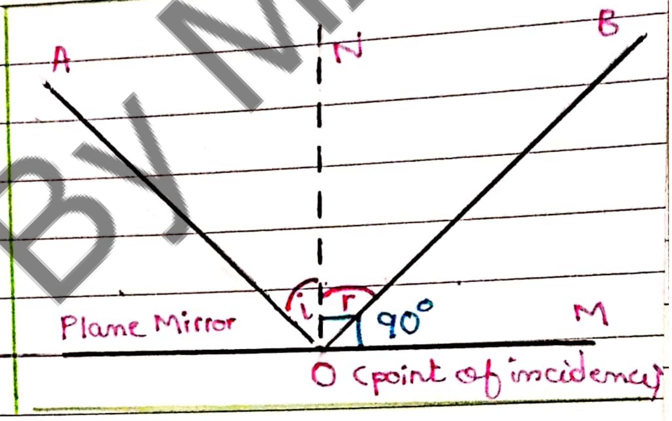
Chapter ~(12)~

Geometrical Optics

Reflection of light

Statement: When light travelling in a certain medium falls or strikes on the surface of other medium, a part of it (light) hits back on the same medium is called "reflection of light".



Explanation:

$\bar{O}$ = Point of incidence

$\overrightarrow{AO}$ = incident ray

$\overrightarrow{OB}$ = reflected ray.

$\overline{ON}$ = normal

$\angle AON$ = angle of incidence

$\angle NOB$ = angle of reflection.

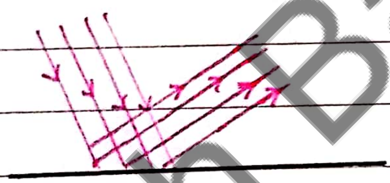
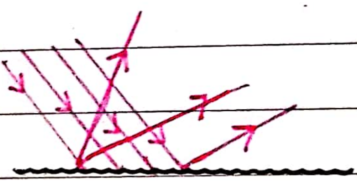
Consider a light ray $\overrightarrow{AO}$ is coming from air and strikes the glass and then the light ray will reflect back $\overrightarrow{OB}$

Laws of Reflection

- The $\overrightarrow{AO}$, $\overrightarrow{OB}$ and N at O all lie in same plane.
- The angle of incidence is equal to the angle of reflection

$\angle i = \angle r$

TYPES OF REFLECTION

Regular	Irregular
* It occurs on smooth surface like mirror	* It take place on rough surface like wood.
* Incident rays are parellel and after reflection, the reflected rays remain parellel.	* Incident rays are parellel but after reflection, the reflected rays does not remain parellel.
* Intensity of light will remain bright.	* Intensity of light will remain dull.
* The reflected rays are reflected in one direction	* The reflected rays are reflected in many directions.
	

Spherical Mirrors

Definition:–

"The mirror whose polished, reflecting surface is a part of hollow sphere of glass or plastic is called spherical mirror."

→ One of the 2 curved surfaces is coated with a thin layer of silver followed by a coating of red lead oxide paint.

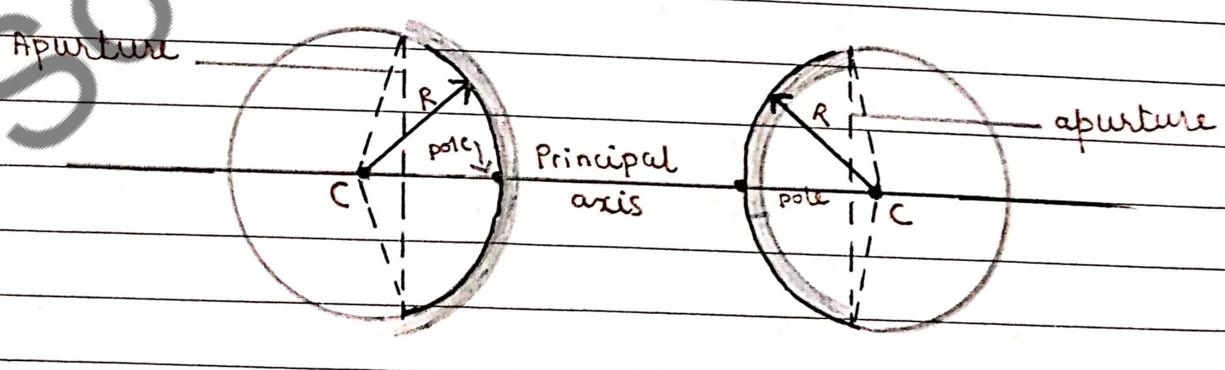
→ One side of spherical mirror is opaque.

