CHAPTER 14 — LIGHT

Class 10 Physics — Complete Notes with Diagrams

Key concepts: Reflection of light · Refraction of light · Optical fibre · Thin lenses · Optical devices · Image formation in a normal eye · Gravitational & acoustic lens · Dispersion of light by prism

1. Reflection of Light

Q.1 Define reflection of light. Discuss its two types.

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).

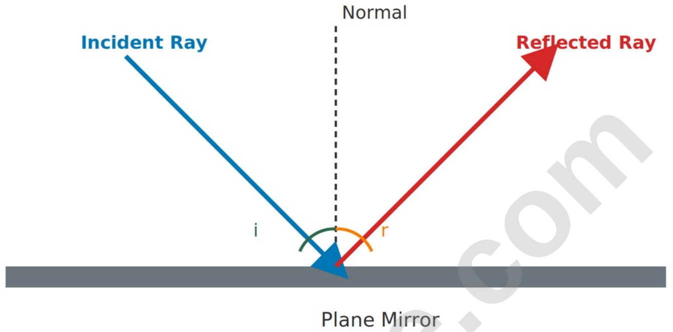

Fig 14.1: Angle of incidence (i) = Angle of reflection (r)

Types of Reflection

- Regular / Specular Reflection: occurs on smooth surfaces (like mirrors); parallel rays reflect in one direction forming a clear image.
- Diffused / Irregular Reflection: occurs on rough surfaces (like paper); light scatters in different directions so no clear image is formed.

Regular reflection (smooth surface) vs Diffused reflection (rough surface)

Laws of Reflection

1. First Law: The incident ray, reflected ray and the normal all lie in the same plane.
2. Second Law: Angle of incidence = Angle of reflection ($\angle i = \angle r$).

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

Q.2 Describe an experiment to find the position and characteristics of an image formed by a plane mirror.

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

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

Procedure: Place the mirror upright with the object in front (not taller than the mirror). Shine light on the object so it is visible. Observe the reflected rays reaching the eye — they appear to come from behind the mirror. Using a ruler and the law of reflection, draw the reflected rays and extend them backward with dotted lines; the point where they meet behind the mirror is the image position.

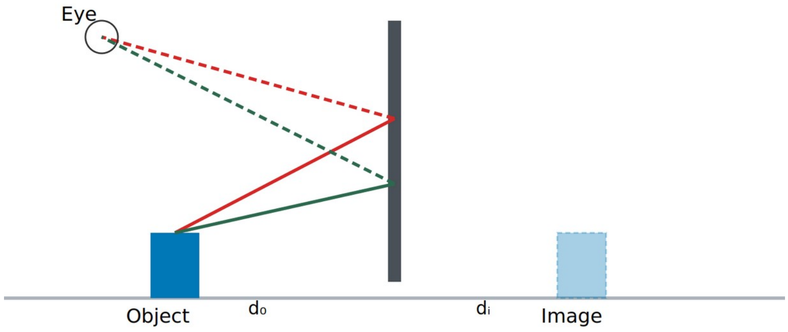

Fig 14.2: Image formation by a plane mirror (dotted lines traced backward locate the image)

Properties of Image Formed by a Plane Mirror

3. Erect — appears upright, just like the object.
4. Same size — image size equals object size: $d_i = d_0$.
5. Laterally inverted — left and right sides appear reversed.
6. Virtual — cannot be captured on a screen since light rays don't actually meet there.

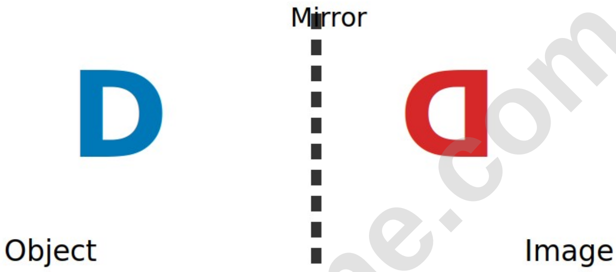

Fig 14.3: Letter 'D' showing lateral inversion in a mirror

2. Refraction of Light

Q.3 What is meant by refraction of light? State laws of refraction.

Definition: Refraction of light occurs when light changes direction as it passes from one medium to another (e.g. from air to water or glass).

- Light travels at different speeds in different materials.
- Moving from a rarer medium (air) to a denser medium (water/glass) — it bends towards the normal.
- Moving from a denser to a rarer medium — it bends away from the normal.
- The amount of bending depends on the refractive index of the medium.

