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PHYSICS

Class 10th (KPK)

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UNIT 12

GEOMETRICAL OPTICS

COMPRHENSIVE QUESTIONS

Give an extended response to the following questions.

Q1. What is meant by reflection of lights? State and explain laws of reflection with diagrams.

Ans: **Reflection of light:**

The bouncing back of light rays from the surface of a certain medium is called reflection of light.

Explanation:

A ray of light travels in one medium (air) but when it falls on the surface of another medium with some angle, it reflects and bounces back to the same medium with same angle. So, the amount of light reflected from the surface of other medium depends upon the nature and smoothness of that surface.

Consider a plane mirror as shown in figure, when a ray of light falls on the shiny surface of plane mirror, it is reflected according to some laws.

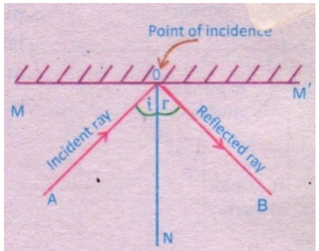


Fig. 12.1 Reflection of Light

Terms related to reflection of light:

To understand the laws of reflection, first we have to know about few terms related to reflection of light which are given below.

1) **Incident Ray:**
   The ray of light which falls on the surface of mirror is called the incident ray. In figure, AO is the incident ray of light
2) **Reflected Ray:**
   The ray of light which is reflected from a reflecting surface (mirror) is called reflected ray. In figure, OB is reflected ray of light.
3) **Point of incidence:**
   The point at which incident ray falls on the reflecting surface (mirror) is called point of incidence. In figure, the point "O" on the surface of mirror is the point of incidence.
4) **Normal:**
   The line drawn at right angles to the reflecting surface at the point of incidence is called normal. In figure, the "ON" is normal to the mirror surface at point "O".
5) **Angle of incidence(θ_i):**
   The angle between the incident ray and the normal is called angle of incidence. It is denoted by "θ_i". In given figure, angle AON is the angle of incidence.
6) **Angle of reflection (θ_r):**
   The angle between the reflected ray and the normal is called angle of reflection. It is denoted by "θ_r". In figure, angle NOB is the angle of reflection.

<u>Laws of reflection of light:</u>

There are two laws of reflection of light, which are given below.

1) **<u>First Law</u>:**

The first law states that the incident ray, the reflected ray and the normal to the surface (at the point of incident), all lie in the same plane.

2) **<u>Second law:</u>**

According to second law of reflection of light, the angle of incidence “θ_i” is always equal to the angle of reflection “θ_r”. i.e.

$$\theta_i = \theta_r$$

Q2. Drive Spherical mirror formula.

Ans. <u>Spherical Mirror Formula:</u>

The spherical mirror formula gives the relation between image distance, object distance and focal length of the spherical mirror.

The following quantities are included in mirror formula:

- f=the focal length of the mirror.
- h_o= the height of object.
- h_i= the height of image.
- d_o= the distance of object from the mirror.
- d_i= the distance of image from the mirror.

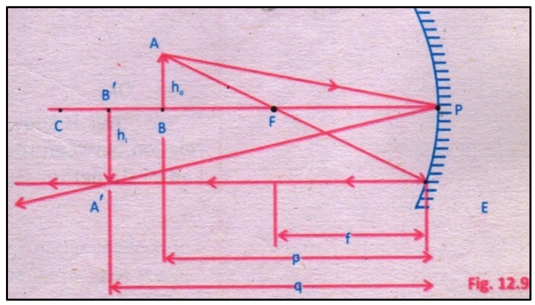


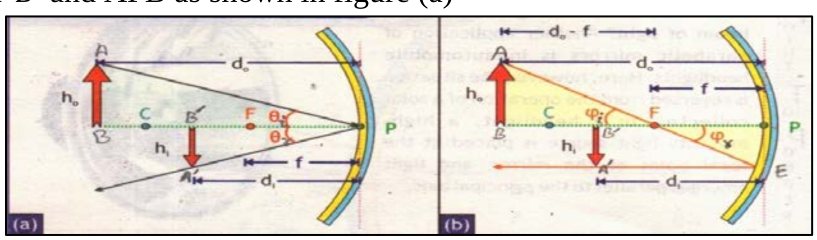
Fig. 12.9

<u>Explanation:</u>

Consider an object “AB” is placed at a distance “d_0” from the pole of the mirror as shown in figure. Let two rays AP and AE, are incident on the mirror, these two rays reflect from the mirror and meet each other and thus produce an image “$A'B'$” as shown in figure. Ray A′P is reflected with the same angle along the direction PA obeying the law of reflection.

<u>Derivation:</u>

Consider two triangles $A'PB'$ and APB as shown in figure (a)



Now in “ ΔAPB” and “$\Delta A'PB'$“,

we have

$\angle\theta_i = \angle\theta_r$ (by law of reflection)

And

$\angle PBA = \angle PB'A'$ (both are right angles)

So, $\Delta APB \cong \Delta A'PB'$

Therefore, the two triangles in this diagram are similar, from which it follows that ratios of equivalent sides of similar triangles are equal.

Thus, we have

$\frac{AB}{A'B'} = \frac{PB}{PB'}$ ------ (1)

From figure "b" we see

AB=h_0 ,$A'B'$= - h_i , PB= d_0 and PB'= d_i

Put above values in eq (1), we get

$\frac{h_o}{-h_i} = \frac{d_o}{d_i}$------------(2)

The image height is negative because it is inverted.

Similarly, ray AE which passes through F become parallel to the principal axis PB.

Now in "ΔABF" and "ΔFPE", we have

∠AFB=∠PFE (opposite angles)

Or

$\angle\varphi_i = \angle\varphi_r$

And

∠ABF=∠EPF (both are right angles)

So ΔABF ≅ ΔFPE

As both triangles ABF and FPE are similar. Thus, by using the same rule of similar triangles we get

$\frac{AB}{EP}=\frac{BF}{FP}$ ------ (3)

Now here, we have

EP= $A'B'$and BF= BP-FP

Eq (3) becomes

$\frac{AB}{A'B'}=\frac{BP-FP}{FP}$ ------ (4)

From Figure, we see

AB= h_0 A′B′= - h_i BP-FP = d_0 – f and FP=f

Put above values in eq (4), we get

$\frac{h_o}{-h_i}= \frac{d_o - f}{f}$ -------- (5)

Comparing equation (2) and (5), we get

$\frac{d_o}{d_i}= \frac{d_o - f}{f}$

By cross multiplication, we get

$d_0 f = d_i(d_0 - f)$

$d_0 f = d_i d_0 - d_i f$ ----- (6)

Dividing both sides of eq (6) by "$d_0 d_i f$",we get

$\frac{d_0 f}{d_0\, d_i f}= \frac{d_i d_0}{d_0\, d_i f}- \frac{d_i f}{d_0 d_i f}$

$\frac{1}{d_i}= \frac{1}{f} - \frac{1}{d_0}$

Rearranging eq, we get

$\frac{1}{f}=\frac{1}{d_0} + \frac{1}{d_i}$

This equation represents spherical mirror formula.

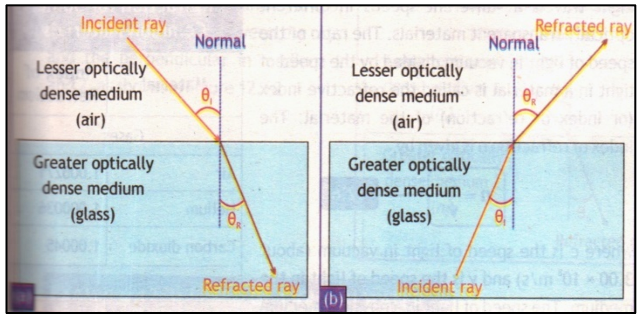
Q3. What is meant by refraction of light? What is the index of refraction? State and explain laws of refraction with diagrams.

Ans: **Refraction of light:**

The change in direction of light as it moves from one medium to another is called refraction of light.

Explanation:

A light travel in straight lines in a transparent medium such as air, if it passes into a different medium, such as water or glass slab, the light rays change their direction (or bond) at the boundary of the two mediums.



Consider a transparent material glass slab as shown in figure, let PQ is the surface of separation between two mediums i.e. air and glass. The rare medium is air and the denser medium is glass. When a ray of light enters from air into the glass, it bends slightly and its direction is changed to OE from its original path "OD".

To understand the laws of refraction, first we have to know about the terms related to refraction of light which are given below.

1) Incident ray:

The ray of light that is entering the boundary between two media is called incident ray. In figure CO is incident ray of light.

2) Refracted ray:

The ray of light that is refracted from the boundary between the two media is called refracted ray. In figure, OE is the refracted ray of light.

3) Point of incidence:

The point at which the incident ray falls on the refracting surface is called point of incidence. In figure, the point "O" on the boundary of glass slab is the point of incidence.

4) Normal:

The line drawn at right angles to the refracting surface at the point of incidence is called normal. In figure, the line NON is the normal to the surface PQ at point O.

