



Light

Handwritten Notes

Table of Contents



Batch 1 : Pages 1 - 6 → Light and Spherical Mirrors

Page No.	Topic	Diagram / Example
1	Nature of Light (Meaning, luminous/non-luminous objects, transparent, translucent, opaque materials, rectilinear propagation, rays and beams)	
2	Reflection of Light (Incident ray, reflected ray, normal, angle of incidence and reflection, laws of reflection, regular and diffuse reflection)	
3	Spherical Mirrors and Related Concepts (Concave and convex mirrors, pole, principal axis, centre of curvature, focal length, relation between R and f)	
4	Concave Mirror - Complete Image Formation (Ray diagrams for different object positions, summary table, solved examples)	
5	Convex Mirror - Image Formation and Applications (Ray diagrams, image characteristics, summary table, applications)	
6	Mirror Formula, Magnification and Numericals (Mirror formula, sign convention, magnification, solved numerical problems)	$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ $m = -\frac{v}{u}$

Batch 2 : Pages 7 - 12 → Refraction and Lenses

Page No.	Topic	Diagram / Example
7	Refraction of Light (Meaning, cause, bending of light, rarer and denser media, examples)	
8	Laws of Refraction and Refractive Index (Snell's law, absolute and relative refractive index, optical density, solved examples)	$n_1 \sin i = n_2 \sin r$
9	Spherical Lenses and Related Concepts (Convex and concave lenses, optical centre, principal foci, focal length, standard rays)	
10	Convex Lens - Complete Image Formation (Ray diagrams, summary table, solved examples)	
11	Concave Lens - Image Formation (Ray diagrams, image characteristics, applications, comparison with convex lens)	
12	Lens Formula, Magnification and Power (Lens formula, sign convention, magnification, power of lens, combination of lenses, solved numericals)	$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ $m = \frac{v}{u}$ $P = \frac{1}{f}$

Batch 3 : Pages 13 - 18 → Human Eye and Optical Phenomena

Page No.	Topic	Diagram / Example
13	Human Eye - Structure and Functioning (Labelled diagram, parts, image formation, accommodation, near and far point)	
14	Defects of Vision and Their Remedies (Myopia, hypermetropia, presbyopia, causes, ray diagrams, correction)	
15	Applications of Spherical Mirrors and Lenses (Shaving mirrors, vehicle mirrors, spectacles, magnifying glass, cameras, microscopes, telescopes, etc.)	
16	Refractive Index - Detailed Applications and Revision (Speed of light, absolute vs relative refractive index, optical density, comparisons, examples and practice questions)	$n = \frac{c}{v}$
17	Dispersion and Scattering of Light (Dispersion through a prism, spectrum, rainbow, scattering, blue sky, red sunset)	
18	Twinkling of Stars and Integrated Revision (Atmospheric refraction, twinkling of stars, comparison, mixed numericals, ray-diagram questions, MCQs with answers)	

1. Nature of Light

1. Meaning of Light

- Light is a form of energy which produces the **sensation of vision** in our eyes.
- It travels in a straight line and helps us to see objects.
- Light is a type of **electromagnetic radiation** which can be detected by the human eye.

2. Sources of Light

- Objects that produce their own light are called **luminous objects**.
- Objects that do not produce their own light are called **non-luminous objects**. They are visible only when light from a luminous source falls on them and is reflected to our eyes.

3. Examples

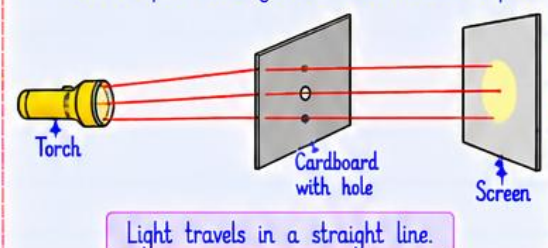


4. Transparent, Translucent and Opaque Materials

Type	Meaning	Examples	Diagram
Transparent	Allow almost all light to pass through them. We can see objects clearly through them.	Clear glass, clean water, air	 Transparent (Glass)
Translucent	Allow only some amount of light to pass through them. We can see objects but not clearly.	Frosted glass, butter paper, tracing paper	 Translucent (Butter paper)
Opaque	Do not allow light to pass through them. We cannot see objects through them.	Wood, metal, brick, stone, cardboard	 Opaque (Wood)

5. Rectilinear Propagation of Light

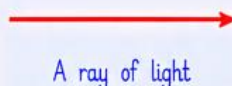
- Light travels in a **straight line** in a homogeneous transparent medium.
- This property is called **rectilinear** propagation of light.
- It can be shown by the following examples :
 - Formation of shadow
 - Pinhole camera
 - Straight beam of light in a dark room
 - Eclipse (during solar and lunar eclipse)



6. Ray of Light

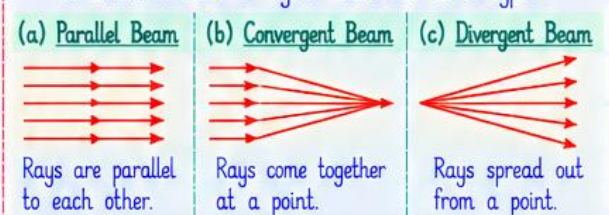
- A ray of light is a straight line which shows the path and direction of light.
- It is represented by a straight line with an arrow.
- Rays help us to represent the path of light easily in diagrams.

Symbol of a ray of light

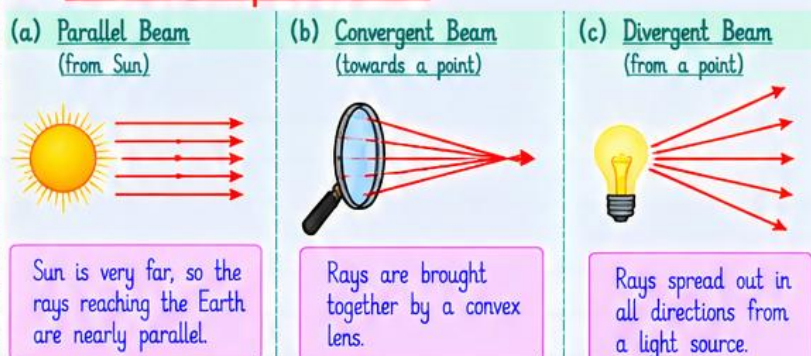


7. Beam of Light

- A collection of a large number of rays of light is called a beam of light. There are three types :



8. Real-life Examples of Beams



9. Important Points

- Light is a form of energy and shows rectilinear propagation.
- Luminous objects produce their own light.
- Non-luminous objects are visible due to reflected light.
- Transparent, translucent and opaque materials differ in the amount of light they allow to pass.
- A group of rays is called a beam, which can be parallel, convergent or divergent.

Reflection of Light

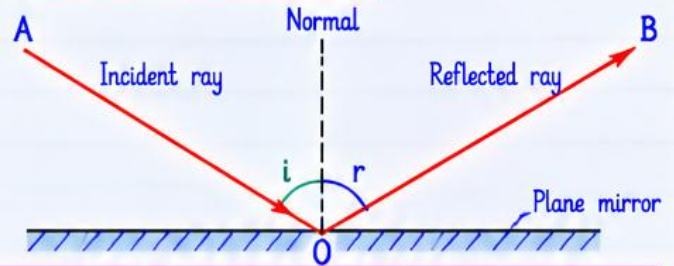
2

1. Meaning

- The phenomenon of bouncing back of light into the same medium after striking a deflecting surface is called **reflection of light**.
- The surface which reflects light is called a **reflecting surface**.

Incident ray : Ray of light coming towards the reflecting surface.
Reflected ray : Ray of light going back into the same medium.
Normal : A line perpendicular to the surface at the point of incidence.

2. Terms used in Reflection



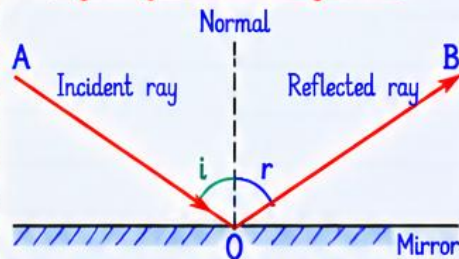
Angle of incidence (i) : Angle between incident ray and normal.
Angle of reflection (r) : Angle between reflected ray and normal.
Point of incidence (O) : Point where incident ray strikes the surface.

3. Laws of Reflection

- The incident ray, reflected ray and the normal at the point of incidence all lie in the same plane.
- The angle of incidence is equal to the angle of reflection.

$$i = r$$

4. Ray Diagram (showing laws)

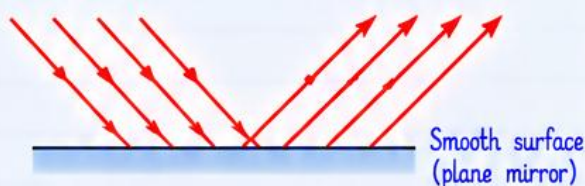


Here,
 $\angle i = \angle r$
 and incident ray, reflected ray and normal lie in the same plane.

5. Types of Reflection

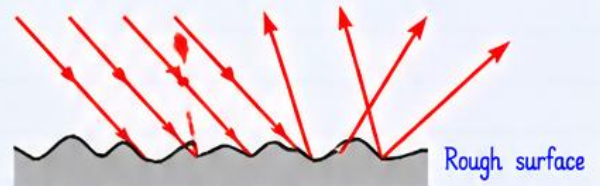
(a) Regular Reflection

- Occurs from a smooth and polished surface.
- Parallel incident rays remain parallel after reflection.
- Produces a clear image.
- Example** : Plane mirror, calm water surface.



(b) Diffuse Reflection

- Occurs from a rough and irregular surface.
- Parallel incident rays are reflected in different directions.
- Does not produce a clear image.
- Example** : Wall, paper, wood, rough surface.



6. Examples

Situation	Type of Reflection
Image in a plane mirror	Regular reflection
Reflection from a polished floor	Regular reflection
Reflection from calm water	Regular reflection
Reflection from a wall	Diffuse reflection
Reflection from a book or paper	Diffuse reflection
Reflection from a tree or rock	Diffuse reflection

7. Solved Examples

Q1. A ray of light is incident on a mirror at an angle of 40° . What is the angle of reflection?

Sol : According to the law of reflection, $i = r$
 Given $i = 40^\circ \Rightarrow r = 40^\circ$

$$r = 40^\circ$$

Q2. The angle between the incident ray and the reflected ray is 100° . Find the angle of incidence.

Sol : Angle between incident and reflected ray = $2i$
 $2i = 100^\circ \Rightarrow i = 50^\circ$
 So, angle of reflection $r = 50^\circ$

$$i = 50^\circ$$

Q3. If the angle of reflection is 65° , what is the angle of incidence?

Sol : $i = r = 65^\circ$

$$i = 65^\circ$$

Spherical Mirrors and Related Concepts

3

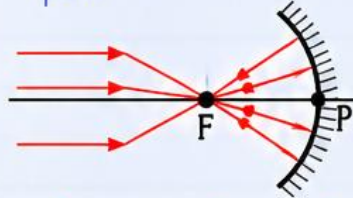
1. Spherical Mirror

- A mirror whose reflecting surface is a part of a sphere is called a spherical mirror.
- It has a curved surface which can be inward (concave) or outward (convex).