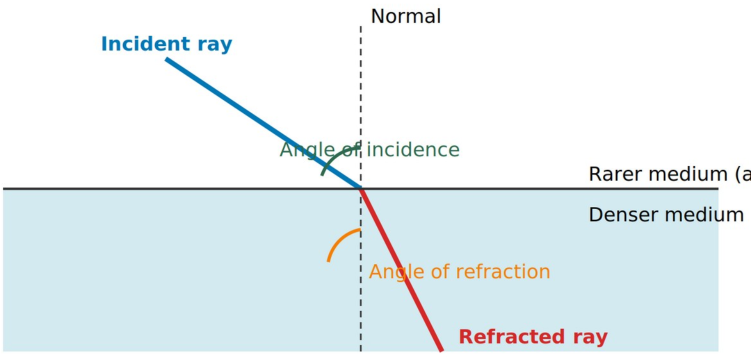

Fig 14.4: Refraction of light — bending towards the normal when entering a denser medium

Laws of Refraction

7. First Law: The incident ray, refracted ray, and normal at the point of incidence all lie in the same plane.
8. Second Law (Snell's Law): The ratio of sine of angle of incidence to sine of angle of refraction is constant for a given pair of media.

> *sin i / sin r = n ...... (14.2)*

Here n is the refractive index of the second medium relative to the first.

Speed of Light in a Medium

- In vacuum, light travels at its maximum speed: 3×10^8 m/s.
- In materials like air, water, or glass it slows down due to interaction with particles of the medium.
- The denser the medium, the slower the speed of light — this variation in speed is what causes refraction.

Q.4 Define refractive index and its mathematical form.

Definition: Refractive index is the ratio of the speed of light in air/vacuum (c) to the speed of light in the given medium (v).

> *n = Speed of light in air / Speed of light in medium ⇒ n = c / v ...... (14.3)*

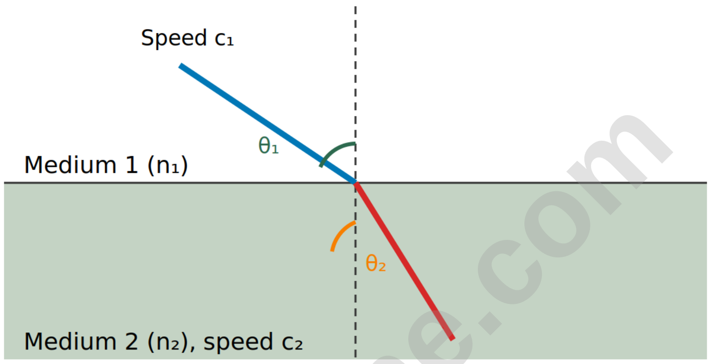

Fig 14.5: Light refraction at the boundary between two media

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

Q.5 What is a prism? Explain refraction through a prism.

Definition: A prism is a transparent optical object with at least two polished plane surfaces inclined towards each other (each angle 60° in a triangular prism).

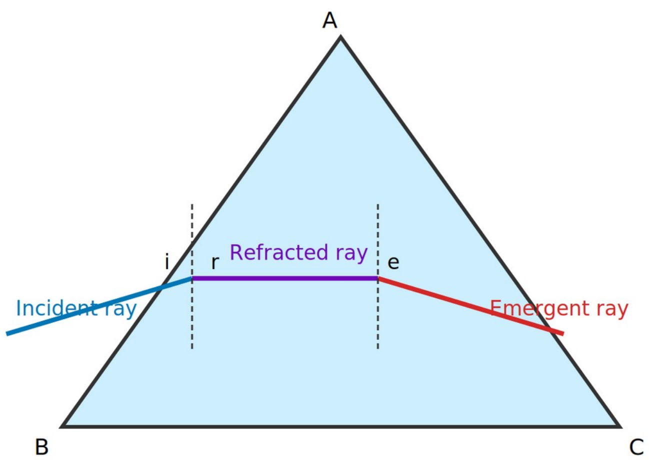

Fig 14.6: Refraction of light through a triangular glass prism

- Light does not emerge parallel to its original path but changes direction.
- Incident ray (PE) bends towards normal at E and travels as refracted ray (EF) inside the prism.

- Inside the prism the ray makes angle of refraction r before reaching the second surface at F.
- On exiting, it bends again forming the emergent ray (FS) at angle e.
- The emergent ray is deviated from the incident ray direction by the angle of deviation, D.
- Used widely in optical instruments, spectrometry, and dispersion experiments.

Q.6 Define critical angle and total internal reflection. State conditions for TIR. Establish relation between critical angle and refractive index.

Critical Angle: The angle of incidence for which the angle of refraction is 90° is called the critical angle.

As angle of incidence increases, the angle of refraction increases too. At the critical angle, the refracted ray travels along the boundary. Beyond the critical angle, light does not refract at all — it reflects entirely back into the same medium. This is total internal reflection (TIR).