5) Angle of incidence (θ_i):

The angle between the incident ray and the normal is called angle of incidence. It is denoted by "θ_i". In figure, angle CON is the angle of incidence.

6) Angle of refraction (θ_r):

The angle between the refracted ray and the normal is called angle of refraction. It is denoted by "θ_r". In figure the angle EON is the angle of refraction.

7) **Optically denser medium:**

A medium having a greater refraction effect is called optically denser medium.

When the light passes from a rare medium to a denser medium (e.g. from air to glass), it bent towards the normal.

When the light passes from denser to rare medium (e.g. from glass to air), it bends away from the normal.

Laws of refraction of light:

There are two laws of refraction of light which are given below.

1) First law of refraction of light:

According to first law, “the incident ray, refracted ray and the normal at the point of incidence, all are lie in the same plane.

2) Second law of refraction of light:

According to second law, “the ratio of sine of angle of incidence and the sine of angle of refraction is constant for a given pair of media”. i.e.

$$\frac{\sin \theta_i}{sin\theta_r} = n - - - - (i)$$

In equation (i), “n” is constant and is known as refractive index of the two transparent medium. The second law of refraction is also called as Snell’s law.

The amount that the light rays changes its direction depends both on the incident angle and the amount that the speed changes. For a ray at a given incident angle, a large change in speed causes a large change in direction, and thus a large change in angle. The exact mathematical relationship is the law of refraction, or “Snell’s law”, which is stated as “the product of the index of refraction of the first medium and the sine of angle of incidence is equal to the product of the index of refraction of the second medium and the sine of angle of refraction”, mathematically

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Refractive Index (n):

The ratio of the speed of light in vacuum (or air) divided by the speed of light in a material (medium) is called the refractive index or index of refraction of the material. It is denoted by “n”. The refractive index is closely related to the velocity of light.

In different medium, light travels with different speed.

Mathematically:

The index of refraction (n) is given by:

$$n = \frac{\text{speed of light in vacuum or air}}{\text{speed of light in any medium}}$$

$$n = \frac{c}{v}$$

Where the value of C in vacuum is equal to 3×10^8m/s. The speed of light in a physical medium such as glass is always less than that the speed of light in vacuum. Therefore, the index of refraction of a material is always greater than or equal to 1. Its value is 1 for vacuum.

Q5. What is total internal reflection? How we can calculate the critical angle for total internal reflection? What are the conditions for total internal reflection?

Ans. **Total Internal Reflection**:

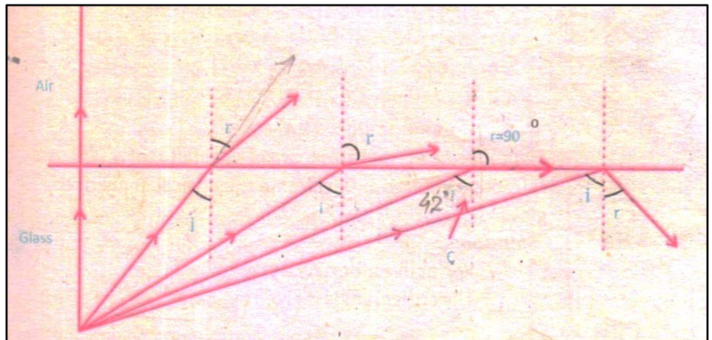


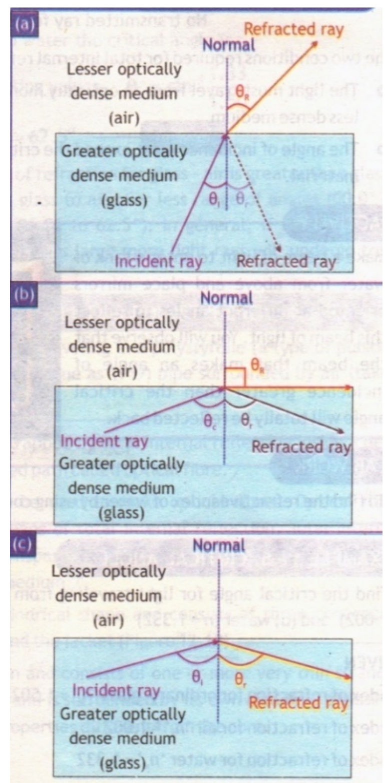
Fig. (12.14) Total Internal Reflection.

When the angle of incidence in the denser medium becomes greater than the critical angle, there is no refracted beam. All the rays are internally reflected back in the optically denser medium. Such a reflection of light is called total internal reflection.

Or

Total internal reflection refers to the complete reflection of a ray of a light within an optically denser medium from the surrounding surfaces of optically less dense media back into the denser medium.

Explanation:



The angle of refraction is larger than the angle of incidence when light passes from a medium of a higher index of refraction (denser medium) into a medium of a lower index of refraction (rare medium), as shown in figure (a). This leads to an interesting phenomenon. As the angle of incidence increases, the angle of refraction also increases.

At a certain angle of incidence "θ_i" known as the critical angle "θ_c", the angle of refraction becomes 90^0 and the refracted light ray lies along the boundary of the two media, as shown in figure (b)

When the light strikes a transparent boundary, even though much of the light is transmitted, some is reflected. Total internal reflection occurs when light traveling from a region of a higher index of refraction (denser medium) to a region of a lower index of refraction (rare medium) strikes the boundary at an angle greater than the critical angle such that all light reflects back into the region of the higher index of refraction (denser medium) as shown in fig (c).

Critical Angle:

To construct an equation for the critical angle of any boundary, we can use Snell's law and substitute $\theta_1 = \theta_c$ and $\theta_2 = 90^0$

$n_1 \sin \theta_c = n_2 \sin 90^0$

Since $\sin 90^0 = 1$

Therefore, $n_1 \sin \theta_c = n_2$

Hence $\sin \theta_c = \frac{n2}{n1}$

Thus we can define critical angle as **"the sine of the critical angle is equal to the index of refraction of the refracting medium divided by the index of refraction of the incident medium".**

No transmitted ray for $\theta_i \geq \theta_c$

<u>Conditions for Total Internal Reflection</u>:

The two conditions required for total internal reflection to occur are as follows.

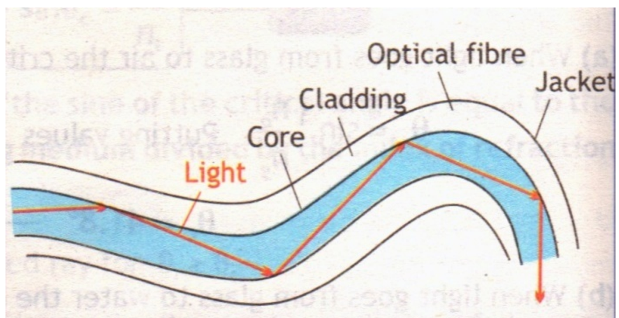
- The light must travel from an optically more dense medium into an optically less dense medium.
- The angle of incidence must exceed the critical angle, θ_c, associated with the material.

Q6. What are optical fibres? Give some applications of optical fibers.

Ans. <u>Optical Fibres:</u>

Light can be trapped by total internal reflection inside a bent glass rod and 'piped' along a curved path called optical fibre.

<u>Construction:</u>



An optical fibre cable has a cylindrical shape and consists of three concentric sections: the core, the cladding and the jacket.

The core is the innermost section and consists of one or more very thin strands, made of glass or plastic. Each strand is surrounded by its own cladding, a glass or plastic coating that has optical properties different from the core. The boundary between the core and cladding acts as a reflector to confine light that would otherwise escape the core. The outermost layer, surrounding one or a bundle of cladded fibres, is the jacket. The jacket is made of plastic and other material layered to protect against moisture, abrasion, crushing and other environmental dangers.

<u>Working:</u>

Various glasses and plastics can be used to make optical fibres. Optical fibre transmits a beam of light by means of total internal reflection. Total internal reflection can occur in any transparent medium that has a higher index of refraction than the surrounding medium. As shown in figure the light traveling through the transparent fibre always hits the internal boundary of the optical fibre at an angle greater than the critical angle, so all of the light is reflected and none of the light is transmitted through the boundary. Thus, the light maintains its intensity over the distance of the fibre.