2. Types of Spherical Mirrors

(a) Concave Mirror

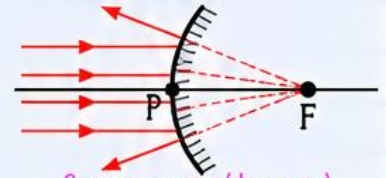
- Reflecting surface is inward curved (like inner surface of a sphere).
- Converges parallel rays to a point.



Concave mirror (converging)

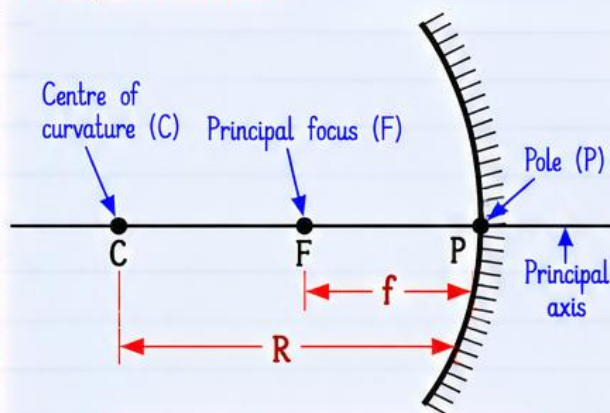
(b) Convex Mirror

- Reflecting surface is outward curved (like outer surface of a sphere).
- Diverges parallel rays as if they are coming from a point behind the mirror.



Convex mirror (diverging)

3. Important Terms



Concave mirror with principal axis

4. Definitions

- Pole (P)** : Geometrical centre of the reflecting surface of the mirror.
- Principal axis** : A straight line passing through the pole and centre of curvature.
- Centre of curvature (C)** : Centre of the sphere of which the mirror is a part.
- Radius of curvature (R)** : Distance between pole (P) and centre of curvature (C).
- Principal focus (F)** : Point on the principal axis where parallel rays converge (concave) or appear to diverge from (convex).
- Focal length (f)** : Distance between pole (P) and principal focus (F).
- Aperture** : Effective diameter (width) of the reflecting surface of the mirror.

5. Relation between Radius of Curvature and Focal Length

- For spherical mirrors, the focal length (f) is half of the radius of curvature (R).

$$f = \frac{R}{2} \quad \text{or} \quad R = 2f$$

- Both f and R have the same sign.
- For concave mirror : f is negative (focus in front).
- For convex mirror : f is positive (focus behind).

6. Sign Convention (New Cartesian)

- Distances are measured from the pole (P).
- Distances measured in the direction of incident light (to the left) are taken as negative.
- Distances measured in the opposite direction (to the right) are taken as positive.

7. Comparison of Concave and Convex Mirrors

Feature	Concave Mirror	Convex Mirror
Shape of surface	Inward curved	Outward curved
Nature	Converging mirror	Diverging mirror
Position of focus	In front of the mirror	Behind the mirror
Focal length (f)	Negative	Positive
Image (for distant object)	Real and inverted (at focus)	Virtual, erect and diminished (at focus)
Uses	Shaving mirror, torches, headlights, solar cookers, etc.	Rear-view mirror in vehicles, security mirrors, wide-angle mirrors, etc.

8. Examples

(a) Example 1 (Concave Mirror)

A concave mirror has a radius of curvature of 20 cm. Find its focal length.

Solution : $R = 20 \text{ cm}$

$$f = \frac{R}{2} = \frac{20}{2} = 10 \text{ cm} \quad \boxed{f = -10 \text{ cm}}$$

Since it is a concave mirror, f is negative.

(b) Example 2 (Convex Mirror)

A convex mirror has a focal length of 15 cm. Find its radius of curvature.

Solution : $f = 15 \text{ cm}$

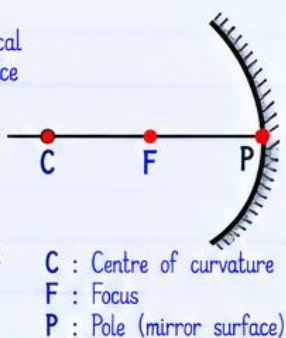
$$R = 2f = 2 \times 15 = 30 \text{ cm} \quad \boxed{R = 30 \text{ cm}}$$

Concave Mirror – Image Formation

4

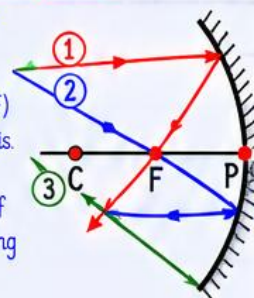
1. Concave Mirror

- A concave mirror is a spherical mirror whose reflecting surface is curved inwards.
- It is also called a converging mirror because it converges parallel rays at the focus.
- It has a real focus in front of the mirror.



2. Important Rays for Ray Diagrams

- A ray parallel to the principal axis is reflected through the focus (F).
- A ray passing through the focus (F) is reflected parallel to the principal axis.
- A ray passing through the centre of curvature (C) is reflected back along the same path.



3. Image Formation in a Concave Mirror

S. No.	Object position	Ray diagram	Image position	Image size	Orientation	Nature
1.	Object at infinity (very far away)		At focus (F)	Highly diminished (point sized)	Inverted	Real
2.	Object beyond C ($u > 2f$)		Between C and F	Diminished	Inverted	Real
3.	Object at C ($u = 2f$)		At C	Same size	Inverted	Real
4.	Object between C and F ($f < u < 2f$)		Beyond C	Enlarged	Inverted	Real
5.	Object at F ($u = f$)		At infinity	Highly enlarged	Inverted	Real
6.	Object between F and P ($u < f$)		Behind the mirror	Enlarged	Upright	Virtual

4. Solved Examples

Q1. An object is placed 30 cm in front of a concave mirror of focal length 10 cm. Find the position, size and nature of the image.

Given : $f = 10$ cm (concave mirror, so $f = -10$ cm)
 $u = -30$ cm

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

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

$$\Rightarrow \frac{1}{v} = \frac{-1}{10} + \frac{1}{30} = \frac{-3+1}{30} = \frac{-2}{30} = \frac{-1}{15}$$

$$v = -15 \text{ cm}$$

Magnification (m) : $m = -\frac{v}{u} = -\frac{(-15)}{(-30)} = -\frac{1}{2}$

Image size = $\frac{1}{2}$ of object, Orientation = inverted, Nature = real

Image is formed at 15 cm in front of the mirror, diminished, inverted and real.

Q2. An object is placed 8 cm in front of a concave mirror of focal length 12 cm. Find the position, size and nature of the image.

Given : $f = 12$ cm ($f = -12$ cm)
 $u = -8$ cm

$$\frac{1}{-12} = \frac{1}{v} + \frac{1}{-8}$$

$$\Rightarrow \frac{1}{v} = \frac{-1}{12} + \frac{1}{8} = \frac{-2+3}{24} = \frac{1}{24}$$

$$v = +24 \text{ cm}$$

Magnification : $m = -\frac{v}{u} = -\frac{24}{-8} = +3$

Image size = 3 times enlarged,

Orientation = upright, Nature = virtual

Image is formed at 24 cm behind the mirror, enlarged, upright and virtual.

5. Important Points / Observations

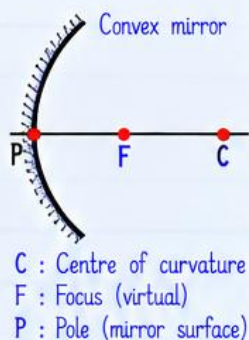
- Concave mirror can form both real and virtual images.
- Real images are formed when the object is at infinity, beyond C, at C or between C and F (they can be obtained on a screen).
- Virtual image is formed when the object is between F and P (cannot be obtained on a screen).
- Image at F is point sized.
- Image at C is same size as the object.
- Image is diminished when object is at infinity or beyond C.
- Image is enlarged when object is between C and F or between F and P.
- Direction of image is inverted for real images and upright for virtual images.

Convex Mirror – Image Formation and Applications

5

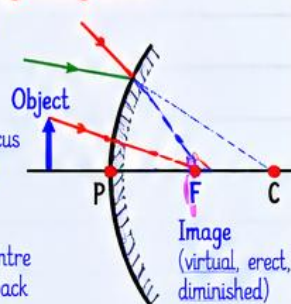
1. Convex Mirror

- A convex mirror is a spherical mirror whose reflecting surface **bulges outwards** (away from the object).
- It is also called a **diverging mirror** because it **diverges** the incident rays.
- A convex mirror always forms a **virtual, erect and diminished image** irrespective of the position of the object.



2. Important Rays for Ray Diagrams

- A ray parallel to the principal axis is reflected as if it is diverging from the focus (F).
- A ray directed towards the focus (F) is reflected **parallel** to the principal axis.
- A ray directed towards the centre of curvature (C) is reflected back along the same path.



3. Image Formation for Different Object Positions

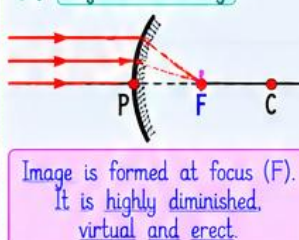
S. No.	Object position	Ray diagram	Image position	Image size	Orientation	Nature
1.	Object at infinity (very far away)		At focus (F)	Highly diminished (point sized)	Erect	Virtual
2.	Object at a finite distance (any position)		Between P and F (behind the mirror)	Diminished	Erect	Virtual
3.	Object near the mirror (between P and F)		Between P and F (behind the mirror)	Diminished	Erect	Virtual
4.	Object beyond C (rare case, object very far)		Between P and F (behind the mirror)	Diminished	Erect	Virtual

4. Characteristics of Image in a Convex Mirror

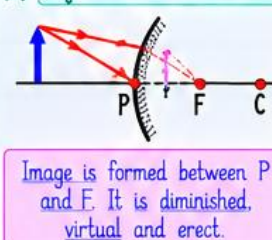
- Always **virtual** (cannot be obtained on a screen).
- Always **erect** (upright).
- Always **diminished** (smaller than the object).
- Formed **behind the mirror between the pole (P) and focus (F)**.
- Image size decreases as the object moves away from the mirror.
- Irrespective of object position, the image is always formed between P and F.
- Cannot form a real image.

5. Examples of Ray Diagrams

(a) Object at infinity



(b) Object at a finite distance



6. Applications of Convex Mirror

Rear-view mirrors in vehicles



- Used as rear-view mirrors in cars, buses and bikes.
- Provide a wide field of view.
- Form erect and diminished images.

Security mirrors



- Used in shops, parking areas and at road intersections.
- Help to see a larger area.

Wide field of view



- Convex mirrors diverge rays, which allows a larger area to be seen at the same time.

Other applications

- In surveillance and security systems.
- In street mirrors at blind turns.
- In ATMs and shopping malls.
- In solar concentrators (as part of optical systems).

7. Solved Example 1

Q1. An object is placed 20 cm in front of a convex mirror of focal length 15 cm. Find the position, nature and magnification of the image.