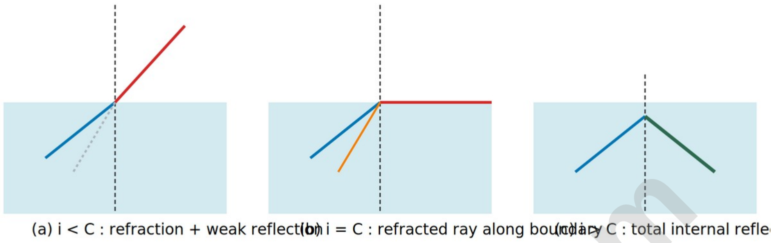

Fig 14.7: Refraction, the critical angle, and total internal reflection

Total Internal Reflection: the phenomenon of reflection of a light ray back into the same (denser) medium when passing from a denser to a rarer medium, provided the angle of incidence is greater than the critical angle.

Table 14.1: Refractive index, speed of light & critical angle

Medium	Refractive Index	Speed of light ($\times 10^8$ m/s)	Critical Angle
Diamond	2.42	1.25	24.4°
Glass (flint)	1.66	1.81	37.0°
Glass (crown)	1.52	2.01	41.0°
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 TIR formula

Starting from Snell's law: $n_1 \sin i = n_2 \sin r$ ...(14.4). At TIR, r = 90°, sin 90° = 1, so at the critical angle C: $\sin C = n_2 / n_1$ ...(14.5), giving $C = \sin^{-1}(n_2/n_1)$ ...(14.6). If the second medium is air ($n_2 = 1$):

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

This relation holds only when light moves from a denser medium (refractive index n) into air.

Q.7 & Q.8 Experiments to study refraction and total internal reflection using transparent blocks

Materials: Laser light, protractor, paper sheet, pencil, ruler, and Perspex blocks (rectangular, semi-circular, prism-shaped).

Method: Place the block on paper, draw a normal at the point where light enters, shine the laser at different angles along the drawn line, and mark/measure the incident and refracted/reflected rays.

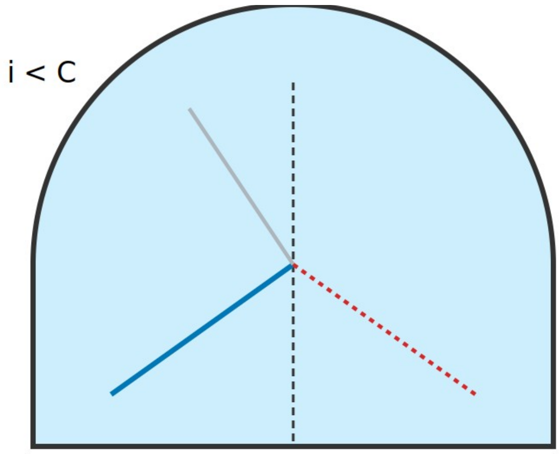

Fig 14.9: Semicircular glass block experiment — refraction, critical angle, and TIR

3. Optical Fibre

Q.9 Describe optical fibre and its advantages.

Optical fibres use the principle of Total Internal Reflection (TIR) to transmit light efficiently over long distances, and are widely used in telecommunications for their high speed and reliability. They consist of thin, hair-like strands of glass or plastic with two main parts: the core (inner, higher refractive index, carries light) and the cladding (outer, lower refractive index, causes TIR at the core–cladding boundary).

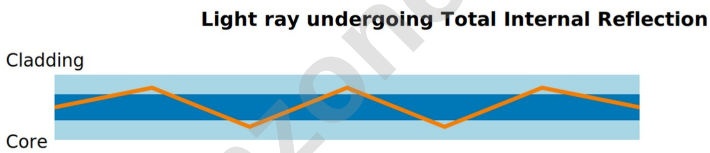

Fig 14.10/11: Structure of optical fibre — light trapped in the core by repeated TIR

Advantages of Optical Fibres (over copper cables)

9. High Bandwidth — carry much more data per second than copper wires.
10. Low Power Consumption — use less power; more durable, lower maintenance cost.
11. Faster Speed — data travels as light pulses, almost at the speed of light.
12. Long Distance Transmission — carry data across long distances (e.g. undersea cables) without losing signal quality.
13. Resistance to Electrical Interference — unaffected by electrical noise, unlike copper wires.

4. Thin Lenses

Q.10 Define lenses, their types, terms and lens equation.

Definition: A lens is a transparent material with two surfaces, at least one of which is curved. It bends (refracts) light to form an image of an object. Used in cameras, eyeglasses, microscopes, telescopes and projectors.

