CHAPTER 14 Light

Student's Learning Outcomes (SLOs)

After studying this chapter, students will be able to:

- define and use the terms normal, angle of incidence, and angle of reflection.
- describe an experiment to find the position and characteristics of an optical image formed by a plane mirror (same size, same distance from mirror as object, and virtual).
- use the law of reflection to solve simple optical problems.
- apply the qualitative principle that a wave refracts towards the normal when it slows down while entering a medium and that it refracts away from the normal if it speeds up when it enters a new medium (in the case the angle of incidence is zero, then the waves continue parallel to the normal).
- define and use the refractive index from vacuum to a medium for light as c/v.
- define refractive index n as; n = sin i/sin r. Apply Snell's law; n = sin i/sin r, to solve simple problems.
- describe an experiment to show refraction of light by transparent blocks of different shapes.
- define the terms critical angle Cand total internal reflection.
- derive the equation; n = 1/sin C.
- apply the equation; n = 1/sin C to solve simple problems.
- describe experiments to show internal reflection and total internal reflection.
- evaluate and illustrate the use of optical fibres, particularly in telecommunications, stating the advantages of their use in each context.
- analyze the action of thin converging and thin diverging lenses on a parallel beam of light.
- define and use the terms focal length, principal axis, and principal focus (focal point).
- draw ray diagrams to illustrate the formation of real and virtual images of an object by a converging lens.
- differentiate between real and virtual images.
- define and calculate linear magnification (as the ratio of image length to object length; state and use the equation; linear magnification = image length/object length).
- describe the use of a single convex lens as a magnifying glass.
- describe the use of a single convex lens in various optical device applications (specifically in the case of a magnifying glass, a camera, projector, and a photographic enlarger). This includes drawing ray diagrams to show how each forms an image.
- explain the dispersion of light by a prism [including the detection of non-visible spectra by a thermometer].

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- draw ray diagrams to show the formation of images in the normal eye, a short-sighted eye, and a long-sighted eye.
- describe the use of converging and diverging lenses to correct long-sightedness and short-sightedness.
- state that extreme gravity from interstellar objects like black holes can cause light to bend (from the perspective of the observer) in a way that is analogous to a simple lens [This is called 'gravitational lensing].

Subjective Type Questions

Long Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

Introduction

Q1. Define light.

Ans. Light is a form of energy that travels in the form of waves and allows us to see the world around us.

14.1 Reflection of light

Q2. What do you understand by reflection of light? Draw a diagram to illustrate reflection at a plane mirror.

Ans. Reflection of light:

"Reflection of light is the bouncing back of light rays from a surface after striking it, so that the light returns into the same medium instead of passing through the surface."

Explanation:

Reflection of light takes place when light hits a surface and bounces back instead of passing through it.

This usually occurs on smooth and shiny surfaces, such as mirrors. The angle at which light strikes the surface (angle of incidence) is always equal to the angle at which it reflects *(angle of reflection) (Fig. 14.1)*

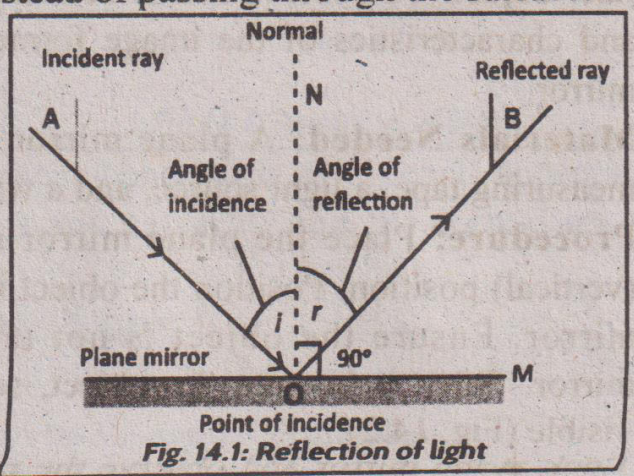


Fig. 14.1: Reflection of light

Q3. Explain types of reflection with the help of diagram.

Ans. Types: There are two types of reflection:

- Regular/ specular Reflection
- Diffused/ Irregular Reflection

1. Regular/Specular Reflection:

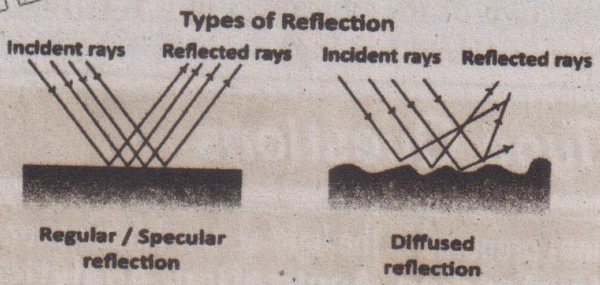
It takes place on smooth surfaces (like mirrors) where light reflects in one direction forming a clear image.

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2. Diffused/ Irregular Reflection:

It occurs on rough surfaces (like paper), where light scatters in different directions, so no clear image is seen.

Reflection is important for mirrors, periscopes, and optical devices, allowing us to see objects and form images.



Q4. State laws of reflection.

Ans. Laws of Reflection:

The reflection of light follows two basic laws:

- **First law:** The incident ray, the reflected ray, and the normal (a line drawn Perpendicular to the surface at the point of reflection) all lie in the same plane.
- **Second law:** The angle of incidence (i) is always equal to the angle of reflection (r).

Formula: $\angle i = \angle r$ .....(14.1)

These laws apply to all reflective surfaces such as mirrors and water, and help us to understand how light bounces back to form images.

Q5. Find the image position of an object in a plane mirror with the help of an activity.

Ans. Object: To observe and understand the position and characteristics of the image formed by a plane mirror.

Materials Needed: A plane mirror, an object, a measuring tape, a light source, and a white paper.

Procedure: Place the plane mirror in an upright (vertical) position. Position the object in front of the mirror. Ensure the object is not taller than the mirror. Shine light onto the object, so it is clearly visible (Fig. 14.2).

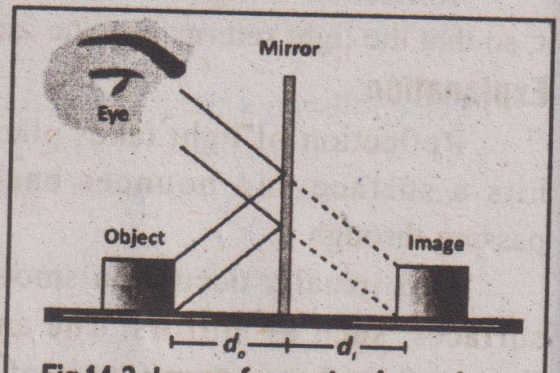


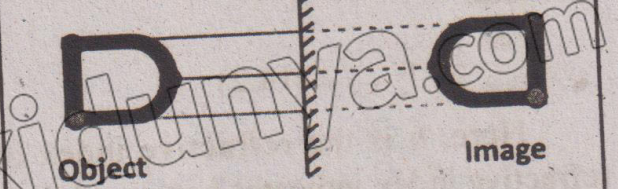
Fig 14.2: Image formation by a plane mirror.

Look at the mirror and observe the rays of light reflecting from the object. When two rays reflect off the mirror and reach the observer's eye, they appear to be coming from behind the mirror. By using a ruler and the law of reflection, we can draw the reflected rays on paper. Extend these reflected rays backward with dotted lines where they meet behind the mirror is the position of the image. This method shows the virtual image location.

There are four properties of an image formed by a plane mirror:

1. The image is erect-It appears upright, just like the object.

2. The image is of the same size - The size of the image is exactly equal to the size of the object. It can be written as: $d_i = d_o$.
3. The image is laterally inverted - The left and right sides of the object appear reversed in the image as shown in Fig. 14.3.



14.3 Letter 'D' showing lateral inversion in a mirror

4. The image is virtual-It cannot be captured on a screen because it is formed behind the mirror where light rays do not actually meet.

14.2 Refraction of Light

Q6. Define refraction of light. Describe the passage of light through one transparent medium to another (glass or water).

Ans. Refraction of light:

Refraction of light is the bending of light when it passes from one transparent medium to another (like air to water) due to a change in its speed"
OR "Refraction of light occurs when light changes direction as it passes from one medium to another, such as from air to water or glass".

Explanation:

This happens because light travels at different speeds in different materials. When light moves from a rarer medium (air) to a denser medium (glass or water), it bends towards the normal. When it moves from a denser medium to a rarer medium, it bends away from the normal. The amount of bending depends on the refractive index of the medium.

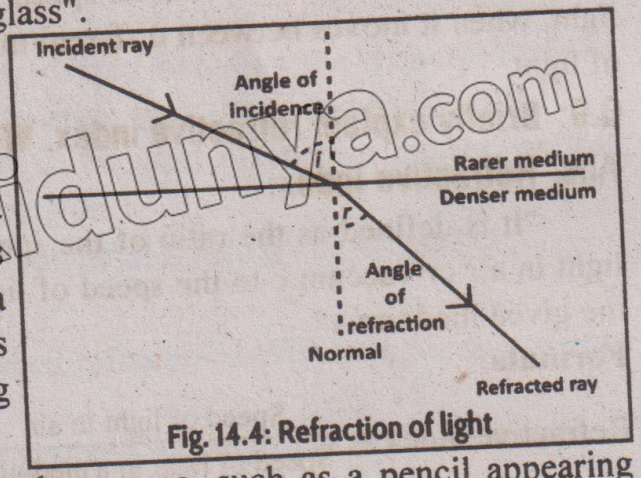


Fig. 14.4: Refraction of light

Examples: Refraction explains many everyday phenomena, such as a pencil appearing bent in water, the working of lenses in glasses and cameras, and the formation of rainbows.

Q7. State the laws of refraction of light and Snell's Law.

Ans. Laws of Refraction of light:

The bending of light during refraction follows two essential principles.

- **First Law:**

The incident ray, refracted ray, and the normal at the point where light enters a new medium all lie in the same plane.

- **Second Law (Snell's law):**

The ratio of the sine of the angle of incidence (i) to the sine of the angle of refraction (r) remains constant for a specific pair of media. This is also known as snell's law.

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Formula:

$$\frac{\sin i}{\sin r} = n \quad \text{.....(14.2)}$$

Here, n is the refractive index of the second medium relative to the first. The refractive index indicates how much light bends when entering a different medium.

Q8. How does the speed of light change when it passes Through different materials, and what is its Maximum value?

Ans. Speed of light in a Medium:

The speed of light is not constant, it varies depending on the medium though which it travels.

Maximum Speed: Light moves at its maximum speed in a vacuum, which is $3 \times 10^8 ms^{-1}$.

Slowing Down: When light passes through materials like air, water, or glass, it slows down due to interactions with the medium particles.

Density and Speed: Generally, the denser the medium, the slower the speed of light becomes in that material.

This change in speed is measured using the refractive index n, which is the ratio of the speed of light in vacuum to its speed in a given medium. The variation in the speed of light, when it moves between different material, is what causes refraction, or the bending of light.

Q.9: Briefly explain refractive index. Write its formula.

Ans. Refractive Index:

"It is defined as the ratio of the speed of light in air or vaccum c to the speed of light in the given medium v"

Formula:

$$\text{Refractive index} = \frac{\text{Speed of light in air}}{\text{Speed of light in a medium}}$$

$$\text{or} \quad n = \frac{c}{v} \quad \text{..... (14.3)}$$

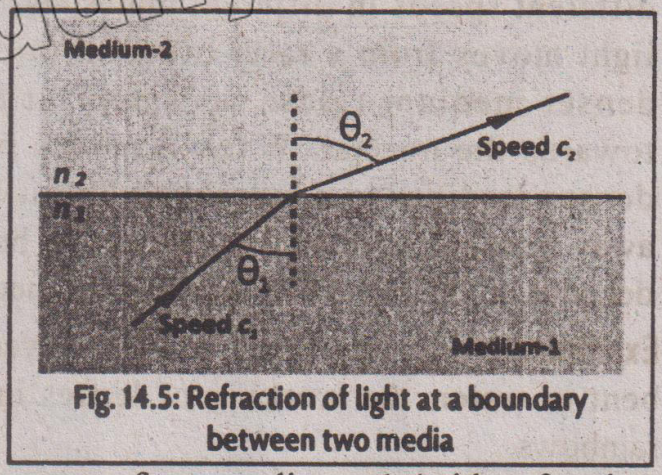


Fig. 14.5: Refraction of light at a boundary between two media

Explanation: A light ray changes direction when passes from medium –1 (with refractive index n_1 and speed c_1 to medium –2 (with refractive index n_2 and speed c_2). The anglesθ_1 (angle of incidence) and θ_2 (angle of refraction) demonstrate how the light bends according to Snell's law due to the difference in refractive indices.

