

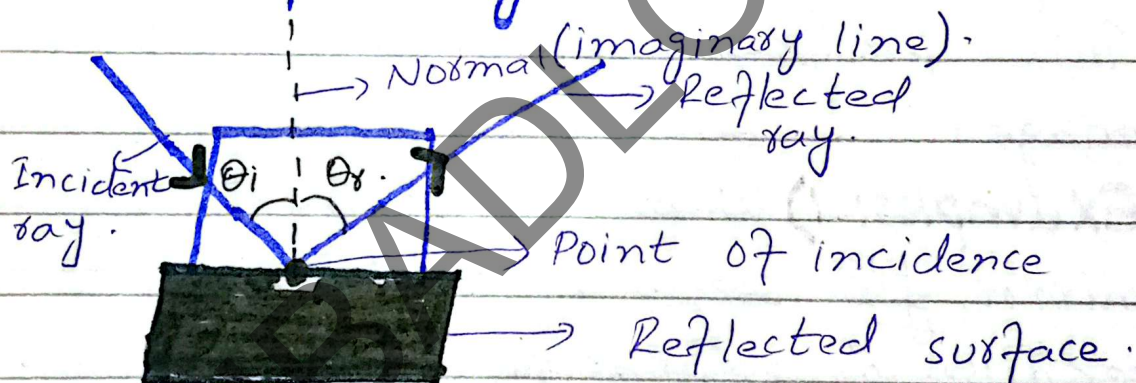
Unit: 14

Optics.

Reflection of Light:

When a ray of light approaches a smooth polished surface and bounces back. It is called reflection of light.

Visual diagram for reflection of light.



Laws of reflection:

- 1) The incident ray, the reflected ray and the normal all lie in the same plane.
- 2) The angle of incidence θ_i and the angle of reflection θ_r are equal. This can be mathematically

as:

$$\theta_i = \theta_r$$

The visual diagram as shown above completely describes ^{two} laws of reflection.

Types of reflection.

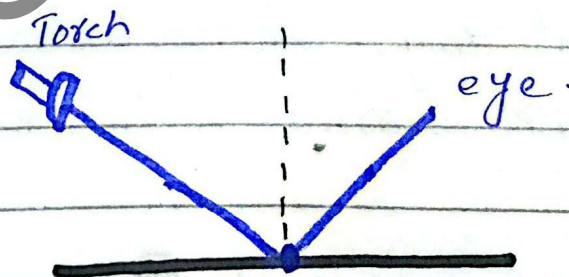
(a) Regular / Specular reflection:

Regular reflection occurs when light rays hit a smooth and polished surface and reflect in single direction.

- This produces a clear and sharp image.

Examples: 1) When we look in a mirror, ^{we} ~~you~~ see a clear image because of regular reflection.

2) A still pond or lake reflect trees or mountains clearly.



The reflection is clear

(b) Diffused reflection:

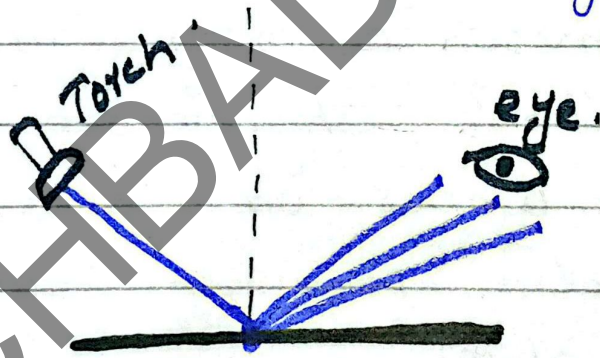
Diffused reflection.

occurs on rough surface where reflected rays scatter in many direction.

The image is unclear and scattered.

Example: 1) In wall, we can see light on a wall but not a clear image because of the scattering of reflecting rays.

2) In paper, light reflects, making it visible but no image is formed.



The image is unclear.

Additional Questions.

Q. Why can't you see a clear image on a rough wall?

Ans. It is because of phenomena of diffused reflection.

Q Why does a mirror form a clear image but paper does not, even though both reflect light?

Ans. Mirror form a clear image because of regular reflection while paper reflect light but we can only see paper because of Diffused reflection.

Q. Why do we see our face in water only when the water surface is calm?

Ans. It is because water surface will be smooth allowing regular reflection. That's why, we see ourself in water when it is calm.

Q. Can reflection occurs in transparent objects like glass?

Ans. Yes, reflection can occur in transparent object. Wearing sunglasses helps to reflect light that's why we are able to see objects.

Refraction of light

Light changes its path when enters from one medium to another. It is called refraction of light.

Example: 1) A pencil in a glass of water looks bent or broken.

2) Lenses in glass or camera work by refracting light.

• Refraction of light from rare to denser medium:

When a ray of light travel from rare to denser medium;

- It slows down means It's speed slows down.

- It bends towards normal.

• Refraction of light from denser to rare medium:

When a ray of light travel from denser to rare medium:

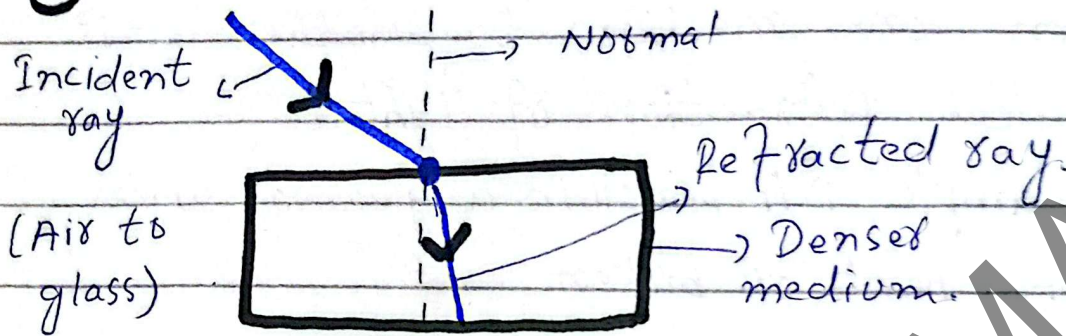
- It speeds up means It's speed increases.

- It bends away from normal.