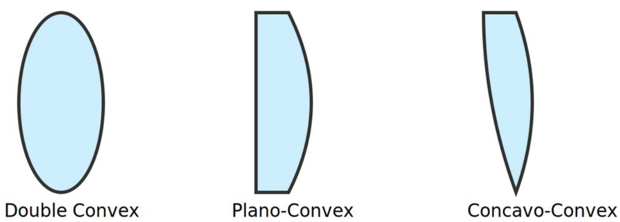

Fig 14.12: Convex (converging) lenses — thicker at centre, thinner at edges

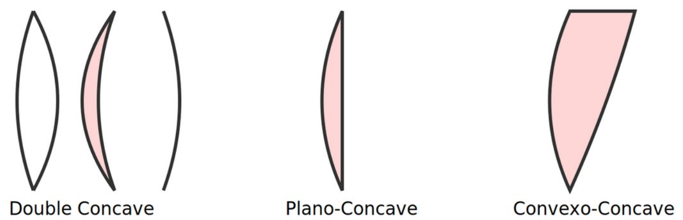

Fig 14.13: Concave (diverging) lenses — thinner at centre, thicker at edges

Important Terms

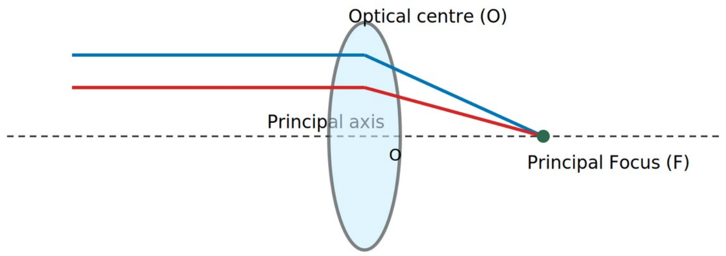

Fig 14.14: Focal length, principal axis, optical centre & principal focus

- Focal length (f): distance from lens to focal point. Positive for converging lenses, negative for diverging lenses.
- Principal axis: imaginary straight line through the centre of the lens.
- Principal focus: point where parallel rays converge (convex) or appear to diverge from (concave).
- Optical centre (O): geometrical middle point; light through it doesn't bend.
- Centre of curvature: centre of the sphere the lens surface is part of; generally at twice the focal length.

$1/f = 1/p + 1/q$ ...... (14.8) (Lens / Mirror equation)

Q.11 Behaviour of converging & diverging lens for parallel beam of light

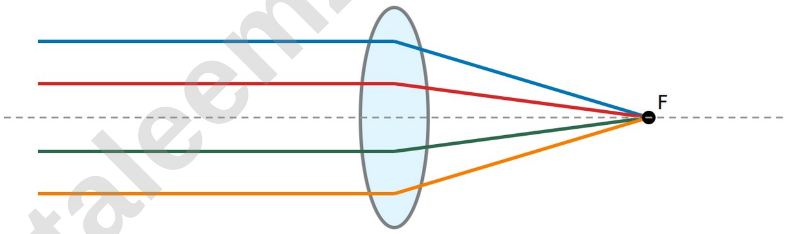

Fig 14.15: Convex lens — all parallel rays converge at the focal point F

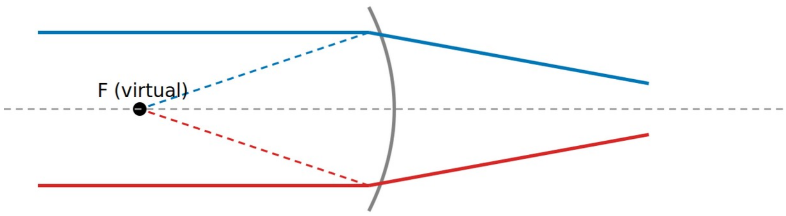

Fig 14.16: Concave lens — rays diverge; appear to come from a virtual focal point

A converging lens generally forms a real, inverted image — but if the object is very close, the image is virtual and upright. A diverging lens always forms a virtual, upright, and smaller image.

Q.12 Define power of a lens and its SI unit.

Definition: The power of a lens is its ability to bend light, defined as the reciprocal of its focal length (in metres).

$P = 1 / f$ ...... (14.9)

Unit: Dioptre (D). 1 D = power of a lens with focal length 1 metre. Convex lens → positive power; Concave lens → negative power. Higher power = light bends more strongly.

Q.13 Rules for image formation in convex lenses; real vs virtual image

Three Principal Rays

14. A ray parallel to the principal axis passes through the focal point F after refraction (ray-1).
15. A ray through the optical centre continues straight without bending (ray-2).
16. A ray through the focal point becomes parallel to the principal axis after refraction (ray-3).