→ other side is a highly polished reflecting surface.

Types of Spherical Mirrors

There are 2 types of spherical mirrors:

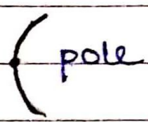
1. Concave Mirror
2. Convex mirror



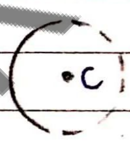
Concave Mirror   Convex Mirror

Important Terminologies

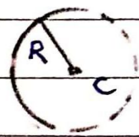
Pole: It is the mid point of curved surface of spherical mirror.



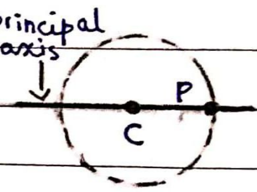
Centre of Curvature (C): It is center of the sphere where the spherical mirror is the part of that sphere.

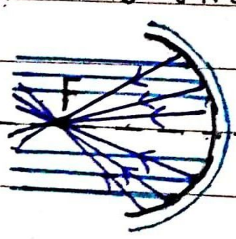
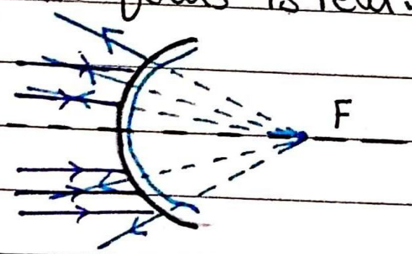


Radius of Curvature (R): The distance b/w the 'C' and the boundry of the mirror is called 'R'.

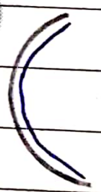
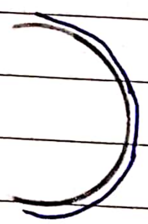


Principal Axis: A line which joins the 'C' and pole is called principal axis.

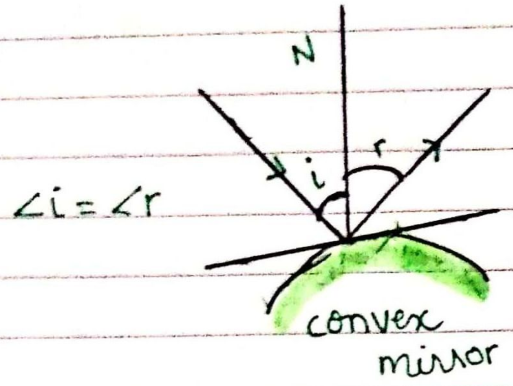


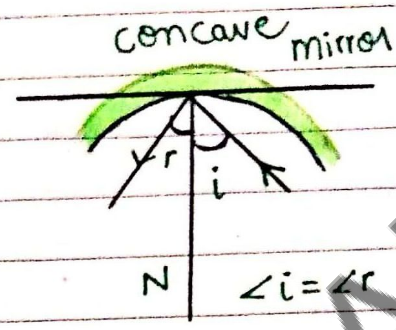
Principal Focus of Convex Mirror (F)	Principal Focus of concave Mirror (F)
* It is a point where light rays diverge after reflection	* It is a point where light rays converge after reflection
* The Focus lies behind the mirror.	* The focus lies infront the mirror.
* The focus is virtual 	* The focus is real. 