Visual representation of refraction:

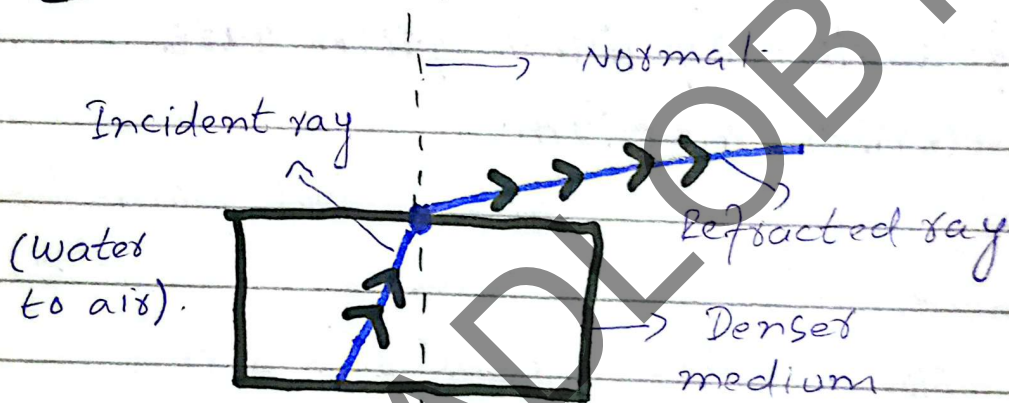
(1)

Rare medium (Rare to denser)



(2)

(Denser to rare)



Speed of light in material media

The speed of light vary in different medium. In Denser medium, It is reduced because molecules are closely packed. While in rare medium, the speed of light increases because molecules are far apart. Water and air are main example to differentiate between speed

of light in different media.

Additional Questions:

Q. Why does a pencil appear bent when placed in a glass of water?

Q. Why does refraction not occur when light enters a medium perpendicularly?

Ans. When it enters perpendicularly its speed changes but angle of incidence is 0° so it continues without any bending.

Refractive index

Define refractive index in terms of speed of media.

The measure of bending of a light ray when passing from one medium to another is called refractive index. such that one medium is vacuum. It tells us how much speed slows down compared to speed of light in vacuum.

- Refractive index of any medium cannot be equal or less than unity.

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

Numerical:

What is speed of light in diamond, a material with a refractive index of 2.49, often found in jewelry?

Given:

Refractive index ' n ' = 2.49

Speed of light ' c ' = $3 \times 10^8 \text{ m/s}$.

Required:

speed of light in medium ' v ' = ?

Solution:

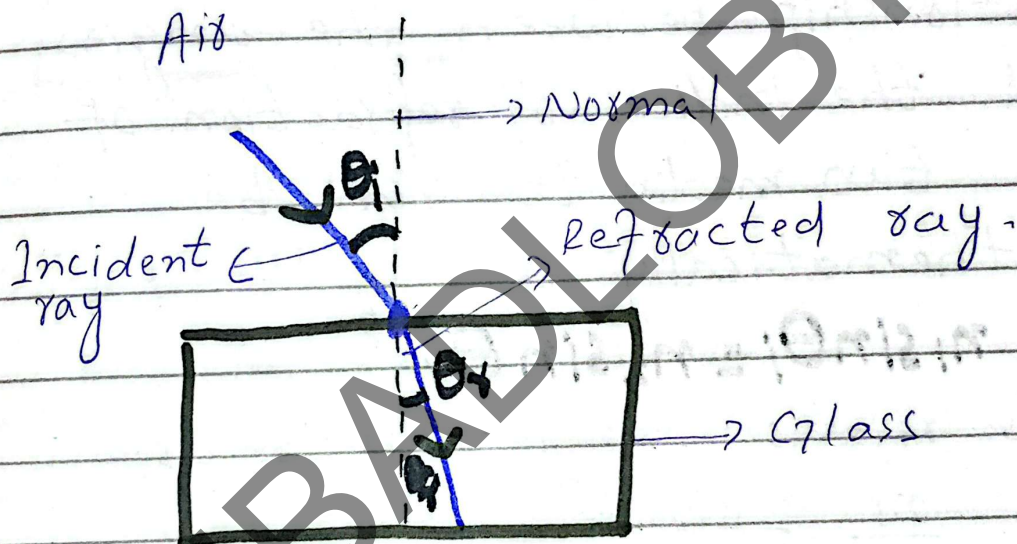
As, $n = \frac{c}{v}$ or $v = \frac{c}{n}$.

$$v = \frac{3 \times 10^8}{2.49} = 1.24 \times 10^8 \text{ m/s}.$$

The speed of light reduces to $1.2 \times 10^8 \text{ m/s}$. Ans.

Snell's Law

- Snell's law describes how light bends when passing from one medium to another.
- This law helps to understand the bending of light and refraction.
- It is used in Optics and vision.



The changing of direction of light ray depends both on incident angle and amount that speed changes. Larger speed results in larger ^{change in} angle of refraction. In the case of larger incident angle. The larger change in refracted angle.

The Snell's law can be given in two points i.e.

1) "The first law states that the incident ray of light, the normal and the refracted ray of light all lie in the same plane."

2) "The second law is about the relationship between the angles and the indices of refraction of the two media. It can be mathematically as:

$$n_1 \sin \theta_i = n_2 \sin \theta_r$$

This relation can be written as:

$$\frac{n_1}{n_2} = \frac{\sin \theta_r}{\sin \theta_i}$$

• If one of two media is vacuum and light enters from vacuum to some medium then $n_1 = 1$.

The relation reduces to:

$$\frac{1}{n_2} = \frac{\sin \theta_r}{\sin \theta_i} \quad \text{or} \quad \boxed{\frac{1}{n} = \frac{\sin \theta_r}{\sin \theta_i}}$$

Case : 02

If light enters from some medium to vacuum, then $n_2 = 1$ and relation will be:

$$\frac{n_1}{n_2} = \frac{\sin \theta_r}{\sin \theta_i} = \frac{n_1}{1} = \frac{\sin \theta_r}{\sin \theta_i}$$

$$n = \frac{\sin \theta_r}{\sin \theta_i}$$

For understanding:

$$\uparrow n_1 \sin \theta_i \downarrow = \downarrow n_2 \sin \theta_r \uparrow$$

It is inversely related between angles and refractive indices.

Additional Questions.

Q. What makes Diamond precious and shiny?

Ans. Diamond has higher refractive index, more bending of light. This results in shiny appearance and makes it precious.

Q. Why does light bent toward the normal in a denser medium instead

of just slowing down without changing direction?

Ans. It bends because its speed changes. Mostly, light ray speed slows down bending towards normal.