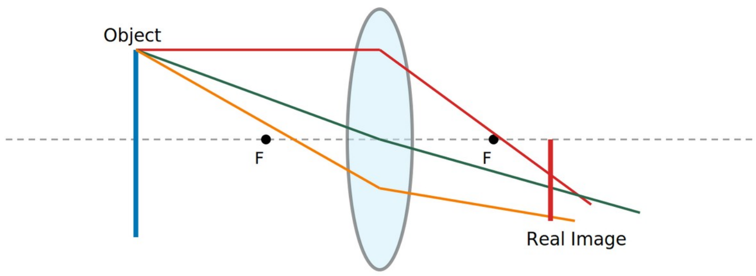

Fig 14.17: Image formation by a convex lens using the three principal rays

Table 14.2: Image formation by a convex lens

Object Position	Image Position	Size	Nature
At infinity	At F	Highly diminished	Real & inverted
Behind 2F	Between F and 2F	Diminished	Real & inverted
At 2F	At 2F	Same as object	Real & inverted
Between F and 2F	Beyond 2F	Enlarged	Real & inverted
At F	At infinity	Highly enlarged	Real & inverted
Between lens and F	Same side as object	Enlarged	Virtual & erect

Difference between Real and Virtual Images

Real Image	Virtual Image
Can be captured/displayed on a screen	Cannot be projected on a screen
Always inverted	Always upright (erect)
Formed when light rays actually meet	Formed when rays only appear to meet
Result of actual intersecting rays	Formed by imaginary extension of diverging rays
Example: image on a TV/cinema screen	Example: our reflection in a mirror

Q.14 Define linear magnification. Write its SI unit.

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

$M = \text{Image Height} / \text{Object Height} = h_i / h_0$ ...... (14.10)

Unit: Linear magnification has no units (it is a ratio).

5. Applications of Lenses in Optical Devices

Q.15 Discuss applications of lenses: Magnifying glass, Camera, Slide projector, Photograph enlarger

1. Magnifying Glass

A convex (converging) lens used to make objects appear larger. Object is placed closer than the focal length (p < f); the refracted rays appear to come from a point behind the lens, creating a virtual, upright, magnified image that cannot be projected on a screen. Also called a simple microscope.

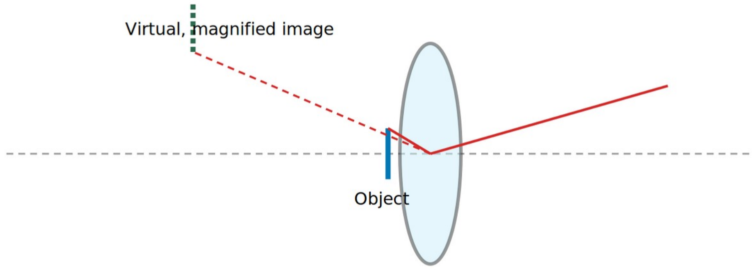

Fig 14.20: Magnifying glass — virtual enlarged image

2. Camera

Consists of a light-proof box with a convex lens at the front and a light-sensitive film/sensor at the back. The lens-film distance is fixed (= focal length). Object is beyond 2F, forming a real, inverted, diminished image on the film.

3. Slide Projector

Projects an enlarged image of a slide onto a screen. Components: a light source at the centre of a concave mirror (produces parallel rays), a condenser lens system (evenly distributes light), and a projection (convex) lens that forms a real, large, inverted image. The slide is placed upside down (between F and 2F) so the final image on screen appears correct.

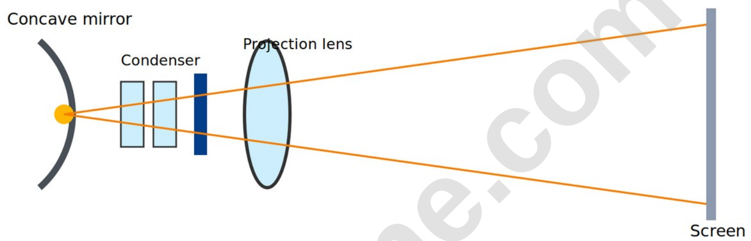

Fig 14.22: Ray diagram of a slide projector

4. Photograph Enlarger

Works similarly to a slide projector but enlarges photographic negatives onto photographic paper. The negative is placed between F and 2F, forming a real, inverted, enlarged image on the paper.

6. Image Formation in a Normal Eye & Defects of Vision

Q.16 Discuss image formation in a normal eye. Discuss defects of vision and their remedies.

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, clear (real, inverted) image — similar to how a convex lens forms a real image.

