पुण्ना International School

Shree Swaminarayan Gurukul, Zundal

Introduction to Light – Reflection & Refraction

Sample note book

Physics(class -10)

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Light :Definition

Light is a form of energy that enables us to see things. Light starts from a source and bounces off objects which are perceived by our eyes and our brain processes this signal, which eventually enables us to see.

Nature of Light

Light behaves as a:

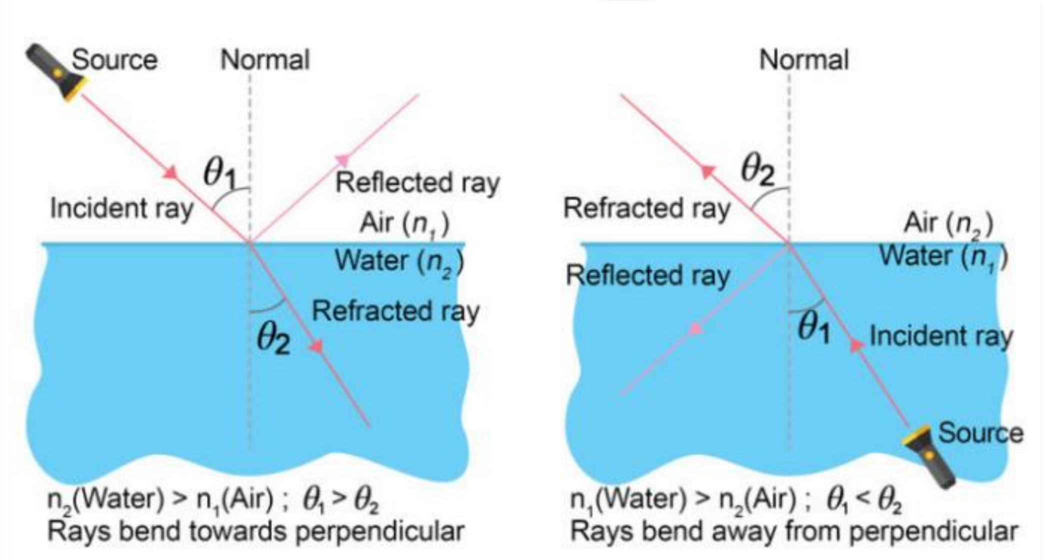
- ray, e.g. reflection
- wave, e.g. interference and diffraction
- particle, e.g. photoelectric effect

- Light incident on another medium

When light travels from one medium to another medium it either:

- gets absorbed (absorption)
- bounces back (reflection)
- passes through or bends (refraction)

When light is incident on a plane mirror, most of it gets reflected, and some of it gets absorbed in the medium.



Characteristics of light

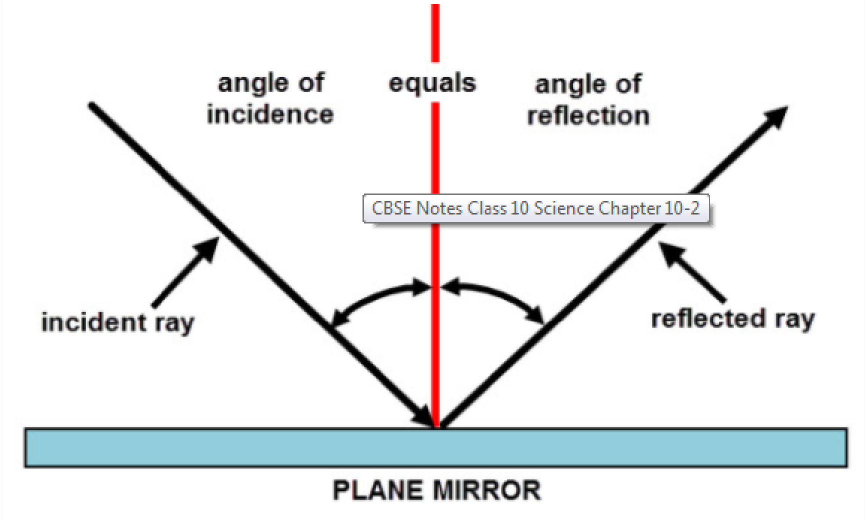
- Speed of light c=λ*μ, where λ is its wavelength and μ is its frequency.
- Speed of light is a constant which is 2.998×108m/s or approximately 3.0×108m/s.