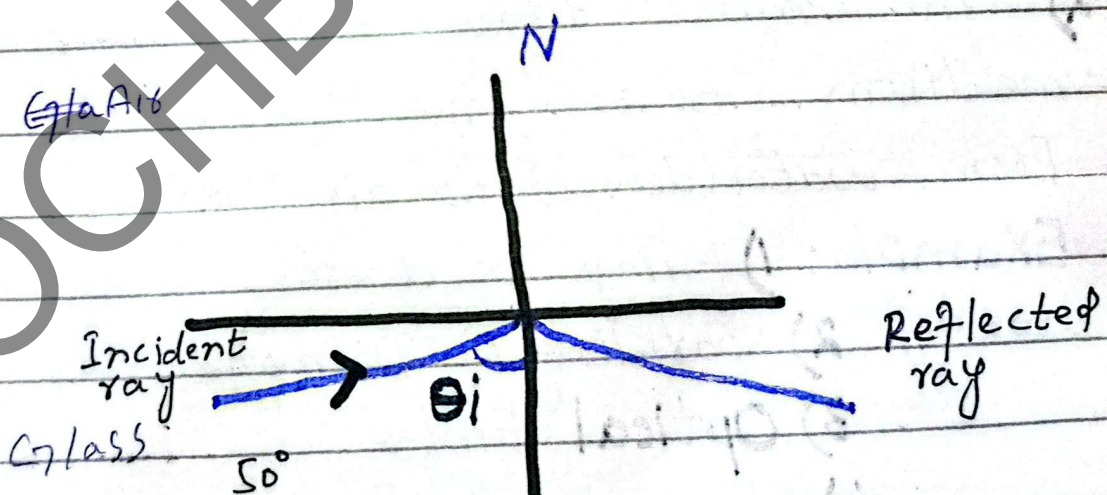
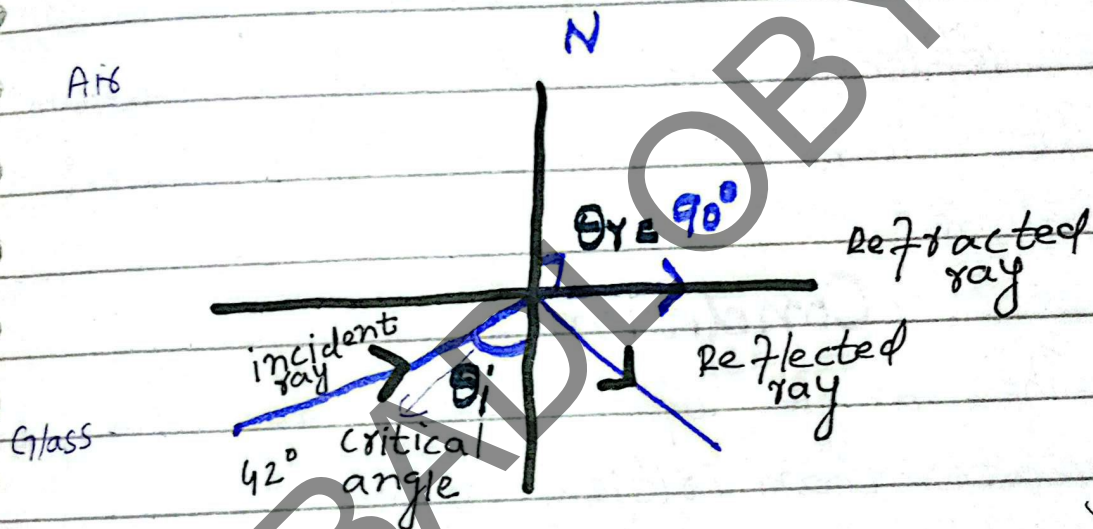
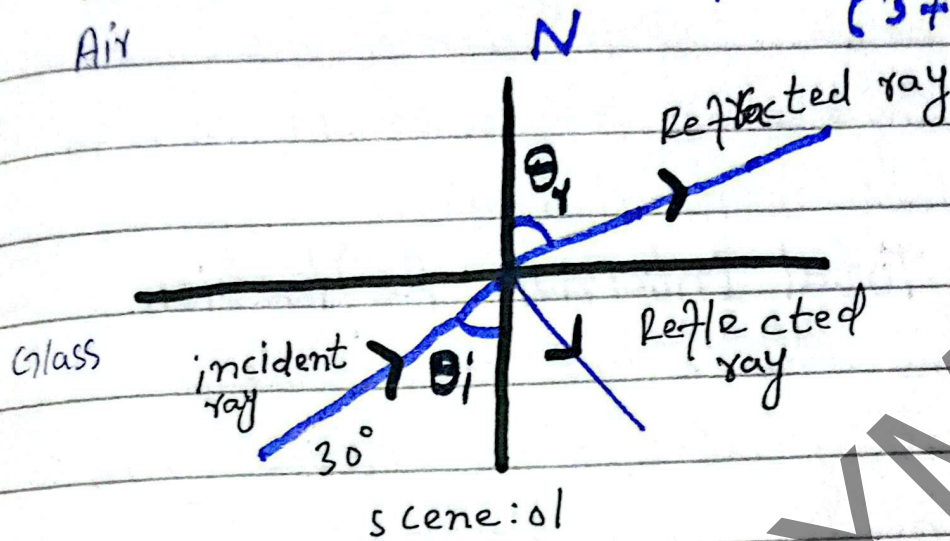
Q3. Can Snell's law be applied to sound waves or is it only for light?

Ans. It is generally for all types of waves. It can be applied in sound waves.

Q. How does the wavelength of light affect the amount it refracts in a medium?

Ans. Shorter wavelength bend more because refractive index of a material depends on wavelength.

Total Internal Reflection: PKM2 (3+ rule)



(Total Internal Reflection)

Critical angle

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

Total Internal Reflection

When the angle of incidence becomes greater than critical angle so, the incident ray instead of refracting it reflects back into same medium.

- It will be reflected back into denser medium.

Conditions

- 1) The angle of incidence must be greater than critical angle.
- 2) Light must travel from denser medium to rare medium.
From water (denser) to air (rare).

Example: 1) Mirage in deserts.

- 2) Sparkling of Diamond.
- 3) Optical Fibres
- 4) Shining of glass objects.

Points to note:

- 1) If $\theta_i < \theta_c \rightarrow$ Light refracts, partial reflection
- 2) If $\theta_i = \theta_c \rightarrow$ Light travels along normal making angle of 90°
- 3) If $\theta_i > \theta_c \rightarrow$ Total internal reflection, it completely reflects into denser medium.

Additional Questions:

- Q. Why does total internal reflection occur only when light travels from denser to a rarer medium?
- Q. Why do diamonds sparkle more than ordinary glass?
- Q. Can total internal reflection occur when light enters water from air?
- Q. Why is Total internal reflection considered more efficient than ordinary reflection?
- Q. What is critical angle and how is it related to TIR?
- Q. Write two conditions for TIR?

Derivation or

Relation between critical angle
and refraction:

Since from Snell's law

$$n_1 \sin \theta_i = n_2 \sin \theta_r$$

$$\therefore \theta_r = 90^\circ$$

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

$$n_1 \sin \theta_c = n_2 (1) \Rightarrow \sin \theta_c = \frac{n_2}{n_1}$$

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

For Air the refractive index
($n_2 = 1$).