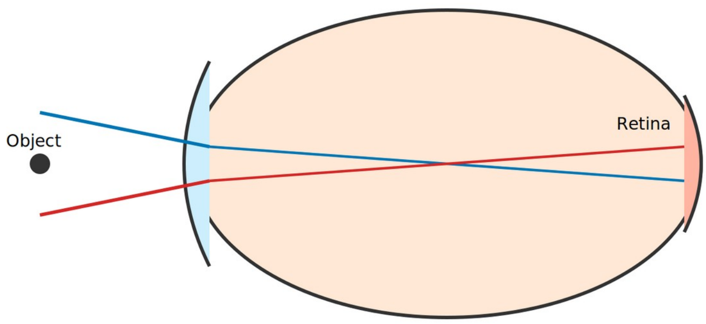

Fig 14.24: Image formation by the normal eye (real, inverted image on the retina)

1. Short-Sightedness (Myopia)

A person can see nearby objects clearly but distant ones appear blurry, because the eye lens bends light too strongly and the image forms in front of the retina. Correction: concave (diverging) lens, which spreads out rays before they enter the eye.

Causes: (i) Lens too strong / too curved. (ii) Eyeball too large (distance between cornea and retina too great).

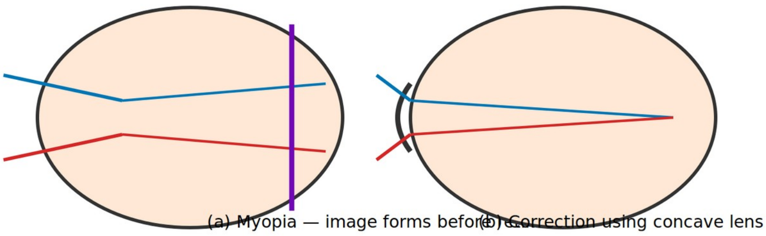

Fig 14.25: Myopia and its correction

2. Long-Sightedness (Hypermetropia)

A person can see distant objects clearly but nearby objects appear blurry, because the eye lens is too weak or the eyeball too small — light from near objects focuses behind the retina. Correction: convex (converging) lens, which bends light more before it enters the eye so it focuses on the retina.

Causes: (a) Lens too weak — doesn't bend light enough. (b) Eyeball too small — retina too close to the lens.

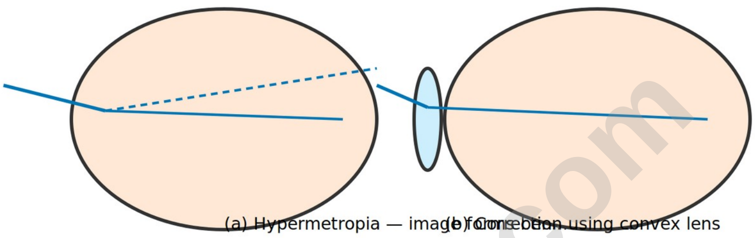

Fig 14.26: Hypermetropia and its correction

> Near point: the closest distance from the eye at which objects appear clear — about 25 cm for a normal eye.

7. Gravitational Lens and Acoustic Lens

Q.17 Describe gravitational and acoustic lenses.

1. 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 — the massive body acts as a "gravitational lens," altering light coming from a distant star or galaxy. This can make the distant object appear magnified, distorted, or even duplicated into multiple images. It is a valuable astronomical tool for studying distant galaxies, dark matter, and the structure of the universe.

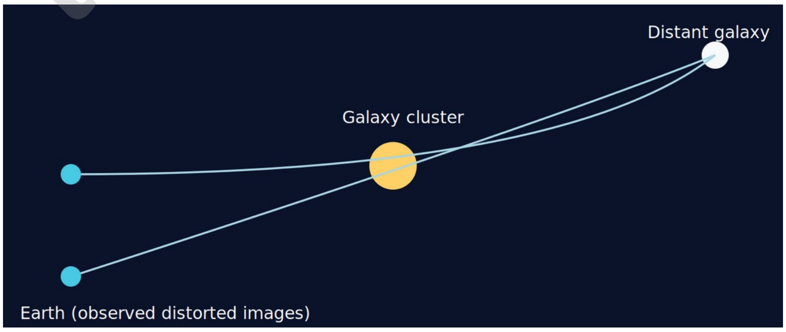

Fig 14.27: Gravitational lensing — light bent by a massive body's gravity

2. Acoustic Lenses

Special devices designed to focus or spread sound waves, similar to how optical lenses control light. Made from materials with different acoustic properties, shaped to redirect and focus sound into a narrow beam or spread it over a wider area.

Used in: (a) Medical imaging (e.g. ultrasound) for accurate scanning; (b) SONAR systems to detect underwater objects; (c) Noise control to focus or reduce sound in specific areas.