Reflection of light by other media

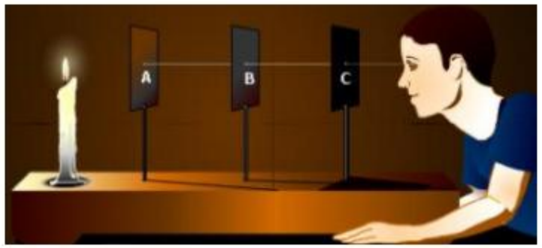
A medium that is polished well without any irregularities on its surface will cause regular reflection of light. For example, a plane mirror. But even then some light gets absorbed by the surface.

Laws of Reflection

The incident ray, reflected ray and the normal all lie in the same plane. Angle of incidence = Angle of reflection
[∠i=∠r]



Propagation of light



Rectilinear propagation of light: Light travels in a straight line between any two points.

Fermat's Theorem

- The principle of least time: Light always takes the quickest path between any two points (which may not be the shortest path).
- Rectilinear propagation of light and the law of reflection [∠i=∠r] can be validated by Fermat's principle of least time.

Plane mirror

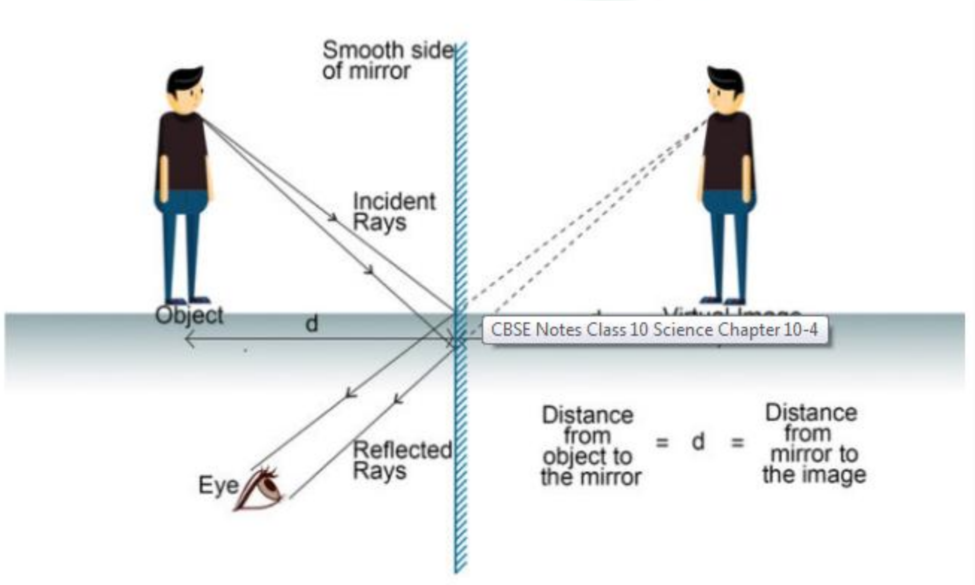
Any flat and polished surface that has almost no irregularities on its surface that reflect light is called as a plane mirror.

Characteristics of images

- Images can be real or virtual, erect or inverted, magnified or diminished. A real image is formed by the actual convergence of light rays. A virtual image is the apparent convergence of diverging light rays.
- If an image formed is upside down then it is called inverted or else it is an erect image. If the image formed is bigger than the object, then it is called magnified. If the image formed is smaller than the object, then it is diminished.

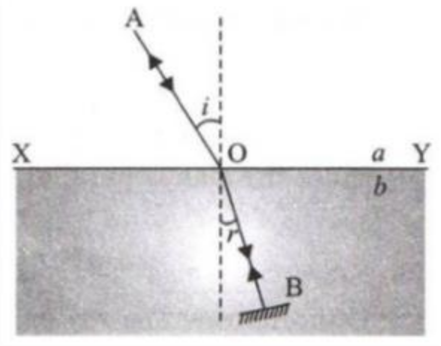
Image formation by a plane mirror

- The image formed by a plane mirror is always virtual and erect.
- Object and image are equidistant from the mirror.