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

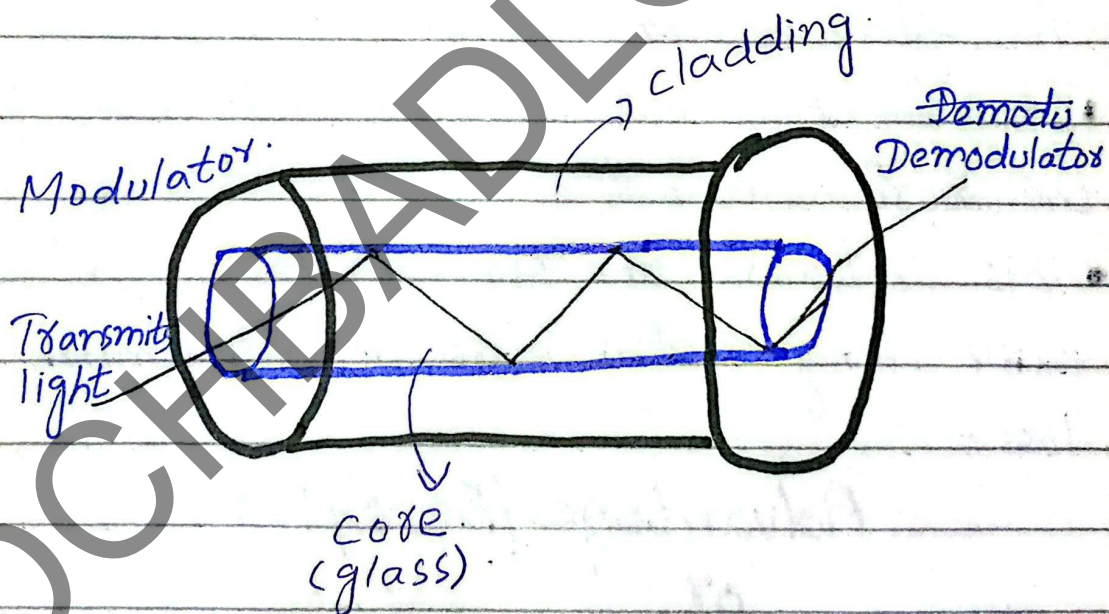
$$\sin \theta_c = \frac{1}{n_1}$$

$$\boxed{\sin \theta_c = \frac{1}{n}}$$

Optical Fibres

Optical fibre is the technology associated with data transmission using light pulses travelling along with a long fibre which is usually made of plastic or glass. The optical fibre use the application of Total Internal reflection of light.

Construction



It consists of two concentric tube one is core and other is cladding.

- 1) Core: The innermost part through which light travels

- It has higher refractive index.
- a) Cladding: It surrounds the core and has a lower refractive index ensuring light stays inside the core.
- 3) Protective coating/Jacket: Outer plastic layer that protects the fibre from damage.

Working

- The electrical signals convert into light by modulator. Light enters the fibre at one end.
- It reflects back and forth inside the core without escaping.
- This allows the signals to travel very long distance with minimum loss.

Advantages/Benefits or

Why optical fibre is better than copper wire for data transmission?

- 1) High Bandwidth: Optical fibre have high Bandwidth. It can transfer larger data

in bits per second.

2) Faster speed: They can transmit data at faster speed due to use of light pulses instead of electrical signals.

3) Resistance to electrical interference: As light is used. So, there is no electrical resistance as compared to copper wires.

4) Long Distance: It can transmit data over long distance.

5) Low power: They consume less power and its durability is much better than copper wire.

Additional Questions

Q. Why is cladding used in optical fibre?

Q. Why is core made with high refractive index.

Q. Why does light not escape when wire is bent?

Q. Why it is more secure for data transmission?

Thin lenses

The transparent objects that refract in a specific way to form images are called thin lenses.

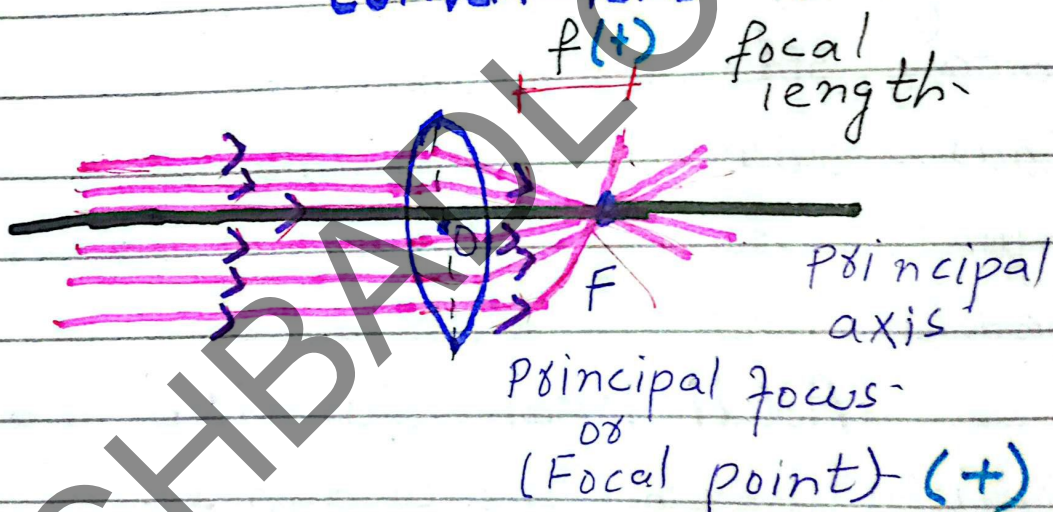
Types of lenses

Generally, there are two types of lenses.

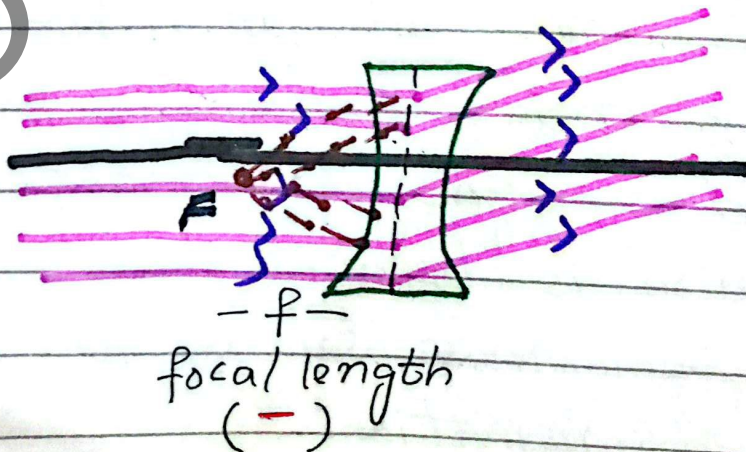
1) Convex lens.

2) Concave lens.

Convex lens (+).