8. Dispersion of Light by Prism

Q.18 Explain dispersion of light by prism.

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

A prism bends light due to refraction. Since visible light consists of a range of wavelengths, and refraction depends on wavelength, different wavelengths bend at different angles. Shorter wavelengths (violet, blue) bend more than longer wavelengths (red, orange), causing the colours to separate into red, orange, yellow, green, blue, indigo, and violet (ROYGBIV) — the visible spectrum. Prisms can also disperse invisible infrared (IR) and ultraviolet (UV) light, detected using devices such as infrared thermometers.

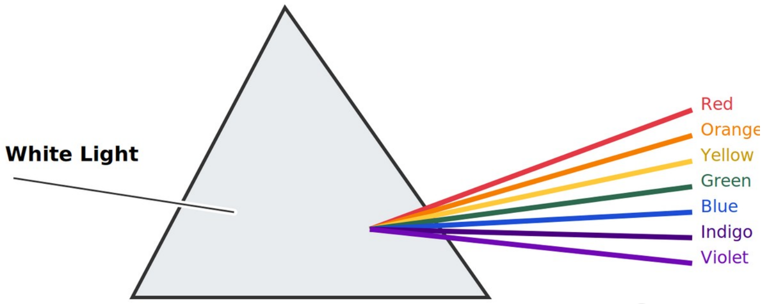

Fig 14.29: Dispersion of white light into seven colours by a prism

Formula Sheet

#	Formula	Description
1	n = sin i / sin r	Refractive index in terms of angles
2	n = c / v	Refractive index in terms of velocities
3	$n_1 \sin \theta_i = n_2 \sin \theta_2$	Snell's Law
4	n = 1 / sin C	Refractive index in terms of critical angle
5	$C = \sin^{-1}(n_2 / n_1)$	Critical angle
6	1/f = 1/p + 1/q	Mirror / Lens equation
7	P = 1/f	Power of a lens
8	$M = h_i / h_0$	Magnification

Solved Examples

Ex 14.1: Light enters air→water, i = 40°, n(water) = 1.33. Find r. sin r = sin40°/1.33 = 0.483 → r ≈ 28.9°

Ex 14.2: n(water) = 1.33, find speed of light in water. v = c/n = $(3\times10^8)/1.33$ → v ≈ 2.26×10^8 m/s

Ex 14.3: Find critical angle of water (n_1=1.33, n_2 air=1). C = $\sin^{-1}(1/1.33)$ → C ≈ 48.8°

Ex 14.4: Concave lens, f = −25 cm = −0.25 m. Find power. P = 1/f = 1/(−0.25) → P = −4.0 D

Ex 14.5: Object h_0 = 8 cm in front of concave mirror, M = −2. Find h_i. $h_i = M \times h_0 = -2\times8$ → h_i = −16 cm (inverted, twice the size)

Multiple Choice Questions

- 1. What type of image is always formed by a convex mirror? (b) Virtual and diminished
- 2. Optical device using a convex lens to magnify by creating a virtual image: (b) Magnifying glass
- 3. Total internal reflection occurs when: (b) Light is completely reflected at the boundary of two media
- 4. Light travelling water→air bends: (b) away from the normal
- 5. Optical device that inverts an image for projection: (c) Photograph Enlarger
- 6. Light entering an optical fibre: (b) undergoes total internal reflection

- 7. Pencil appears bent in water due to: (c) Refraction
- 8. Key advantage of optical fibres over copper cables: (c) Faster data speed using light
- 9. Lens thinner at centre, thicker at edges: (c) Concave lens
- 10. Distance from optical centre to principal focus: (c) Focal length
- 11. Lens with f = −0.5 m has power: (b) −2.0 D
- 12. In a myopic eye, the image of a distant object forms: (c) In front of the retina
- 13. Lens used to correct hypermetropia: (c) Convex lens
- 14. In a simple camera, object beyond 2F forms image that is: (b) Real, inverted, and diminished
- 15. For magnifying glass to give virtual, upright, enlarged image, object must be: (d) Between the lens and F

Key Short Questions (Exercise + Board)

14.1 What happens when light passes from air to water?

It slows down and bends towards the normal — this bending is called refraction.

14.2 Define refractive index. Values for air & water?

Ratio of speed of light in air (or vacuum) to speed in the medium: $n = c/v$. Air ≈ 1.00, Water ≈ 1.33.

14.3 Principle behind optical fibres?

Total internal reflection — light travelling from the denser core to the rarer cladding at an angle greater than the critical angle is totally reflected back, allowing travel over long distances with minimal loss.