Principle of Reversibility of light

If the direction of a ray of light is reversed due to reflection off a surface, then it will retrace its path.



Spherical mirror

Consider a hollow sphere with a very smooth and polished inside surface and an outer surface with a coating of mercury so that no light can come out. Then if we cut a thin slice out of the shell, we get a curved mirror, which is called a spherical mirror.

Relationship between focus and radius of curvature

Focal length is half the distance between pole and radius of curvature.

F = R/2

Curved Mirror

A mirror (or any polished, reflective surface) with a curvature is known as a curved mirror.

Important terms related to spherical mirror

- **Pole (P)**: The midpoint of a spherical mirror.
- **Centre of curvature (C)**: The center of the sphere that the spherical mirror was a part of.
- **The radius of curvature (r):** The distance between the center of curvature and the spherical mirror. This radius will intersect the mirror at the pole (P).
- **Principal Axis:** The line passing through the pole and the center of curvature is the main or principal axis.
- **Concave Mirror:** A spherical mirror with the reflecting surface that bulges inwards.
- **Convex Mirror:** A spherical mirror with the reflecting surface that bulges outwards.
- **Focus (F):** Take a concave mirror. All rays parallel to the principal axis converge at a point between the pole and the centre of curvature. This point is called as the focal point or focus.
- **Focal length**: Distance between pole and focus.

Rules of ray diagram for representation of images formed

- A ray passing through the center of curvature hits the concave spherical mirror and retraces its path.
- Rays parallel to the principal axis passes through the focal point or focus.

Image formation by spherical mirrors

For objects at various positions, the image formed can be found using the ray diagrams for the special two rays. The following table is for a concave mirror.

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At focus F	Highly diminished, point sized	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Same size	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between P and F	Behind the mirror	Enlarged	Virtual and erect

Uses of spherical mirror based on the image formed

Concave and Convex mirrors are used in many daily purposes.
Example: Rear view mirrors in vehicles, lamps, solar cookers.

Sign convention for ray diagram

Distances measured towards positive x and y axes (coordinate system) are positive and towards negative x and y-axes are negative. Keep in mind the origin is the pole (P). Usually, the height of the object is taken as positive as it is above the principal axis and height of the image is taken as negative as it is below the principal axis.

Mirror formula and Magnification

- 1/v + 1/u = 1/f where ‘u’ is object distance, ‘v’ is the image distance and ‘f’ is the focal length of spherical mirror, which is found by similarity of triangles.
- The magnification produced by a spherical mirror is the ratio of the height of the image to the height of the object. It is usually represented as ‘m’.

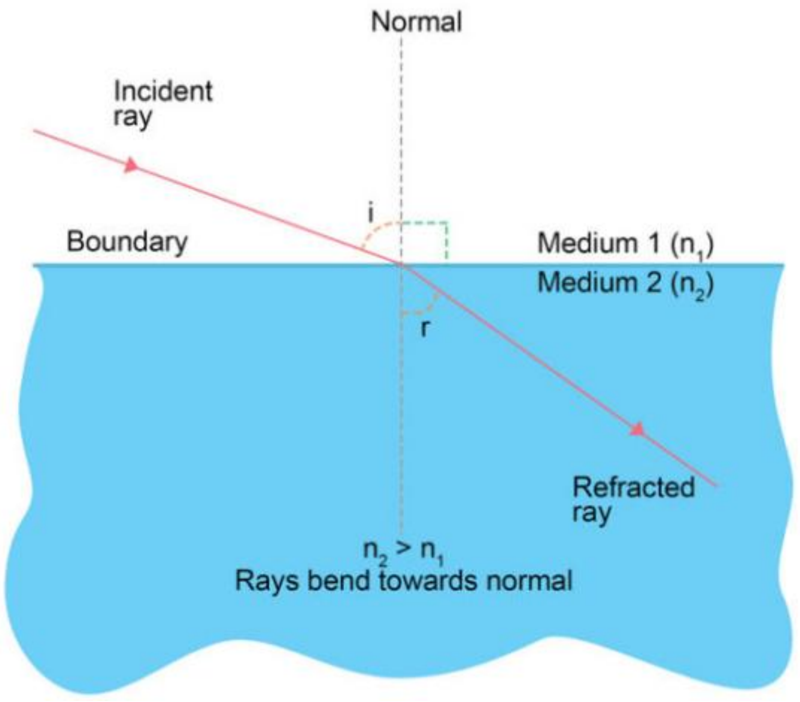
Position and Size of image formed

Size of image can be found using the magnification formula m = h’/h = – (v/u) If m is -ve it is a real image and if it is +ve it is a virtual image.