Q10: How Refraction occurs through prism?

(OR) Define a prism and explain the processes of refraction of light through a triangular glass prism.

Ans. Refraction through prism:

Prism: A prism is a transparent optical object with atleast two polished plane surfaces inclined towards each other. It is usually made of optical glass and is used to refract

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(bend) light. In a standard triangular prism, the refracting surfaces are at a 60° angle to each other.

Process: When a ray of light passes through a triangular prism does not emerge parallel to its origional path but instead changes direction.

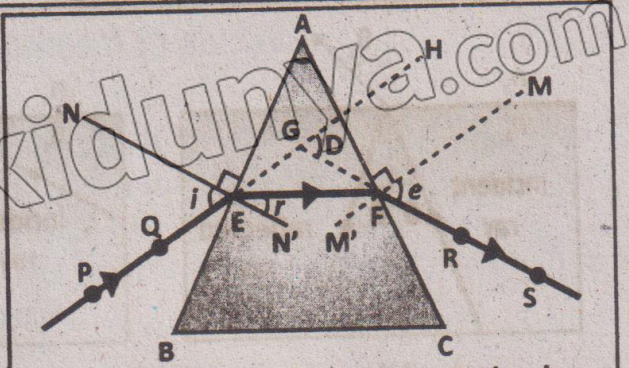


Fig. 14.6: Refraction through a triangular glass prism

- **Incident ray (PE):**

When an incident ray (PE) strikes the prism at point E, it bends towards the normal N.

- **Refracted Ray (EF):**

After bending towards the normal N and travels inside the prism as refracted ray (EF). Inside the prism, the ray makes an angle of refraction r before reaching the second surface at point F.

- **Emergent Ray (FS):**

As it exits the prism, it bends again, forming an emergent ray (FS) at an angle e.

- **Angle of Deviation (D):**

The emergent ray (FS) is not parallel to the incident ray (PE) but is instead deviated by an angle D, known as the angle of deviation.

"The angle of Deviation (D) is the angle formed between the direction of the original incident ray (extended farward) and the emergent ray (extended backward)."

This bending effect is what allows prisms to be used in speetro meters, optical instruments, and experiments involving light dispersion.

Q.11: Define Critical Angle. Write a briefly note on total internal reflection?

Ans. Critical angle:

"The angle of incidence for which the angle of refraction is 90° is called the critical angle."

Explanation: When a light ray is incident at a boundary between two different media, it splits into two parts:

- One part reflects back into the original medium (reflected ray).
- The other part passes into the second medium (transmitted or refracted ray).

If the angle of incidence increases then refraction angle also increases. The more the angle of incidence increases, the greater the angle of refraction becomes.

At a particular angle, the refracted ray no longer enters the second medium but travels along the boundary. This angle is called critical angle. (Fig. 14.7-b).

Total Internal Reflection: "Total internal Reflection is the phenomenon of the reflection of light ray back to the same medium when passing from denser medium to rarer medium in such a way that angle of incidence is greater than its critical angle".

Explanation: Now, if the angle of incidence is increased beyond the critical angle, the light ray does not refract at all. Instead, it reflects entirely back into the same medium. This phenomenon is called total internal reflection.

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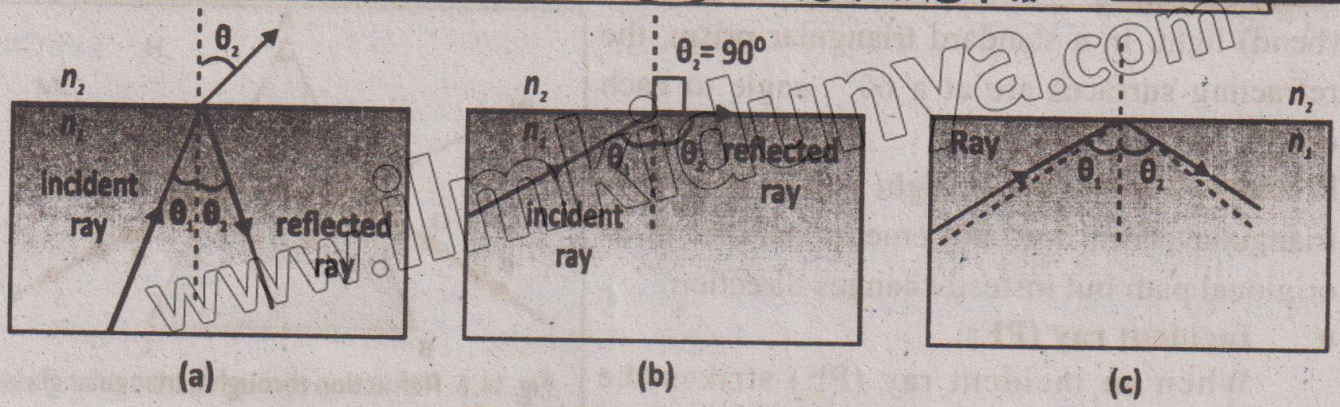


Fig. 14.7: Total internal reflection

Table 14.1: Refractive index, speed of light, and critical angle for different media

Medium	Refractive Index	Speed of Light ($\times 10^8$ m s^{-1})	Critical Angle
Diamond	2.42	1.25	24.4°
Glass (flint)	1.66	1.81	37.0°
Glass (crown)	1.52	2.01	41.2°
Perspex	1.49	2.00	42.0°
Water	1.33	2.25	48.8°
Ice	1.31	2.30	49.8°
Air	1.00	2.99	88.6°
Vacuum	1.00	3.00	90.0°

Derivation of the formula for Total Internal Reflection:

To derive a formula for total internal reflection, we start with Snell's law:

$n_1 \sin i = n_2 \sin r$. ..... (14.4)

When total internal reflection occurs, the refracted angle becomes 90°. So, the equation becomes:

$n_1 \sin i = n_2$, because $\sin(90°) = 1$

Now, if 'i' is the critical angle C, the formula becomes:

$$\sin C = \frac{n_2}{n_1} \quad \text{..... (14.5)}$$

To find the critical angle C, we rearrange it as:

$$C = \sin^{-1}\left(\frac{n_2}{n_1}\right) \text{.....(14.6)}$$

This only works when $n_1 > n_2$ meaning the light must travel from a denser medium to a rarer medium.

If the second medium is air (where $n_2 = 1$), the equation becomes. $\sin C = 1/n$

From the above equation, the refractive index of the first material (demser medium) can be founds,

$$n = \frac{1}{\sin C} \quad \text{..... (14.7)}$$

This relation only holds true if the light is moving from a denser medium with refractive index n in to air.

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Q.12: How can we understand Refraction by experiment to study?

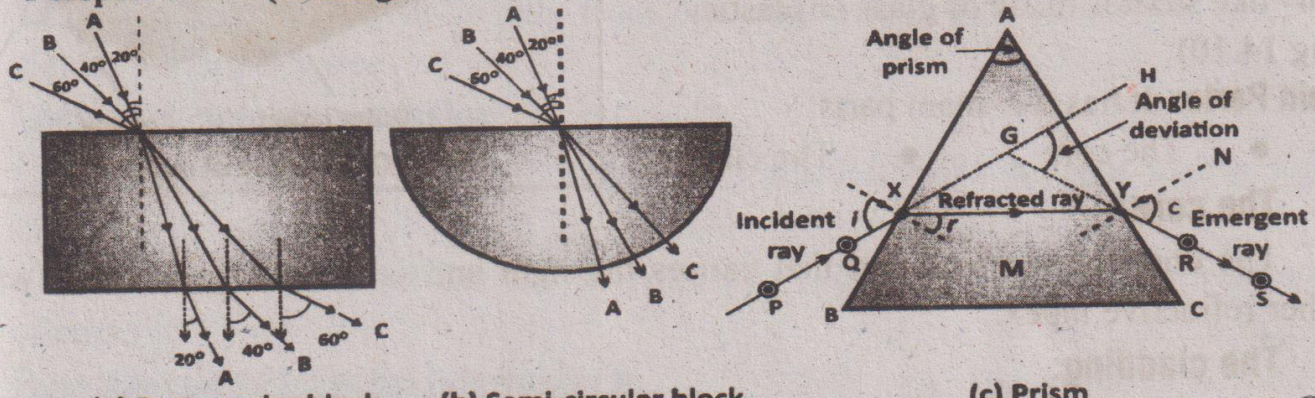
Ans: Experiment to study refraction:

To understand how light bends (refracts) when it passes through different transparent materials, we can perform a simple experiment using blocks of different shapes right in our classroom or school laboratory. (Fig.14.8)

Aim of the Experiment: To observe how light refracts (bends) when it passes through a rectangular block, semi-circular block, and glass prism.

Materials Needed:

- Laser light
- Protractor
- Paper sheet
- Pencil
- Ruler
- Perspex block (rectangular, semi-circular, and prism-shaped).



(a) Rectangular block (b) Semi-circular block (c) Prism

Fig. 14.8: Experiment for refraction of light

Method of Experiment:

- Place the rectangular glass block on a sheet of paper and observe its result.
- Draw a straight line at one edge where the light will enter.
- Draw a normal (a straight perpendicular line) at the point wher light will hit the block.
- Shine the laser light at an angle on the block along the drawn line.

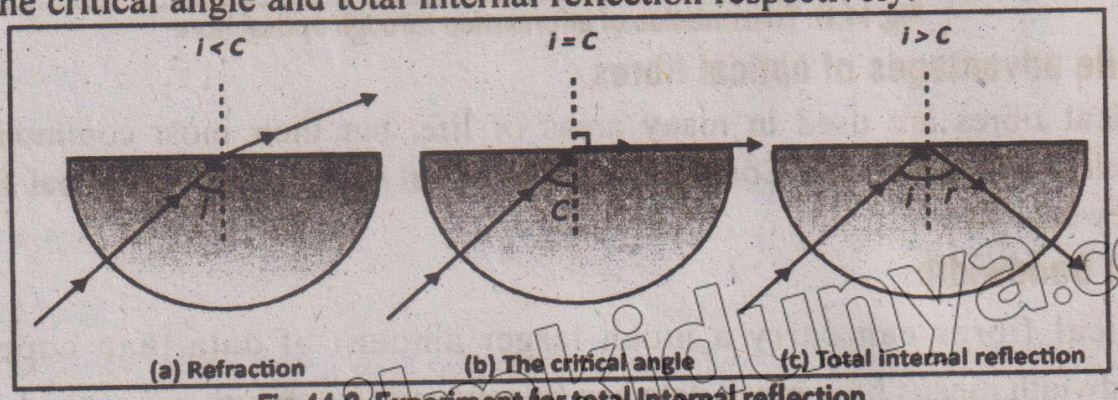
Experiment to study Total Internal Reflection:

Aim of the Experiment: To study how total internal reflection of light occurs using a semi-circular glass block. (Fig. 14.9)

Materials Needed:

- Light ray
- protractor
- Paper
- Pencil
- Ruler
- Semi-circular Perspex (glass) block.

Figure 14.9 (a) demonstrates the refraction, while Fig 14.9 (b) and Fig 14.9 (c) illustrate the critical angle and total internal reflection respectively.



(a) Refraction (b) The critical angle (c) Total internal reflection

Fig. 14.9: Experiment for total internal reflection

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Q.13: Write a note on optical fibre?