Focal length of Convex Mirror (f)	Focal length of concave mirror (f)
* Distance b/w pole and the Focus is called focal length	* Distance b/w pole and the Focus is called focal length
* Its 'f' is taken as virtual	* Its 'f' is taken as real
* Its 'f' is +ive	* Its 'f' is -ive

Convex Mirror	Concave Mirror
* Its outer curved surface is reflecting.	* Its inner curved surface is reflecting.
* The size of image is always smaller than the object.	* The size of image depends on the position of object.
* virtual and erect image is formed.	* Virtual and real images can be formed.
	

Reflection of Light by Spherical Mirrors





Tangent is such a line which touch the circle only at one point.

Laws of Reflection:-

(i) The incident, the reflected ray and the Normal all lie in same plane.

(ii) $\angle i = \angle r$.

- convex image will be erect.
- concave image will erect at some point and it will get inverse at some point.

Relation b/w 'f' and 'R'

→ focal length 'f' is equal to half of radius of curvature.

$$f = \frac{2}{R}$$

→ This means that as the 'R' is reduced, so too is the 'f' of the reflecting surface.

Image Location by Spherical Mirror Formula

Definition

Mirror formula is the relationship b/w object distance, image distance from mirror and focal length of mirror.

It can be written as: $\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$

p = Position of object of mirror
q = Position of image of mirror
f = focal length

Sign Conventions

Quantity	Concave	Convex
f	+	−
p	+ (Real)	+
q	+	−
	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$ (Real)	$-\frac{1}{f} = \frac{1}{p} - \frac{1}{q}$
	$\frac{1}{f} = \frac{1}{p} - \frac{1}{q}$ (virtual)	

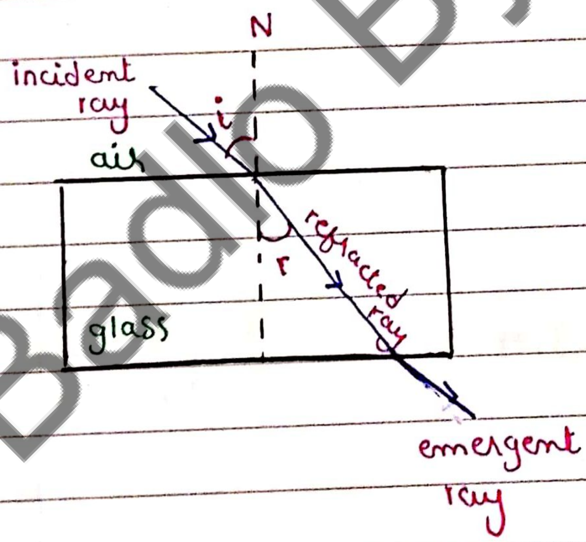
Refraction of Light

Definition

The bending of light as it passes from one transparent medium to another is called refraction.

Explanation

Consider a light ray coming from rare medium to denser medium. When the incident ray will move from rare medium to denser medium, the refracted ray will bend toward the normal.



Laws of Refraction

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

- $\angle i > \angle r$ (when light move from rare medium to denser medium)
- $\angle i < \angle r$ (when light move from denser medium to rare medium)

2. The ratio of the sine of angle of incidence 'i' to the sine of angle of refraction is equal to certain constant. That constant is known as 'refractive index'. It is represented by 'n'

$$\frac{\sin i}{\sin r} = n$$ → It is called "Snell's Law"

Speed of Light in a medium

- Speed of light in air = 3.0×10^8 m/s
- Speed of light in water = 2.3×10^8 m/s
- Speed of light in glass = 2.0×10^8 m/s