Refraction Through a Glass Slab and Refractive Index

Refraction

The shortest path need not be the quickest path. Since light is always in a hurry, it bends when it enters a different medium as it is still following the quickest path. This phenomenon of light bending in a different medium is called refraction.



Laws of Refraction

- The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.
- The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant, for the light of a given colour and for the given pair of media. This law is also known as Snell's law of refraction.

Absolute and Relative Refractive Index

Refractive index of one medium with respect to another medium is called relative refractive index. When taken with respect to vacuum, it's known as an absolute refractive index.

Refraction through a rectangular glass slab

When the light is incident on a rectangular glass slab, it emerges out parallel to the incident ray and is laterally displaced. It moves from rarer to denser medium and then again to the rarer medium.

Refraction at a planar surface

Following Snell's Law:

- Light bends towards the normal when moving from rarer to denser medium at the surface of the two media.
- Light bends away from the normal when moving from denser to rarer medium at the surface of contact of the two media.

Refractive Index

The extent to which light bends when moving from one medium to another is called refractive index. This depends on the ratio of the speeds in the two media. The greater the ratio, more the bending. It is also the ratio of the sine of the angle of incidence and the sine of the angle of refraction, which is a constant for any given pair of media. It is denoted by:
$n = \sin \angle i / \sin \angle r$ = speed of light in medium 1/speed of light in medium2.

Total internal reflection

- When the light goes from a denser to a rarer medium it bends away from the normal. The angle at which the incident ray causes the refracted ray to go along the surface of the two media parallelly is called critical angle.
- When the incident angle is greater than the critical angle, it reflects inside the denser medium instead of refracting. This phenomenon is known as Total Internal Reflection.
  E.g. mirages, optical fibers.

Spherical Lens

Refraction at curved surfaces

When light is incident on a curved surface and passes through, the laws of refraction still hold true. For example lenses.

Spherical lenses

Spherical lenses are the lenses formed by binding two spherical transparent surfaces together. Spherical lenses formed by binding two spherical surfaces bulging outward are known as convex lenses while the spherical lenses formed by binding two spherical surfaces such that they are curved inward are known as concave lenses.

Important terms related to spherical lenses

- **Pole (P):** The midpoint or the symmetric Centre of a spherical lens is known as its *Optical Centre*. It is also called as the pole.
- **Principal Axis:** The line passing through the optical center and the center of curvature.
- **Paraxial Ray:** A ray close to principal axis and also parallel to it.
- **Centre of curvature (C):** The centers of the spheres that the spherical lens was a part of. A spherical lens has two centers of curvatures.
- **Focus (F):** It is the point on the axis of a lens to which parallel rays of light converge or from which they appear to diverge after refraction.
- **Focal length:** Distance between optical centre and focus.
- **Concave lens:** Diverging lens
- **Convex lens:** Converging lens

Rules of ray diagram for representation of images formed

- A ray of light parallel to principal axis passes/appears to pass through the focus.
- A ray passing through the optical center undergoes zero deviation.

Image formation by spherical lenses

The following table shows image formation by a convex lens.

Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Infinitely large or highly enlarged	Real and inverted
Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

Lens formula and magnification

Lens formula:

1/v = 1/u = 1/f,

gives the relationship between the object-distance (u), image-distance (v), and the focal length (f) of a spherical lens.

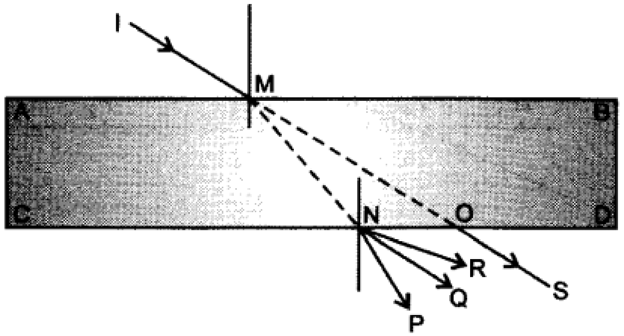
Power of a Lens

Power of a lens is the reciprocal of its focal length i.e.