Ans. Optical Fibre:

"Optical fibres use the principle of Total Internal Reflection (TIR) to transmit ligh efficiently over long distances"

Use: These fibres are widely used in the telecommunication industry due to their high speed and reliability

Structure: An optical fibre consists of thin, hair- like strands made of glass or plastic. (Fig 14.10)

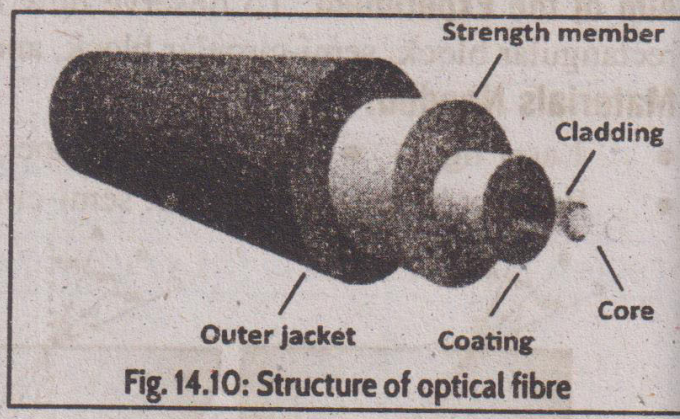


Fig. 14.10: Structure of optical fibre

Main Parts: It has two main parts:

- The core
- The cladding

1. The core:

The core is the inner part that carries the light and is made of a material with a higher refractive index.

2. The cladding:

Surrounding the core is the cladding, which has a lower refractive index and helps in total internal reflection.

Process: When light enters one end of the core, it hits the core-cladding boundary at an angle greater then the critical angle, causing it to reflect bach into the core. (Fig. 14.11)

This repeated reflection allows light to travel long distances with minimal energy loss.

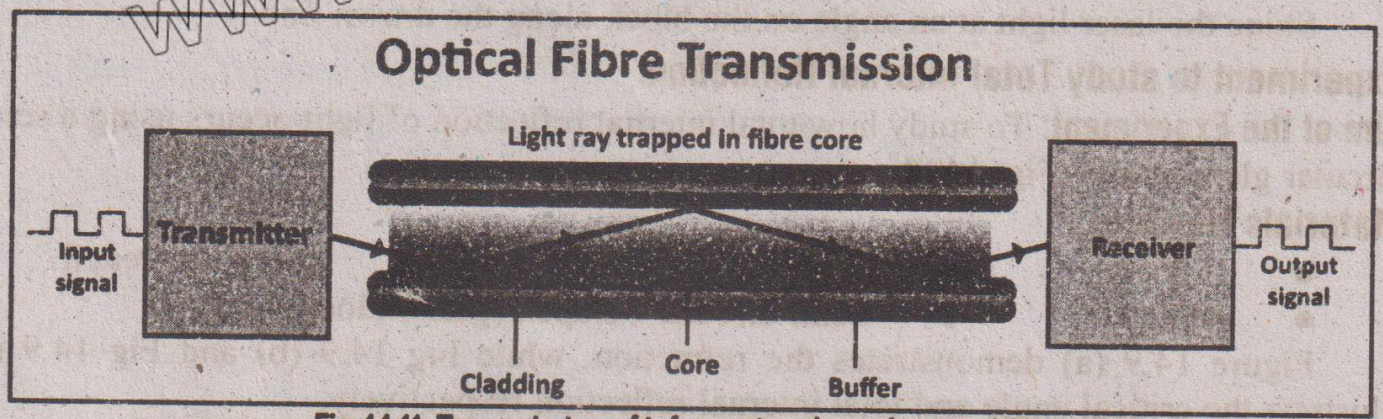


Fig. 14.11: Transmission of information through optical fibre

Q.14: Write advantages of optical fibres.

Ans. Optical fibres are used in many areas of life, but their most common use is in modern telecommunications. Compared to traditional copper cables, optical fibres offer several key benefits.

(1) High Bandwidth:

- Optical fibres can carry a much larger amount of data than copper wires. Bandwidth means how much data can be sent over a network per second.

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- In today's world, where we need fast internet, optical fibres are the best choice because they support high speed data transfer.

(2) Low Power Consumption:

- They use less power than copper cables.
- Also, because they last longer and are more durable, they reduce the cost of repairs and maintenance.

(3) Faster Speed:

- They send data using light pulses, which travel extremely fast almost at the speed of light.
- This allows data to move quickly from one place to another, faster than electrical signals in copper wires

(4) Long Distance Transmission:

- Optical fibres can carry data across very long distances without losing signal quality
- This makes them ideal for use in undersea cables and connections between continents.

(5) Resistance to Electrical Interference.

- Since optical fibres use light instead of electricity, they are not affected by electrical noise or interference.
- This is a big advantage over copper wires, which often face signal problems due to electrical disturbances.

14.4 Thin lenses

Q.15:Write a briefly note on lens. Also write its types.

Ans: Lens:

"A lens is a transparent material with two surfaces, at least one of which is curved."

Explanation with Examples:

It bends (refracts) light in a way that forms an image of an object. Lenses come in different types and are widely used in optical devices such as cameras, eyeglasses, microscopes, telescopes, and projectors. They play an important role in correcting vision.

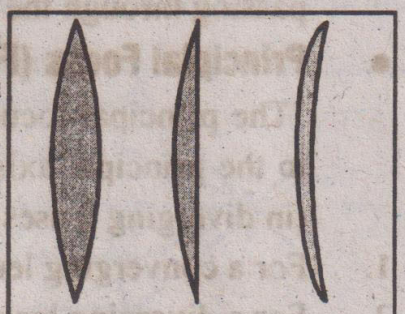


Fig. 14.12: Convex lenses

Types of lenses:

Lenses are classified based on how they bend light rays:

1. Convex lens
2. Concave lens

1. Convex lens:

- A convex lens, also known as a converging lens, brings parallel light rays together at a point.

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- It is thicker in the centre and thinner at the edges. (Fig. 14.12)

2. Concave lens:

- Concave lens, also called a diverging lens, causes parallel light rays to spread out.
- This lens is thinner in the centre and thicker at the edges. (Fig. 14.13)



Fig. 14.13: Concave leneses

Q.16: Explain important terms related to lenses.

Ans. Terms related to lenses:

To understand how lenses form images, it is important to learn some basic terms.

- **Focal length:**

"The focal length (f) is the distance from the lens (optical centre) to the principal focus, where light rays either meet (converge) or appear to spread out (diverge)."

Symbol: It is denoted by (f)

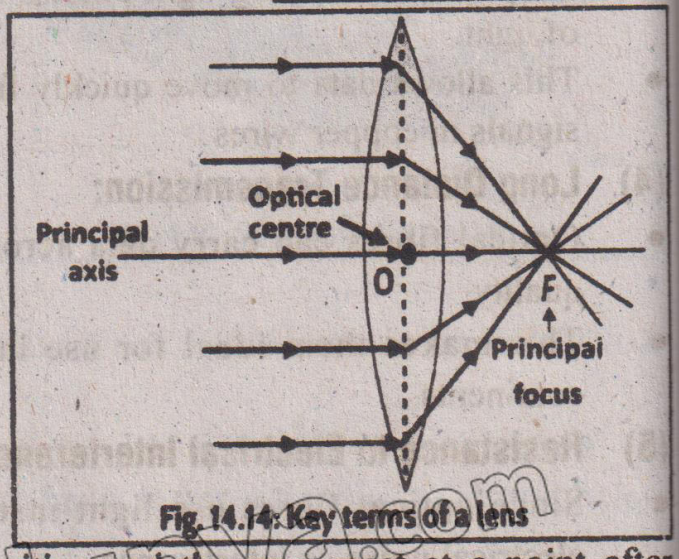


Fig. 14.14: Key terms of a lens

1. Converging lenses:

In converging lenses, focal length is positive and the rays meet at a point after passing through the lens.

2. Diverging lenses:

In diverging lenses, focal length is negative and rays seem to spread out from a virtual point on the same side of the lens as the light source.

- **Principal Axis**

"This is a straight, imaginary line that passes through the centre of the lens."

- Light rays that travel along the principal axis do not bend or change direction when passing through the lens.
- **Principlal Focus (Focal Point):**

"The principal focus is the point on principal axis where light rays that are parallel to the principal axis come together (in converging lenses) or appear to come from (in diverging lenses)."

1. For a converging lens, the focus is on the opposite side of the incoming rays.
2. For a diverging lens, the focus is on the same side as the incoming rays and appears to be behind the lens.

- **Optical Centre:**

"The optical centre is the geometrical middle point of the lens through which the principal axis passes."

1. Light passing through this point does not bend.

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2. It is usually marked as O.

- **Centre of Curvature:**

"Lenses are made from parts of a sphere. The centre of this imaginary sphere is called the centre of curvature."

It is generally located at twice the focal length from the lens.

Q.17: Describe the relation between lens and Mirror Formula.

Ans. Lens:

"A lens is a transparent material with two surfaces, atleast one of which is curved."

Relation between lens and Mirror Formula:

The relationship between the focal length f, object distance p, and image distance q for both lenses and mirrors is expressed by the lens/mirror formula as:

$$\frac{1}{f}=\frac{1}{p}+\frac{1}{q} \quad .....(14.8)$$

This fundamental equation helps determine the position and nature of the image formed by a given optical system.

Q.18: Describe the action of parallel rays on lenses?

Ans. Action of Lenses on Paralell Rays:

When a set of parallel rays pass through a lens, they refract and show specific patterns based on the lens type Depending on how they interact with the rays, lenses are grouped into converging and diverging lenses.

(1) Refraction and Convergence for Convex lens:

- **Principal axis:**

As the rays enter the lens, they bend towards the principal axis due to refraction. This bending takes place because of the the lens's curved surfaces and its refractive index.

- **Focal Point:**

After passing through the lens, all the rays meet at a common point on the principal axis this is known as the focal point.

(2) Formation of image:

The type of image formed depends on the object's distance from the lens.

Generally, a converging lens forms a real and inverted image, but if the object is very close to the lens, the image can be virtual and upright.

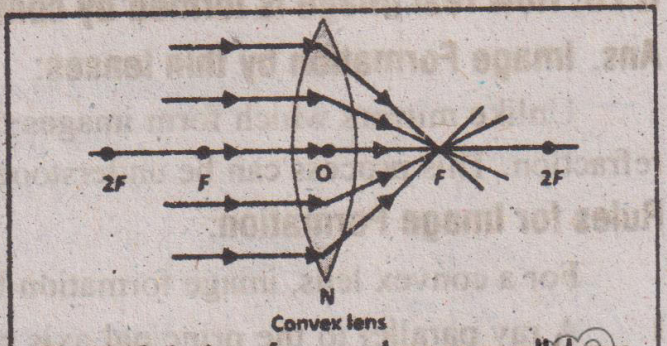


Fig. 14.15: Action of convex lens on parallel rays

(3) Refraction and Divergence of Concave lens:

The rays are bent away from the principal axis. This bending gives the illusion that they originate from a point behind the lens, the virtual focus. This is a result of refraction

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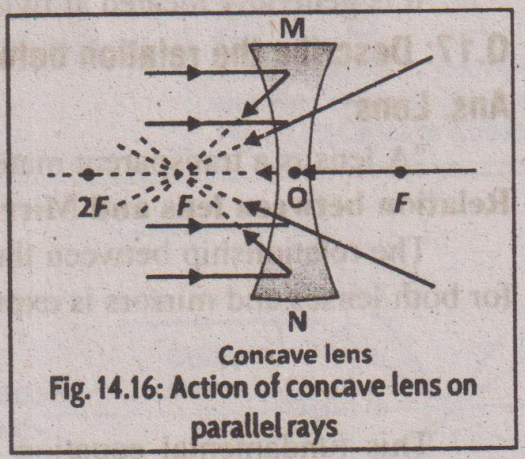
through the curved surface of the lens.

(4) Virtual Focal Point:

In a diverging lens, the rays do not actually meet at a point Instead, when extended backward, they appear to spread out from a common point on the same side of the lens. This is called a virtual focal point.