Given : $u = -20$ cm, $f = +15$ cm (convex mirror)

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

$$\frac{1}{15} = \frac{1}{v} - \frac{1}{20} \Rightarrow \frac{1}{v} = \frac{1}{15} + \frac{1}{20} = \frac{4}{60} + \frac{3}{60} = \frac{7}{60}$$

$$v = \frac{60}{7} \approx +8.6 \text{ cm (behind the mirror)}$$

Magnification : $m = -\frac{v}{u} = -\frac{(+8.6)}{(-20)} = +0.43$

Image is formed 8.6 cm behind the mirror. It is virtual, erect and diminished.

8. Solved Example 2

Q1. A convex mirror forms an image at 6 cm behind the mirror. If the focal length is 12 cm, find the position of the object.

Given : $v = +6$ cm, $f = +12$ cm

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

$$\frac{1}{12} = \frac{1}{6} + \frac{1}{u} \Rightarrow \frac{1}{u} = \frac{1}{12} - \frac{1}{6} = \frac{1}{12} - \frac{2}{12} = -\frac{1}{12}$$

$$u = -12 \text{ cm (object in front of the mirror)}$$

1. Mirror Formula

- The relationship between object distance (u), image distance (v) and focal length (f) of a spherical mirror is given by the mirror formula.

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

where, f = focal length (cm)
 v = image distance (cm)
 u = object distance (cm)

(All distances are measured from the pole of the mirror)

2. Sign Convention (New Cartesian)

- All distances are measured from the pole (P) of the mirror.
- Distances measured in the direction of incident light (to the right) are taken as positive.
- Distances measured in the opposite direction (to the left) are taken as negative.
- Heights measured upward are positive and downward are negative.
- Focal length (f) is negative for a concave mirror and positive for a convex mirror.

3. Magnification

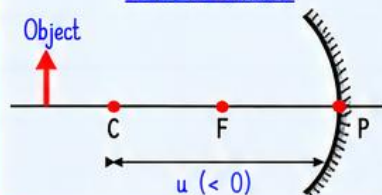
- Magnification (m) is the ratio of the height of image (h') to the height of object (h).

$$m = \frac{h'}{h} = -\frac{v}{u}$$

- If m is negative, image is inverted.
- If m is positive, image is upright.
- $|m| > 1$: image is enlarged.
- $|m| = 1$: image is same size.
- $|m| < 1$: image is diminished.

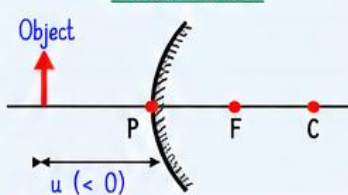
4. Sign of Distances for Different Cases

Concave Mirror



For concave mirror (real object):
 $u < 0$, $f < 0$
 v can be negative (real image) or positive (virtual image).

Convex Mirror



For convex mirror (real object):
 $u < 0$, $f > 0$
 v is always positive (virtual image).

5. Relationship between u , v and f

- If object is placed at infinity ($u = -\infty$), then $v = f$ (image at focus).
- If object is placed at focus ($u = f$), image is formed at infinity ($v = \infty$).
- Object and image distances are measured from the pole of the mirror.
- Mirror formula can be used for both concave and convex mirrors using the sign convention.

6. Solved Numericals

Example 1

An object is placed 20 cm in front of a concave mirror of focal length 10 cm. Find the position, size and nature of the image.

Given : $f = 10$ cm (concave, so $f = -10$ cm)
 $u = -20$ cm

Find : v , m and nature of image.

Solution :

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

$$\frac{1}{-10} = \frac{1}{v} + \frac{1}{-20}$$

$$\frac{1}{v} = \frac{1}{-10} + \frac{1}{20} = \frac{-2+1}{20} = \frac{-1}{20}$$

$$v = -20 \text{ cm}$$

Magnification : $m = -\frac{v}{u} = -\frac{(-20)}{(-20)} = -1$

Image size = same as object
 Orientation = inverted
 Nature = real

Image is formed at 20 cm in front of the mirror (same size, inverted and real).

Example 2

An object is placed 6 cm in front of a concave mirror of focal length 12 cm. Find the position, size and nature of the image.

Given : $f = -12$ cm
 $u = -6$ cm

Find : v , m and nature of image.

Solution :

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

$$\frac{1}{-12} = \frac{1}{v} + \frac{1}{-6}$$

$$\frac{1}{v} = \frac{-1}{12} + \frac{1}{6} = \frac{-1+2}{12} = \frac{1}{12}$$

$$v = +12 \text{ cm}$$

Magnification : $m = -\frac{v}{u} = -\frac{(12)}{(-6)} = +2$

Image size = 2 times enlarged
 Orientation = upright
 Nature = virtual

Image is formed at 12 cm behind the mirror (enlarged, upright and virtual).

Example 3

An object is placed 15 cm in front of a convex mirror of focal length 10 cm. Find the position, size and nature of the image.

Given : $f = +10$ cm
 $u = -15$ cm

Find : v , m and nature of image.

Solution :

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

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

$$\frac{1}{v} = \frac{1}{10} + \frac{1}{15} = \frac{3+2}{30} = \frac{5}{30} = \frac{1}{6}$$

$$v = +6 \text{ cm}$$

Magnification : $m = -\frac{v}{u} = -\frac{(6)}{(-15)} = +0.4$

Image size = 0.4 times (diminished)
 Orientation = upright
 Nature = virtual

Image is formed at 6 cm behind the mirror (diminished, upright and virtual).

7. Common Mistakes in Numericals

- Not using the correct sign convention.
- Using wrong sign for focal length (f).
- Taking u as positive (it is usually negative for real objects).
- Incorrect substitution in the formula.
- Confusing magnification formula ($m = -\frac{v}{u}$).
- Not mentioning the nature, orientation and size of the image.

8. Key Formulas (Quick Revision)

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

← Mirror formula

$$m = \frac{h'}{h} = -\frac{v}{u}$$

← Magnification formula

f = focal length (cm)
 v = image distance (cm)
 u = object distance (cm)
 h = height of object (cm)
 h' = height of image (cm)
 m = magnification
 (All distances from pole P)

Refraction of Light

7

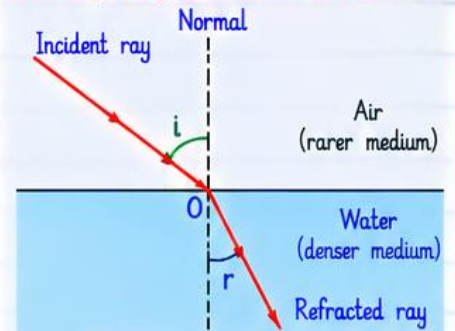
1. Meaning of Refraction

- Refraction of light is the change in direction (bending) of light when it passes from one transparent medium to another due to change in its speed.
- The speed of light is different in different media.
- When light obliquely enters a medium in which its speed changes, it bends at the interface. This is called refraction.

2. Cause of Refraction

- Light travels with different speeds in different media.
- When light goes from a rarer medium to a denser medium, its speed decreases and it bends towards the normal.
- When light goes from a denser medium to a rarer medium, its speed increases and it bends away from the normal.

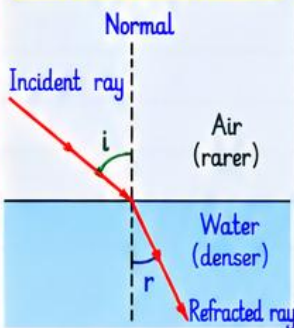
3. Ray Diagram of Refraction



Here, light bends towards the normal because it goes from rarer to denser medium.

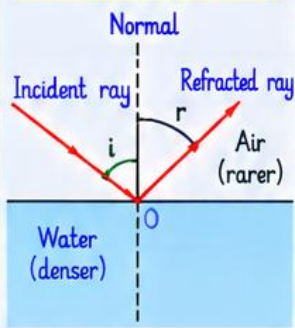
4. Bending towards or away from the Normal

Rarer to Denser Medium



Bends towards the normal ($i > r$) and speed decreases.

Denser to Rarer Medium



Bends away from the normal ($i < r$) and speed increases.

5. Optically Denser and Rarer Medium

- Optically denser medium: The medium in which the speed of light is less. (e.g. water, glass)
- Optically rarer medium: The medium in which the speed of light is more. (e.g. air, vacuum)

When light goes from rarer to denser medium, it bends towards normal. When it goes from denser to rarer medium, it bends away from normal.

6. Diagram with Refractive Index (Relative Information)

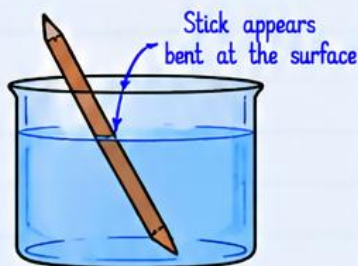
Speed of light in different media:

Medium	Speed (approx)
Vacuum	3×10^8 m/s
Air	$\sim 3 \times 10^8$ m/s
Water	$\sim 2.25 \times 10^8$ m/s
Glass	$\sim 2 \times 10^8$ m/s

Light travels slowest in optically denser medium and fastest in optically rarer medium.

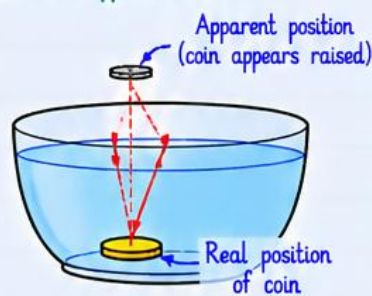
7. Apparent Bending of Objects

(a) Stick in water appears bent



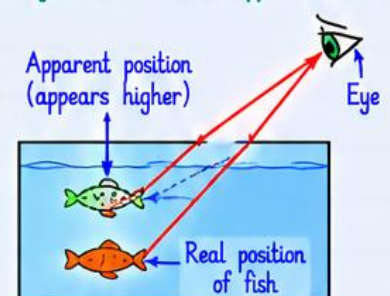
This happens because light from the submerged part changes direction when it comes from water to air.

(b) Coin appears raised



The coin in water appears at a shallower depth (raised) than its real depth due to refraction.

(c) Objects under water appear nearer



Objects under water appear nearer to the surface due to refraction at the water-air interface.

8. Everyday Examples of Refraction

(a) Twinkling of stars



Stars appear to twinkle due to refraction of their light by different layers of air in the atmosphere.

(b) Mirage on hot roads



On hot days, light from the sky gets refracted by layers of hot air of different densities, making it appear like water on the road (mirage).

(c) Diamond sparkles



Diamond sparkles due to multiple refractions of light inside it.

(d) Lenses



Spectacles and magnifying glasses work on the principle of refraction of light.

1. Refraction of Light

- The bending of light when it passes from one transparent medium to another is called **refraction of light**.
- It occurs because the speed of light **changes** when it moves from one medium to another.
- The ray bends towards or away from the normal depending on whether the speed decreases or increases.

2. Laws of Refraction

① First law :

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

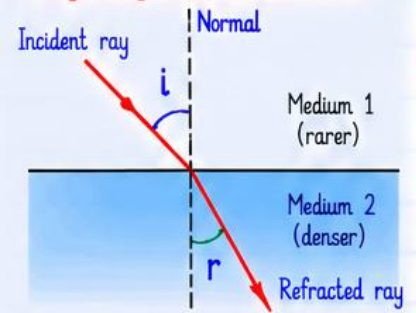
② Second law (Snell's law) :

For a given pair of media, the ratio of sin of angle of incidence (i) to the sin of angle of refraction (r) is constant.

$$\frac{\sin i}{\sin r} = \text{constant or } n_{21}$$

n_{21} is called the **refractive index** of second medium w.r.t. first medium.