1/f (in meter). The SI unit of power of a lens is diopter (D).

VERY SHORT QUESTIONS (1 MARK)

1. If a light ray IM is incident on the surface AB as shown, identify the correct emergent ray?



Answer. Ray NQ, as it has to be parallel to ray OS.

2. Draw a schematic representation of different type of mirrors.
Answer: Types of mirror:

1. Plane mirror

2. Spherical mirror


Concave mirror

(i) concave mirror


Convex mirror

(ii) convex mirror

3. Define one dioptre?
Answer: dioptre is the power of a lens whose focal length is 1 meter.

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

4. Define focus?
Answer: Principal focus: A point on the principal axis of a spherical mirror where the rays of light parallel to the principal axis meet or appear to meet after reflection from the spherical mirror is called principal focus.

5. What is concave and convex mirror?
Answer:

- Concave mirror: A spherical mirror, whose reflecting surface is curved inwards, that is it faces towards the centre of the sphere, is called a concave mirror.
- Convex mirror: A spherical mirror whose reflecting surface is curved outwards, is called a convex mirror.

Short Questions :
1. Define
i) Reflection of light
ii) Beam of light
Answer:
i) Reflection: When light falls on a surface and bounces back to the medium, the phenomena is called reflection.
ii) Beam: A beam is a bundle of rays, which originates from a common source and travels in the same direction.

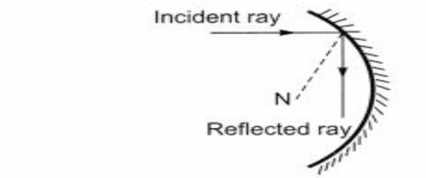
2. Define light and write its properties.
Answer: Light: It is a form of energy which produces the sensation of sight.

- Light exhibits dual nature i.e., wave as well as particle nature.
- It travels with speed of 3×10^8 m/s in vacuum. However, speed is inversely proportional to optical density of medium.

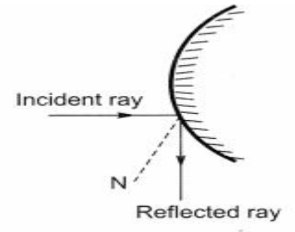
3. State laws of reflection.
Answer: Laws:

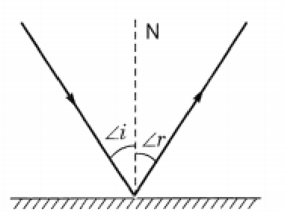
1. The angle of incidence is equal to the angle of reflection.
2. The incident ray, the normal to the mirror at the point of incidence and reflected ray, all lie in the same plane.

These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces.



Reflection on spherical surfaces





Reflection on plane mirror

4. Write four difference between real and virtual image?

Answer:

Real image:

1. When rays of light after reflection meets at a point real image is formed.
2. Real image can be obtained on screen.
3. Real image is formed in front of mirror.
4. Real image is always inverted.

Virtual image:

1. When rays of light do not actually meet but appear to meet at a point after reflection, virtual image is formed.
2. Virtual image cannot be obtained on screen.
3. Virtual image is formed behind the mirror.
4. Virtual image is always erect.

5. If the speed of light in vacuum is 3×10^8 ms^{-1}, find the speed of light in a medium of absolute refractive index 1.5.

Answer:

$$\frac{v_1}{v_2} = \frac{n_2}{n_1} \quad \text{or} \quad \boxed{\frac{v_2}{v_1} = \frac{n_1}{n_2}}$$

Here, $v_1 = 3 \times 10^8$ m/s, $n_1 = 1$, $n_2 = 1.5$

$v_2 = 11.5 \times 3 \times 10^8$

$v_2 = 2 \times 10^8$ m/s

6. An object of height 6 cm is placed perpendicular to the principal axis of a concave lens of focal length 5 cm. Use lens formula to determine the position, size and nature of the image if the distance of the object from the lens is 10 cm.

