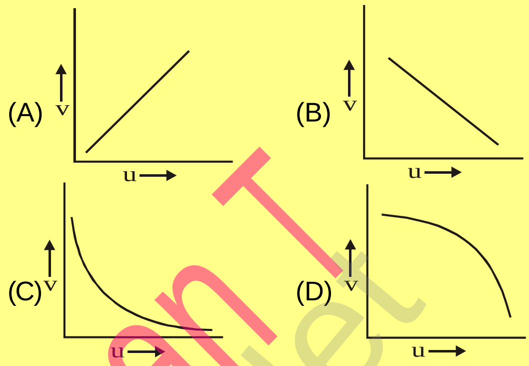
(A) Dispersion

(B) Interference

(C) Diffraction

(D) Total internal reflection

40. The distance v of the real image formed by a convex lens is measured for various object distancesu. A graph is plotted between v and u. Which one of the graphs shown in fig. is approximately correct?



41. The distance of an object from the focus of a concave mirror of focal length f is x and the distance of the real image from the focus is y. Then

(A) $\frac{1}{x}+\frac{1}{y}=\frac{1}{f}$ (B) $\frac{1}{x}-\frac{1}{y}=\frac{1}{f}$

(C) $xy = f^2$ (D) none of these

42. The distance of an object from the focus of a convex mirror of focal length f is x and the distance of the image from the focus is y. Then

(A) $\frac{1}{y}-\frac{1}{x}=\frac{1}{f}$ (B) $\frac{1}{y}+\frac{1}{x}=\frac{1}{f}$

(C) $xy = f^2$ (D) none of these

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ANSWER KEY

1.	(D)	2.	(C)	3.	(B)	4.	(C)	5.	(D)
6.	(C)	7.	(B)	8.	(A)	9.	(B)	10.	(A)
11.	(A)	12.	(B)	13.	(A)	14.	(A)	15.	(D)
16.	(D)	17.	(B)	18.	(C)	19.	(D)	20.	(A)
21.	(C)	22.	(C)	23.	(D)	24.	(D)	25.	(D)
26.	(A)	27.	(C)	28.	(C)	29.	(B)	30.	(B)
31.	(C)	32.	(B)	33.	(C)	34.	(C)	35.	(D)
36.	(C)	37.	(A)	38.	(ABD)	39.	(D)	40.	(C)
41.	(C)	42.	(D)						

EXERCISE - IV (BOARD LEVEL)

1. An object is placed in front of a plane mirror. If the mirror is moved away from the object through a distance x, by how much distance will the image move

2. A ray of light falls on a plane mirror. Show that if the mirror is tilted through an angle q, the reflected ray tilts through an angle 2q.

3. A 2cm high object is placed at a distance of 32cm from a concave mirror. The image is real, inverted and 3cm in size. Find the focal length of the mirror and the position where the image is formed.

4. A ray of light travelling in air falls on the surface of a glass slab. The ray makes an angle of 45° with the normal to the surface. Find the angle made by the refracted ray with the normal within the slab. Refractive index of glass = 3/2.

5. Yellow light of wavelength 590 nm travelling in air is refracted into water $\left(\mu = \frac{4}{3}\right)$. Find the wavelength of this light in water.

6. A cube of edge 6 cm is placed over a printed page. At what distance from the top surface of the cube will be letters appear when seen from above ? Refractive index of glass = 1.5.

7. An object is placed on the principal axis of a concave lens at a distance of 20 cm from it. If the focal length of the lens is also 20 cm, find the location of the image.

8. A beam of light travelling to the principal axis of a concave lens appears to diverge from a point 20 cm behind the lens after passing through the lens. Find the power of the lens.

9. A convex lens of power 4D is placed at a distance of 40 cm from a wall. At what distance from the lens should a candle be placed so that its image is formed on the wall ?

10. A convex lens of focal length 20 cm is placed in contact with a concave lens of focal length 12.5 cm in such a way that they have the same principal axis. Find the power of the combination.

11. A convex mirror used for rear-view on an automobile has a radius of curvature of 3.00 m. If a bus is located at 5.00 m from this mirror, find the position, nature and size of the image.

12. An object, 4.0 cm in size, is placed at 25.0 cm in front of a concave mirror of focal length 15.0 cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image ? Find the nature and the size of the image.

13. A concave lens has focal length of 15 cm. At what distance should the object from the lens be placed so that it forms an image at 10 cm from the lens ? Also, find the magnification produced by the lens.

14. A 2.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the nature, position and size of the image. Also find its magnification.

15. An object placed in front of a diverging mirror at a distance of 30 cm, forms a virtual and erect image which is 1/5 of the size of the object. Calculate : (i) the position of the image, (ii) the focal length of the diverging mirror.

16. A light of wavelength 500 nm in air enters a glass block of refractive index 1.5. Find (a) speed; (b) frequency; (c) wavelength of light in glass. Velocity of light in air is 3×10^8 m/s.

17. Consider a system of two plane mirror inclined to each other at a right angle. Show that when a ray of light is incident on the system, the outgoing ray is parallel to the incident ray and this result is independent of the incident direction.

18. A near sighted person wears eye glass with power of –5.5D for distant vision. His doctor perscribes a correction of +1.5D in near vision section of his bifocals, which is measured relative to main part of the lens.

(i) What is the focal length of his distant viewing part of lens ?

(ii) What is the focal length of near vision section of the lens ?

19. The radius of curvature of a convex mirror used on a moving automobile is 2.0 m. A truck is coming behind it at a constant distance of 3.5 m. Calculate (i) the position, and (ii) the size of image relative to the size of the truck. What will be the nature of the image ?

20. The refractive index of dense flint glass is 1.65, and for alcohol, it is 1.36 with respect to air. What is the refractive index of the dense flint glass with respect to alcohol ?

21. A convex lens forms a real and inverted image of a needle at a distance of 50 cm from the lens.Where is the needle placed in front the convex lens, so that this image is of the same size as the object ? Also, find the power of the lens.

22. A person can not see objects distinctly at distances less than 1 m. Calculate the power of the spectacles lens that he should use in order to read a book at a distance of 25 cm.

23. Name the type of mirror used in the following situations :

(a) Head lights of a car.

(b) Side rear view mirror of a vehicle.

(c) Solar furnace.

Support your answer with reason.

24. What kind of lens can form a (i) Virtual, erect, diminished image? (ii) virtual, erect, magnified image?

25. Which lens has greater power, a convex lens of focal length 10 cm or a convex lens of focal length 20 cm?

26. A man standing in front of a special mirror finds his image having a small face, big tummy and legs of normal size. What are the shapes of three parts of the mirror?

27. Can you change focal length of a given spherical mirror by changing the object distance from the mirror?

28. Can you change linear magnification of a spherical mirror by changing the object distance from the mirror?

29. What is the basic cause of refraction?

30. What are the conditions for no refraction of light?

31. A concave mirror is used as a head mirror by ENT specialists. The same mirror can also be used as a shaving mirror. Why?

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