3. Ray Diagram of Refraction



When light goes from a rarer to a denser medium, it bends **towards** the normal ($r < i$). When it goes from a denser to a rarer medium, it bends **away** from the normal ($r > i$).

4. Snell's Law of Refraction

$$n_{21} = \frac{\sin i}{\sin r}$$

- n_{21} = refractive index of medium 2 with respect to medium 1.
- i = angle of incidence (in medium 1)
- r = angle of refraction (in medium 2)

The ratio $\frac{\sin i}{\sin r}$ is **constant** for a given pair of media and is equal to n_{21} .

5. Refractive Index

(a) Absolute Refractive Index (n)

- Refractive index of a medium with respect to vacuum (air).

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

where, c = speed of light in vacuum
 $= 3 \times 10^8$ m/s
 v = speed of light in the medium

6. Relative Refractive Index (n_{21})

- Refractive index of medium 2 with respect to medium 1.

$$n_{21} = \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

- v_1 = speed of light in medium 1
- v_2 = speed of light in medium 2
- n_1 = absolute refractive index of medium 1
- n_2 = absolute refractive index of medium 2

7. Relation between Refractive Index and Speed

- Speed of light in a medium is **inversely** proportional to its refractive index.

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

- If n is large, speed v is small.
- If n is small, speed v is large.

8. Optical Density

- A medium with higher refractive index is called **optically denser**.
- A medium with lower refractive index is called **optically rarer**.
- When light enters an optically denser medium, it **bends towards the normal**.
- When light enters an optically rarer medium, it **bends away from the normal**.

9. Comparison of Media

Medium	Refractive index (n)	Speed of light (v)	Optical nature
Air ($\approx$ vacuum)	1.0	3×10^8 m/s	Rarer
Water	1.33	2.25×10^8 m/s	Denser than air
Glass	1.50	2.0×10^8 m/s	Denser than water
Diamond	2.42	1.24×10^8 m/s	Most dense (among these)

10. Solved Numerical Examples

(a) Example 1 : Find angle of refraction

A ray of light is incident from air ($n = 1$) into glass ($n = 1.5$) at an angle of 30° . Find the angle of refraction.

Given : $n_1 = 1$ (air), $n_2 = 1.5$ (glass)
 $i = 30^\circ$

Using Snell's law : $n_1 \sin i = n_2 \sin r$
 $1 \times \sin 30^\circ = 1.5 \times \sin r$
 $0.5 = 1.5 \sin r$
 $\sin r = \frac{0.5}{1.5} = \frac{1}{3}$
 $r = \sin^{-1}\left(\frac{1}{3}\right) \approx 19.5^\circ$

$$r \approx 19.5^\circ$$

(b) Example 2 : Find speed of light in medium

The refractive index of water is 1.33. Find the speed of light in water.

Given : $n = 1.33$, $c = 3 \times 10^8$ m/s

Using : $v = \frac{c}{n}$
 $v = \frac{3 \times 10^8}{1.33}$
 $v = 2.26 \times 10^8$ m/s

$$v \approx 2.26 \times 10^8 \text{ m/s}$$

(c) Example 3 : Find refractive index

The angle of incidence in air is 45° and the angle of refraction in a medium is 30° . Find the refractive index of the medium.

Given : $n_1 = 1$ (air), $i = 45^\circ$, $r = 30^\circ$

Using Snell's law : $n = \frac{\sin i}{\sin r}$
 $n = \frac{\sin 45^\circ}{\sin 30^\circ}$
 $n = \frac{\sqrt{2}/2}{1/2} = \sqrt{2}$
 $n = 1.414$

$$n \approx 1.41$$

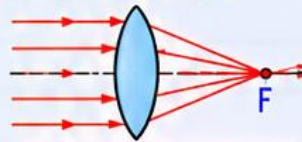
1. Spherical Lens

- A transparent optical device made of glass or other material with two spherical surfaces is called a **spherical lens**.
- It refracts light at two surfaces and can **converge** or **diverge** light rays.
- Spherical lenses are of two types :
 - Convex lens (converging)
 - Concave lens (diverging)

2. Types of Spherical Lenses

(a) Convex Lens

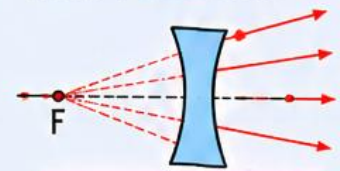
- Thicker at the **centre** and thinner at the edges.
- Converges** parallel rays of light to a point.
- Also called a **converging** lens.
- It has a **real focus**.



Convex lens (converging)

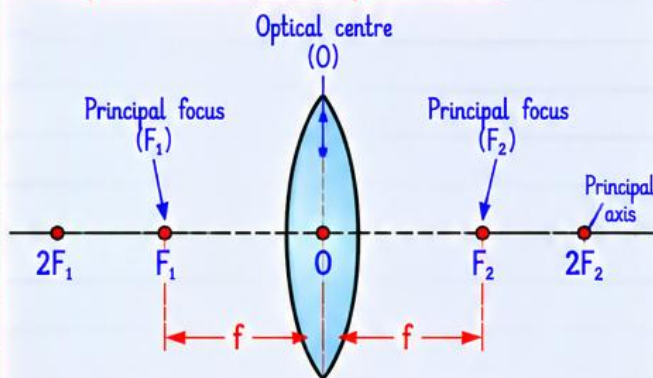
(b) Concave Lens

- Thinner at the centre and thicker at the edges.
- Diverges** parallel rays of light as if coming from a point.
- Also called a **diverging** lens.
- It has a **virtual focus**.



Concave lens (diverging)

3. Important Terms in a Spherical Lens



Convex lens with principal axis, foci and optical centre

4. Definitions

- Optical centre (O)** : Geometrical centre of the lens. A ray passing through O goes undeviated.
- Principal axis** : Straight line passing through optical centre and centres of curvature of the two spherical surfaces.
- Principal focus (F_1, F_2)** : Point on the principal axis where parallel rays meet (convex) or appear to diverge from (concave).
- Focal length (f)** : Distance between optical centre (O) and principal focus (F).
- Aperture** : Effective diameter (width) of the lens through which light passes.
- Converging action** : Convex lens converges parallel rays to a point.
- Diverging action** : Concave lens diverges parallel rays as if coming from a point.

5. Ray Diagrams for Standard Rays (Convex Lens)

(i) Parallel ray

A ray parallel to the principal axis passes through F_2 after refraction.

(ii) Ray through optical centre

A ray passing through optical centre goes undeviated.

(iii) Ray through focus

A ray passing through F_1 emerges parallel to the principal axis.

6. Ray Diagrams for Standard Rays (Concave Lens)

(i) Parallel ray

A ray parallel to the principal axis appears to diverge from F_1 .

(ii) Ray through optical centre

A ray passing through optical centre goes undeviated.

(iii) Ray towards focus

A ray directed towards F_2 emerges parallel to the principal axis.

7. Comparison of Convex and Concave Lenses

Feature	Convex Lens	Concave Lens
Shape	Thicker at centre, thinner at edges	Thinner at centre, thicker at edges
Action on parallel rays	Converges to a point	Diverges as if from a point
Nature of focus	Real focus	Virtual focus
Focal length (f)	Positive	Negative
Form of image (for distant object)	Real and inverted (at focus)	Virtual, erect and diminished
Symbol		

8. Real-life Examples

(a) Convex Lens (Converging)

- Magnifying glass
- Camera lens
- Microscope
- Telescope
- Spectacles for hypermetropia
- Projectors



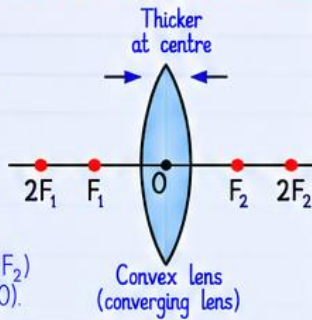
(b) Concave Lens (Diverging)

- Spectacles for myopia
- Door viewer (peephole)
- Optical instruments where a wide field of view is needed



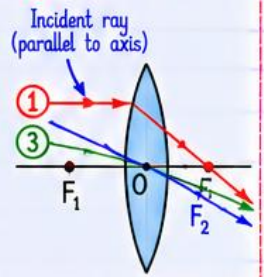
1. Convex Lens

- A convex lens is a transparent lens which is thicker at the centre and thinner at the edges.
- It is a converging lens because it converges parallel rays of light to a point called focus (F).
- A convex lens has two foci (F_1 and F_2) on either side of the optical centre (O).



2. Important Rays for Ray Diagrams

- A ray parallel to the principal axis after refraction passes through the focus (F_2).
- A ray passing through the focus (F_1) after refraction emerges parallel to the principal axis.
- A ray passing through the optical centre (O) goes undeviated.



3. Image Formation by a Convex Lens

S. No.	Object position	Ray diagram	Image position	Image size	Orientation	Nature
1.	Object at infinity ($u = \infty$)		At F_2	Highly diminished (point sized)	Inverted	Real
2.	Object beyond $2F_1$ ($u > 2f$)		Between F_2 and $2F_2$	Diminished	Inverted	Real
3.	Object at $2F_1$ ($u = 2f$)		At $2F_2$	Same size	Inverted	Real
4.	Object between F_1 and $2F_1$ ($f < u < 2f$)		Beyond $2F_2$	Enlarged	Inverted	Real
5.	Object at F_1 ($u = f$)		At infinity	Highly enlarged	Inverted	Real
6.	Object between F_1 and optical centre O ($u < f$)		On the same side of the lens (as the object)	Enlarged	Upright	Virtual

4. Solved Examples

Example 1 : Object beyond $2F_1$

An object is placed at 40 cm in front of a convex lens of focal length 10 cm. Find the position, size and nature of image.

Given : $f = +10$ cm, $u = -40$ cm

Using lens formula : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\frac{1}{10} = \frac{1}{v} - \frac{1}{(-40)}$$

$$\frac{1}{10} = \frac{1}{v} + \frac{1}{40}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{40} = \frac{4-1}{40} = \frac{3}{40}$$

$$v = +13.3 \text{ cm}$$

$$\text{Magnification : } m = \frac{v}{u} = \frac{13.3}{-40} = -0.33$$

Image is diminished, inverted and real.

Example 2 : Object at $2F_1$

An object is placed at 20 cm in front of a convex lens of focal length 10 cm. Find the position, size and nature of image.

Given : $f = +10$ cm, $u = -20$ cm

$$\frac{1}{10} = \frac{1}{v} - \frac{1}{(-20)}$$

$$\frac{1}{10} = \frac{1}{v} + \frac{1}{20}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{20} = \frac{2-1}{20} = \frac{1}{20}$$

$$v = +20 \text{ cm}$$

$$\text{Magnification : } m = \frac{v}{u} = \frac{20}{-20} = -1$$

Image is same size, inverted and real.