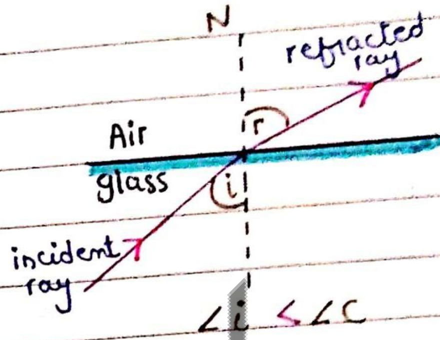
Refractive Index

→ It is the ratio of speed of light in air to the speed of light in medium

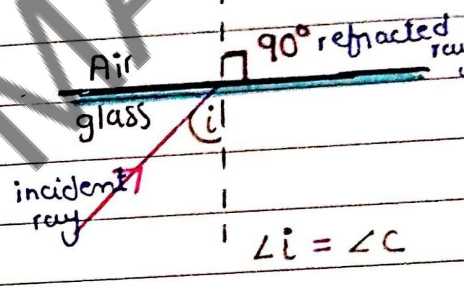
$$n = \frac{C_{air}}{V_{medium}}$$

Total Internal Reflection

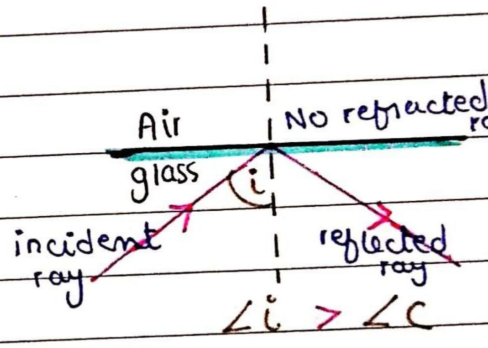
Consider a light ray coming from denser medium to rare medium and the $\angle i < \angle c$ it will refract and bends away from the Normal.



The light ray coming from denser medium when the $\angle i = \angle c$ the light ray will refract and becomes parallel to the boundary of glass and the angle of refraction becomes 90°



When the light ray coming from denser medium and the $\angle i > \angle c$ then the light ray reflecte into the same medium. That is known as "total internal reflection"

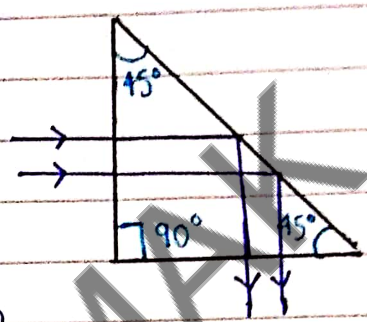


critical angle $\angle c$ is such an incident angle $\angle i$ in which the angle of refraction is 90°

Applications of Total Internal Reflection

Totally Internal Reflecting Prism

When the light ray strikes the face of prism perpendicularly it will pass straight with deviation and strikes the hypotenuse at angle of 45°. As the angle of incidence is greater than critical angle of glass which is 42° so the light is totally internally reflected by the prism through an angle of 90°

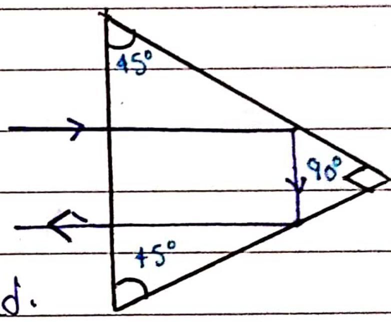


Use

Two such prisms are used in periscope.

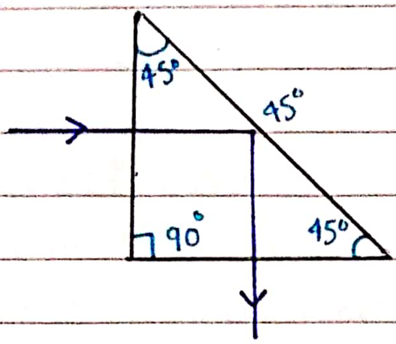
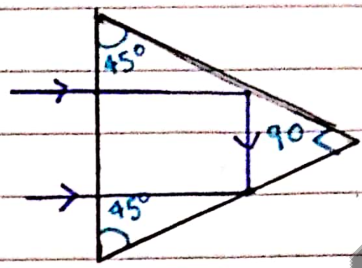
Reflection at 180°

The light ray strikes the face of prism perpendicularly and enters into the prism straight without bending at ~~an~~ an angle of 45° which is greater than the critical angle of glass which is 42° and become totally internally reflected. Again it will strike the hypotenuse with 45° and gets totally internally reflected. The totally reflected ray with 90° and comes out of the prism without any deviation. Thus we get total reflection of light by the prism through an angle of 180°.