(5) Formation of Image:

When an object is placed far from a diverging lens (at infinity), the image formed is virtual, upright, and smaller than the actual object.



Concave lens

Fig. 14.16: Action of concave lens on parallel rays

Q.19: Explain the power of a lens.

Ans. Power of a Lens:

"The reciprocal of focal length (f) is called power of a lens."

(5) Formula:

It is given by the formula $P = 1/f$..... (14.9)

Unit:

The SI unit of power is diopter (D) where $1D = 1m^{-1}$.

Diopter:

One diopter is the power of lense haye 1m focal length.

Convex lens:

A convex lens has a positive focal length, so its power is positive.

Concave lens:

A concave lens has a negative focal length, so its power is negative.

Importance:

Lenses with higher power bend light more strongly, and this concept is important in eyeglasses, microscopes, and optical instruments.

Q.20: How real image is formed by converging lenses? Explain by diagram.

Ans. Image Formation by thin lenses:

Unlike mirrors which form images through reflection, lenses create images through refraction. This process can be understood using ray diagrams.

Rules for Image Formation:

For a convex lens, image formation follows three rules (Fig. 14.17).

1. A ray parallel to the principal axis passes through the focal point F after refraction from the lens (ray-1).
2. A ray passing through the optical centre of the lens continues straight without bending (ray-2).

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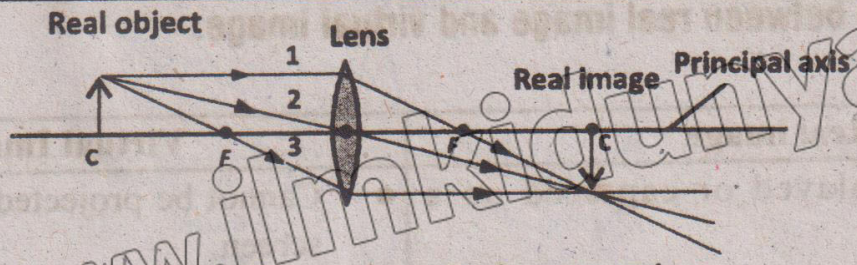


Fig. 14.17: Image formation by a convex lens

3. A ray passing through the focal point after refraction from the lens, becomes parallel to the principal axis (ray-3).By tracing these rays, we can determine where and how an image is formed. The position, size, and nature of the image depend on where the object is placed in relation to the lens. These principles are important in devices like cameras, magnifying glasses, microscopes, and eyeglasses. The image formation by a convex lens for different positions is described in Table 14.2

Table 14.2: Image formation by a convex lens

Position of the Object	Position of the Image	Size of the Image	Nature of the Image
At infinity	At F	Highly diminished	Real and inverted
Behind 2F	Between F and 2F	diminished	Real and inverted
At 2F	At 2F	Same as that of the object	Real and inverted
Between F and 2F	Beyound 2F	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between Lens and F	Same side as the object	Enlarged	Virtual and erect

Formation of Real Image by a Converging Lens:

A convex lens produces a real image when the object is placed beyond 2F. As illustrated in Fig. 14.18.

Image appears:

The image appears on the opposite side of the lens from where the object is located.

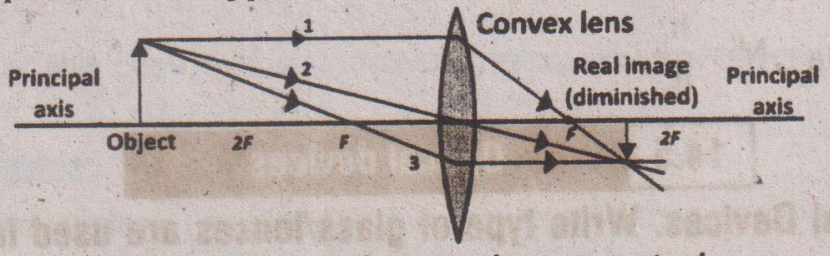


Fig. 14.18: Real image formation by a converging lens

Formation of a virtual image by a converging lens:

For a convex lens to produce a magnified virtual image, the object should be placed within the focal length of the lens as illustrated in Fig. 14.19.

In this arrangement, the image appears on the same side of the lens as the object. It is upright, larger in size, and cannot be projected onto a screen, as it is virtual. Such an image is visible only when viewed through the lens. This principle is used in magnifying glasses.

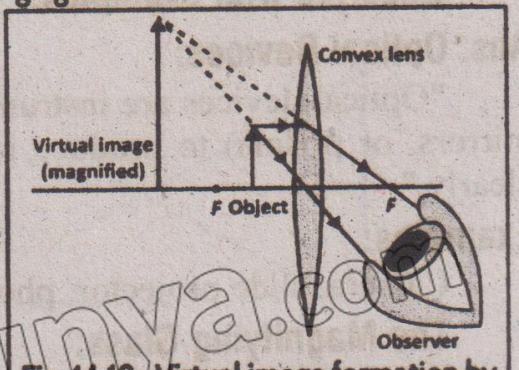


Fig. 14.19: Virtual image formation by a converging lens

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Q21. Differentiate between real image and virtual image.

Ans.

Real image	Virtual Image
• Can be displayed or captured on a screen. • Always appears upside down (inverted). • Created when light rays actually meet after reflecting or refracting. • Result of actual light rays intersecting. • Can be displayed on a screen (like a wall or sensor)	• Cannot be projected or caught on a screen. • Always appears upright (erect). • Created when light rays only seem to meet, they do not actually converge. • Formed by the imaginary extension of diverging light rays.

Q.22. Define linear magnification, Write its formula. Also write steps.

Ans. Linear Magnification:

"Linear magnification is the ratio of the height (or length) of the image to the height (or length) of the object."

Formula:

It indicates how much larger or smaller the image is compared to the object.

$$\text{Linear magnification} = \frac{\text{Image Height}}{\text{Object Height}}$$

or $$M = \frac{h_i}{h_o} \quad \text{..... (14.10)}$$

Steps to Calculate linear Magnification:

1. Measure the height of the object h_o.
2. Measure the height of the image h_i.
3. Use the formula ; $M = \frac{h_i}{h_o}$

14.5 Optical devices

Q.23: Define Optical Devices. Write type of glass/lenses are used in optical device. Describe with examples.

Ans. Optical Devices:

"Optical devices are instruments that use light and optical components (like lenses, mirrors, or prisms) to produce images, magnify objects, or help us to see things more clearly."

Examples:

Camera, slide projector, photograph enlager, and telescope etc.

1. The Magnifying Glass:

"A magnifying glass is a convex (converging) lens used to make objects appear larger.

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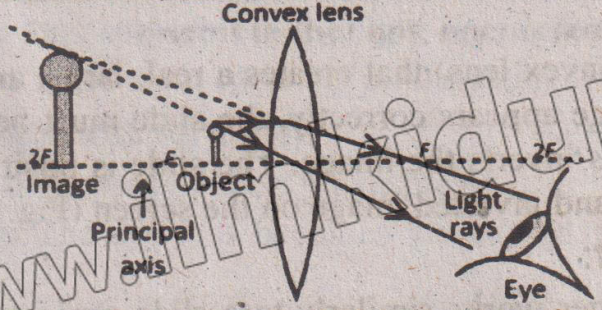


Fig. 14.20: Image formation by magnifying glass

Simple Microscope:

When an object is placed closer to the lens than its focal length ($p < f$), the refracted light rays do not meet but appear to come from a point behind the lens. This creates a virtual, upright and magnified image, which cannot be projected on a screen (Fig. 14.20). This simple use of convex lens is also known as simple microscope.

2. Camera:

"A camera consists of a light - proof box with a convex lens at the front and a light sensitive film or sensor at the back. The lens focuses light onto the film to capture an image".

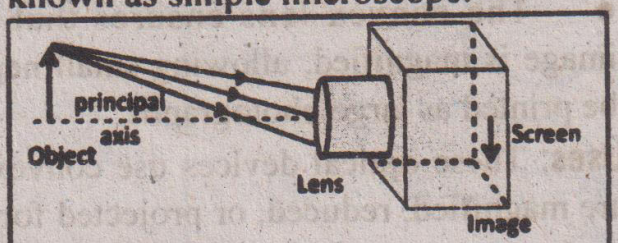


Fig. 14.21: Image formation by camera

Simple comera: In a simple camera, the lens - film distance is fixed and equal to the focal length of the lens.

Distance: The object is placed beyond 2F, forming a real, inverted, and smaller (diminished) image on the film (Fig. 14.21).

3. Slide projector:

"A slide projector works by projecting an enlarged image of a slide or film onto a screen."

It consists of:

- A light source at the centre of a concave mirror, which reflects light as parallel rays.

A condenser lens system:

A condenser lens system (two plane convex lenses) that evenly distributes light across the slide.

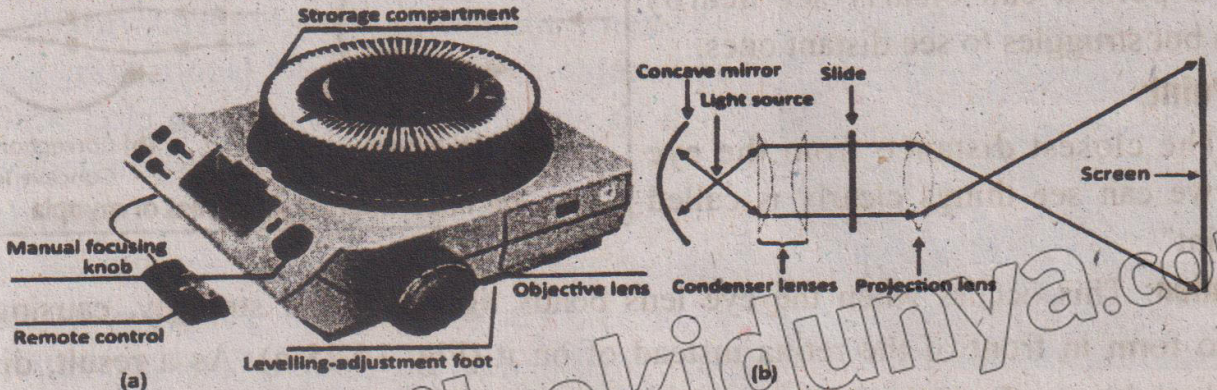


Fig. 14.22: (a) Slide projector (b) Ray diagram of slide projector

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A projection lens:

A projection lens (convex lens) that creates a real, large, and inverted image on the screen. To ensure the image appears correctly, the slide must be placed upside down be because the projection lens inverts the image. The slide is positioned between F and 2F to form a real, magnified, and inverted image on the screen (Fig.14.22-b)

4. Photograph Enlarger:

"A photograph enlarger works similarly to a slide projector but is used to enlarge photographic negatives onto photographic paper.

- The negative (object) is placed between F and 2F, forming a real, inverted, and enlarged image on the paper.
- The convex lens ensures that the final image is magnified, allowing small negatives to be printed as large photographs.

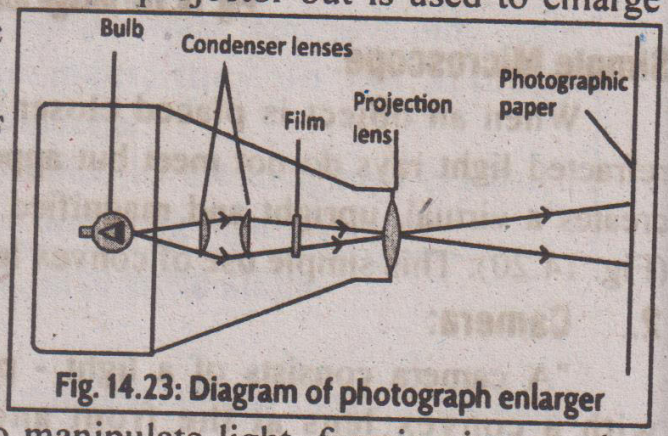


Fig. 14.23: Diagram of photograph enlarger

Uses: These optical devices use convex lenses to manipulate light, forming images that are magnified, reduced, or projected for various practical applications.

14.6 Image Formation in a Nomal Eye

Q24. How image formed in a normal eye?