Applications of optical fibers:

Some of the most popular uses of fiber optics cables are listed below:

1. **Internet:**
Fiber optic cables transmit large amount of data at very high speeds. This technology is therefore widely used in internet cables. As compared to traditional copper wires, fiber optic cables are less bulky, lighter, and more flexible and carry more data.
2. **Cable Television:**
The use of fiber optic cables in the transmission of cable signals has grown explosively over the years. These cables are ideal for transmitting signals for high definition television (HDTV), because they have greater bandwidth and speed. Also fiber optic cables are cheaper as compared to the same quantity of copper wire.
3. **Telephone:**
Calling telephones within or outside the country has never been so easy. With the use of fiber optic communication, we can connect faster and have clear conversations without any lag on either side.
4. **Computer Networking:**
Networking between computers in a single building or across nearby structures is made easier and faster with the use of fiber optic cables. Users can see a marked decrease in the time it takes to transfer files and information across networks.
5. **Mechanical Inspections:**
Fiber optic cables are widely used in the inspection of hard-to-reach places. Some such applications are on-site inspections for engineers and also inspection of pipes for plumbers.
6. **Medical Industry:**
Fiber optic cables are widely used in the field of medicine and research. Optical communication is as important part of non-intrusive surgical methods, popularly known as endoscopy. In such applications, a minute bright light is used to light up the surgery area within the body, making it possible to reduce the number and size of incisions made. Fiber optics are also used in microscopy and biomedical research.
7. **Lighting and Decoration:**
The use of fiber optics in the area of decorative illumination has also grown over the years. Fiber optic cables provide an easy economical and attractive solution to lightning projects. As a result, they are widely used in lighting decorations and illuminating Christmas trees.
8. **Military and space:**
With the high level of data security required in military and aerospace applications, fiber optic cables offer the ideal solution for data transmission in these areas.
9. **Automotive Industry:**
Fiber optic cables play an important role in the lighting and safety features of present day automobiles. They are widely used in lighting, both in the interior and exterior of vehicles. Because of its ability to conserve space and provide superior lighting, fiber optics is used in more vehicles every day. Also, fiber optic cables can transmit signals between different parts of the vehicle at lightning speed.

Q7. Describe the behavior for a ray of light after passing through a prism.

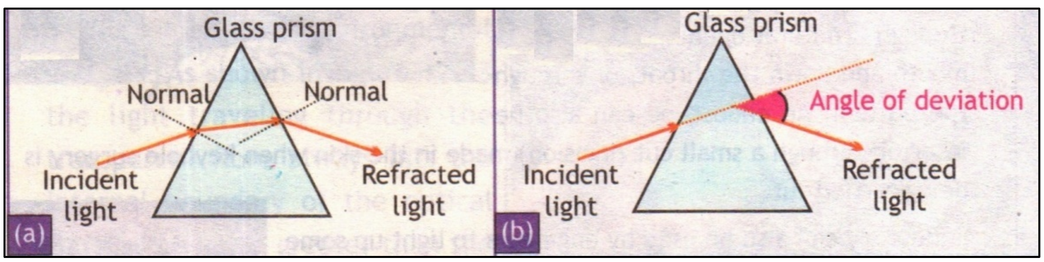
Ans. <u>Refraction of light through a Prism:</u>

A prism is a transparent body having three rectangular and two triangular surfaces. The three rectangular surfaces inclined to each other making a triangular boundary, while the two triangular flat surfaces are parallel to each other.

The angle between the two refracting rectangular surfaces opposite to the base is called the angle of prism (∠A)

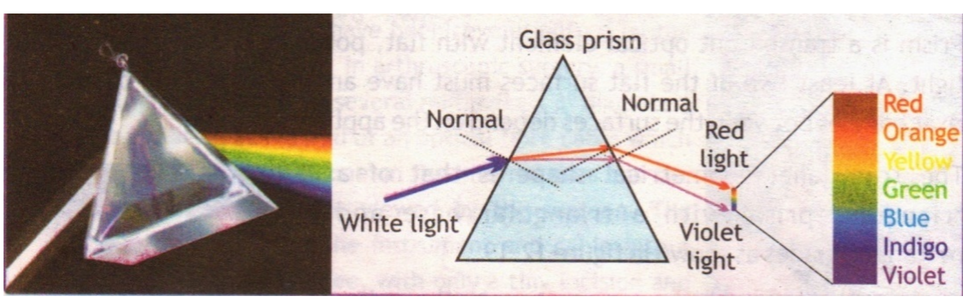
a. Deviation of light through prism:

In the prism shown in Figure, the incident light ray travels through the air and enters the left side of the glass. The light bends toward the normal in the glass, because glass has a higher index of refraction (optical density) than the air. When the light leaves the glass and emerges into the air on the other side of the prism, the light is refracted away from the normal. Notice that the direction of the light leaving the glass is different from that of the light entering it. The change in direction of the light as it passes through the glass is known as its deviation. The amount of change is called the angle of deviation, θ_{dev} as shown in figure the angle of deviation can be determined for any shape of prism by applying Snell's law at each air-glass interface.



b. Dispersion of light through prism:

When sunlight (white light) falls on a triangular glass prism a band of colors called a spectrum is obtained. The effect is termed dispersion. It arises because white light is a mixture of many colours; the prism separates the colours because the refractive index of glass is different for each colour (it is greatest for violet light).



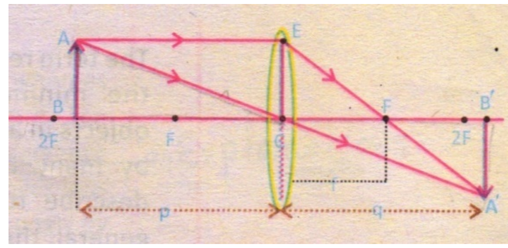
Q8. Derive thin lens equation.

Ans. **Lens Equation:**

The lens equation gives the relation between image distance, object distance and focal length of the given lens. This formula is accurate only if the thickness of the lens is small compared to its diameter.

The following quantities are included in lens formula:

- f=the focal length of the lens.
- h_o= the height of object.
- h_i= the height of image.
- d_o= the distance of object from the lens.
- d_i= the distance of image from the lens.



Explanation:

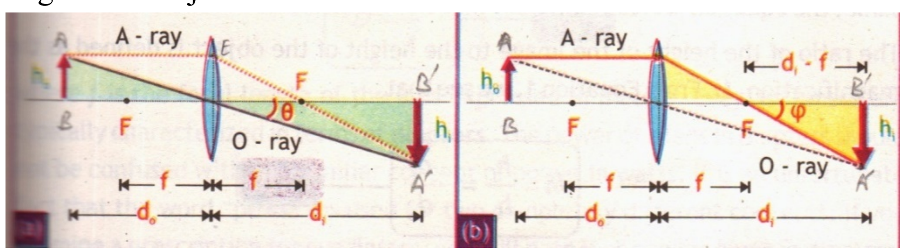
Consider an object "AB" placed at a distance "$d_\circ$" from the optical center "C" of the lens as shown in figure.

Let two rays "AE" and "AC" starts from "A" and meet each other at point "A′" after refraction. Thus "A′B′" becomes the image of the object "AB".

Derivation:

Consider two triangles ABC and A′B′C as shown in fig (a)

Now in "ΔABC" and "ΔA′B′C", we have



∠ABC = ∠A′B′C (both are right angles)

And

∠ACB = ∠A′CB′ (both are opposite angles)

So, ΔABC≅ΔA′B′C

Therefore, the two triangles in their diagram are similar, from which it follows that ratios of equivalent sides of similar triangles are equal.

Thus, we have

$\frac{AB}{A'B'}=\frac{BC}{B'C}$------(1)

From figure, we see

AB = h_0, A′B′ = - h_i ,BC=d_0 , B′C = d_i

Put above values in eq (1), we get

$$\frac{h_0}{-h_i}=\frac{d_0}{d_i}------(2)$$

The image height is taken negative because it is inverted

Now in ΔCEF and ΔA′B′F, we have

∠ECF =∠A′B′F (both are right angles)

∠CFE =∠A′FB′ (both are opposite angles)

So ΔCEF ≅ Δ A′B′F

As both triangles CEF and A′B′F are similar.

Thus by using the same rule of similar triangles, we get

$\frac{EC}{A'B'} = \frac{CF}{FB'}$------(3)

Now here, we have

EC=AB and FB′ = CB′ - CF

Eq (3) becomes

$\frac{AB}{A'B'} = \frac{CF}{CB'-CF}$ ------ (4)

Since

AB=h_0 , A′B′= - h_i , CF=f, CB′-CF= d_i –f

Put above values in eq (4), we get

$$\frac{h_0}{-h_i} = \frac{d_0}{d_i - f} - - - - -(5)$$

Comparing eq (2) and (5), we get

$\frac{d_0}{d_i} = \frac{f}{d_i - f}$

By cross multiplication, we get

$d_0 (d_i – f) = d_i f$

$d_0 d_i - d_0 f = d_i f$ -------(6)

Dividing both sides of eq (6) by "$d_0 d_i f$", we get

$\frac{d_0 d_i}{d_0 d_i f} - \frac{d_0 f}{d_0 d_i f} = \frac{d_i f}{d_0 d_i f}$

$$\frac{1}{f} - \frac{1}{d_i} = \frac{1}{d_0}$$

Rearranging eq, we get

$$\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i}$$

Q9. Describe power of lens and its resolving power. What are its units?

Ans. <u>Power of lens:</u>

A convex lens converges the light rays falling on it whereas a concave lens diverges the light rays falling on it. The power of a lens is a measure of the degree of convergence or divergences of light rays falling on it.