Use

Two such prisms are used in binoculars.

	
* light ray are falling on the perpendicular of Total Internal Reflection	* light rays are falling on the hypotenuse of Total Internal Reflection
* Total Internal Reflection takes place only once	* Total Internal Reflection takes place twice.
* Inversion of image takes place at 90°	* Inversion of image takes place at 180°
* It is used in periscope	* It is used in binoculars

Optical Fibre

- Optical fibre consists of hair size threads of glass or plastic through which light can travel.

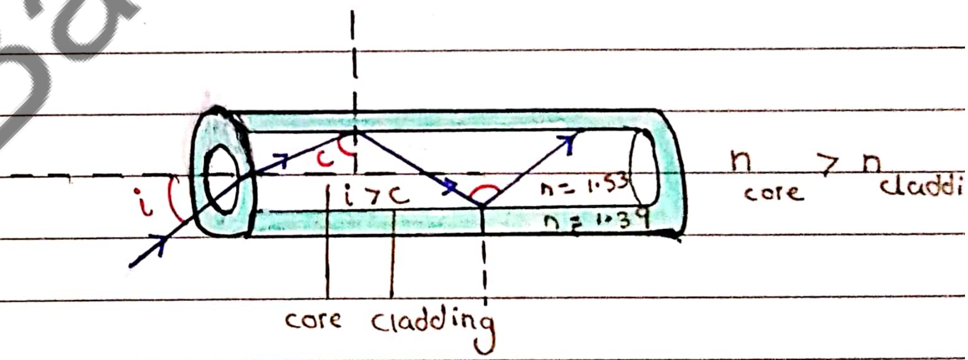
Construction

1. The inner part is called core and it is made of glass or plastic of high refractive index. It carries the light.

2. The outer concentric shell is called cladding and it is also made of glass or plastic of low refractive index.

Working

The light move through optical fibre by total internal reflection. Light enters from one end of the core strikes the core cladding boundary at and angle of incidence greater than the critical angle and is reflected back into the core.



Advantages

- light travels many Kilometers with small loss of energy.
- we can listen thousands of phone calls without any disturban

Use

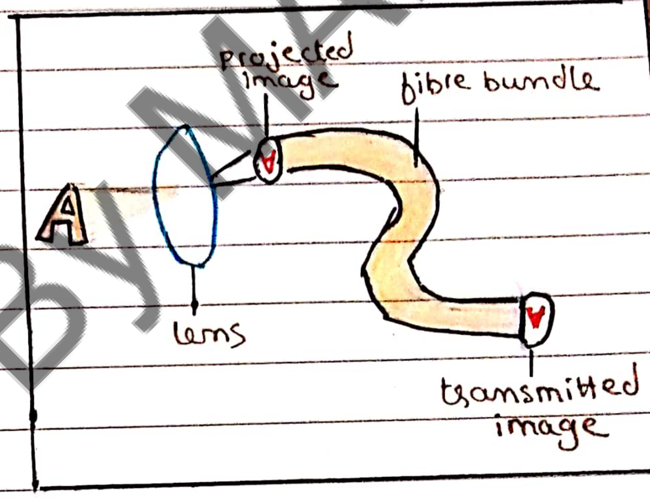
It is used in telephone and advanced telecommunication systems.

Light Pipe

Light pipe is a bundle of thousands of optical fibres bounded together.

Uses

- They are used to illuminate the inaccessible places
- They are used to transmit images from one place to another.



Endoscope

Uses

→ It is a medical instrument used for exploratary diagnostics and surgical purposes.