Example 3 : Object between F_1 and $2F_1$

An object is placed at 15 cm in front of a convex lens of focal length 10 cm. Find the position, size and nature of image.

Given : $f = +10$ cm, $u = -15$ cm

$$\frac{1}{10} = \frac{1}{v} - \frac{1}{(-15)} \Rightarrow \frac{1}{v} = \frac{1}{10} - \frac{1}{15} = \frac{3-2}{30} = \frac{1}{30}$$

$$v = +30 \text{ cm}$$

$$m = \frac{30}{-15} = -2$$

Image is enlarged (2 times), inverted and real.

Example 4 : Object between F_1 and O

An object is placed at 5 cm in front of a convex lens of focal length 10 cm. Find the position, size and nature of image.

Given : $f = +10$ cm, $u = -5$ cm

$$\frac{1}{10} = \frac{1}{v} - \frac{1}{(-5)} \Rightarrow \frac{1}{v} = \frac{1}{10} - \frac{1}{5} = \frac{1-2}{10} = -\frac{1}{10}$$

$$v = -10 \text{ cm}$$

$$m = \frac{v}{u} = \frac{-10}{-5} = +2$$

Image is enlarged (2 times), upright and virtual.

5. Important Points

- Convex lens is a converging lens.
- Real images are formed on the opposite side of the lens and are inverted.
- Virtual images are formed on the same side of the lens as the object and are upright.
- Object at infinity forms a point image at the focus.
- Object at F_1 forms image at infinity.
- Image is real and diminished for $u > 2f$.
- Image is real and same size for $u = 2f$.
- Image is real and enlarged for $f < u < 2f$.
- Image is virtual, enlarged and upright for $u < f$.

$$\text{⑩ Magnification } m = \frac{v}{u}$$

$m < 0 \Rightarrow$ inverted image (real)

$m > 0 \Rightarrow$ upright image (virtual)

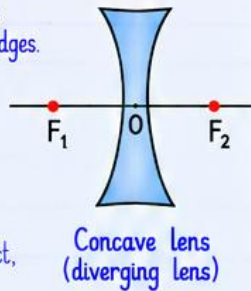
$|m| > 1 \Rightarrow$ enlarged image

$|m| = 1 \Rightarrow$ same size image

$|m| < 1 \Rightarrow$ diminished image

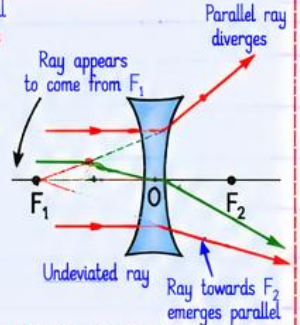
1. Concave Lens

- A concave lens is a **diverging** lens which is **thinner** at the centre and **thicker** at the edges.
- It **diverges** parallel rays of light.
- It has a **virtual focus** (F) on both sides (F_1 and F_2).
- A concave lens always forms a **virtual, erect and diminished** image for a real object, regardless of the object position.



2. Important Rays for Ray Diagrams

- A ray parallel to the principal axis after refraction **diverges** as if it is coming from the **focus** (F_1) on the same side.
 (Parallel ray diverges)
- A ray directed towards the **focus** (F_2) after refraction emerges **parallel** to the principal axis.
 (Ray appears to come from F_1)
- A ray passing through the optical centre (O) goes **undeviated**.
 (Ray towards F_2 emerges parallel)



3. Image Formation by a Concave Lens

S. No.	Object position	Ray diagram	Image position	Image size	Orientation	Nature
1.	Object at infinity ($u = \infty$)		At focus (F_1) on the <u>same</u> side	Highly diminished (point sized)	Erect	Virtual
2.	Object beyond $2F_1$ ($u > 2f$)		Between O and F_1	Diminished	Erect	Virtual
3.	Object at $2F_1$ ($u = 2f$)		Between O and F_1	Diminished	Erect	Virtual
4.	Object between F_1 and $2F_1$ ($f < u < 2f$)		Between O and F_1	Diminished	Erect	Virtual
5.	Object at F_1 ($u = f$)		Between O and F_1	Diminished	Erect	Virtual
6.	Object between F_1 and optical centre O ($u < f$)		Between O and F_1	Diminished	Erect	Virtual

4. Characteristics of Images Formed by a Concave Lens

- The image is always formed on the **same side** of the lens as the object.
- The image is always **virtual** and cannot be obtained on a screen.
- The image is always **erect**.
- The image is always **diminished** (smaller than the object).
- As the object moves closer to the lens, the image size increases, but it is always smaller than the object.

5. Solved Example

- An object of height 4 cm is placed at 20 cm in front of a concave lens of focal length 10 cm. Find the position, size and nature of the image.

Given : $u = -20$ cm, $f = -10$ cm, $h = 4$ cm

Using lens formula : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\frac{1}{-10} = \frac{1}{v} - \frac{1}{-20} \Rightarrow \frac{1}{v} = \frac{1}{-10} - \frac{1}{20} = \frac{-2-1}{20} = \frac{-3}{20}$$

$$v = \frac{-20}{3} = -6.67 \text{ cm}$$

$$\text{Magnification : } m = \frac{v}{u} = \frac{(-6.67)}{(-20)} = +0.33$$

$$h' = m \times h = 0.33 \times 4 = 1.33 \text{ cm}$$

Image is formed at 6.67 cm in front of the lens, of height 1.33 cm, **virtual, erect and diminished**.

6. Applications of Concave Lenses

- Used in spectacles to correct **myopia** (short-sightedness).
- Used in door viewers (peepholes) to get a wide field of view.
- Used in telescopes and binoculars (as part of eyepiece).
- Used in cameras (to reduce spherical aberration in combinations).
- Used in optical instruments to spread light rays.

7. Comparison between Concave and Convex Lenses

Property	Concave Lens (Diverging)	Convex Lens (Converging)
Shape	Thinner at centre, thicker at edges	Thicker at centre, thinner at edges
Nature	Diverges parallel rays	Converges parallel rays
Focus	Virtual focus (F)	Real focus (F)
Image for real object	Always virtual, erect, diminished	Can be real or virtual (inverted or erect, diminished or enlarged)
Use in spectacles	Corrects myopia (short-sightedness)	Corrects hypermetropia (long-sightedness)

8. Ray Diagram Comparison

Concave Lens	Convex Lens
Parallel rays diverge and appear to come from F_1 .	Parallel rays converge at F_2 .

1. Lens Formula

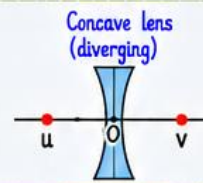
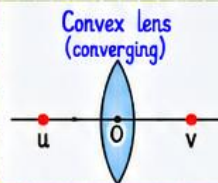
- The relationship between the object distance (u), image distance (v) and focal length (f) of a thin lens is given by the **lens formula**.

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

- f = focal length (cm)
- v = image distance (cm)
- u = object distance (cm)

2. Sign Convention (New Cartesian)

- All distances are measured from the optical centre (O) of the lens.
- Distances measured in the direction of **incident light (to the right)** are taken as **positive**.
- Distances measured in the **opposite direction (to the left)** are taken as **negative**.
- Heights measured **upward** are **positive** and **downward** are **negative**.



3. Magnification (m)

- Magnification (m) is the ratio of the height of image (h') to the height of object (h).

$$m = \frac{h'}{h} = \frac{v}{u}$$

- If m is negative, image is **inverted**.
- If m is positive, image is **upright**.
- $|m| > 1$: image is **enlarged**.
- $|m| = 1$: image is **same size**.
- $|m| < 1$: image is **diminished**.

4. Power of a Lens (P)

- Power of a lens is the reciprocal of its focal length (in metres).

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

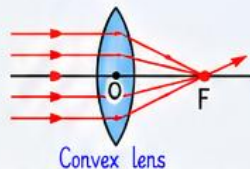
- Unit of power is **diopetre (D)**.
- 1 diopetre (1 D) = power of a lens whose focal length is 1 metre.

$$1 \text{ D} = 1 \text{ m}^{-1}$$

5. Nature of Lenses

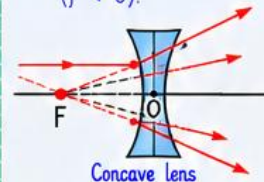
(a) Converging (Convex) Lens

- Thicker at the **centre** thinner at the **edges**.
- Converges parallel rays to a point (focus).
- Focal length is **positive** ($f > 0$).



(b) Diverging (Concave) Lens

- Thinner at the **centre** and thicker at the **edges**.
- Diverges parallel rays as if coming from a focus.
- Focal length is **negative** ($f < 0$).



6. Combination of Lenses

- When two or more thin lenses are placed in contact, the total power is the algebraic sum of their powers.

$$P_{\text{total}} = P_1 + P_2 + P_3 + \dots$$

- The focal length of the combination is

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \dots$$

- If lenses are of different types, take $+P$ for convex and $-P$ for concave.

7. Sign Convention Summary for Lenses

Quantity	Positive (+)	Negative (-)
Object distance (u)	Object on right side (incident light side)	Object on left side
Image distance (v)	Image on right side	Image on left side
Focal length (f)	Convex lens (converging)	Concave lens (diverging)
Height (h, h')	Upward	Downward

8. Important Points

- Use the correct sign convention.
- For convex lens, f is positive and for concave lens, f is negative.
- If v comes out positive, image is real and on the right side.
- If v comes out negative, image is virtual and on the left side.
- Use magnification to find the nature and size of image.
- Power is in diopetre (D) and f must be in metres.

9. Solved Numerical Examples

Example 1 : Find the image position

An object is placed at 30 cm in front of a convex lens of focal length 15 cm. Find the position, size and nature of the image.

Given : $f = +15 \text{ cm}$, $u = -30 \text{ cm}$

Using lens formula : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\frac{1}{15} = \frac{1}{v} - \frac{1}{(-30)}$$

$$\frac{1}{15} = \frac{1}{v} + \frac{1}{30}$$

$$\frac{1}{v} = \frac{1}{15} - \frac{1}{30} = \frac{2}{30} - \frac{1}{30} = \frac{1}{30}$$

$$v = +30 \text{ cm}$$

Magnification : $m = \frac{v}{u} = \frac{30}{-30} = -1$

Image is **real, inverted and same size**.

Image is formed at 30 cm on the **right side, real, inverted and same size**.

Example 2 : Virtual image by concave lens

An object is placed at 20 cm in front of a concave lens of focal length 10 cm. Find the position, size and nature of the image.

Given : $f = -10 \text{ cm}$, $u = -20 \text{ cm}$

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

$$\frac{1}{-10} = \frac{1}{v} - \frac{1}{-20}$$

$$\frac{1}{v} = \frac{-1}{10} - \frac{1}{20} = \frac{-2}{20} - \frac{1}{20} = \frac{-3}{20}$$

$$v = \frac{-20}{3} = -6.67 \text{ cm}$$

Magnification : $m = \frac{v}{u} = \frac{(-6.67)}{(-20)} = +0.33$

Image is **virtual, upright and diminished**.

Image is formed at 6.67 cm on the **left side, virtual, upright and diminished**.

Example 3 : Power of a lens

(a) Find the power of a convex lens of focal length 20 cm.