Concave lens (-)



Definitions

Convex lens: A convex lens is a transparent optical device that is thicker at center and thinner at edges. It is converging lens because the light rays meet at one point.

Concave lens: A concave lens is a transparent lens that is thinner in the middle and thicker at edges. It is also called a diverging lens because it spreads out (diverges) parallel rays of light.

Terms related to lenses

1) **Principal axis:** Principal axis is an imaginary line passing through center of lens.

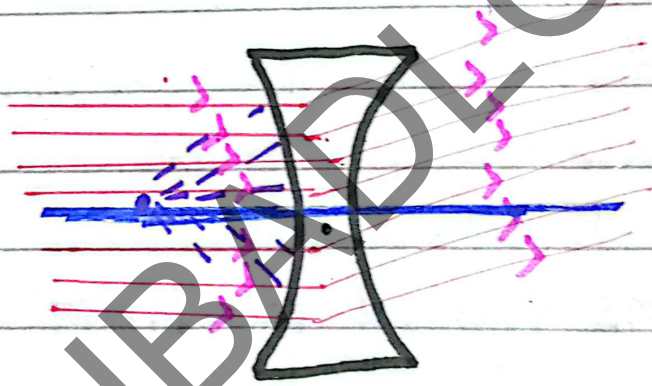
2) **Optical center:** The center of lens from which principal axis passes. It is represented by .

3) **Principal focus (focal point):** The principal focus is also called the focal

point where light rays converge from a converging lens and diverge from diverging lens.

4) Centre of curvature: As lenses are part of spherical materials then the center of sphere is called centre of curvature of lens.

Formation of Image on concave lens



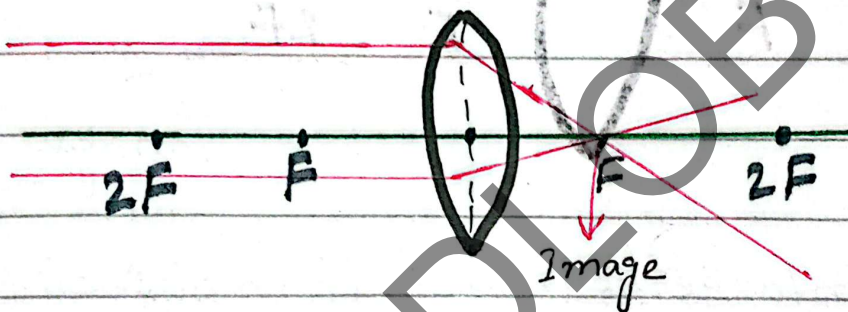
In concave, the image is formed at virtual focal point. This image will be virtual, upright and diminished.

Formation of Image on Convex lens.

"Six Cases of Image formation in convex lens"

Case : 1

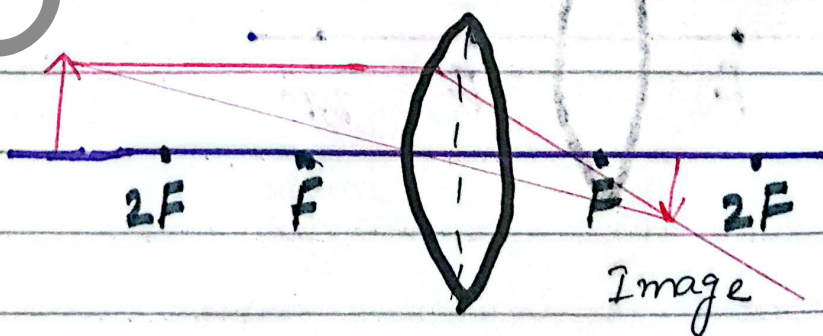
Object at Infinity



Size: Point sized image - highly diminished
Nature: Real & Inverted
Position: At the focus (F)

Case : 2

Object beyond $2F$



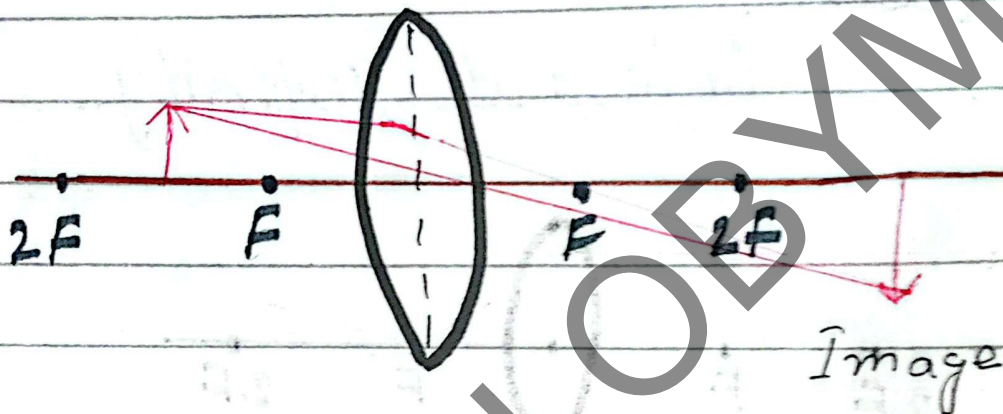
Size: Diminished

Nature: Real & inverted

Position: Between F and $2F$.

Case : 3

Object between F & $2F$



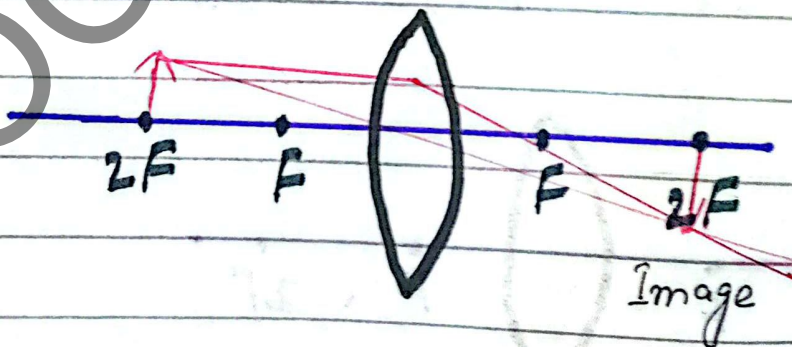
Size: Enlarged, larger than object

nature: Real & inverted

Position: Beyond $2F$.