<u>Explanation:</u>

If a convex lens converges a beam of parallel light rays more strongly by focusing them closer to the optical center. It is said to have greater power than another convex lens which focuses the same parallel light rays at a greater distance from the optical center. The power of a lens depends on it focal length. The smaller the focal length the greater is the convergence or divergence power of the lens.

The power of a lens is defined as the reciprocal of its focal length in meters. It is denoted by D.

Power of a lens,

$$D = \frac{1}{\text{Focal length of the lens in (metres)}}$$

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

Unit:

The unit of the power of a lens is diopter. One diopter is the power of a lens whose focal length is 1 meter.

Resolving Power:

Resolving power is the capacity of an instrument to distinctively separate two points which are close together. The sharpness of vision-in particular, the ability to visually separate closely spaced objects-is referred to as resolution.

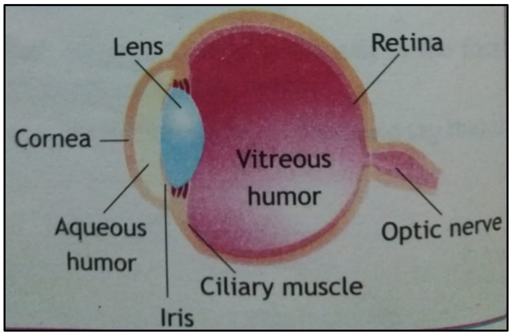
Example:

We see a bright light in the distance that may be the single headlight of an approaching motorcycle or the unresolved image of two headlights on a car. As the car approaches closer, the separation between the lights will increase. As the car continues to approach, its individual headlights become increasingly distinct. So the two points are distinctively separated.

Q10. How the human eye works? How the defects in the eye like short sightedness and long sightedness be corrected by using lenses?

Ans. Human Eye:

The human eye is like a camera in its basic structure, but is more complex. The interior of the eye is filled with a transparent gel-like substance called the vitreous humor with index of refraction n= 1.337. Light enters in this region through the cornea and lens. Between the cornea and lens is a watery fluid, the aqueous humor with n = 1.336. The iris adjusts automatically to control the amount of light entering the eye, similar to a camera.



The retina, which plays the role of the film or sensor in a camera, is on the curved back surface of the eye. The retina in composed of a many nerves which act to change light energy into electrical signals that travel along the nerves to brain for interpretation.

The lens of the eye (n=1.386 to 1.406) does little of the bending of the light rays. Most of the refraction is done at the front surface of the cornea at its interface with air. The lens acts as a fine adjustment for focusing at different distances. This is accomplished by the ciliary muscles, which change the curvature of the lens so that its focal length is changed.

To focus on a distant object, the ciliary muscles of the eye are relaxed and the lens is thin, as shown in figure, and parallel rays focus at the focal point (on the retina). To focus on a nearby object, the muscles contract, causing the centre of the lens to thicken, figure, thus shortening the focal length so that images of nearby objects can be focused on the retina, behind the new focal point. This focusing adjustment is called **accommodation.**

The closest distance at which the eye can focus clearly is called the near point of the eye. For young adults it is typically 25cm, as people grow older, the ability to accommodate is reduced and the near point increases.

A given person's far point is the farthest distance at which an object can be seen clearly. Since we can focus on the Moon and starts, it is clear that the normal far point is essentially infinity. Many people have eyes that do not accommodate within the normal range of 25cm to infinity or have some other defect. Two common defects are short-sightedness and long-sightedness. Both can be corrected to a large extent with lenses-either eyeglasses or contact lenses.

<u>Defects of Vision</u>:

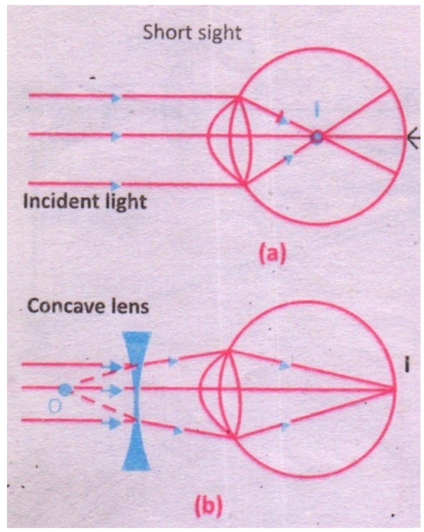
The defects of vision arise due to the inability of the eye lens to produce sharp image at the retina.

There are two main defects of vision.

a) Short – Sightedness (Myopia)

b) Long – Sightedness (Hypermetropia)

<u>(a)</u> <u>Short Sightedness</u>:



Short sightedness is that defect of the eye due to which an eye cannot see the distinct objects clearly though it can see the nearby objects clearly.

Cause:

This defect of eye is caused due to high converging power of the eye-lens, or due to eye ball too long.

<u>Image Formation</u>:

Due to the greater converging power of the eye lens, the image of distinct objects is formed in front of the retina and hence the eye cannot see clearly.

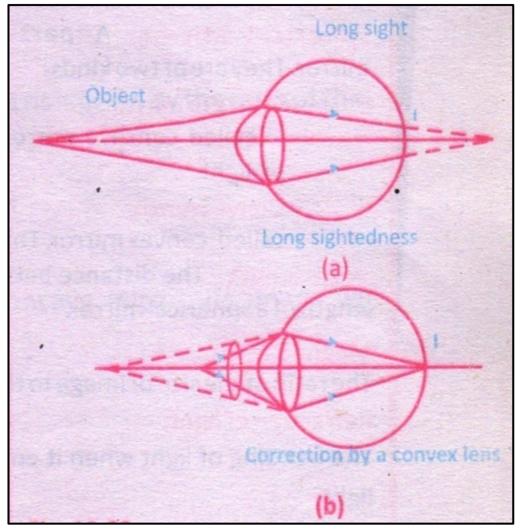
In other cases, in the eye suffering from myopia, the eye-ball is too long due to which the retina is at a larger distance from the eye lens. The condition also results in formation of the image of a distant object in front of the retina.

<u>Correction Method:</u>

This defect can be corrected by using spectacles containing concave lens of suitable power. When a concave lens of suitable power is placed in front of the eye, then the parallel rays coming from distinct object are first diverged by concave lens and then converged on the retina by concave lens and the image of distant object is formed on the retina. Hence eye can see objects clearly.

(b) Long Sightedness:

Long sightedness is that defect of the eye due to which an eye cannot see the nearly objects clearly though it can see the distinct objects clearly.



Cause:

This defect of eye is caused due to low converging power of the eye-lens or due to eye ball too short.

Image Formation:

Due to low converging power of eye lens, the image of nearly objects is formed behind the retina and hence the eye cannot see clearly.

In other cases, in an eye suffering from hyperopia the eye-ball is too short due to which the retina is at a smaller distance from the eye lens. This condition also results in the formation of the image of a nearby object behind the retina.

Correction Method:

This defect can be corrected by using spectacles containing convex lens of suitable power. When a convex lens of suitable converging power is placed in front of the eye, then the rays coming from the nearby objects are first converged by convex lens and then by the eye lens. Due to combined converging action, the image of the nearby objects is formed at retina. Hence eye can see objects clearly.

Q11. What is a simple microscope? Using a ray diagram explain its working, angular magnification and magnifying power.

Ans. Simple Microscope:

A simple microscope is a convex lens of short focal length. It is also called magnifying glass.

Working Principal:

It works on the principal that when the object is placed with in its focal length, a magnified, virtual and erect image is formed.

Working: (Explanation)

The simple microscope is an ordinary convex lens of small focal length which is held closer to eye for magnifying the image.

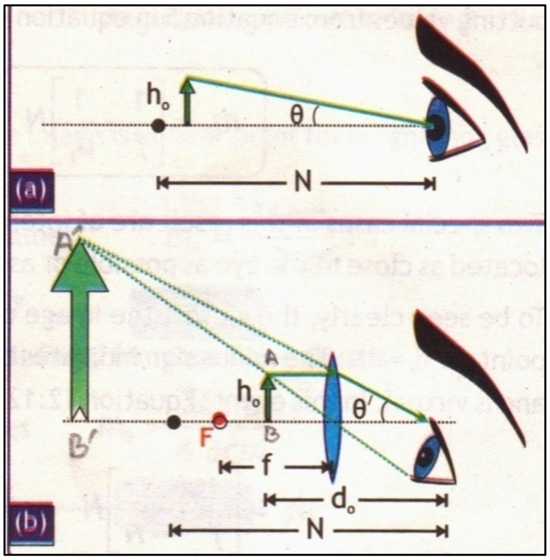
Now consider an object "AB" is placed between the lens and its focus as shown in figure. The lens forms a magnified, virtual and erect image "$A'B'$" of the object "AB" which can be see clearly by an eye which is held closer to the lens.

Angular Magnification: (Magnifying Power)

The angular magnification (or magnifying power) m_θ is the angular size θ' of the final image produced by the instrument divided by a reference angular size θ. The reference angular size is the angular size of the object when seen without the instrument.