Given : $f = 20 \text{ cm} = 0.20 \text{ m}$

$$P = \frac{1}{f} = \frac{1}{0.20} = +5 \text{ D}$$

Power = +5 diopetre

(b) Find the focal length of a concave lens of power -2 D.

Given : $P = -2 \text{ D}$

$$f = \frac{1}{P} = \frac{1}{-2} = -0.5 \text{ m} = -50 \text{ cm}$$

Focal length = -50 cm

1. Introduction

- Eye is a natural optical device which helps us to see the objects around us.
- It forms a **real, inverted and diminished image** of the object on the **retina**.
- It works similar to a camera, where the eye lens acts like a **convex lens** and the retina acts like a **screen**.

2. Structure of Human Eye

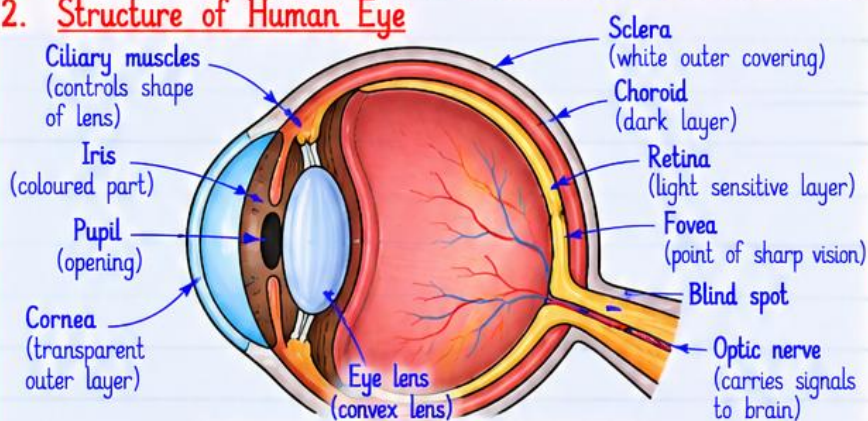


Diagram of the human eye (sectional view)

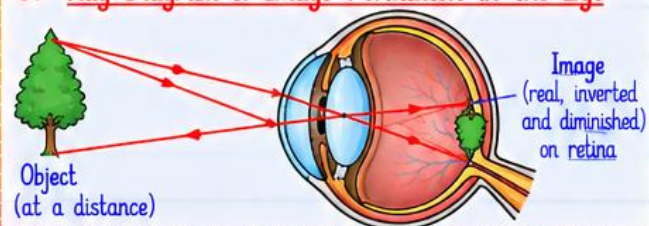
3. Functions of Different Parts

Part	Function
Cornea	Transparent outer layer. Refracts most of the light entering the eye and protects inner parts.
Iris	Coloured diaphragm. Controls the size of the pupil.
Pupil	Opening through which light enters the eye. Its size changes with the amount of light.
Eye lens	Convex and transparent lens. Changes its shape to focus the image on the retina (accommodation).
Ciliary muscles	Muscles attached to the lens. Contract or relax to change the focal length of the lens.
Retina	Light sensitive layer. The image is formed here. It contains millions of photoreceptor cells.
Fovea	Central part of retina. Provides sharp and detailed vision.
Blind spot	Point on retina where optic nerve leaves the eye. No light sensitive cells, so no vision at this point.
Optic nerve	Carries electrical signals from retina to the brain.

4. How Does the Eye See ?

- Light from an object enters the eye through the **cornea** and **pupil**.
- The cornea and eye lens together **refract** the light and focus it on the **retina**.
- A **real, inverted and diminished image** is formed on the retina.
- The light sensitive cells convert the light into **electrical signals** which are sent to the **brain** through the optic nerve.
- The brain interprets these signals and we see the object in its correct position (**upright**).

5. Ray Diagram of Image Formation in the Eye



6. Accommodation

- The ability of the eye lens to change its focal length (with the help of ciliary muscles) so that clear images can be formed on the retina for objects at different distances is called **accommodation**.
- When we look at a **near object**:
 - Ciliary muscles **contract**.
 - Lens becomes **thicker**.
 - Focal length **decreases**.
- When we look at a **distant object**:
 - Ciliary muscles **relax**.
 - Lens becomes **thinner**.
 - Focal length **increases**.

Accommodation helps us to see both near and distant objects clearly.

7. Near Point and Far Point

- Near point (of normal eye)**: Minimum distance at which the object can be seen clearly without strain.

For a normal adult, near point = 25 cm.

- Far point (of normal eye)**: Maximum distance at which the object can be seen clearly.

For a normal eye, far point = infinity (∞).

8. Everyday Examples

Reading a book



For a near object, lens becomes **thicker** due to contraction of ciliary muscles.

Watching a distant object



For a distant object, lens becomes **thinner** due to relaxation of ciliary muscles.

Adjusting to light



Bright light (pupil becomes smaller) Dim light (pupil becomes larger)

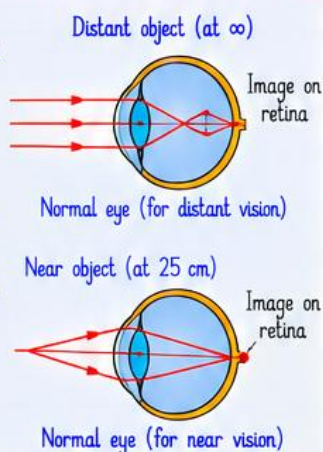
9. Key Points to Remember

- Eye lens is a convex lens.
- Image on retina is **real, inverted and diminished**.
- Accommodation is done by ciliary muscles.
- Near point of normal eye = **25 cm**.
- Far point of normal eye = **infinity**.
- Pupil controls the amount of light entering the eye.
- Fovea provides sharp vision.
- Blind spot has no light sensitive cells.
- Optic nerve carries signals to the brain.

1. Normal Vision

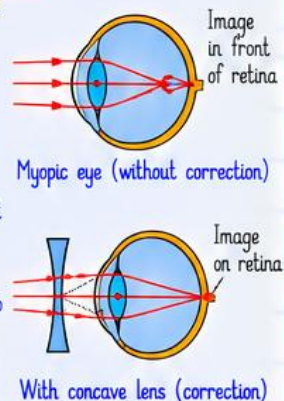
- A person with normal vision can see near as well as distant objects clearly.
- For distant objects (at infinity), image is formed on the retina.
- For near objects (at least distance of distinct vision 25 cm), image is also formed on the retina by adjusting the focal length of the eye lens (accommodation).

Near point = 25 cm
Far point = Infinity (∞)



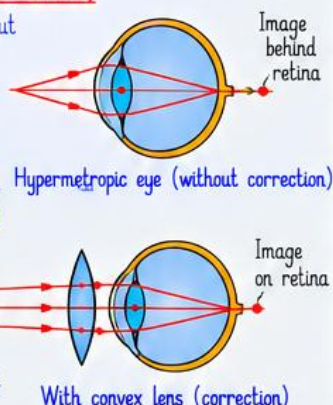
2. Myopia (Short-sightedness)

- Nearby objects are seen clearly but distant objects appear blurred.
- Cause:** Eyeball becomes elongated or eye lens becomes too powerful (more converging).
- Far point is at a finite distance instead of infinity.
- Distant object forms image in front of the retina.
- Correction:** Use a concave lens (diverging lens) of suitable power to diverge the incoming rays so that image is formed on the retina.



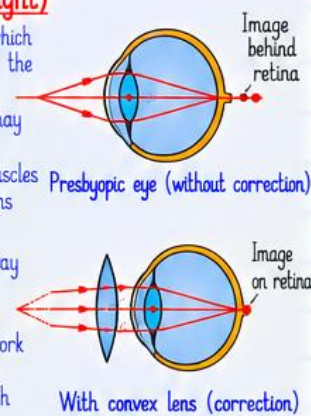
3. Hypermetropia (Long-sightedness)

- Distant objects are seen clearly but near objects appear blurred.
- Cause:** Eyeball becomes shorter or eye lens becomes less powerful (less converging).
- Near point is greater than 25 cm.
- Image of a near object is formed behind the retina.
- Correction:** Use a convex lens (converging lens) of suitable power to converge the incoming rays so that image is formed on the retina.



4. Presbyopia (Old-age sight)

- It is an age-related defect in which the power of accommodation of the eye lens decreases.
- Both near and distant vision may be affected.
- Cause:** Weakening of ciliary muscles and loss of flexibility of eye lens with age.
- Near point gradually moves away from 25 cm.
- Correction:** Use a convex lens with suitable power for near work (reading glasses). Sometimes bifocal lenses are used for both near and distant vision.



5. Comparison of Normal Vision and Defects

Feature	Normal Vision	Myopia	Hypermetropia	Presbyopia
Objects seen clearly	Near and distant	Near	Distant	Distant (near vision weak with age)
Far point	Infinity (∞)	Finite (less than ∞)	Infinity (∞)	Infinity (∞)
Near point	25 cm	25 cm	Greater than 25 cm	Greater than 25 cm (increases with age)
Image formation (without correction)	On retina	In front of retina (for distant objects)	Behind retina (for near objects)	Behind retina (for near objects)
Type of lens for correction	-	Concave (diverging)	Convex (converging)	Convex (converging) (Reading glasses)

6. Important Points

- Myopia is corrected by concave lenses.
- Hypermetropia and presbyopia are corrected by convex lenses.
- Power of lens, $P = \frac{1}{f}$ (f in metres).
- Concave lens has negative power and convex lens has positive power.
- Suitable power is chosen so that the image of the object is formed on the retina.

Power (P) = $\frac{1}{f}$ (f in metres)
1 dioptre (D) = power of a lens whose focal length is 1 m ($P = 1D$)

7. Solved Numerical Examples

(a) Myopia

The far point of a myopic person is 80 cm. Find the focal length and power of the lens required to correct the defect.

Given: Far point = 80 cm = 0.80 m
For distant objects ($u = \infty$), $v = -80$ cm

Using lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{-80} - 0$$

$$f = -80 \text{ cm} = -0.80 \text{ m}$$

$$\text{Power: } P = \frac{1}{f} = \frac{1}{-0.80} = -1.25 \text{ D}$$

Concave lens of power -1.25 D is required.

(b) Hypermetropia

A hypermetropic person has near point 100 cm. Find the focal length and power of the lens required to read a book at 25 cm.

Given: Near point = 100 cm
Desired near point = 25 cm
 $u = -25$ cm, $v = -100$ cm
(virtual image at near point)

Using lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-100} - \frac{1}{-25}$$

$$\frac{1}{f} = \frac{-1}{100} + \frac{1}{25} = \frac{-1+4}{100} = \frac{3}{100}$$

$$f = \frac{100}{3} \text{ cm} = 0.33 \text{ m}$$

$$\text{Power: } P = \frac{1}{f} = \frac{1}{0.33} \approx +3.0 \text{ D}$$

Convex lens of power +3.0 D is required.

(c) Presbyopia

A person with presbyopia needs a lens of power +2 D for reading. Find the focal length of the lens.

Given: $P = +2 \text{ D}$

$$\text{Using } P = \frac{1}{f} : f = \frac{1}{P} = \frac{1}{2} \text{ m}$$

$$f = 0.5 \text{ m} = 50 \text{ cm}$$

A convex lens of focal length 50 cm is required for near vision.