Case : 4

Object at $2F$



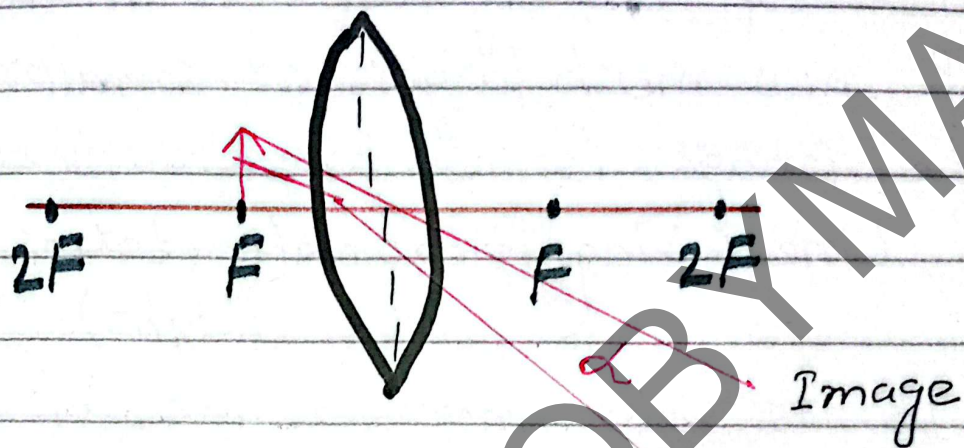
Size: same as object.

nature: Real & inverted

Position: At $2F$.

Case: 05

Object at F



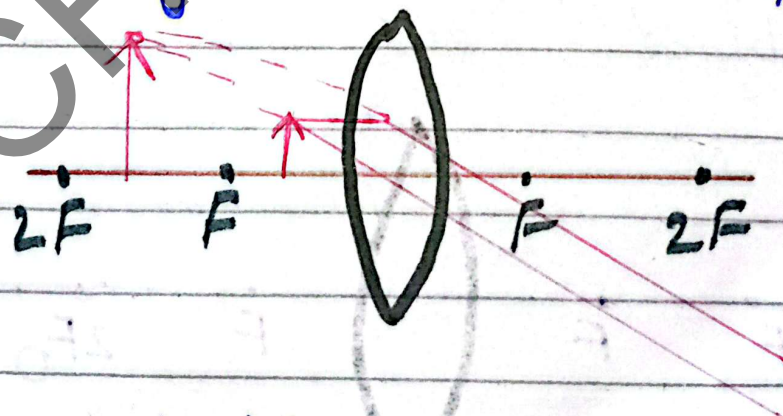
Size: Highly large.

Nature: Real & inverted.

Position: At infinity (∞)

Case: 06

Object between F & lens



Size: highly enlarged

Nature: Virtual & erect.

Position: Same side as the object.

Linear Magnification

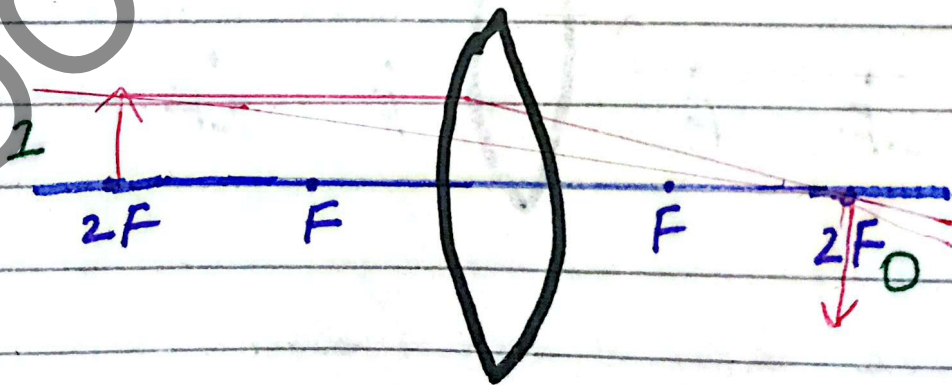
Linear Magnification refers to the ratio of size of an image to the size of the object. It is measure of how much larger or smaller the image is compared to the object.

Linear Magnification (in terms of height)

It is also known as lateral magnification or transverse magnification. It can be mathematically as;

$$\therefore M = \frac{I}{O}$$

Here M is magnification, I is height of image & O is height of object



Linear Magnification (in terms of distance from lens)

$$|M| > 0$$

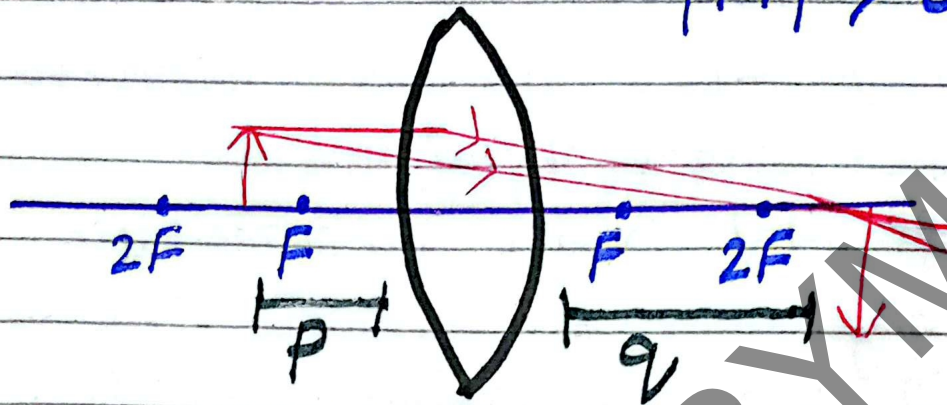
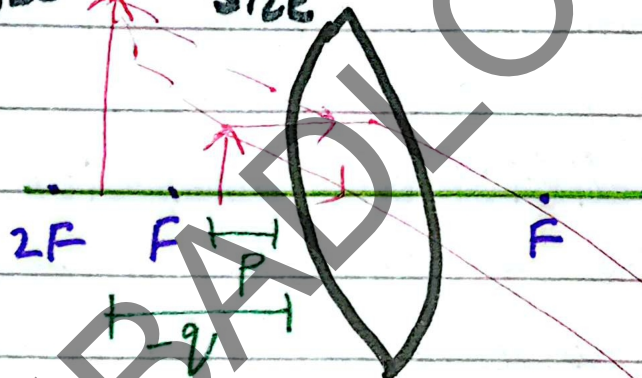


Image size
object size

$$|M| < 0$$



The linear magnification can be given as;

$$M = \frac{I}{O} = \frac{q}{p}$$

If the image is real, it will be $+q$, or. If the image is virtual, it will be $-q$.

Conditions

- 1) If $M > 1$: Image is magnified (larger than object).
- 2) If $M < 1$: Image is diminished (smaller than object).
- 3) If $M = 1$ Image is same size as object.
- 4) If $M > 0$ The image will be real and inverted.
- 5) If $M < 0$ The image will be virtual and erect.

Additional Questions

Q. What does a positive magnification indicate about orientation and nature of image.

Q. If Magnification of mirror is -2. What can we say about size and orientation of image.

Q. If the magnification is less than 1 but positive, what is the orientation and relative size of image?

Difference between real and virtual image

Real image

- It can be caught on screen.
- It is always inverted.
- It is formed when rays of light converge.
- It is formed by actual intersection of light rays.
- It is formed by only convex lens.