Answer:

h = 6 cm, f = -5 cm, u = -10 cm

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

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

$$\Rightarrow \quad \frac{1}{v} + \frac{1}{10} = \frac{1}{-5} \quad \Rightarrow \quad \frac{1}{v} = -\frac{1}{5} - \frac{1}{10}$$

$$\boxed{v = \frac{-10}{3}\text{cm}}$$

$$\therefore \quad h = \frac{v}{u} = \frac{\frac{-10}{3}}{-10} = \frac{1}{3}$$

Image is diminished and erect.

7. Write some illustrations of refraction.
Answer:
Some applications of refraction:

1. Bottom of a tank or a pond containing water appears to be raised due to refraction.
2. When a thick glass slab is placed over some printed matter the letters appear raised when viewed through the glass slab.
3. When a pencil is partly immersed in water, it appears to be bent at the interface of air and water.
4. A lemon kept in water in a glass tumbler appears to be bigger than its actual size, when viewed from the sides.

8. Name the type of mirror used in solar furnace. How is high temperature achieved by this device? (CBSE 2012)
Answer:
Concave mirror is used in solar furnace. The solar furnace is placed at the focus of the large concave reflector. The concave reflector focus the Sim's heat rays on the furnace and a high temperature is achieved

Long Questions:

1. Define refractive index and relative refractive index.
Answer:
1. Refractive index: The ratio of speed of light in vacuum (c) to the speed of light in any medium (v) is called refractive index of the medium.

$$n_m = \frac{\text{Speed of light in air}}{\text{Speed of light in the medium}} = \frac{c}{v}$$

2. Relative refractive index: The relative refractive index of a medium with respect to other medium is the ratio of the speed of light in the first medium with respect to the second medium.

$$n_{21} = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}} = \frac{v_1}{v_2}$$

Here, n_{21} = Relative refractive index of medium 2 with respect to medium 1 is

$$n_{12} = \frac{\text{Speed of light in medium 2}}{\text{Speed of light in medium 1}} = \frac{v_2}{v_1}$$

Here, n_{12} = Relative refractive index of medium 1 with respect to medium 2.

2. The absolute refractive indices of glass and water are 43 and 32 respectively. If the speed of light in glass is 2×10^8 ms^{-1}, calculate the speed of light in (i) vacuum and (ii) water.
Answer:
Given, μ_g= 43 and μ_w = 32
Speed of light in glass = 2×10^8 ms^{-1}
(i) Speed of light in vacuum, $c = \mu_g \times v_g = 43 \times 2 \times 10^8 = 2.67 \times 10^8$ ms^{-1}
(ii) Speed of light in water,

$$v_w = \frac{c}{\mu_w} = \frac{2.67 \times 10^8}{\frac{3}{2}} = 2.67 \times 10^8 \times \frac{2}{3} = 1.78 \times 10^8 \text{ ms}^{-1}$$

3. Define power of a lens. What is its unit? One student uses a lens of focal length 50 cm and another of -50 cm. What is the nature of the lens and its power used by each of them?
Answer:
Power of a lens: The power of a lens is defined as reciprocal of its focal length.
P = 1f
f= focal length (in meter)
The SI unit of power is 'diopter'. It is denoted by the letter D.
Here, f= 50 cm = 0.5 m
Power P = 1f=10.5 = +2D
f = – 50 cm = -0.5 m
Power P = 1f=1−0.5 = -2D

4. Define lens. What is difference between convex and concave lens?
Answer:
Lens: A transparent medium bound by two surfaces, of which one or both surfaces are spherical, forms a lens:
Convex lens: A lens having two spherical surfaces, bulging outwards is called a double convex lens or convex lens.

- It is thicker at the middle as compared to the edges.
- Convex lens converges light.
  Hence, convex lens are called converging lens.

Concave lens: A double concave lens is bounded by two spherical surfaces curved inwards.

- It is thicker at edges than in the middle.
- Concave lens is diverging in nature.