Angular Magnification = $\dfrac{\textit{Angular size of final image produced by optical instrument}}{\textit{Reference angular size of object seen without optical instrument}}$

$$m_\theta = \frac{\theta'}{\theta} \ldots\ldots\ldots (1)$$



Consider an object of size AB=h_o placed at a distance "N" from eye without using magnifying glass as shown in **figure (a)**

So, we have

$\tan\theta' = \frac{Perpendicular}{Base}$

$\Longrightarrow \tan\theta' = \frac{h_0}{d_0}$---------(3)

Hence "θ" and "θ'" are very small angles, so we put tan θ and θ and tan θ'=θ',

So, eq (2) and eq (3) can be written as

$\theta = \frac{h_0}{N}$---------(4)

$\theta' = \frac{h_0}{d_0}$---------(5)

Thus, by putting eq (4) and eq (5) in eq (1), we get

$m_\theta = \frac{\left(\frac{h_0}{d_0}\right)}{\left(\frac{h_0}{N}\right)}$

$m_\theta = \frac{h_0}{d_0} \text{x} \frac{N}{h_0}$

$\Longrightarrow m_\theta = \frac{N}{d_0}$--------(6)

According to the thin-lens equation, we have

$\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i}$

Or

$\frac{1}{d_0} = \frac{1}{f} - \frac{1}{d_i}$------(7)

Putting values from eq (7) in eq (6), we get

$m_\theta = \left[\frac{1}{f} - \frac{1}{d_i}\right]$ N --------(A)

Equation (A) represents the angular magnification of simple microscope.

Special cases:

Two special cases of this result, depending on whether the image is located as close to the eye as possible or as far away as possible.

Case-1:

For nearer image, we put

d_i=-N

The minus sign indicates that the image lies to the left of the lens and is virtual.

So eq (A) becomes

$m_\theta = \left[\frac{1}{f} - \frac{1}{(-N)}\right]N$

$m_\theta = \left[\frac{1}{f} + \frac{1}{N}\right]N$

$m_\theta = \frac{N}{f} + \frac{N}{N}$

$\Rightarrow m_\theta = \frac{N}{f} + 1$--------(8)

<u>Case 2:</u>

For farthest image, we put

$d_i = \infty$

So eq (A) becomes

$m_\theta = \left[\frac{1}{f} - \frac{1}{\infty}\right]N$

$m_\theta = \left[\frac{1}{f} - 0\right]N \left(\because \frac{1}{\infty} = 0\right)$

$m_\theta = \frac{N}{f}$--------(9)

Q.12What is a compound microscope? Using ray diagram for a compound microscope, mention its magnifying power.

Ans: <u>Compound Microscope:</u>

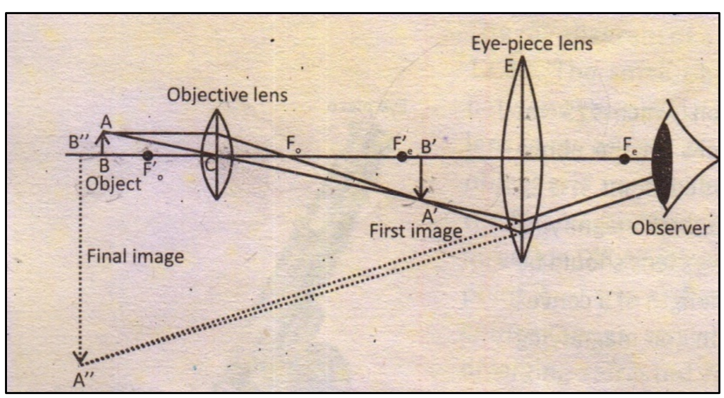
The compound microscope is an instrument which is used for observing small objects clearly.

Or

To increase the angular magnification beyond that possible with a magnifying glass, an additional converging lens can be included to "premagnify" the object before the magnifying glass comes into play. The result is an optical instrument known as the compound microscope. The magnifying glass is called the eyepiece and the additional lens is called the objective.

<u>Working:</u>

The objective lens forms a real, inverted image "$A'B'$", if an object "AB" placed beyond the focus of objective. This image "$A'B'$" acts as a real object for the eye-piece, which produces final virtual and magnified image "$A''B''$" , as shown in **(figure).**



<u>Magnifying Power:</u>

The magnifying power of a compound microscope is the product of the magnifications produced by the two lenses. (objective and eye-piece)

i.e. $m = M_o \times m_e$ --------- (i)

Now, the magnification produced by objective lens. For this, the object to be examined is placed only a small distance beyond the focal point of the objective "f_o", which means that $d_o \approx f_o$. The magnification "M_o" produced by the objective is given by

$M_o = -\frac{h_i}{h_o}$

$\Rightarrow M_o = -\frac{d_i}{d_o}$

Putting $d_o = f_o$ in above equation

$M_o = -\frac{d_i}{f_o}$ ---------- (2)

The negative sign shows that the image is inverted.

Here the eye-piece acts like a simple magnifier or simple microscope. If we assume that the eye is relaxed, the eyepiece angular magnification "m_e" will be

$m_e = \frac{N}{f_e}$ ------------ (3)

Putting the eq (2) and eq (3) in eq (1), we get

$m = -\frac{d_i}{f_o} \times \frac{N}{f_e}$ ------------ (4)

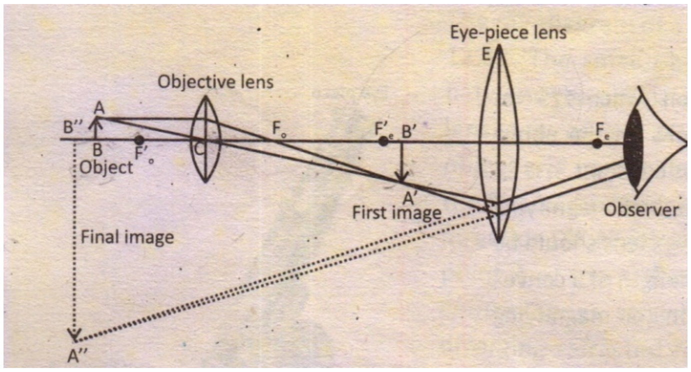
The minus sign indicates that the image is inverted. Equation (4) represents the magnifying power of compound microscope.

Q13.What is telescope? Using a ray diagram explain its working angular magnification and magnifying power.

Ans: <u>Telescope:</u>

A telescope is an instrument for magnifying distant objects, such as stars and planets.

A telescope consists of two convex lenses. (Objective and eye-piece). These lenses are filled at the outer ends of the two metal tubes which can slide into one another. The objective lens is of large focal length and the eye-piece is of short focal length.



<u>Working:</u>

The objective lens forms real and inverted image "$A'B'$" of an object "AB" which is placed at infinity. This image ($A'B'$) acts as an object for the eye-piece which forms a magnified image"$A''B''$". The final image is virtual, magnified and formed at infinity.

<u>Magnification:</u>

Since the object is far away, the angular size seen by the unaided eye is nearly the same as the angle θ subtended at the objective of the telescope as shown in **(figure).**

The angular size of the image formed by the objective lens is given by

$\theta = -\frac{h_i}{f_o}$ ----------- (1)

Here h_i is the height of the first image and f_o is the focal length of the objective. The minus sign shows that image is inverted.

The image of the objective is the object for the eyepiece which is basically a magnifier. Thus, if the image of the objective is placed at the focal point of the eye piece, it will form an image that is at infinity, as show in figure and the observer can view the final image of the telescope with a completely relaxed eye.

The angular size of the image formed by the eyepiece is approximately. ″

$$\theta' = \frac{h_i}{f_e} \text{ ----------- } (2)$$

To find the total angular magnification of the telescope, we consider the definition of angular magnification as

$$m_\theta = \frac{\theta^/}{\theta} \text{ ----------- } (3)$$

Putting eq (1) and eq (2) in eq (3), we get

$$m_\theta = \frac{\frac{h_i}{f_e}}{-\frac{h_i}{f_o}}$$

$$m_\theta = -\frac{h_i}{f_e} \times \frac{f_o}{h_i}$$

$$\Longrightarrow m_\theta = -\frac{f_o}{f_e} \text{ -------- } (4)$$

Equation (4) represents the magnifying power of telescope.

Length of telescope:

The distance between two lenses gives the length of telescope. The length of telescope in normal adjustment is

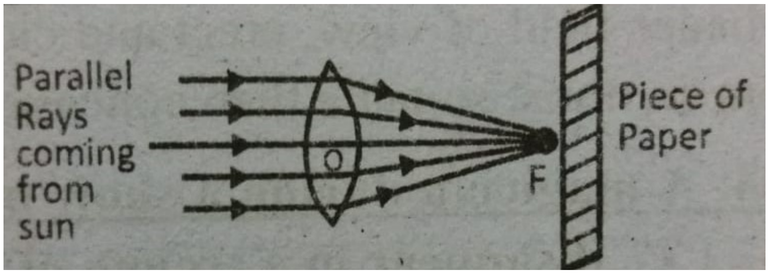
$L = f_o + f_e$

CONCEPTUAL QUESTIONS

Give a brief response to the following questions.