Example: Image on our TV screen.

Virtual image

- It cannot be caught on the screen.
- It is always erect.
- It is formed when rays of light diverge which appear to meet at some point.
- It is formed on concave lens, convex lens and plane mirrors also.

- It is formed by imaginary intersection of light rays.
Example: our reflection in mirror.

Application of lenses

Magnifying Glass

A magnifying glass is used to magnify objects. The lens is convex lens which is used. When the object is placed near the lens, it will produce an enlarged, virtual and erect image. Following steps should be taken to use a magnifying glass.

- 1) Position: Hold the glass close to object.
- 2) Distance: Move lens closer to or further from the object until image comes into clear focus.
- 3) Viewing: Look through the lens to see the magnified image.

Dispersion of light by Prism

A prism is an optical element which is usually made of glass with triangular or rectangular sides. The splitting of white light into seven constituent colours when passed through prism is called dispersion of light.

As light is a mixture of different colours often represented as VIBGYOR. When white light enters the prism, it bends because of change in medium (air $\rightarrow$ glass).

This results in shorter wavelength such as violet and blue bend more than longer wavelength like red and orange. As a result, the light exits the prism split into seven distinct colours.

The collection of colours is known as visible light spectrum.

Beyond visible spectrum, there are wavelength of light that human eye cannot perceive. such as infrared and ultraviolet. These wavelength can be dispersed but they are invisible. One such method involves thermometers equipped with sensors that can detect broad range of wavelength. When light disperse through prism, they can detect both infrared and visible light. These thermometers can also detect the radiations emitted by human body.

Visible spectrum

The collection of seven colours which are visible to human eye or can be perceived by human eye is called visible spectrum. It is generally known as VIBGYOR.

Order of wavelength:

Red > Orange > Yellow > Green > Blue > Indigo > violet

Order of frequency:

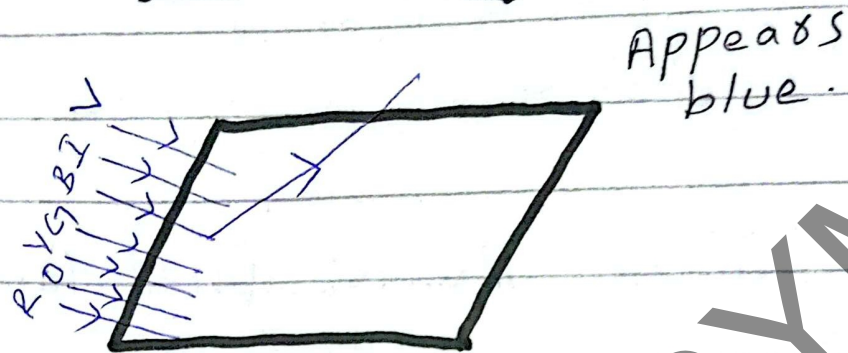
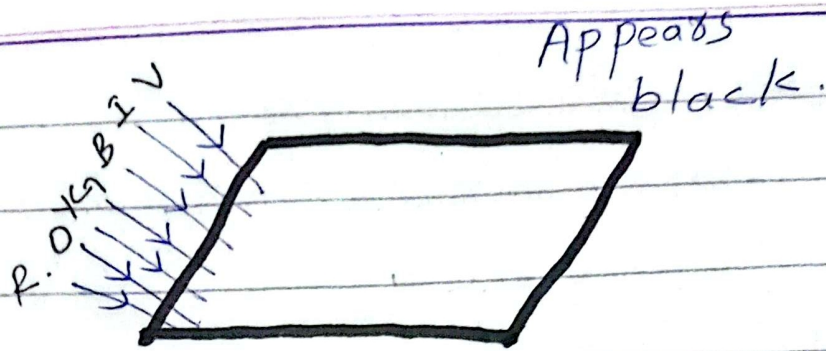
violet > indigo > Blue > Green > Yellow > Orange > Red

SLO's Based Question

Q. Why some surface appear black, while some coloured. Briefly explain in context of visible spectrum?

Black surface: They appear black because they absorb almost all wavelength and reflect none. As All wavelength absorbs, it seems black.

Coloured surfaces: They appear colored because they reflect only certain wavelengths of visible spectrum (e.g. red reflects red wavelength, blue reflects blue wavelength) and absorb others.

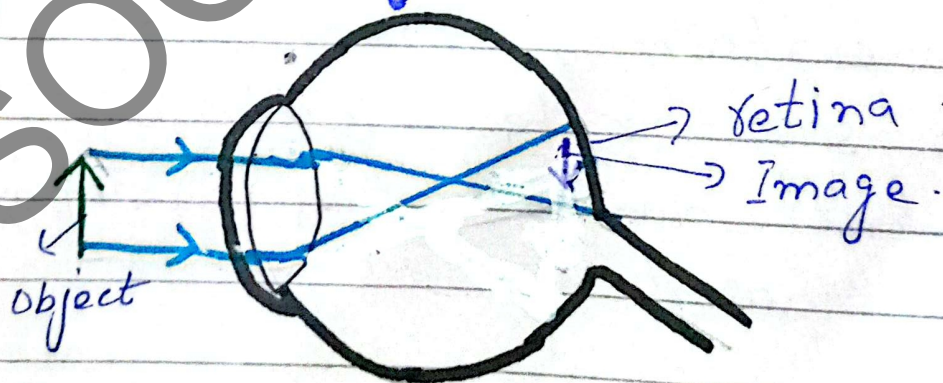


Points to note:

The visible spectrum range is between 380nm to 780nm.

Moreover red, has highest wavelength and smallest frequency. Whereas. Violet has lower wavelength and highest frequency.

Formation of image on normal eye



The image for a normal eye is made on retina. i.e all rays converge and makes the clear image of object on retina.

Short sightedness (myopia)

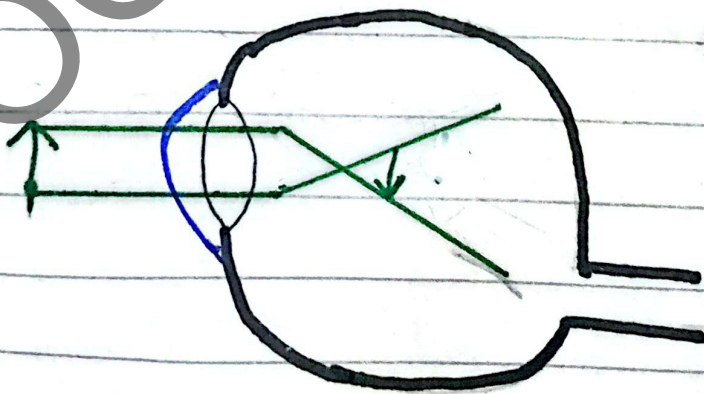
Definition: Short-sightedness also known as myopia is condition in which a person can see near objects clearly but cannot see distant objects clearly. The distant object seems blurry. This condition usually occurs in early ages or adults.