Ans: Image formation in a Normal Eye: In a healthy eye, light rays from an object pass through the cornea and lens, and are focused directly onto the retina, forming a sharp and clear image. As shown in Fig. 14.24, rays from the top and bottom of the object converge at specific points on the retina, allowing us to see a clear image. This process is similar to how a convex lens forms a real image.

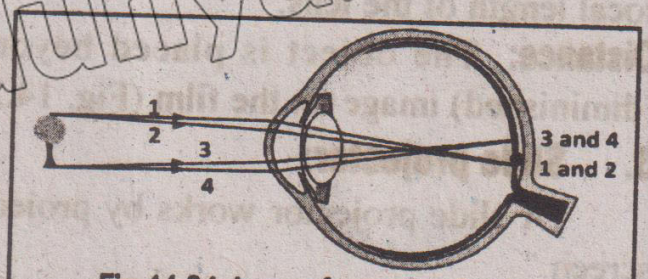


Fig. 14.24: Image formation by eye

Q.25: How myopia occurs? Write its correction.

Ans. Short-Sightedness (Myopia):

"Short-sightedness is a condition where a person can clearly see nearby objects but struggles to see distant ones.

Near Point:

"The closest distance from the eye where we can see things clearly is called near point"

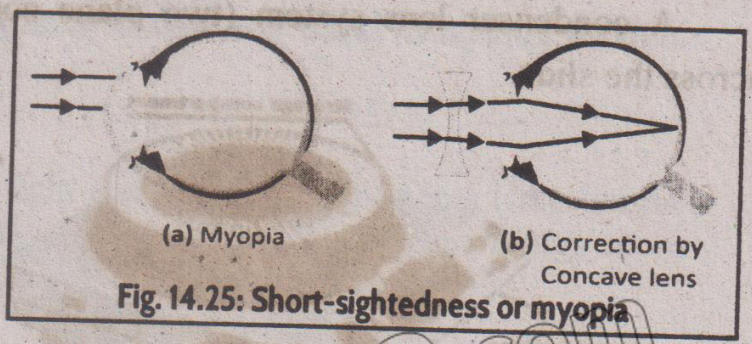


Fig. 14.25: Short-sightedness or myopia

Explanation: This occurs when the eye lens bends light rays too strongly, causing the image to form in front of the retina instead of on it (Fig. 14.25-a). As a result, distant objects look blurry. To correct this, concave lenses are used in glasses or contact lenses.

Correction: A concave lens spreads out the light rays before they enter the eye, helping the eye's natural lens to focus them correctly on the retina (Fig. 14.25-b).

Causes of Short- Sightedness (Myopia):

There are two main causes of short sightedness:

1. **Lens too strong:** The eye lens becomes too curved, focusing light in front of the retina.
2. **Eyeball too large:** The distance between the cornea and retina increases, so the focused image falls short of the retina.

Q.26: How hypermetropia occurs? Write its correction.

Ans. Long - Sightedness (Hypermetropia) and its Correction.

"Long - sightedness is a condition where a person can see distant objects clearly but nearby objects appear blurry."

Explanation: In a normal eye, light rays from nearby objects focus directly on the retina, creating a clear image (Fig. 14.26-a).

This long sightedness happens when the eye lens is too weak or the eyeball is too small, so the light rays from the near objects are not bent enough. As a result, the rays focus behind the retina instead of on it (Fig. 14.26-b).

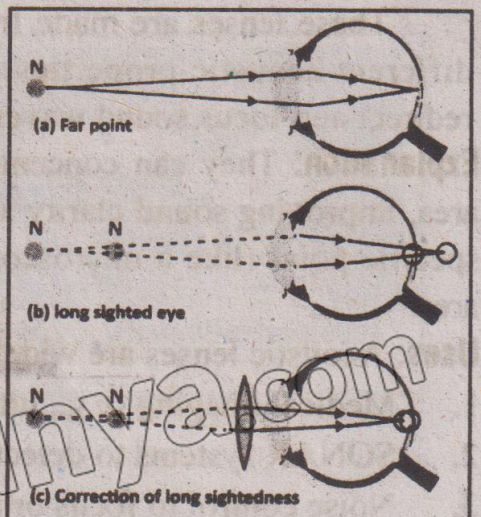


Fig. 14.26: Long-sightedness

Correction: To correct this, convex lenses are used in glasses or contact lenses. A convex lens bends the light rays more before they enter the eye, helping them focus directly on the retina.

Causes of Long-Sightedness: There are two main causes:

1. **Lens too weak:** The lens does not bend the light rays enough.
2. **Eyeball too small:** The retina is too close to the lens.

In both cases, the image is formed behind the retina, makeing close - up vision blurry.

14.7 Gravitational Lens and Acoustic Lens

Q27. Explains the concepts of Gravitational lensing and Acoustic lens.

Ans. Gravitational Lensing:

"Gravitational lensing occurs when the strong gravitational field of a massive object, like a black hole or galaxy, bends the path of light travelling near it"

Explanation:

Just like an optical lens bends and focuses light, a massive celestial body act as a "gravitational lens" altering the path of light from a distant object such as a star or galaxy.

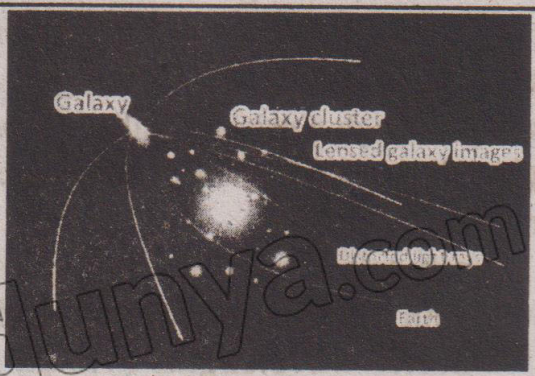


Fig. 14.27: Diagram of gravitational lens

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Effect on observation: This effect can cause the distant object to appear magnified, distorted, or even duplicated, creating multiple images (Fig. 14.27).

Gravitational lensing is a valuable tool in astronomy. It helps scientists study distant galaxies, dark matter, and the structure of the universe, providing insights into objects that are otherwise too far to observe directly.

Acoustic Lenses:

"Acoustic lenses are special devices designed to focus or spread sound waves, similar to how optical lenses control light.

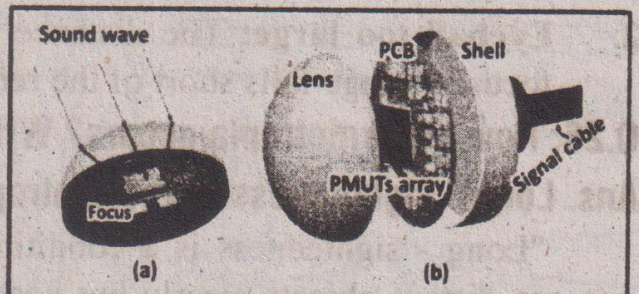


Fig. 14.28: Diagram of acoustic lens

Composition and Function:

These lenses are made from materials with different acoustic properties and are shaped to redirect and focus sound waves.

Explanation: They can concentrate sound into a narrow beam or spread it over a wider area, improving sound clarity and control (Fig. 14.28). These lenses can focus sound to a specific point (like a microscope or sensor), or diverge sound to spread it over a wider area.

Uses: Acoustic lenses are widely used in:

1. Medical imaging (e.g., ultrasound) to improve scanning accuracy.
2. SONAR systems to detect underwater objects.
3. Noise control to focus or reduce sound in specific areas.

Both gravitational and acoustic lenses demonstrate how the principles of wave manipulation apply to both light and sound, playing an important role in astronomy, medicine, and technology.

14.8 Dispersion of Light by Prism

Q.28: Explain Dispersion of light by prism?

Ans. Prism:

"A prism is an optical object typically made of glass with triangular and rectangular sides. It bends light passing through it due to refraction."

Since visible light consists of a range of wavelengths, and refraction depends on wavelength, different wavelengths bend at different angles, causing dispersion.

Dispersion of light: "The splitting of white light into its seven constituent colours when passing through a prism is called dispersion of light"

Explanation: When white light enters a prism, it slows down and bends toward the normal.

Each colour has a unique wavelength, and as light travels through the prism, each wavelength refracts at a different angle.

Shorter wavelengths (violet, blue) bend more than longer wavelengths (red, orange).

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As a result, the light exiting the prism separates into seven distinct colors: red, orange, yellow, green, blue, indigo, and violet forming the visible light spectrum (Fig. 14.29).

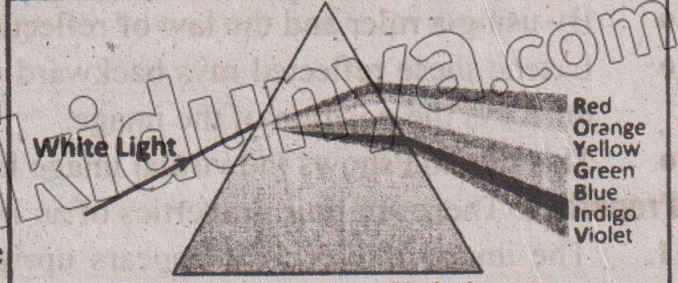


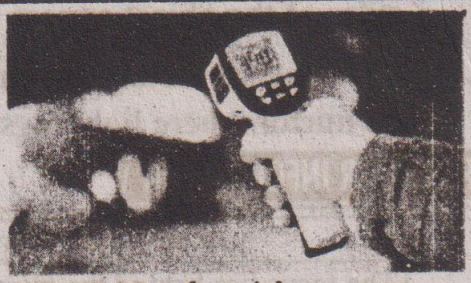
Fig. 14.29: Dispersion of light by prism

Dispersion of prism: Beyond the visible spectrum, prisms can also disperse infrared (IR) and ultraviolet (UV) light, though these wavelengths are invisible to the human eye.

Methods: Special detection methods, such as infrared thermometers with sensors, are used to measure these wavelength.

Infrared Thermometers:

- These devices detect IR radiation emitted by objects, which correlates with their temperature.
- When dispersed light from a prism reaches an IR thermometer, it can measure both visible and infrared light.
- By analyzing the intensity of IR radiation, the thermometers determines the temperature of the emitting object.


Fig. 14.30: Infrared thermometers

- This technology allows for non-contact temperature measurement, such as checking human body temperature (Fig. 14.30).

ACTIVITIES

Activity 14.1: Finding the Image Position in a Plane Mirror:

Objectives: To observe and understand the position and characteristics of the image formed by a plane mirror.

Materials Needed:

- A plane mirror
- An object
- A measuring tape
- A light source
- A white paper

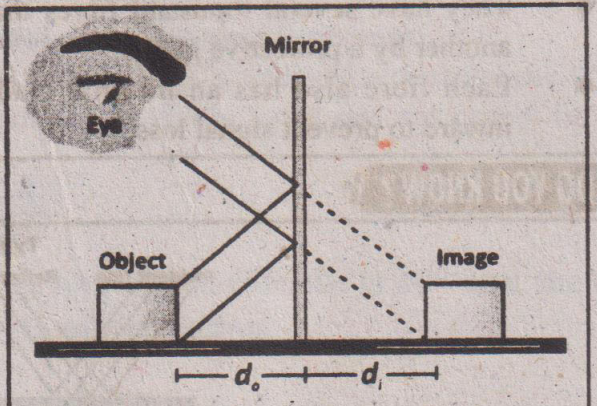


Fig. 14.2: Image formation by a plane mirror

Procedure:

- Place the plane mirror in an upright (vertical) position.
- Position the object in front of the mirror.
- Ensure the object is not taller than the mirror.
- Shine light onto the object so it is clearly visible (Fig 14.2).
- Look at the mirror and observe the rays of light reflecting from the object.
- When two rays reflect off the mirror and reach the observer's eye, they appear to be coming from behind the mirror.

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- By using a ruler and the law of reflection, we can draw the reflected rays on paper.
- Extend these reflected rays backward with dotted lines where they meet behind th mirror is the position of the image.
- This method shows the virtual image location.