Q1. Which type of lens would you use to start fire from light from sun concave or convex, would work best? At what distance from the lens should the paper be held for best results?

Ans: We will use a convex lens to start fire from light of sun. A convex lens focuses or converges the parallel sun rays to a single point after refraction through the lens. The focusing point is known as principle focus “F”. The paper should be placed at a distance equal to the focal length of the lens. The lens converge sunlight on the paper. After sometime the paper heat up and catches fire instantly.



Q2. If a concave mirror produces a real image, is the image necessarily inverted? Explain.

Ans: **A** real image is an image formed when light rays actually pass through the point where the image is formed. Real image can be produced by a concave mirror only if the object is placed beyond focal point (F) of the mirror. This real image will always be inverted. This is because a concave mirror focuses light rays, thus inverting the real image. However, if the object is placed between pole "P" and focus "F", the image formed will be upright and virtual not real. That is why it is said that a real image formed by a concave lens will always be inverted.

Q3. Are rearview mirrors use in cars concave or convex?

Ans. Convex mirrors are useful for rare view in vehicles, as they provide a larger field of view than the concave mirror. Convex mirrors give erect, virtual and diminished image of distant objects with a wider field of view.

On the other hand, concave mirror forms inverted images of the distant objects with a smaller field of view. Thus for a broader field of view, erect and clear images, convex mirrors are used.

Q4. A magician during a show makes a glass lens with n=1.47 disappear in a trough of liquid. What is the refractive index of the liquid? Could the liquid be water?

Ans. The refractive index of the liquid should be equal to the refractive index of glass lens (i.e. 1.47) for it to disappear in the liquid. Because if the lens is surrounded by liquid having the same refractive index as the lens, then no reflection and no refraction occurs and the lens becomes invisible.

The liquid could not be water because the refractive index of water is 1.33 which is much less than that of glass lens. It can be glycerin or turpentine both are "clear" liquid with their refractive index equal to 1.47.

Q5. Suppose that you were handed a lens and a ruler and told to determine the focal length of the lens. How would you proceed?

Ans. We can easily find the focal length of a lens using ruler (or meter rod). In open air, make the rays focused on a wall (finding the point where the all rays are concentrated, which will be the principal focus of lens) and measure the distance between the lens and the wall with the help of meter rod. This will be the focal length of the given lens.

Q6. Can we achieve total internal reflection from optically rare medium to optically dense medium?

Ans. No, we cannot achieve total internal reflection when light travels from optically rare medium to optically dense medium. For total internal reflection the following conditions must be satisfied.

1. The incident light must pass from an optically dense medium into an optically rare medium (e.g from water to air or from glass to air).

2. The angle of incidence in denser medium must be greater than the critical angle of the medium. Thus total internal reflection will not take place if light is travelling from optically rare medium to optically dense medium (e.g from air to water).

Q7. Will a nearsighted person who wears corrective lenses in her glasses be able to see clearly underwater when wearing those glasses?

Ans. She will not see clearly under water when wearing those glasses because of the different refractive index of water than air.

Water has a refractive index of 1.33 which is much greater than that of air (1.002). The high refractive index of water affects the refraction of light rays due to which she (near sighted person) will not be able to see clearly in water by wearing glasses having corrective lenses.

Q8. When you use a simple magnifying glass, does it matter whether you hold the object to be examined closer to the lens that its focal length or farther away? Explain.

Ans. A double convex lens may be used as a simple magnifying glass (or simple microscope). A convex lens always forms a real and inverted image on the opposite side of the lens, when the object is place away from the focal point. For virtual, erect and magnified image, the object should be placed within the focal length of the lens.

Thus, to use a simple magnifying glass, the object should lie within the focal length of the lens, so that to get an erect, enlarged and virtual image of the object.

Q9. In blind turns on hilly roads, mirrors are used to help drivers. Are these mirrors plane mirrors, concave mirrors or convex mirrors? Explain.

Ans. Convex mirrors are generally used at blind corners, as they give a wider field of view. They also form erect, virtual and diminished images of objects lying away from the focal point.

On the other hand, plane mirrors form erect images of the same size reducing the field of view. And concave mirrors form erect and virtual images only when the object lie within its focal length. So, only convex mirrors are used at blind turns on hilly roads to help drivers for safe driving.

ASSIGNMENTS

12.1) A dentist uses a concave mirror with focal length 2.0cm to examine some teeth. If the tooth under examination is 1.1cm high and mirror is place at 0.9 cm. Calculate the distance of image formed, the height of the image and magnification.

Given Data:

Focal length = f = 2cm

Height of object (tooth) = h_o=1.1cm

Distance of object = d_o= 0.9 cm

Required:

a) Distance of image = d_i= ?
b) Height of image = h_i =?
c) Magnification = M = ?

Solution:

(a) As it is knowing that

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$=> \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$

$=> \frac{1}{d_i} = \frac{d_o - f}{f\, d_o}$

$=> d_i = \frac{f d_o}{d_o - f}$---------eq(i)

Putting values in equation (i), we get

$d_i = \frac{2 \times 0.9}{0.9 - 2}$

$d_i = \frac{1.8}{-1.1}$

$\boxed{d_i = -1.64 \text{ cm}}$

(b) Using Formula

$\frac{h_i}{h_o} = \frac{d_i}{d_o}$

By cross multiplication

$h_i \times d_o = d_i \times h_o$

Dividing "d_o" on both sides

$\frac{h_i \times d_o}{d_o} = \frac{d_i \times h_o}{d_o}$

$h_i = \frac{d_i \times h_o}{d_o}$....................(ii)

Putting values, in eq (ii), we get

$h_i = \frac{-1.64 \times 1.1}{0.9}$

$h_i = \frac{-1.804}{0.9}$

h_i = -2.0cm

(c) we know that

M = $\frac{h_i}{h_o}$ ---------------------eq(iii)

Putting values in eq (iii), we get

M = $\frac{-2.0}{1.1}$

M = -1.8

Q12.2: A convex security mirror in a warehouse has a -0.50m focal length. A 2.0m tall forklift is 5.0m from the mirror. What is the image position and image height?

Given Data:

Focal length =f = -0.50m

Height of object= h_o= 2m

Distance of object = d_o= 5.0m

Required:

a) Image position (distance)=d_i=?

b) Height of image=h_i=?

Solution:

(a)As we know that

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$=> \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

$$=> \frac{1}{d_i} = \frac{d_o - f}{f d_o}$$

$$=> \quad d_i = \frac{f d_o}{d_o - f} \text{..................(i)}$$

Putting values in eq (i), we get

$$d_i = \frac{-0.50 \times 5.0}{5.0 - (-0.50\ )}$$

$$d_i = \frac{-2.5}{5.0 + 0.50}$$

$$d_i = \frac{-2.5}{5.50}$$

d_i= - 0.45

The image is virtual and formed behind the mirror.

(b) We know that

$$\frac{h_i}{h_o} = \frac{d_i}{d_o}$$

by cross multiplication

$h_i \times d_o = d_i \times h_o$

Dividing "d_o" on both sides

$$\frac{h_i \times d_o}{d_o} = \frac{d_i \times h_o}{d_o}$$

$$=> h_i = \frac{d_i \times h_o}{d_o} \text{......................(ii)}$$

Putting values in eq (ii), we get

$$h_i = \frac{-0.45 \times 2}{5.0}$$

$$h_i = \frac{-0.9}{5.0}$$

$$h_i = \boxed{- 0.18\text{m}}$$

Q2.3: If the speed of light in kerosene oil is 2.08 × 10^8 m/s, calculate the index of refraction.

Given that:

Speed of light in kerosene oil = v = 2.08 × 2.08 × 10^8 m/s

Speed of light in vacuum = c = 3 × 10^8 m/s

Required:

Index of refraction = n= ?

Solution:

As we know that,

n = $\frac{c}{v}$

Putting values

n = $\frac{3\times10^8}{2.08\times10^8}$

n =$\frac{3}{2.08}\times 10^{8-8}$

n = 1.44 × 10°

n = 1.44 × 1 $(\therefore 10^\circ = 1)$

n = 1.44

Q 12.4: Find the index of refraction for medium 2, if medium 1 in air with index of refraction n_a= 1.00, the incident angle is 30.0° and the angle of refraction is 22.0°. Compare the result with the table and identify the nature of medium 2.

Given data:

Refractive index of air = n_1 = 1.00

Angle of incidence = θ_1= 30.0°

Angle of refraction = θ_2= 22.0°

Required:

Refractive index of medium 2 = n_2 =?