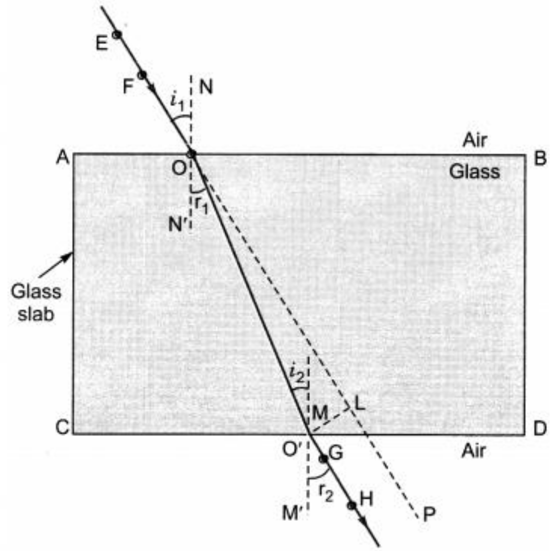
5. Write the laws of refraction. Explain the same with the help of ray diagram, when a ray of light passes through a rectangular glass slab. (NCERT Exemplar)
Answer:
Laws of refraction:

- The incident ray, the refracted ray and the normal at the point of incidence, all lie in the same plane.
- The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given colour and for the given pair of media. This law is also known as Snell's law of refraction.

If i is the angle of incidence and r is angle of refraction.
$\sin i / \sin r = \text{constant}$

Refraction through glass slab:

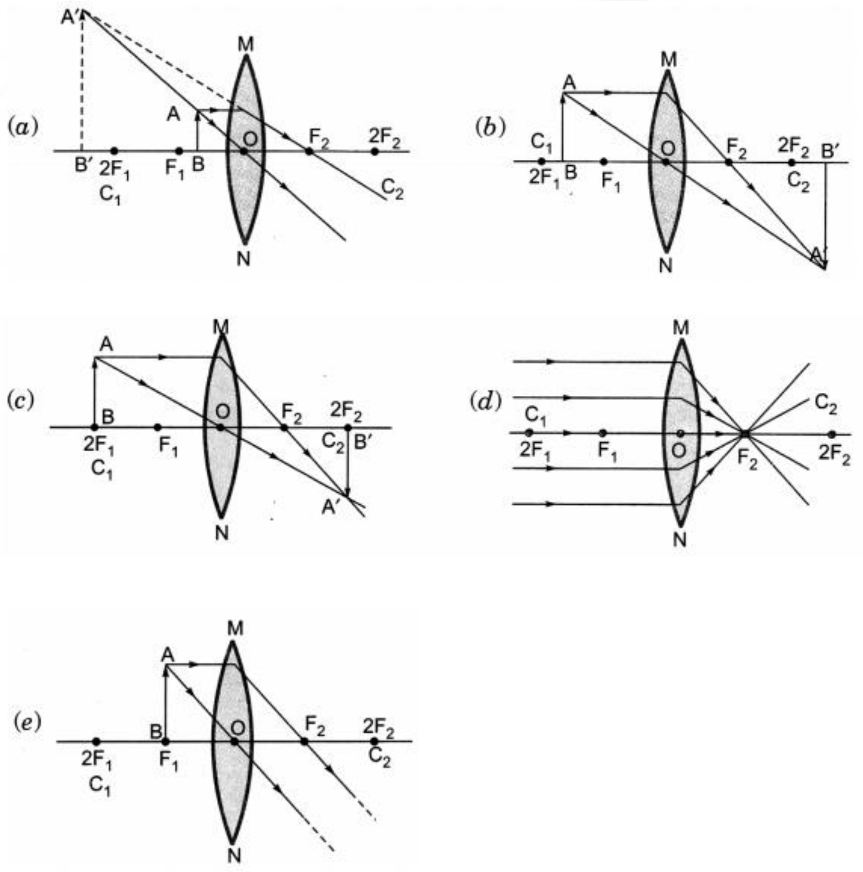
- The ray of light enters from rarer to denser medium at point O that is from air to glass and bends towards the normal.
- At 'O', the light ray enters from glass to air, that is, from a denser medium to a rarer medium. The light here bends away from normal.
- The emergent ray is parallel to the incident ray. However the light ray shifts slightly sideward.
- Refraction is due to change in speed of light when it enters from one medium to another.