8. Common Observations

- Myopia is more common in young people.
- Hypermetropia and presbyopia are more common in old age.
- Presbyopia can be corrected using reading glasses or bifocal lenses.
- Laser surgery (e.g., LASIK) can also be used to correct myopia and hypermetropia.

1. Applications of Concave Mirror

(a) Shaving mirror



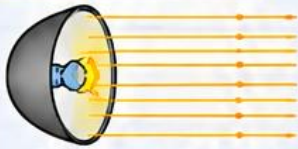
- Concave mirror gives an **erect and magnified** image when the object is within the focal length.
- Useful for shaving, makeup, etc.

(b) Dentist's mirror



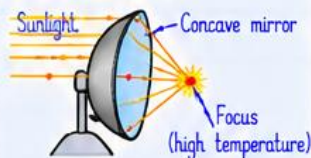
- Concave mirrors are used to get a **magnified and bright** image of teeth.
- Help the dentist to see small details clearly.

(c) Headlights and torches



- Bulb is placed at the focus of a **concave mirror**.
- It produces a **parallel beam** of light to get long range.
- Used in **vehicle headlights**, searchlights and torches.

(d) Solar furnace



- Sunrays are parallel and get focused at the focus (F).
- Produces very high temperature used for research and industrial purposes.

2. Applications of Convex Mirror

(a) Rear-view mirror in vehicles



- Convex mirror gives a **diminished, erect and virtual** image.
- Provides a wide field of view so that a larger area behind the vehicle can be seen.
- Used in cars, buses and bikes.

(b) Security mirrors



- Used in shops, parking areas and at road intersections.
- Helps to see a larger area and avoid accidents.

(c) Side mirrors in vehicles



- Give a wide field of view.
- Images are **erect and diminished**.
- Help in safe driving by showing vehicles from a large area.

(d) Street corner mirrors



- Used at blind turns and narrow roads.
- Help in seeing vehicles coming from the other side.
- Reduce the risk of accidents.

3. Applications of Convex Lens

(a) Magnifying glass (Simple microscope)



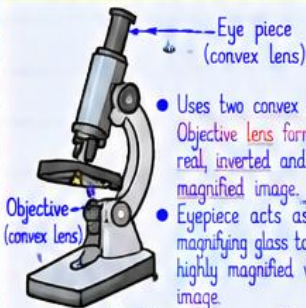
- Convex lens gives a **magnified, erect and virtual** image when the object is within the focal length.
- Used to see small objects like insects, stamps, etc.

(b) Camera



- Convex lens forms a **real, inverted and diminished** image on the film/sensor.
- Used in cameras and mobile phones.

(c) Microscope (Compound microscope)



- Uses two convex lenses. Objective lens forms a **real, inverted and magnified** image.
- Eyepiece acts as a magnifying glass to give a highly magnified virtual image.
- Used to see very small objects like cells, bacteria, etc.

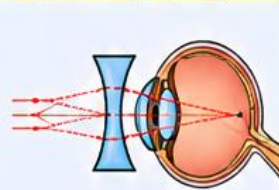
(d) Telescope (Astronomical telescope)



- Used to see distant objects like stars and planets.
- Objective lens forms a **real, inverted and diminished** image.
- Eyepiece magnifies this image.
- Used in astronomical observations.

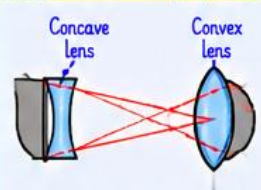
4. Applications of Concave Lens

(a) Spectacles for myopia (short-sightedness)



- Concave lens **diverges** the incoming rays.
- Helps to **bring** the image on the retina.
- Used to correct myopia.

(b) Door viewer (peephole)



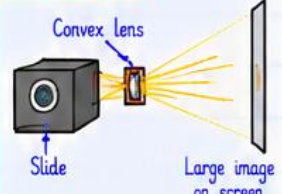
- Combination of concave and convex lenses.
- Provides a wide field of view.**
- Used in doors for security.

(c) Spectacles for presbyopia



- Convex lenses are used in bifocal or progressive lenses.
- Help elderly people to see near objects clearly.
- Corrects **presbyopia** (age-related weakening of accommodation).

(d) Projector



- Convex lens forms a **real, inverted and enlarged** image on the screen.
- Used in slide projectors and multimedia projectors.

5. Summary Table

Optical Device	Type of Mirror/Lens	Position of Object	Nature of Image	Main Use
Shaving / Dentist mirror	Concave mirror	Between P and F	Virtual, erect, magnified	To see enlarged image
Headlights / Torch	Concave mirror	At focus	Parallel beam of light	Long range illumination
Solar furnace	Concave mirror	At focus	Concentrated real image	High temperature
Rear-view / Security mirror	Convex mirror	Any position	Virtual, erect, diminished	Wide field of view
Magnifying glass	Convex lens	Within focal length	Virtual, erect, magnified	To see small objects
Camera	Convex lens	Beyond 2F	Real, inverted, diminished	Photography
Microscope	Convex lenses (two)	Very close / adjusted	Highly magnified (final virtual)	To see tiny objects
Telescope	Convex lenses (two)	Distant object	Magnified (final virtual)	To see distant objects
Spectacles (myopia)	Concave lens	-	Brings image on retina	Corrects short-sightedness
Spectacles (presbyopia)	Convex lens	-	Helps near vision (bifocal)	Corrects age-related defect
Projector	Convex lens	Between F and 2F	Real, inverted, enlarged	To project image on screen

1. Refractive Index and Speed of Light

- Refractive index (n) of a medium is the ratio of **speed of light** in vacuum to the speed of light in the medium.

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

where, c = speed of light in vacuum
 $= 3 \times 10^8 \text{ m/s}$

v = speed of light in the medium

- If $n > 1$, then $v < c$ (speed decreases).
- If $n = 1$, medium is vacuum (no change).
- If $n < 1$, not possible for ordinary media.

2. Absolute and Relative Refractive Index

(a) Absolute refractive index (n)

- Refractive index of a medium with respect to vacuum (air).

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

(b) Relative refractive index (n_{21})

- Refractive index of medium 2 with respect to medium 1.

$$n_{21} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

$$\text{Also, } n_{21} = \frac{\sin i}{\sin r}$$

3. Physical Meaning

- Higher refractive index means **lower** speed of light in the medium.
- A medium with higher refractive index is **optically denser**.
- A medium with lower refractive index is **optically rarer**.
- When light goes from **rarer** to **denser** medium, it **bends towards the normal**.
- When light goes from **denser** to **rarer** medium, it **bends away from the normal**.

4. Optical Density and Comparison of Media

- A medium with **higher** refractive index is **optically denser** and has **lower** speed of light.
- A medium with **lower** refractive index is **optically rarer** and has **higher** speed of light.

Medium	Refractive index (n)	Speed of light (m/s)	Optical nature
Air ($\approx$ vacuum)	1.00	3.0×10^8	Rarer
Water	1.33	2.25×10^8	Denser than air
Glass	1.50	2.0×10^8	Denser than water
Diamond	2.42	1.24×10^8	Most dense (among these)

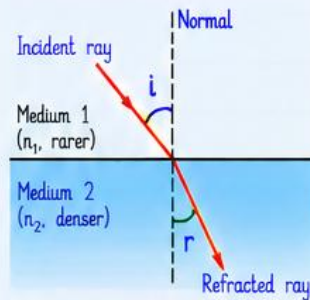
Optically rarer (lower n)

Optically denser (higher n)

5. Snell's Law and Refractive Index

- For a given pair of media, the ratio of $\sin i$ to $\sin r$ is **constant**.

$$\frac{\sin i}{\sin r} = n_{21} = \text{constant}$$



6. Some Useful Relations

- $n = \frac{c}{v}$
- $n_{21} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$
- $v = \frac{c}{n}$
- $n_{21} = \frac{\sin i}{\sin r}$
- If light goes from medium 1 to 2 and $n_2 > n_1$, then $r < i$.
- If light goes from medium 1 to 2 and $n_2 < n_1$, then $r > i$.
- $n_{12} \times n_{21} = 1$
- For same medium, refractive index is constant (for a given wavelength).

7. Solved Numerical Examples

(a) Example 1 : Speed of light in glass

The refractive index of glass is 1.5. Find the speed of light in glass.

Given : $n = 1.5$, $c = 3 \times 10^8 \text{ m/s}$

Solution : $v = \frac{c}{n} = \frac{3 \times 10^8}{1.5}$

$$v = 2.0 \times 10^8 \text{ m/s}$$

(b) Example 2 : Relative refractive index

The speed of light in water is $2.25 \times 10^8 \text{ m/s}$ and in glass is $2.0 \times 10^8 \text{ m/s}$. Find the refractive index of glass with respect to water.

Given : $v_{\text{water}} = 2.25 \times 10^8 \text{ m/s}$
 $v_{\text{glass}} = 2.0 \times 10^8 \text{ m/s}$

Solution : $n_{\text{glass, water}} = \frac{v_{\text{water}}}{v_{\text{glass}}} = \frac{2.25 \times 10^8}{2.0 \times 10^8} = 1.125$

$$n_{\text{glass, water}} = 1.125$$

(c) Example 3 : Angle of refraction

A ray of light goes from air ($n_1 = 1$) into a medium of refractive index 1.5 at an angle of incidence 30° . Find the angle of refraction.

Given : $n_1 = 1$, $n_2 = 1.5$, $i = 30^\circ$

Using Snell's law : $n_1 \sin i = n_2 \sin r$

$$1 \times \sin 30^\circ = 1.5 \times \sin r$$

$$0.5 = 1.5 \sin r$$

$$\sin r = \frac{0.5}{1.5} = \frac{1}{3}$$

$$r = \sin^{-1}\left(\frac{1}{3}\right) \approx 19.5^\circ$$

$$r \approx 19.5^\circ$$

8. Conceptual Questions (with answers)

Q1. Why does light bend towards the normal when it enters a denser medium?

Ans : Because the speed of light decreases in the denser medium ($n_2 > n_1$).

Q2. Which has higher optical density: water or air?

Ans : Water, because its refractive index (1.33) is higher than air (≈ 1).

Q3. If the refractive index of a medium is 2, what is the speed of light in it?

Ans : $v = \frac{c}{n} = \frac{3 \times 10^8}{2} = 1.5 \times 10^8 \text{ m/s}$.

Q4. Can refractive index be less than 1?

Ans : For ordinary media, no. It is 1 for vacuum and greater than 1 for all other media.

9. Additional Example

The speed of light in a medium is $1.5 \times 10^8 \text{ m/s}$. Find (i) its refractive index and (ii) the relative refractive index of this medium with respect to water.