Properties: There are four properties of an image formed by a plane mirror:

1. The image is erect - It appears upright, just like the object.
2. The image is of the same size – The size of the image is exactly equal to the size of the object. It can be written as: $d_i = d_o$.
3. The image is laterally inverted – The left and right sides of the object appear reversed in the image.
4. The image is virtual - It cannot be captured on a screen because it is formed behind the mirror where light rays do not actually meet.



Fig. 14.3: Letter 'D' showing lateral inversion in a mirror

FOR YOUR INFORMATION

Convex Mirror	Concave Mirror
The focus lies behind the mirror	The focus is in front of the mirror
The focus is virtual as the rays of light after reflection appear to come from the focus.	The focus is real as the rays of light after reflection converge at the focus.

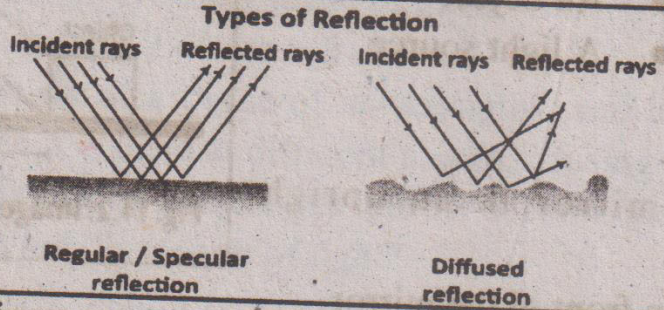
What is a Fibre Optic Cable?

Fibre optic cables are composed of very thin strand of extremely pure glass fibres.



- They transmit information using light from lasers of LEDs that is modulated with date or used in some cases as a light source.
- They have several thousand fibres that are insulated from one another by a protective jacket.
- Each fibre also has an internal cladding that bounces light inward to prevent signal loss.

DO YOU KNOW?

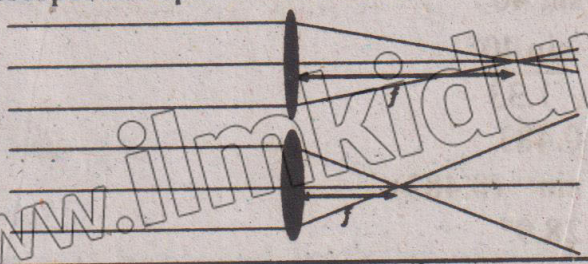


Some sign conventions for mirrors are:

Quantity	When Positive (+)	When Negative (–)
Object distance p	Real object	Virtual object
Image distance q	Real image	Virtual image
Focal length f	Concave mirror	Convex mirror

The thicker lens "bends" the light more, so it has a greater POWER than the thin lens. This concept is

important in eyeglasses, microscopes and optical instruments.



Facts About Magnifying Glass

Did you know that if your eyes can only focus to within about 15 cm in front of them? Anything closer will be blurry. If your eyes could focus you would not need magnifiers!



Tidbits

1. **Why do diamonds sparkle so brightly?**

Ans. Diamonds sparkle because they have a very high refractive index, causing multiple total internal reflections inside.

2. **How can a convex lens produce both inverted and upright images depending on its positions?**

Ans. A convex lens can flip our image upside down, but when it is close to our eye (like in a magnifier), it stays upright and larger.

Brain Teaser

1. **Place a pencil in a glass of water, it appears bent. What does this tell about the speed of light in water compared to air?**

Ans. The pencil appears bent because light slows down when it enters water from air. This shows that the speed of light in water is less than its speed in air, causing refraction (bending of light).

2. **Why can we use optical fibres to send data around bends and corners without much loss?**

Ans. Optical fibres can send data around bends because light undergoes total internal reflection inside the fiber. This keeps the light trapped with in the core, so very little energy is lost even when the fiber bends.

3. **Why is the image in a plane mirror considered virtual, even though it looks real?**

Ans. The image in a plane mirror is virtual because the reflected light rays do not actually meet behind the mirror. They only appear to come from that point, so the image looks real but cannot be formed on a screen.

Examples

14.1 A ray of light enters from air into water. The angle of incidence is 40° and the refactive index of water is 1.33. Find the angle of refraction.

Sol. **Given that;**

Angle of incidence = $i = 40°$

Refractive index of water = n = 1.33

To find;

Angle of refraction = r = ?

Using Snell's law:

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

Substituting the values:

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$$1.33 \times \sin r = \sin 40°$$

$$\sin r = \frac{\sin 40°}{1.33}$$

$$\sin r = 0.483$$

$$r = \sin^{-1}(0.483)$$

or $r = 28.9°$

Hence, the angle of refraction is 28.9°.

14.2 The refractive index of water is 1.33. What is the speed of light in water?

Sol. Given that;

Refractive index of water = n = 1.33

Speed of light in vacuum = $c = 3 \times 10^8 ms^{-1}$

To find;

Speed of light in water = v = ?

Using the formula:

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

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

Substituting the values:

$$v = \frac{3 \times 10^8 ms^{-1}}{1.33}$$

$$v = 2.26 \times 10^8 ms^{-1}$$

The speed of light in water is $2.26 \times 10^8 ms^{-1}$.

14.3 Find the value of critical angle for water (refracted angle = 90°). The refractive index of water is 1.33 and that of air is 1.

Sol. Using Snell's law:

$n_1 \sin i = n_2 \sin r$

For the Critical angle, the refracted angle r = 90° , and i = C so sin (90°) = 1.

$$n \sin C = 1$$

Rearranging for C:

$$C = \sin^{-1}(1/n)$$

Substituting the values

$$C = \sin^{-1}(1/1.33)$$

$$C = \sin^{-1}(0.752)$$

$$C = 48.8°$$

The critical angle for water is 48.8°

14.4 A concave lens has a focal length of –25 cm find its power.

Sol. Given that;

$$f = -25cm = -0.25m$$

To find; P = ?

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Using the formula:

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

$$P = 1/(-0.25m)$$

$$P = -4.0\ D$$

14.5 An object 8cm tall is placed in front of a concave mirror. The linear magnification is – 2. Find the height of the image.

Sol. Given that;

$h_o = 8cm$

$M = -2$

To find;

$h_i = ?$

Using the formula:

$$M = \frac{h_i}{h_o}$$

$$h_i = M \times h_o$$

$$h_i = -2 \times 8cm$$

$$h_i = -16cm$$

The negative sign shows that the image is inverted and twice the size of the object

Objective Type Questions

Additional MCQ's

Multiple Choice Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

14.1 Reflection of Light

1. According to the second law of reflection the Angle of incidence (i) is always:

(a) Greater than the Angle of reflection (r)
(b) Less then the Angle of reflection (r)
(c) Equal to the Angle of reflection (r)
(d) Twice the Angle of reflection (r)

2. Which type of reflection occurs on rough surface like paper, where light scatter in different direction?

(a) Regular Reflection (b) Specular Reflection
(c) Diffused Reflection (d) Mirror Reflection

3. In a ray diagram for Reflection, the "Normal" is defind as:

(a) The line parallel to the surface

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(b) The line perpendicular to the surface at the point of incidence.
(c) The path the reflected ray takes
(d) The Angle between the incident and reflected ray

14.2 Refraction of Light

4. Refraction occurs because light travel at different _____ in different materials
(a) Frequencies (b) Speeds (c) Colors (d) Intensities

5. When light moves from a rarer medium (air) to a denser medium (glass), it bends.
(a) Away from the normal (b) Towards the normal
(c) Back into the first medium (d) In a straight line without bending

6. The speed of light in a vacuum is approximately:
(a) $3 \times 10^5\ ms^{-1}$ (b) $3 \times 10^8\ ms^{-1}$ (c) $3 \times 10^{10}\ ms^{-1}$ (d) $3 \times 10^6\ ms^{-1}$

7. Snell's law is expressed by the formula:
(a) $n = \frac{\sin r}{\sin i}$ (b) $n = \frac{\sin i}{\sin r}$ (c) $n = c \times u$ (d) $n = i \times r$

8. The refractive index (n) of a medium is defind as the ratio of the speed light in vacuum (c) to:
(a) The speed of light in the medium (u) (b) The Angle of incidence
(c) The thickness of the medium (d) The speed of sound in the medium

9. The critical angle is the angle of incidence for which the angle of refraction is:
(a) 0° (b) 45° (c) 90° (d) 180°

10. Total internal reflation only occurs when light travel from:
(a) A rarer medium to a denser medium (b) A denser medium to rarer medium
(c) Air to water (d) Vacuum to glass

11. Which of the following material has the highest refractive index?
(a) Water (b) Glass (c) Demand (d) Ice

12. In the experiment with a semi-circular glass block if (incidence angle)*i* < c (critical angle) what happens?
(a) Total internal reflection (b) Refraction in to air
(c) Light stops completely (d) Light turn into a rainbow

13. What is the of value of critical angle for water, If its refractive index 1.33:
(a) 42.0° (b) 48.8° (c) 24.4° (d) 90.0°

14. Diamond sparke because they have a very high refractive index. This cause:
(a) High absorption (b) Multiple total internal reflection
(c) Simple refraction (d) Regular reflection

15. The formula to find out critical angle C when the second medium is air is:
(a) $\sin C = n$ (b) $\sin C = 1/n$ (c) $\sin C = n/\sin i$ (d) $n = C \times \sin r$

16. Which material has the lowest speed of light?
(a) Ice (b) Water (c) Diamond (d) Air

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14.3 Optical Fibre

17. **Optical fibre works on the principle of:**
(a) Refraction (b) Total internal reflaction
(c) Dispersion (d) Regular Reflection

18. **In an optical fibre, the "core" is surrounded by a layer with a lower refractive index called the**
(a) Beffer (b) Outer Jacket
(c) Cladeling (d) Straight member

19. **Which of the following is an advantage of optical fibre over copper wires?**
(a) Higher power consumption (b) Lower band width
(c) Resistance to electrical interference (d) Slower data transmission

20. **What allows optical fibres to carry data over very long distance without losing signal quality?**
(a) Their thickness (b) High energy loss
(c) Minimal energy loss during repeated reflection
(d) The use of electricity instead of light.

14.4 Thin lenses

21. **A lens that is thicker in the center and thinner at the edges is called a:**
(a) Concave lens (b) Diverging lens
(c) Convex lens (d) Plano concave lens

22. **A convex lens is also a _____ lens because it brings parallel light rays together at a point.**
(a) Point (b) Converging (c) Reflecting (d) Refracting

23. **The distance from the lens to its focus Point (f) is know as the:**
(a) Principle axis (b) Optical center
(c) Focal length (d) Radius of curvature

24. **In a diverging (concave) lens, the focal length (f) is considered:**
(a) Positive (b) negative (c) zero (d) Infinite

25. **The imaginary line passing through the center of the lens that light rays travel along without bending is the:**
(a) Normal (b) Refracted ray (c) Principle axis (d) Incident ray

26. **According to definition, a lens must have atleast one surface that is:**
(a) Flat (b) Curved (c) Reflection (d) Opaque

27. **A lenes that is thinner at the center and thicker at the edges is a:**
(a) Cenvex lens (b) Converging lens
(c) Concave lens (d) Double convex lens

28. **Which type of lens is also know as a converging lens:**
(a) Concave (b) Convex (c) Plano - concave (d) Diverging

29. **A concave lens cause parallel light rays to:**
(a) Meet at a single point (b) Reflect back to source

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(c) Spread out (diverg) (d) Turn into white light

30. **The straight imaginary line passing through the center of lens is called the:**
(a) Focal length (b) Principal axis (c) Optical center (d) Normal

31. **In a converging (convex) lens, the focal length is always consider**
(a) Negative (b) Positive (c) Zero (d) Neutral

32. **The distance from the optical center of the lens to its principle focus is the:**
(a) Radius (b) Focal length (c) Apreture (d) Optical path

33. **Light rays travel exactly along the principal axis of a lens will:**
(a) Bend at 45° angle (b) No bend or change direction
(c) Reflect 180° (d) Diverge immediately

34. **For a diverging lens, the focal length is mathematically treated as,**
(a) Positive (b) Negative (c) Infinite (d) Variable