6. Draw ray diagrams showing the image formation by a convex lens when an object is placed
(a) between optical centre and focus of the lens
(b) between focus and twice the focal length of the lens
(c) at twice the focal length of the lens
(d) at infinity
(e) at the focus of the lens
Answer:
Nature, position and relative size of the image formed by a convex lens for various positions of the object

Position of the object	Position of the image	Relative size of the image	Nature of the image

(a) Between optical centre O and focus F_1	On the same side of the lens as the object	Enlarged	Virtual and erect
(b) Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
(c) At $2F_1$	At $2F_2$	Same size	Real and inverted
(d) At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted
(e) At focus F_1	At infinity	Infinitely large or highly enlarged	Real and inverted



7. A spherical mirror produces an image of magnification -1 on a screen placed at a distance of 50 cm from the mirror.
(a) Write the type of mirror.
(b) Find the distance of the image from the object.
(c) What is the focal length of the mirror? (CBSE 2014)
Answer:
(a) Concave mirror
(b) m = -1, u = -50 cm,

$$m = \frac{h'}{h} = \frac{-v}{u} \qquad \Rightarrow -1 = \frac{-v}{-50}$$

∴ v = -50 cm

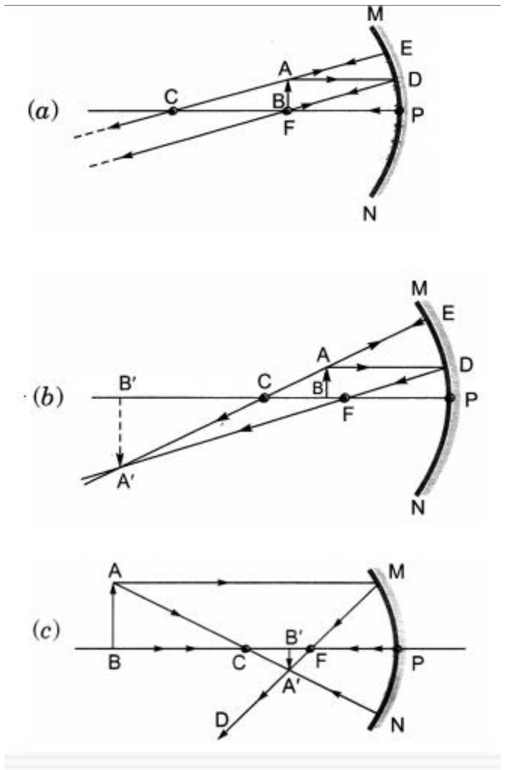
(c)

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{-50}-\frac{1}{50}=\frac{1}{f}$$

∴ f = -25 cm

8. Draw ray diagram for the image formation by a concave mirror.

Answer:



9. The refractive indices of water and glass with respect to air are 4/3 and 3/2 respectively. If the speed of light in glass is 2×10^8 ms^{-1}, find the speed of light in (i) air, (ii) water.
Answer:
(i) Let v_1 = speed of light in air,
v_2 = speed of light in glass,
then, n2n1 = refractive index of glass with respect to air = 32
v1v2=n2n1 , $v_2 = 2 \times 10^8$ m/s
n1n2 = 23
$v_1 = 32 \times 2 \times 10^8$ m/s $= 3 \times 10^8$ m/s
(ii) Let = speed of light in water,
v_2 = speed of light in air,
then n2n1 = refractive index of water with respect to air
v1v2=n2n1 Here, $u_2 = 3 \times 10^8$ m/s
= n1n2 = 43
$v_1 = 34 \times 3 \times 10^8 = 1.5 \times 10^8$ m/s.

10. The image of a candle flame formed by a lens is obtained on a screen placed on the other side of the lens. If the image is three times the size of the flame and the distance between lens and image is 80 cm, at what distance should the candle be placed from the lens? What is the nature of the image at a distance of 80 cm and the lens?
Answer:
m = vu = – 3, v = +80 cm[m is negative since image is real (obtained on a screen)]
vu = -3

$$\Rightarrow \quad u = \frac{v}{-3} = \frac{-80}{3} \text{ cm}$$

Image is real (obtained on screen), inverted and enlarged. The lens is convex.