14.4 How does a convex lens form real or virtual images?

Real, inverted image when the object is beyond the principal focus. Virtual, upright, magnified image (cannot be projected) when the object is between the lens and F.

14.5 Power of a lens vs focal length?

$P = 1/f$ (unit: Dioptre D). Shorter focal length → greater power. Convex lens: positive power; Concave lens: negative power.

14.6 Snell's Law

The ratio of sin(angle of incidence) to sin(angle of refraction) is constant for a given pair of media, equal to the refractive index: $n = \sin i / \sin r$, or $n_1 \sin i = n_2 \sin r$.

What is lateral inversion?

The left side of an object appears as the right side in its mirror image, and vice versa, because the image is formed behind the mirror causing a left–right reversal while remaining upright.

Regular vs diffused reflection

Regular: from smooth/polished surfaces; parallel rays stay parallel after reflection, forms a clear image (e.g. mirror). Diffused: from rough surfaces; rays scatter in different directions, no clear image (e.g. wall).

Critical angle & Total Internal Reflection

Critical angle: angle of incidence in the denser medium for which the angle of refraction in the rarer medium becomes 90°. TIR: complete reflection back into the same medium when light travels from denser to rarer medium at an angle greater than the critical angle. Conditions: (i) light must go from denser to rarer medium, (ii) angle of incidence must exceed the critical angle.

Focal length & Principal focus

Focal length: distance between optical centre and principal focus. Principal focus: point on the principal axis where parallel rays converge (or appear to diverge from) after refraction.

Linear magnification

Ratio of image height to object height: $M = h_i/h_0$. No units.

Constructed Response Questions (Reasoning)

14.1 Why does a pencil appear bent in water?

Due to refraction — light's speed changes and bends away from the normal going from water to air, so the submerged part appears displaced/bent.

14.2 Why can a prism disperse light but a slab cannot?

Due to dispersion. A prism has non-parallel surfaces so different wavelengths refract by different amounts and spread apart. A slab has parallel surfaces, so colours recombine on exit — no net separation.

14.3 Why does TIR occur water → air but not air → water?

TIR needs: (1) light travelling from denser to rarer medium, and (2) angle of incidence greater than the critical angle. Going air → water, light bends towards the normal, so incidence angle can never exceed the critical angle.

14.4 What if cladding had higher refractive index than the core?

TIR would not occur and light would escape from the core, since TIR requires n(core) > n(cladding).

14.5 Object–focal length relation for a magnifying glass?

Object distance must be less than the focal length (object between lens and F) for the image to be virtual, upright, and magnified.

Numerical Problems (Selected)

Q 14.1: Speed of light in water = 2.25×10^8 m/s. Find n. Solution: $n = c/v = 3\times10^8/2.25\times10^8 = 1.33$

Q 14.2: Light (n_1=1.0) hits glass (n_2=1.5) at i=30°. Find r. Solution: $\sin r = (1.0\times0.5)/1.5 = 0.333 \rightarrow r \approx 19.5°$

Q 14.3: Light in air hits glass slab at i=40° (n_2≈1.52). Find r. Solution: $\sin r = \sin40°/1.52 \approx 0.4229 \rightarrow r \approx 25.0°$

Q 14.4: Air → liquid, i=45°, r=30°. Find n(liquid). Solution: $n_2 = \sin45°/\sin30° = 0.7071/0.5 \rightarrow n_2 \approx 1.41$

Q 14.5: Air → liquid, i=50°, r=32°. Find n(liquid) and speed of light in liquid. Solution: $n_2 = \sin50°/\sin32° \approx 1.445$; $v = c/n_2 \approx 2.08\times10^8$ m/s

Q 14.6: Glass block n=1.6, find critical angle for glass–air. Solution: $\sin C = 1/1.6 = 0.625 \rightarrow C \approx 38.68°$

Q 14.7: Object 15 cm from a convex mirror, virtual image 7.5 cm behind. Find f. Solution: $1/f = 1/15 + 1/(-7.5) = -0.0667 \rightarrow f \approx -15$ cm

Q 14.8: Object 30 cm tall, 10.5 cm from concave mirror, f=16 cm. Find image position & height. Solution: $1/q = 1/16 - 1/10.5 \approx -0.0327 \rightarrow q \approx -30.6$ cm (virtual, behind mirror); $M \approx 2.908 \rightarrow h_i \approx 87.3$ cm (upright, enlarged)

Q 14.9: Object 30 cm from concave lens, f = −15 cm. Find image distance. Solution: $1/q = 1/(-15) - 1/30 = -3/30 \rightarrow q = -10$ cm (virtual image, same side as object)

Compiled Notes — Physics 10, Chapter 14: Light" (pages 84–115). Diagrams redrawn schematically for clarity.