Reason: The parallel rays coming from the distant object

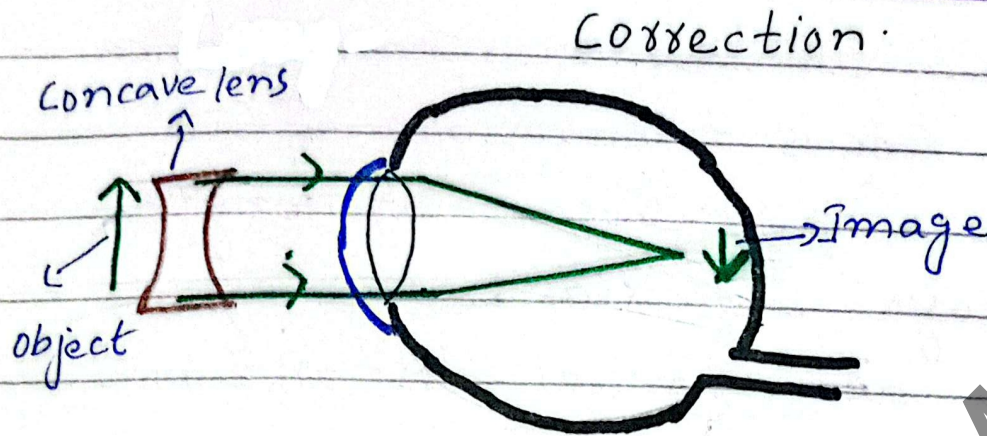
due to which they cross in front of retina and image is formed in front of retina. The other reasons for short-sightedness are if the eye-lens becomes thick it converges more and focus the image before retina. The other is

If length of eye increases, the eye lens focus at normal distance but retina is moved backward and image is not formed on retina.

Correction: This defect can be corrected by using concave lens. With the help of concave lens, they diverge and image is formed on retina.



myopia



Long Sightedness (Hyperopia)

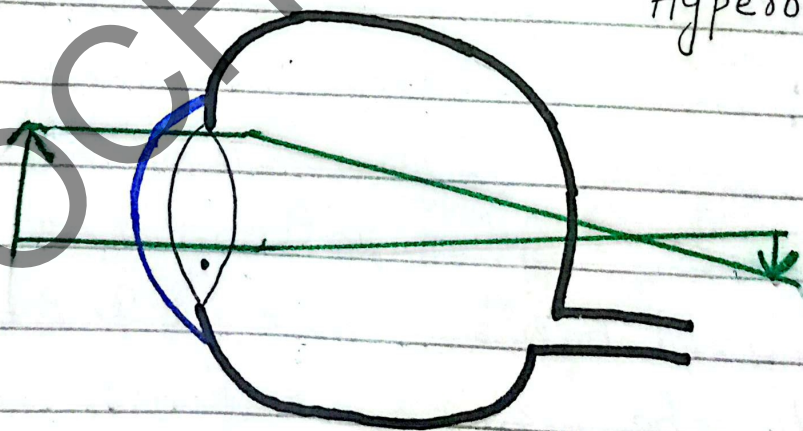
Definition: Long sightedness also known as Hyperopia in which a person can see distant objects clearly but near object seems blurry. Hyperopia is also known as hypermetropia. This condition usually occurs in elderly ages.

Reason: The rays coming from nearer objects due to which they cross after passing the retina and hence image is formed behind the retina. The other reasons for long sightedness are if eye lens becomes thin so

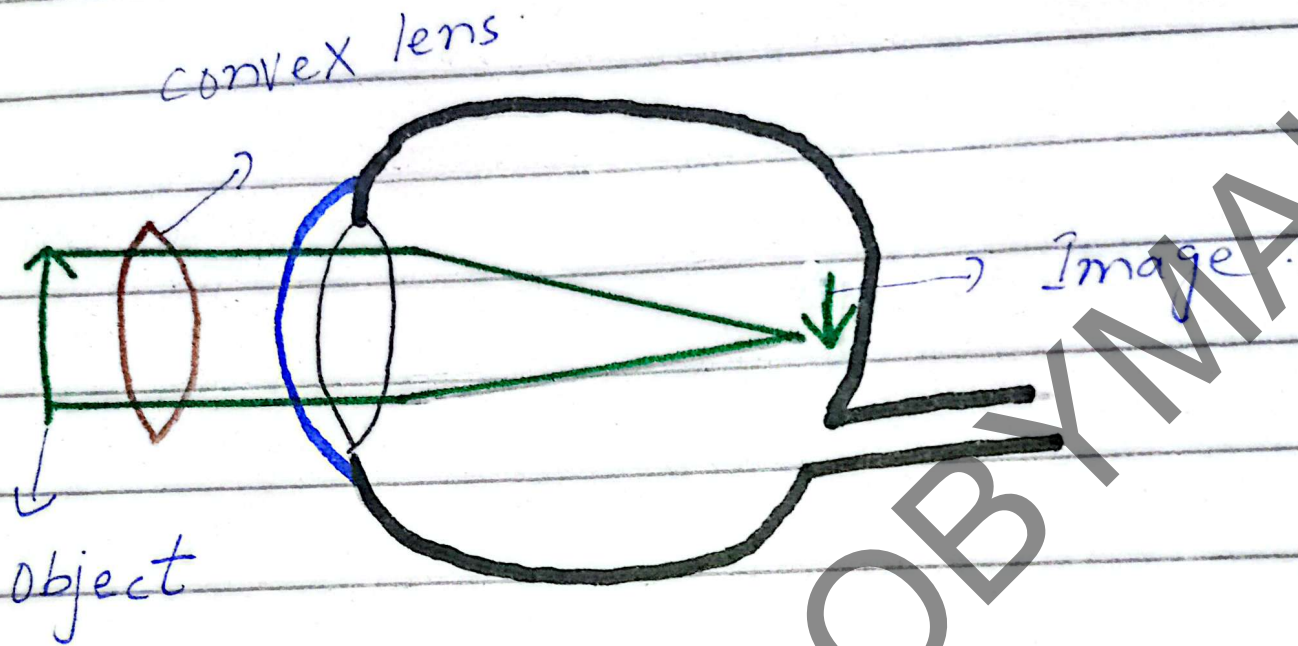
there will be less convergence and focus the image after retina. The other is if length of eye decreases, the eye focus at normal distance but due to short eye, retina is moved forward and image does not form on retina.

Correction: This defect can be corrected by using convex lens. With the help of convex lens, they converge and image is formed on retina.

Hypertopia.



Correction.



The End