35. **Parallel rays entering a convex lens meet at point called the:**
(a) Optical center (b) Principal focus
(c) Center of curvature (d) Incident point

14.5 Optical devices
14.6 Image Formation in a Normal Eye
14.7 Gravitational Lens and Acoustic Lens
14.8 Dispersion of Light by Prism

36. **When light rays enter a prism, the bending of light at different angle cause,**
(a) Reflection (b) Total internal reflection
(c) A change in the ray's path (d) Absorption of all color

37. **The angle between the incident ray and the imergent ray in a prism is know as the;**
(a) Angle of incidence (b) Angle of refraction
(c) Angle of deviation (d) Critical angle

38. **In simple camera distance between lens and film equal to:**
(a) F (b) 2F (c) between F and 2F (d) Beyond 2F

39. **Which lens is used for the correction of myopia?**
(a) Convex (b) Concave (c) Plane (d) Double convex

40. **SONAR systems to detect _____ objects.**
(a) space (b) air (c) underwater (d) underground

41. **Infrared Thermometers detect _____ radiation.**
(a) IR (b) UV (c) X-rays (d) Thermal

42. **Acoustic lens focus or spread _____ waves.**
(a) sound (b) radio (c) heat (d) water

Answers

1. (c) 2. (c) 3. (b) 4. (b) 5. (b) 6. (b) 7. (b)

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8.	(a)	9.	(c)	10.	(b)	11.	(c)	12.	(b)	13.	(b)	14.	(b)
15.	(b)	16.	(c)	17.	(c)	18.	(c)	19.	(c)	20.	(c)	21.	(c)
22.	(b)	23.	(c)	24.	(b)	25.	(c)	26.	(b)	27.	(c)	28.	(b)
29.	(c)	30.	(b)	31.	(b)	32.	(b)	33.	(b)	34.	(b)	35.	(b)
36.	(c)	37.	(c)	38.	(a)	39.	(b)	40.	(c)	41.	(a)	42.	(a)

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Additional Short Questions

Short Answer Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

14.1 Reflection of Light

1. Define Reflection of light Also write its types?

Ans. Reflection of light: "Reflection take place when lights hit a surface and bounces back instead of passing through it"

Types:

- Regular / specular Reflection
- Diffused/Irregular Reflection

2. State the first law of reflection?

Ans. The incident ray the reflected ray and the normal (a line drawn perpendicular to the surface at the point of reflection) all lie in the same plane.

3. What is the relationship between the angle of incidence (i) and the angle of reflection (r)?

Ans. According to the second law of reflection, the angle of incidence (i) is always equal to the angle of reflection (r).

$$\angle i = \angle r$$

4. Differentiate between regular and diffused reflection?

Ans. Regular reflection: Regular reflection occurs on smooth surfaces (like mirror) and reflects light in one direction to form a clear image.

Diffused reflection: Diffused reflection occurs on rough surfaces (like paper) and scatters light in different directions, so no clear image is seen

5. Why is reflection important for seeing objects that are not light sources themselves?

Ans. Reflection allows us to see objects and form images by bouncing light off their surfaces into our eyes.

14.2 Refraction of Light

6. What is refraction of light?

Ans. Refraction is the bending of light that occurs when it changes direction as it passes from one medium to another, such as from air to water or glass.

7. Why does light change direction when it passes from one medium to another?

Ans. This happens because light travels at different speed in different materials.

8. According to snell's law, what is the ratio of the sine of the angle of incidence to the sine of the angle of refraction?

Ans. The ratio of the sine of the angle of incidence (i) to the sine of the angle of refraction (r) remains constant for a specific pair of media.

$$\left(n=\frac{\sin i}{\sin r}\right)$$

9. How does the speed of light change when it enters a denser medium?

Ans. Light slows down when it passes through denser materials like air, water, or glass due to interactions with medium particles

10. Define "refractive index" in terms of the speed of light?

Ans. It is defined as the ratio of the speed of light in air or vacuum (c) to the speed of light in the given medium (v)

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

11. Define the critical angle?

Ans. The critical angle is the specific angle of incidence for which the angle of refraction is 90°

12. What happens to a light ray if the angle of incidence is greater than the critical angle?

Ans. The light ray does not refract at all; instead, it reflects entirely back into the same medium, a phenomenon called total internal reflection.

13. Under what two conditions does total internal reflection occurs?

Ans. (i) It occurs when light passes from a denser medium to a rarer medium.
(ii) When the angle of incidence is greater than its critical angle.

14. What is the value of critical angle for water?

Ans. The critical angle for water is 48.8°

15. Why do diamonds sparkle so brightly?

Ans. Diamonds sparkle because they have a very high refractive index, which causes multiple total internal reflections inside the diamond.

16. What is an optical prism?

Ans. A prism is a transparent optical object with atleast two polished plane surfaces inlined towards each other, usually used to refract light

17. Define the "Angle of Deviation" in prism.

Ans. The angle of Deviation (D) is the angle by which the emergent ray is bent away from the original path of the incident ray.

18. What path does a light ray take as it enters and then exists a triangular glass prism?

Ans. The incident ray bends towards the normal as it enters the prism and then bends away from the normal as it exists the prism, forming an emergent ray that is not parallel to the incident ray.

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14.3 Optical Fibre

19. Which principle of light is used by optical fibres to transmit information over long distances?

Ans. Optical fibres use the principle of total internal reflection to transmit information efficiently with minimal energy loss.

20. What are the two main primary layers of an optical fibres?

Ans. An optical fibre consists of a "core" (the inner part that carries light) and a cladding (the surrounding layer with a lower refractive index)

21. Why are optical fibre preffered over coper wires for data transmission?

Ans. They offer higher bandwidth (car carry more data), lower power consumption and are resistant to electrical interference.

14.4 Thin lenses

22. Define a lens and its primary function.

Ans. A lens is a transparent material with at least one curved surface that refracts light to form an image.

23. What is the difference between a converging (convex) and a diverging (concave) lens?

Ans. Convex lense: A convex lens is thicker in the middle and converges light rays to a point.

Concave lense: While a concave lens is thinner in the middle and spreads light rays apart.

24. Define the " focal length" of a lens.

Ans. The focal length (f) is the distance from the optical center of the lens to the principal focus where light rays either meet or appear to diverge from.

25. What is the SI unit for the power of a lens?

Ans. The SI unit for the power of lens is the dioptre (D).

14.5 Optical devices

26. Under what condition is a real image formed by a lens.

Ans. A real image is formed when light rays actually intersect after passing through the lens, it is always inverted and can be projected onto a screen.

27. What is virtual image?

Ans. A virtual image is formed when light rays only appear to meet when traced backward, it is upright and cannot be caught on a screen.

28. Where must an object be placed to use a convex lens as a magnifying glass.

Ans. The object must be placed between the optical center and the principle focus (F) of the lens to produce a magnified upright and virtual image.

14.6 Image Formation in a Normal Eye

29. What is "accommodation" of the human eye?

Ans. Accommodation is the process where the ciliary's muscles change the thickness (focal length) of the eye lens to focus clearly on object at various distance.

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30. Define short sightedness (Myopia).

Ans. Myopia is a vision defect where a person can see nearby object clearly, but distant appear blurred because the image form in front of retina.

31. How is myopia corrected?

Ans. It is corrected by using a concave (diverging) the light rays before they enter the eye, moving the focus point back onto the retina.

32. What is long sightedness (Hypermetropia).

Ans. Hypermetropia is a condition where a person can see distant object clearly, but nearby object appear blurred because the image forms behind the retina.

33. Which is used to correct Hypermetropia?

Ans. A convex (converging) lens is used to provide extra converging power, bringing the focus point forward onto the retina.

14.7 Gravitational Lens and Acoustic Lens

34. What is gravitational lensing?

Ans. Gravitational lensing occurs when the strong gravitational field of a massive object like black hole or galaxy, bonds the path of light traveling near it.

35. What is the effect of gravitational lensing?

Ans. This effect cause the distant to appear magnified, distorted or even duplicated, creating multiple images.

36. What is the importance of gravitational lensing?

Ans. Gravitational lensing is a valuable tool in astronomy. It help scientists study distant galaxies, dark matter, and the structure of universe.

37. What is the working of acoustic lense?

Ans. These lenses can focus sound to a specific point (like a microscope or sensor), or diverge sound to spread it over a wide area.

14.8 Dispersion of Light by Prism

38. What is dispersion?

Ans. "The splitting of white light into its seven constituent colours when passing through a prism is called dispersion."

39. What is prism?

Ans. A prism is an optical object typically made of glass with triangular and rectangular sides. It bends light passing through it due to refraction.

40. What are infrared thermometers?

Ans. These devices detect IR radiation emitted by objects which correlates with their temperature.

Exercise Questions (Solved)

A. Multiple Choice Questions

☆ **Tick (✓) the correct answer.**

14.1 What type of image is always formed by a convex mirror?

(a) Real and inverted (b) Virtual and diminished

(c) Real and magnified (d) Virtual and magnified

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14.2 The optical device which uses a convex lens to magnify an object by creating a virtual image:

(a) camera (b) microscope (c) magnifying glass (d) slide projector

14.3 Which statement best describes the phenomenon of total internal reflection?

(a) Light bends when it enters a new medium

(b) Light is completely reflected at the boundary of two media

(c) Light slows down as it enters a denser medium

(d) Light passes through a medium without changing direction

14.4 A ray of light travelling from water to air bends:

(a) toward the normal (b) away from the normal

(c) at 90° to the normal (d) parallel to the normal

14.5 The optical device which works on the principle of inverting an image for projection is:

(a) magnifying glass (b) photograph Enlarger

(c) slide projector (d) plane mirror

14.6 What happens to light when it enters an optical fibre?

(a) It is absorbed by the fibre (b) It undergoes total internal reflection

(c) It gets refracted at every point

(d) It travels in a straight line without deviation

14.7 Which of the following phenomenom explains why a pencil appears bent when partially immersed in water?

(a) Reflection (b) Diffraction (c) Refraction (d) Interference

Answers

14.1 (b) **14.2** (c) **14.3** (b) **14.4** (b) **14.5** (c) **14.6** (b) **14.7** (c)

B. Short Answer Questions

14.1 What happens when light passes from air to water?

Ans. When light passes from air to water, it slows down and bends toward the normal because water is optically denser than air.

14.2 Define refractive index. What is the refractive index of air and water?

Ans. Refractive Index:

"It is defined as the ratio of the speed of light in air or vacuum 'c' to the speed of light in the given medium 'v'.

$$\text{Refractive Index} = \frac{\text{Speed of light in air}}{\text{Speed of light in medium}}$$

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

The refractive index of air is approximately 1.00

The refractive index of water is approvimately 1.33

14.3 What is the principle behind optical fibres?

Ans. Optical fibers work based on the principle of total internal reflection. Light stays

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trapped inside the core by constantly reflecting off the cladding boundry at angles greater than the critical angle.

14.4 Describe briefly how a convex lens forms a real or virtual image.

Ans. A convex lens forms a real image when the object is beyond the focal length and a virtual image when the object is within the focal length.

14.5 How does the power of a lens relate to its focal length?

Ans. Power (P) is the reciprocal of the focal length (f). It is measured in Diopters (D).

$$P = \frac{1}{f(\text{in meters})}$$

14.6 Write Snell's law and define the terms used in the equation.

Ans. Snell's law:

"The ratio of sine of the angle of incidence (i) to the sine of angle of reflection (r) remains constant for a specific pair of media. This is known as snell's law".

Snell's law is written as:

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

n_1 is refractive index of the first medium.

θ_1 is the angle of incidence (the angle between the incident ray and the normal to the surface)

n_2 is the refractive index of the second medium.

θ_2 is the angle of refraction (the angle between the refracted ray and the normal to the surface).

C. Constructed Response Questions

14.1 When a pencil is partially dipped in water, it appears bent or broken. What principle of light explains this phenomenon, and how does it relate to changes in speed?

Ans. The principle of refraction of light explains this phenomenon. It relates to changes in speed because light bends when its speed changes as it passes from one medium to another.