Solution:

As, we know that

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

=> $n_2 \sin\theta_2 = n_1 \sin\theta_1$

Dividing "sin θ_2" on both sides

$\frac{n_2 \sin\theta_2}{\sin\theta_2} = \frac{n_1 \sin\theta_1}{\sin\theta_2}$

=> $n_2 = \frac{n_1 \sin\theta_1}{\sin\theta_2}$ …………………..(i)

Putting values in eq (i), we get

$n_2 = \frac{1.00\times\sin 30.0^\circ}{\sin 22.0^\circ}$

$n_2 = \frac{1.00\times0.5}{0.375}$

$n_2 = \frac{0.5}{0.375}$

n_2 = 1.33

If we compare the values of “n_2" with the table, it match with refractive index of water, so the medium 2 is water.

Q12.5: What is the critical angle for light traveling in a polystyrene (a type of plastic with index of refraction for polystyrene as 1.49) pipe surrounded by air (take index of refraction of air to be 1.00)?

Given Data:

Refractive index of polystyrene = n_1 = 1.49

Refractive index of air = n_2 = 1.00

Required:

Critical angle = θ_c= ?

Solution:

We know that

$\sin\theta_c = \frac{n_2}{n_1}$

Putting values

$\sin\theta_c = \frac{1.00}{1.49}$

$\sin\theta_c = 0.671$

=> $\theta_c = \sin^{-1}(0.671)$

$\theta_c = 42.14°$

$\boxed{\theta_c = 42.2°}$

Q 12.5: An object is placed 30.0 cm in front of a converging lens and then 12.5 cm in front of a diverging lens. Both lenses have a focal length of 10.0cm. For both cases, find the image distance and the magnification. Describe the images.

Given Data:

a) Object distance from convex lens = d_o= 30.0cm
b) Object distance from concave lens = d_o =12.5

Focal length = f = 10cm

Required:

a) Image distance =d_i= ?
Magnification = M = ?
b) Image distance = d_i= ?
Magnification = M = ?

Solution:

a) As, we know that

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

=> $\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$

$$\frac{1}{d_i} = \frac{d_o - f}{f d_o}$$

$=> d_i = \frac{f d_o}{d_o - f}$ ……………………..(i)

putting values in eq (i), we get

$$d_i = \frac{10 \times 30}{30 - 10}$$

$$d_i = \frac{300}{20}$$

$$d_i = \boxed{15\ \text{cm}}$$

Now for magnification, using formula

M = $-\frac{d_i}{d_o}$

Putting values

M = $-\frac{15}{30}$

M = $\boxed{-0.5}$

Therefore, when the object distance is greater than twice the focal length (d_o> 2f), for convex lens:

- The image distance is less than twice the focal length | (i.e. 15cm < 20cm)
- The image is real (distance positive)
- The image is inverted (magnification negative)
- The image is smaller than the object (magnification is less than 1)

(b) Putting values in eq (i), we get

Here f = -10cm (for concave lens)

$$d_i = \frac{f d_o}{d_o - f}$$

$$d_i = \frac{-10 \times 12.5}{12.5 - (-10)}$$

$$d_i = \frac{-125}{12.5 + 10}$$

$$d_i = \frac{-125}{22.5}$$

d_i = -5.555cm

or

d_i= $\boxed{-5.56\text{cm}}$

Now for magnification, using formula

M = $-\frac{d_i}{d_o}$

Putting values

M = $-\frac{(-5.56)}{12.5}$

M = $\frac{+5.56}{12.5}$

M = 0.4448

OR

M = $\boxed{0.445}$

Therefore, in a concave lens, the image is virtual, erect and smaller in size than object.

Q12.7: An 8cm focal length converging lens is used as a jeweler's loupe, which is a magnifying glass. Estimate the magnification (a) when the eye is relaxed, and (b) if the eye is focused at its near point.

Given Data:

Focal length = f = 8cm

Near point distance = N = 25cm

Required:

a) Magnification (when eye is relaxed) = m_θ= ?
b) Magnification (when eye is focused at its near point = m_θ= ?

Solution:

(a) Magnification (when eye is relaxed) is given by formula,

$m_\theta = \frac{N}{f}$……………………(i)

Putting values in eq (i), we get

$m_\theta = \frac{25}{8}$

m_θ= 3.12

0r

m_θ= $\boxed{\text{3 times}}$

(b) Magnification (when eye is focused at its near point) is given by formula

$m_\theta = \frac{N}{f} + 1$ …………………(ii)

Putting values in eq (ii), we get

$m_\theta = \frac{25}{8} + 1$

m_θ= 3.12 + 1

m_θ = 4.12

or

m_θ= 4

m_θ = $\boxed{\text{4 times}}$

Q 12.8: If the focal length of the eye piece is increased, does the magnitude of the magnification increase or decrease. Check your response by calculating the magnification when the focal length of the eyepiece is 3.5cm.

Given Data:

We used data given in example (12.8)

Focal length of objective = f_o=1.0cm

Near point distance = N =25cm

Object distance = d_o = 1.1cm

Focal length of eyepiece =f_e = 3.5cm

Required:

a) Effect on magnification =?
b) Magnification = m = ?

Solution:

First we fine image distance by using formula,

$$\frac{1}{f_o} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$\frac{1}{d_i} = \frac{1}{f_o} + \frac{1}{d_o}$$

$$\frac{1}{d_i} = \frac{d_o - f_o}{f_o d_o}$$

$$=> d_i = \frac{f_o d_o}{d_o - f_o}$$

$$d_i = \frac{1.0 \times 1.1}{1.1 - 1.0}$$

$$d_i = \frac{1.1}{0.1}$$

d_i =11cm

Now, we know that magnification of compound microscope is given by,

$$m = -\frac{d_i}{f_o} \times \frac{N}{f_e} \ldots\ldots\ldots\ldots\ldots\ldots\text{(i)}$$

Eq (i) shows that the magnification of compound microscope is inversely proportional to the focal length of eye piece $'f_e'$.

i.e. if the focal length of eye-piece is increased then the magnification will be decreased.

(b) Now, find the magnification.

Putting the values of eq (i), we get

$$m = -\frac{11}{1.0} \times \frac{25}{3.5}$$

$$m = -\frac{275}{3.5}$$

m = -78.57

m = -78.6

m = -79

Q.12.9: An astronomical telescope has the following specifications: f_o= 985 mm and f_o = 5.00mm. From these data points, find (a) the angular magnification and (b) the approximate length of this telescope.

Given data:

Focal length of objective = f_o = 985mm

Focal length of eye piece = f_e = 5.00mm

Required:

a) Angular magnification = m_θ= ?

b) Length of telescope = L = ?

Solution:

a) We know that, the angular magnification of telescope is given by,

$m_\theta = -\frac{f_o}{f_e}$

putting values

$m_\theta = -\frac{985}{5.00}$

$m_\theta = -197$

b) Also we know that, the length of telescope is given by,

$L = f_o + f_e$

Putting values

L = 985 + 5.00

L = $\boxed{990mm}$

NUMERICAL PROBLEMS

Q1. A 1.50cm high object is placed 20.0cm from a concave mirror with radius of curvature 30.0cm. Determine (a) the position of the image, and (b) its size, also draw the ray diagrams.

Given Data:

Height of object = h_o = 1.50cm

Distance of object = d_o = 20cm

Radius of curvature = R = 30cm

Required:

a) Position of image = d_i = ?

b) Size of image = h_i = ?

Solution:

a) As we know that

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$=> \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$

$\frac{1}{d_i} = \frac{d_o - f}{f d_o}$

$=> d_i = \frac{f d_o}{d_o - f}$ …………………(i)

First we find focal length. So for focal length, we have

f = $\frac{1}{2}$ R

Putting values

f = $\frac{1}{2} \times 30$

f = $\boxed{15cm}$

Now, putting values in eq (i), we get

$d_i = \frac{15 \times 20}{20 - 15}$

$d_i = \frac{300}{5}$

$d_i = \boxed{60cm}$

(b) Now, using formula

M= $\frac{h_i}{h_o}$………………(ii)

Also

M=$\frac{d_i}{d_o}$………………(iii)

Comparing eq (ii) and (iii), we get

$\frac{h_i}{h_o} = \frac{d_i}{d_o}$

$h_i = \frac{d_i}{d_o} \times h_o$……………………….(iv)

Putting values in eq (iv), we get

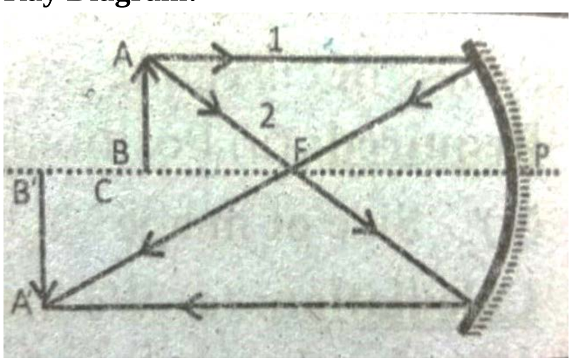
$h_i = \frac{60}{20} \times 1.50$

$h_i = \frac{60 \times 1.50}{20}$

$h_i = \frac{90}{20}$

$h_i = \boxed{4.5cm}$

Ray Diagram:



Q2. A candle of height 8.0cm is located at a distance of 300 mm from a convex mirror, its virtual image is formed behind the mirror at a distance of 3.0cm from the pole (or vertex). Find the focal length of the mirror and height of the image formed.