Given : $v = 1.5 \times 10^8 \text{ m/s}$
 $c = 3 \times 10^8 \text{ m/s}$
 $v_{\text{water}} = 2.25 \times 10^8 \text{ m/s}$

(i) Refractive index : $n = \frac{c}{v} = \frac{3 \times 10^8}{1.5 \times 10^8} = 2$

(ii) Relative refractive index w.r.t. water :

$$n_{\text{medium, water}} = \frac{v_{\text{water}}}{v_{\text{medium}}} = \frac{2.25 \times 10^8}{1.5 \times 10^8} = 1.5$$

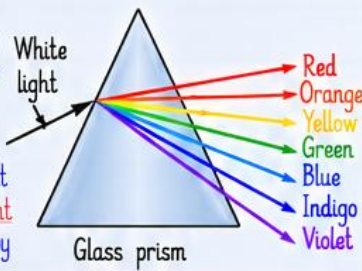
$$n_{\text{medium, water}} = 1.5$$

10. Quick Revision Points

- Refractive index is the ratio of speed in vacuum to speed in the medium.
- Higher $n \rightarrow$ lower speed $\rightarrow$ optically denser.
- Lower $n \rightarrow$ higher speed $\rightarrow$ optically rarer.
- Rarer to denser : **bends towards normal**.
- Denser to rarer : **bends away from normal**.
- $n_{21} = \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$
- $n = 1$ for vacuum, > 1 for other media.
- Optical density $\propto$ refractive index.
- Speed of light decreases as optical density increases.
- Refractive index depends on the nature of medium and wavelength (colour) of light.

1. Dispersion of Light

- Dispersion of light is the **splitting of white light** into its constituent **colours** (VIBGYOR) when it passes through a transparent medium like a prism.
- White light is a **mixture** of seven colours. Each colour has a different wavelength and therefore a **different speed** in glass. Hence, they bend by different amounts and separate.
- This phenomenon is called **dispersion**.



Dispersion of white light through a glass prism

2. Formation of Spectrum

- The band of seven colours obtained after dispersion is called the **spectrum**.
- The colours always appear in the same order.

Red	Maximum wavelength (≈ 700 nm)	Least deviation
Orange	Least deviation	
Yellow		
Green		
Blue		
Indigo		
Violet	Minimum wavelength (≈ 400 nm)	Maximum deviation

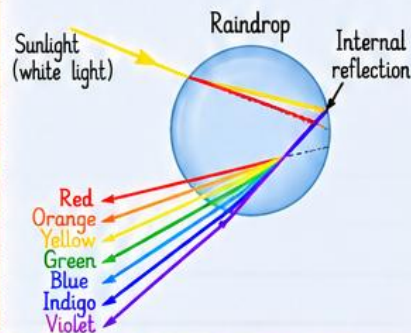
3. Why Does White Light Separate?

- Different colours of light have **different wavelengths**.
- When white light enters a prism, each colour travels with a **different speed** in glass and hence bends by a different amount (refractive index is different).
- Violet light (shortest wavelength) bends the **most**.
- Red light** (longest wavelength) bends the **least**.
- Therefore, white light splits into seven colours.

Different deviation of colours due to different speeds in glass causes dispersion of light.

4. Rainbow Formation

- A rainbow is caused by **dispersion, reflection and refraction** of sunlight in tiny water droplets present in the atmosphere after rain.
- Sunlight enters a raindrop, gets **refracted** and **dispersed** into colours, **reflects** from the **inner surface** and again refracts out, forming a **spectrum**.
- We see a circular arc of colours in the sky with **red** on the outer side and **violet** on the inner side.

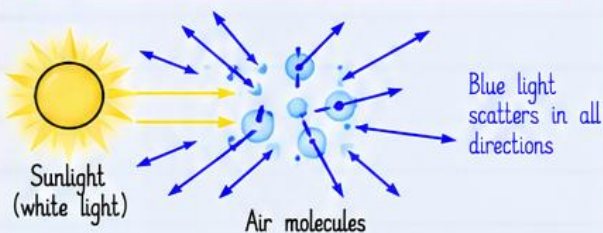


Rainbow in the sky

5. Scattering of Light

- Scattering of light is the **change in direction** of light rays when they collide with tiny particles (molecules or dust) present in a medium like air.
- The **shorter** the wavelength, the **more** the scattering.

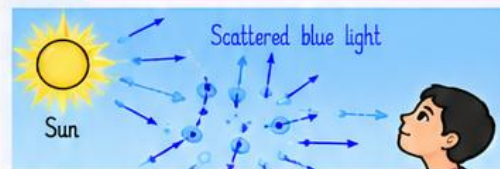
Blue and violet light (shorter wavelength) scatter much more than red light (longer wavelength).



6. Blue Colour of the Sky

- Sunlight entering the Earth's atmosphere is scattered by air molecules.
- Blue light (shorter wavelength) is **scattered the most** in all directions.
- Hence, the sky appears blue to us during the day.

The sky looks blue because blue light is scattered much more than other colours.



Blue light enters our eyes from all directions

7. Reddish Sunrise and Sunset

- During **sunrise and sunset**, sunlight has to travel a much **longer distance** through the atmosphere.
- Most of the blue and violet light gets scattered away from the line of sight.
- The **red and orange light** (longer wavelength) are scattered the **least** and reach our eyes.
- Hence, the Sun appears **reddish or orange** at sunrise and sunset.



Reddish Sun at sunset

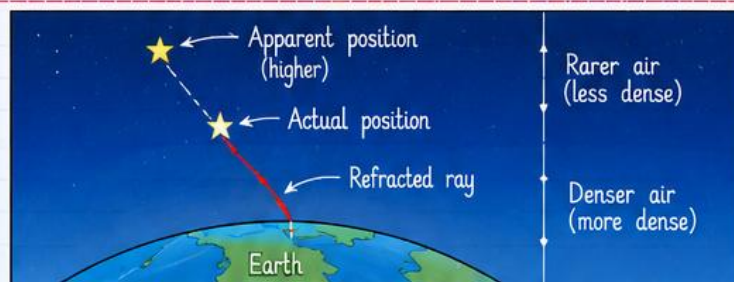
At sunrise and sunset, shorter wavelengths are scattered away, so the Sun appears red.

8. Key Points to Remember

- Dispersion**: splitting of white light into seven colours.
- Spectrum order**: VIBGYOR (Red, Orange, Yellow, Green, Blue, Indigo, Violet).
- Violet deviates the most, red deviates the least.
- Caused due to **different speeds** of colours in a medium.
- Rainbow: due to dispersion, reflection and refraction in water droplets.
- Scattering of light**: change in direction due to tiny particles.
- Blue sky: due to more scattering of blue light.
- Reddish sunrise and sunset: due to less scattering of red and orange light.

1. Atmospheric Refraction

- When light from stars enters the Earth's atmosphere, it passes through layers of air having **different densities** and **refractive indices**.
- Due to continuous refraction, the path of light keeps **bending towards the normal** (towards denser layers).
- As a result, the star appears at a slightly **higher position** than its actual position.



Atmospheric refraction of starlight

2. Twinkling of Stars

- Stars are at very large distances, so they appear as **point sources** of light.
- Light from stars passes through atmospheric layers of **varying density** and temperature.
- Continuous and **irregular refraction** changes the **apparent position** and **brightness** of stars rapidly.
- Therefore, stars appear to **flicker or twinkle**.



Twinkling of stars due to atmospheric refraction

Why planets do not twinkle?

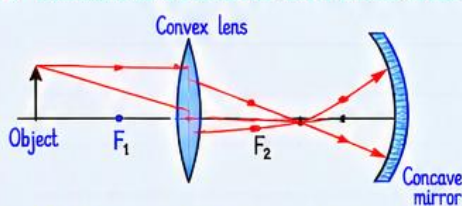
- Planets are **much closer** to the Earth.
- They appear as **extended sources** (not point sources).
- The light from different parts of a planet **averages out the fluctuations**.
- Hence, planets generally **do not twinkle**.

3. Comparison of Reflection, Refraction, Dispersion and Scattering

Property	Reflection	Refraction	Dispersion	Scattering
Meaning	Bouncing back of light from a surface.	Bending of light when it passes from one medium to another.	Splitting of white light into its constituent colours.	Change in direction of light by small particles of medium.
Cause	Change in direction at surface	Different speed in different media	Different refractive index for different colours	Interaction with tiny particles of size comparable to wavelength
Occurs in	Same medium	Different media	Prism (or other dispersing medium)	Atmosphere, dust, water droplets etc.
Effect	Light returns in same medium	Path changes	White light splits into seven colours	Light spreads in different directions
Example	Plane mirror	Light from air to water	Glass prism	Blue sky, red sunset

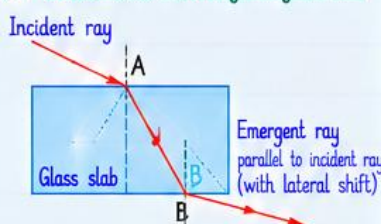
4. Mixed Ray-Diagram Questions (Revision)

(a) Combination of a convex lens and a concave mirror



- First, the convex lens forms a real image of the object between F and 2F.
- This image acts as an object for the concave mirror.
- Final image is real and may be inverted or enlarged depending on positions.

(b) Refraction at a rectangular glass slab



- Ray bends towards normal while entering.
- Ray bends away from normal while leaving.
- Emergent ray is parallel to incident ray but shows lateral displacement.

5. Solved Numerical Examples

Example 1 : Mirror formula

An object is placed at 15 cm in front of a concave mirror of focal length 10 cm. Find the image distance and magnification.

Given : $u = -15$ cm $f = -10$ cm

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

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

$$\Rightarrow \frac{1}{v} = \frac{-1}{10} + \frac{1}{15} = \frac{-3 + 2}{30}$$

$$\Rightarrow \frac{1}{v} = \frac{-1}{30} \Rightarrow v = -30 \text{ cm}$$

$$\text{Magnification : } m = \frac{-v}{u} = \frac{-(-30)}{-15} = -2$$

Image is real, inverted and enlarged.

Example 2 : Lens formula

A convex lens of focal length 20 cm forms a real image at 60 cm. Find the object distance and magnification.

Given : $v = +60$ cm $f = +20$ cm

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

$$\frac{1}{20} = \frac{1}{60} - \frac{1}{u} \Rightarrow \frac{1}{u} = \frac{1}{60} - \frac{1}{20}$$

$$= \frac{1 - 3}{60} = -\frac{2}{60} = -\frac{1}{30}$$

$$\Rightarrow u = -30 \text{ cm}$$

$$\text{Magnification : } m = \frac{v}{u} = \frac{60}{-30} = -2$$

Image is real, inverted and enlarged.

Example 3 : Refractive index

The speed of light in air is 3×10^8 m/s and in a medium it is 2×10^8 m/s. Find the refractive index of the medium.

Given : $c = 3 \times 10^8$ m/s $v = 2 \times 10^8$ m/s

$$n = \frac{c}{v} = \frac{3 \times 10^8}{2 \times 10^8} = \frac{3}{2} = 1.5$$

The medium has refractive index 1.5 and is **optically denser** than air.

If $n > 1$, the medium is optically denser.
If $n < 1$, the medium is optically rarer.

6. Syllabus-Based MCQs

- The phenomenon responsible for the twinkling of stars is:
 - Scattering
 - Dispersion
 - Atmospheric refraction
 - Reflection

Ans. (c) Atmospheric refraction

- The sky appears blue due to:
 - Reflection
 - Refraction
 - Dispersion
 - Scattering

Ans. (d) Scattering

- White light splits into seven colours when it passes through a:
 - Plane mirror
 - Concave mirror
 - Convex lens
 - Prism

Ans. (d) Prism (Dispersion)