14.2 Why can a prism separate white light into its component colours while a plane glass slab cannot, even though both cause refraction?

Ans. A prism separates white light into its component colours due to dispersion, where the refractive index of the prism material varies with the wave length of light, causing different colours to refract at different angles.

A plane glass slab does not separate colours because the parallel surfaces cause the light rays to emerge parallel to their original direction, cancelling out the dispersion effect.

14.3 Why does light undergo total internal reflection when travelling from waterto air at a certain angle but not the other way around?

Ans. Light undergoes total internal reflection when traveling from water to air at a certain angle because light bends away from the normal when going from a denser

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to a rarer medium, and at an angle of incidence greater than the critical angle, it is entirely reflected. It does not happen the other way around (air to water) because light bends towards the normal when going from a rarer to a denser medium, and thus will always refract into the denser medium.

14.4 Optical fibres use total internal reflection for signal transmission. What would happen if the cladding had a higher refractive index than the core, and why?

Ans. For an optical fibre to work, the core must have a higher refractive index than the cladding to allow total internal reflection. If the cladding had a higher refractive index , the light would refract out of the core into the cladding instead of reflecting back, causing total signal loss.

14.5 A person uses a magnifying glass to read small print. What must be the relationship between the object distance and the focal length of the lens for the image to be upright and magnified?

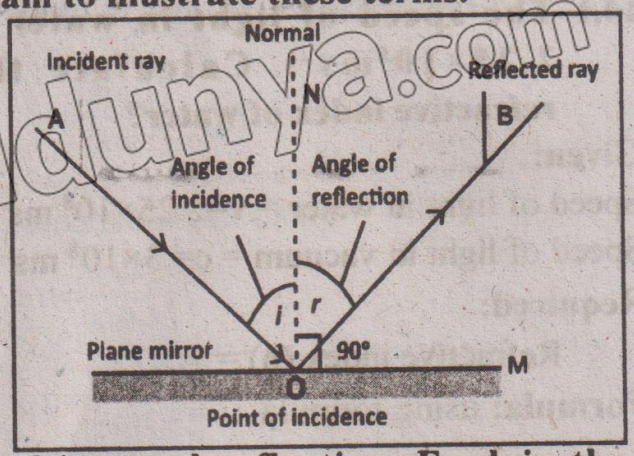
Ans. For a convex lens to produce an upright, magnified and virtual image, the object distance (p) must be less than the focal length (f) of the lens ($p < f$)

D. Descriptive Questions

14.1 Explain the terms; normal, angle of incidence and angle of reflection in the context of light reflection. Provide a diagram to illustrate these terms.

Ans. Normal:

An imaginary line perpendicular to the reflecting surface at the point of incidence.



- **Angle of incidence (i):**

The angle between the incident ray and the normal.

- **Angle of reflection (r):**

The angle between the reflected ray and the normal.

14.2 Define the terms critical angle and total internal reflection. Explain the conditions required for total internal reflection to occur.

Ans. For Answer See Q.11

14.3 Derive the equation; (n = 1 / sin C) for the refractive index in terms of the critical angle C. Include all steps and assumptions.

Ans. Derivation of the formula for Total Internal Reflection:

To derive a formula for total internal reflection, we start with Snell's law:

$n_1 \sin i = n_2 \sin r$

When total internal reflection occurs, the refracted angle becomes 90°. So, the equation becomes:

$n_1 \sin i = n_2$, because $\sin(90°) = 1$

Now, if 'i' is the critical angle C, the formula becomes:

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

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To find the critical angle C, we rearrange it as:

$$C = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

This only works when $n_1 > n_2$ meaning the light must travel from a denser medium to a rarer medium.

If the second medium is air (where $n_2 = 1$), the equation becomes. $\sin C = 1/n$

From the above equation, the refractive index of the first material (demser medium) can be founds,

$$n = \frac{1}{\sin C}$$

This relation only holds true if the light is moving from a denser medium with refractive index n into air.

14.4 Describe the structure of an optical fibre. Write its any two advantages.

Ans. For Answer See Q.13,14

14.5 What is long-sightedness? Discuss its causes.

Ans. For Answer See Q.26

E. Numerical Problems

14.1 The speed of light in water is $2.25\times10^8 ms^{-1}$. Calculate the refractive index of water?

Given:

Speed of light in water = $v=2.25\times10^8\ ms^{-1}$

Speed of light in vacuum = $c= 3\times10^8\ ms^{-1}$

Required:

Refractive index (n) = ?

Formula: using formula

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

Solution:

By substituting values:

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

$$n = \frac{3.0\times10^8 ms^{-1}}{2.25\times10^8 ms^{-1}}$$

$$n = 1.333$$

Result:

The refractive index (n) of water is 1.33

14.2 A light ray in air (n_1=1.0) strikes a glass surface (n_2=1.5) at an angle of incidence 30°. Find the angle of refraction inside the glass.

Sol. Given:

refractive index of air = $n_1 = 1.0$

refractive index of glass = $n_2 = 1.5$

Angle of incidence = $\angle i = 30°$

Required:

Angle of refraction = $\angle r = ?$

Formula:

$n_1 \sin(i) = n_2 \sin(r)$

Solution:

By using snell's law:

$n_1 \sin(i) = n_2 \sin(r)$

By substituting values:

$(1.0)\sin(30°) = (1.5)\sin(r)$

So, $\sin(30°) = (1.5)\sin(r)$

$0.5 = 1.5 \sin(r)$

$$\sin(r) = \frac{0.5}{1.5}$$

$\sin(r) = 0.333$

$\angle r = \sin^{-1}(0.333)$

$\angle r = 19.5°$

Result: The angle of refraction inside the glass is 19.5°

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4.3 A beam of light in air hits a glass slab at an incidence angle of 40°.Find the angle of refraction inside the glass.

Given:

In air $n_1 = 1.0$

In glass slab $n_2 = 1.5$

Angle of incidence $= \angle i = 40$

Required:

Angle of refraction $(\angle r) = ?$

Formula:

$n_1 \sin(i) = n_2 \sin(r)$

Solution:

By substituting values.

$(1.0) \sin(40°) = (1.5) \sin(r)$

$(1.0)(0.6428) = (1.5) \sin(r)$

$0.6428 = (1.5) \sin(r)$

$$\sin(r) = \frac{0.6428}{1.5}$$

$\sin(r) = 0.4285$

$\angle r = \sin^{-1}(0.4285)$

$\angle r = 25.3°$

(Rounded to the nearest degree)

$\angle r = 25°$

Result: The angle of refaction inside the glass is 25°.

14.4 A ray of light travels from air into an unknown liquid. The angle of incidence in air is 45°, and the angle of refraction in the liquid is 30°.Calculate the refractive index of the liquid.

Given:

Angle of incidence in air $= \angle i = 45°$

Angle of refraction in liquid $= \angle r = 30°$

Required:

Refractive index of liquid $= n = ?$

Formula:

$$n = \frac{\sin(i)}{\sin(r)}$$

Solution:

$$n = \frac{\sin(i)}{\sin(r)}$$

By substituting values:

$$n = \frac{\sin(45°)}{\sin(30°)}$$

$$n = \frac{0.7071}{0.5} = 1.41$$

Result:

Refractive index of the liquid is 1.41

14.5 A ray of light passes from air into a liquid. The angle of incidence in air is 50°, and the angle of refraction inside the liquid is 32°.The speed of sound in air is 340 ms^{-1} and in the same liquid is 1500 $m\ s^{-1}$.

Calculate: (a) the refractive index of the liquid (b) the speed of light in the liquid.

Given:

Angle of incidence in air $= \angle i = 50°$

Angle of refraction in liquid $= \angle r = 32°$

Speed of light in vacuum $= c = 3 \times 10^8\ ms^{-1}$

Required:

(a) Refrective index $= n = ?$

(b) Speed of light in the liquid $v = ?$

Formula:

(a) $$n = \frac{\sin(i)}{\sin(r)}$$ (b) $$n = \frac{c}{v}$$

Solution:

(a) For refective index using

$$n = \frac{\sin(i)}{\sin(r)}$$

$$n = \frac{\sin(50°)}{\sin(32°)}$$

$$n = \frac{0.7660}{0.5299} = 1.45$$

(b) speed of light in liquid,

$n = 1.45$

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

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

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

$$v = \frac{3 \times 10^8\ ms^{-1}}{1.45}$$

$v = 2.0689 \times 10^8\ ms^{-1}$

$= 2.07 \times 10^8\ ms^{-1}$

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Result:

(a) The refractive index of the liquid is 1.45

(b) speed of light in the liquid is $2.07 \times 10^8\ ms^{-1}$

14.6 Light travels inside a glass block of refractive index n = 1.6. It strikes the glass-air boundary. Calculate the critical angle for total internal reflection.

Given:

Refractive index = n = 1.6

Required:

Critical angle = C = ?

Formula:

$$\sin C = \frac{1}{n}$$

Solution:

Using formula

$$\sin C = \frac{1}{n}$$

Substitute the values

$$\sin C = \frac{1}{1.6}$$

$$\sin C = 0.625$$

$$C = \sin^{-1}(0.625)$$

$$C = 38.68°$$

14.7 An object is placed 15.0 cm in front of a convex mirror, forming a virtual image 7.5 cm behind the mirror. What is the focal length of the mirror?

Given:

Object distance = p = 15.0 cm

image distance = q = –7.5 cm

(for convex mirror)

Required:

Focal length = f = ?

Formula:

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Solution:

Using formula:

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

By substituting values:

$$\frac{1}{f} = \frac{1}{15} + \frac{1}{-7.5}$$

$$\frac{1}{f} = \frac{1}{15} - \frac{2}{15}$$

$$\frac{1}{f} = \frac{1-2}{15}$$

$$\frac{1}{f} = \frac{-1}{15}$$

$$f = -15cm$$

Result:

The focal length (f) of the mirror is –15cm.

14.8 An object 30 cm tall is located 10.5 cm from a concave mirror with focal length 16 cm. (a) Where is the image located? (b) How high is it?

Given:

Object height = h_o = 30cm

Object distance = p = 10.5 cm

Focal length = f = 16cm

Required:

(a) Image location = q = ?

(b) Height of image = h_i = ?

Formula:

(a) Image location (q)

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

(b) Height of image(h_i)

$$h_i = M \times h_o$$

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Solution:

a) **image location (q)**

$$\frac{1}{f}=\frac{1}{p}+\frac{1}{q}$$

For (q)

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}$$

By substituing values

$$\frac{1}{q}=\frac{1}{16}-\frac{1}{10.5}$$

$$\frac{1}{q}=0.0625-0.0952$$

$$\frac{1}{q}=-0.0327$$

$$q=\frac{-1}{0.0327}=-30.58\text{cm} \approx -30.6\text{cm}$$

(b) **height of image (h_i)**

To find the height, we first need the Magnification.

$$M=\left|\frac{q}{p}\right|$$

$$M=\frac{30.6}{10.5}=2.91$$

(This means the image is nearly 3 times larger than the object)

Now, we calculate the height

$h_i = M \times h_o$

$h_i = 2.91 \times 30$

$h_i = 87.3$ cm

Result:

(a) The image is located at – 30.6cm

(b) The leight of image is 87.3 cm.

14.9 An object is placed at 30 cm to the left of a concave lens with focal length -15cm. Find the image distance and describe the image.

Given:

Object distance = p = 30cm

Focal lenght = f = –15cm (for concave lens)

Required:

image distance = q = ?

nature = ?

Formula:

$$\frac{1}{f}=\frac{1}{p}+\frac{1}{q}$$

Solution:

Rearrange the farmula

$$\frac{1}{f}=\frac{1}{p}+\frac{1}{q}$$

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}$$

Substitute the values.

$$\frac{1}{q}=\frac{-1}{15}-\frac{1}{30}$$

$$\frac{1}{q}=-\frac{2}{30}-\frac{1}{30}$$

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

$$\frac{1}{q}=-\frac{1}{10}$$

By taking reciprocal

$q = -10$ cm

Result:

The image distance is – 10cm

The image is virtual and upright formed on the same side of the object.



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