Given Data:

Height of object= h_o = 8.0cm

Distance of object = d_o = 300mm

$= \frac{300}{10}$cm

d_o =30cm

Distance of image = d_i = -3cm

Required:

Focal length= f =?

Height of image=h_i=?

Solution:

(a) We know that

$\frac{1}{f}= \frac{1}{d_o}+ \frac{1}{d_i}$……………………….(i)

Putting values in eq (i), we get

$\frac{1}{f}= \frac{1}{30}+ \frac{1}{-3}$

$\frac{1}{f}= \frac{1}{30}- \frac{1}{3}$

$\frac{1}{f} = \frac{1-10}{30}$

=> $\frac{1}{f}= \frac{-9}{30}$

=>f = $\frac{-30}{9}$

f = $\boxed{-3.33cm}$ (-ive sign is because of convex mirror)

(b) We know that

M= $\frac{h_i}{h_o}$……………………………..(ii)

And also,

M = $\frac{d_i}{d_o}$……………………………..(iii)

Comparing eq (ii) and (iii)

$\frac{h_i}{h_o}= \frac{d_i}{d_o}$

$h_i= \frac{d_i}{d_o}\times$ h_o……………………(iv)

Putting values in eq(iv)

$h_i = \frac{-3}{30} \times 8.0$

$h_i = \frac{-24}{30}$

h_i= $\boxed{-0.8cm}$

Q3. Calculate the speed of light is zircon with index of refraction n = 1.923, a material used in jewelry to replicate diamond.

Given that:

Speed of light in vacuum = c = 3× 10^8m/sec

Refractive index = n = 1.923

Required:

Speed of light in zircon = v =?

Solution:

By using formula

$n = \frac{c}{v}$

$v = \frac{c}{n}$……………………………………..(i)

Putting values in eq (i) we get

$v = \frac{3\times10^8}{1.923}$

$v = \frac{3}{1.923} \times 10^8$

$v = 1.56 \times 10^8$ m/sec

So, speed of light in zircon is 1.56×10^8 m/sec

Q**4. A light ray strikes an air / water surface at an angle of 46º with respect to the normal. The refraction index of water is 1.33. Find the angle of refraction when the direction of ray is (a) from air to water and (b) from water to air.**

Given Data:

Angle of incidence = θ_i = 46°

Refractive index of air = n_{air}=1.00

Refractive index of water = n_w=1.33

Required:

a) Angle of refraction (from air to water) = θ_r= ?
b) Angle of refraction (from water to air) = θ_r= ?

Solution:

a) From Snell's law, we have

$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$ ……………………………………(i)

From air to water, we put

$n_1=n_{air}$, $n_2=n_w$, $\theta_1=\theta_i$ and $\theta_2=\theta_r$

So, equation (i) becomes

$$\frac{n_{air}}{n_w} = \frac{\sin\theta_r}{\sin\theta_i}$$

By cross multiplication

$n_{air}\sin\theta_i = n_w\sin\theta_r$

=>$n_w\sin\theta_r = n_{air}\sin\theta_i$

=>$\sin\theta_r = \frac{n_{air}\sin\theta_i}{n_w}$

$\theta_r = \sin^{-1}\left(\frac{n_{air}\sin\theta_i}{n_w}\right)$……………………………….(ii)

Putting values in eq (ii), we get

$\theta_r = \sin^{-1}\left(\frac{1.00\times\sin 46°}{1.33}\right)$

$\theta_r = \sin^{-1}\left(\frac{1.00\times0.72}{1.33}\right)$

$\theta_r = \sin^{-1}\left(\frac{0.72}{1.33}\right)$

θ_r= sin^{-1}(0.54)

θ_r=32.68^0

θ_r =33^0

(b) From water to air, we put

$n_1=n_w$, $n_2=n_{air}$,$\theta_1 = \theta_i$ and $\theta_2 = \theta_r$

So, eq (i) becomes

$\frac{n_w}{n_{air}} = \frac{\sin\theta_r}{\sin\theta_i}$

By cross multiplication

=>$n_w \times \sin\theta_i = n_{air} \sin\theta_r$

=>$n_{air} \sin\theta_r = n_w \times \sin\theta_i$

$\sin\theta_r = (\frac{n_w \times \sin\theta_i}{n_{air}})$

$\theta_r = \sin^{-1}(\frac{n_w \times \sin\theta_i}{n_{air}})$……………………………(iii)

Putting values in eq(iii), we get

$\theta_r = \sin^{-1}(\frac{1.33\times\sin 46°}{1.00})$

$\theta_r = \sin^{-1}(\frac{1.33\times0.72}{1.00})$

$\theta_r = \sin^{-1}(\frac{0.96}{1.00})$

$\theta_r = \sin^{-1}(0.96)$

θ_r =73.73

θ_r=73.8

Or

θ_r =74^0

Q5. An optical fiber is made from flint glass with index of refraction 1.666 and is surrounded by a cladding made of crown glass with index of refraction 1.52. What is the critical angle?

Given Data:

Refractive index of flint glass =n_1 =1.66

Refractive index of crown glass =n_2=1.52

Required:

Critical angle=θ_c =?

Solution:

We know that

$\sin\theta_c = \frac{n_1}{n_2}$ ………………………………….(i)

Putting values in eq(i), we get

$\sin\theta_c = \frac{1.52}{1.66}$

$\sin\theta_c$=0.915

θ_c= sin^{-1}(0.91566265)

θ_c =66.3^0

So, critical angle is 66.3^0

Q6. Suppose the book page is held 7.50cm from a convex lens of focal length 10.0cm and concave lens of focal length -10cm, what magnification is produced in each case?

Given data:

Distance of object $= d_o = 7.50cm$

a) Focal length of convex lens = f =10cm
b) Focal length of concave lens = f = -10cm

Required:

a) Magnification in case of convex lens = M = ?
b) Magnification in case of concave lens = M = ?

Solution:

a) First we find image distance in case of convex lens

Now, by using formula.

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

$$\frac{1}{d_i} = \frac{d_o - f}{f d_o}$$

$$d_i = \frac{f d_o}{d_o - f} \text{ ……………………………………(i)}$$

Putting values in equation (i), we get

$$d_i = \frac{(10)\times 7.50}{7.50-10}$$

$$d_i = \frac{75.0}{7.50-10}$$

$$d_i = \frac{75.0}{-2.5}$$

$$d_i = -30 \text{ cm}$$

Now, we know that the magnification is given by

$$M = \frac{-d_i}{d_o} \text{ ……………………(ii)}$$

Putting values in eq (ii)

$$M = \frac{-(-30)}{7.50}$$

$$M = \frac{30}{7.50}$$

$$M = 4$$

(b)Now, in case of concave lens, putting values in eq (i) we get

$$d_i = \frac{f d_o}{d_o - f}$$

$$d_i = \frac{-10 \times 7.50}{7.50-(-10)}$$

$$d_i = \frac{-75.0}{7.50+10}$$

$$d_i = \frac{-75.0}{17.50}$$

$$d_i = -4.29cm$$

Now, we know that the magnification is given by

$M = \frac{-d_i}{d_o}$

Putting values

$M = \frac{-(-4.29)}{7.50}$

$M = \frac{4.29}{7.50}$

M=0.572

Q7. Gulalai is viewing a flea using a magnifier with f = 3.0cm. If her near point is at N = 25cm then calculate the maximum magnification she can get.

Given Data:

Focal length= f = 3.0cm

Near point distance =N =25cm

Required:

Maximum magnification=m_θ=?

Solution:

For maximum magnification, we have

$m_\theta = \frac{N}{f} + 1$

Putting values

$= \frac{25}{3.0} + 1$

$= 8.33 + 1$

$m_\theta = 9.33$

Hence, maximum magnification is 9.33

Q8. A telescope has a magnification of 40.0 and a length of 1230mm. What are the focal lengths of the objective and eyepiece?

Given Data:

Magnification of telescope = m_θ = 40

Length of telescope=L= 1230mm

Required:

a) Focal length of objective=f_o=?
b) Focal length of eyepiece = f_e =?

Solution:

We know that magnification of telescope is given by

$m_\theta = \frac{f_o}{f_e}$

$\Rightarrow f_o = m_\theta f_e$………………………………..(i)

Also the length of telescope is given by

$L = f_o + f_e$ ……………………………(ii)

Putting eq (i) in eq (ii), we get

$L = m_\theta f_e + f_e$

$L = (m_\theta + 1)f_e$

$=> \frac{L}{(m_\theta+1)} = f_e$

$f_e = \frac{L}{m_\theta+1}$……………………….(iii)

Putting values in eq (iii), we get

$f_e = \frac{1230}{40+1}$

$f_e = \frac{1230}{41}$

f_e = 30mm

Now, putting values in eq(i), we get

$f_o = m_\theta f_e$

f_o =40 × 30

$f_o = \boxed{1200mm}$