→ It is used to explore the interior organs of body.

Types

- Gastroscope —— stomach
- Cystoscope —— bladder
- Bronchoscope —— throat

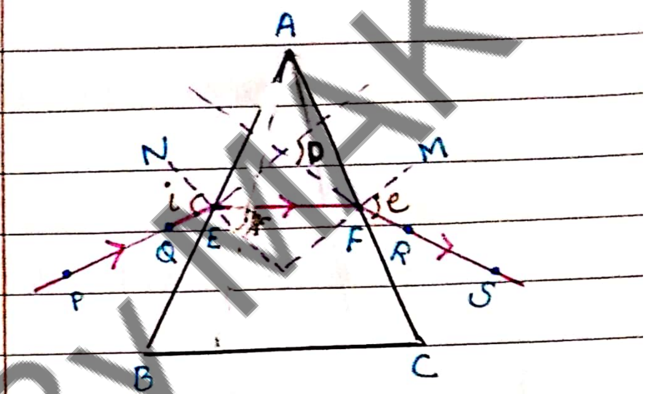
Working

* A medical endoscope uses 2 fibre optic tubes through a pipe.
* A medical procedure using any type of endoscope is called endoscopy.
* The light shines on the organ of patient.
* light is transmitted back to the physician's viewing lens through the other fibre tube by total internal reflection.
* Flexible endoscopes have a tiny camera attached to the end.
* Doctor can see the view recorded by the camera on a computer screen.

Refraction through Prism

Prism is a transparent object made of glass. two smooth plane faces inclined toward each and light is refracted.

Explanation



In case of triangular prism, when light rays enters it will refract.

PQ = incident ray
EF = refracted ray
RS = emergent ray
$\angle D$ = angle of deviation

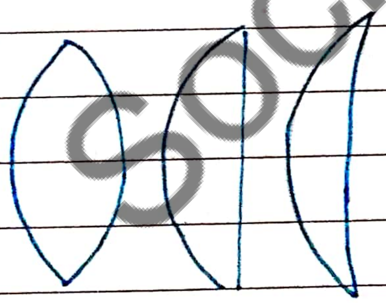
* PQ falls at E (point of incidence) that will refract as EF and becomes parallel to BC [EF ∥ BC]

* EF move out the glass as emergent ray RS
  $\angle e$ = emergent angle
  $\angle e$ b/w the emergent ray and the normal.
  emergent ray is not parallel to PQ

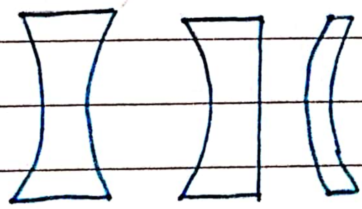
* The emergent ray deviated from incident ray by an angle that angle is known as angle of deviation.

Lens	Mirror
1. No surface is polished	1. One surface is polished
2. Light refract	2. Light reflect
3. light ray will pass through the lens	3. No light ray will pass through the mirror
4. real image is obtained on other side of lens.	4. real image will form at mirror
5. Virtual image will form on same side of object by the lens.	5. Virtual image will be formed behind the mirror
6. focal length of con-cave [illegible] is -ive	6. focal length of co-ncave mirror is +ive
7. focal length of convex lens is +ive	7. focal length of convex mirror is -ive

Convex Lens	Concave Lens
* It is thick at the centre and thin at the edges	* It is thin at the centre and thick at the edges.
* parallel rays after refraction converge.	* parallel rays after refraction diverge.
* Focal length is +ive	* Focal length is -ive
* It forms real and inverted image.	* It forms virtual and erect image.
* object appear closer and larger.	* object appear smaller and farther.
* It is used to correct Farsightedness	* It is used to correct short sightedness



Double convex   Plano convex   concavo convex



Double concave   Plano concave   convexo concave

Lens Terminology

Principal Axis Such a line which is passing through the optical centre is known as principal Axis.

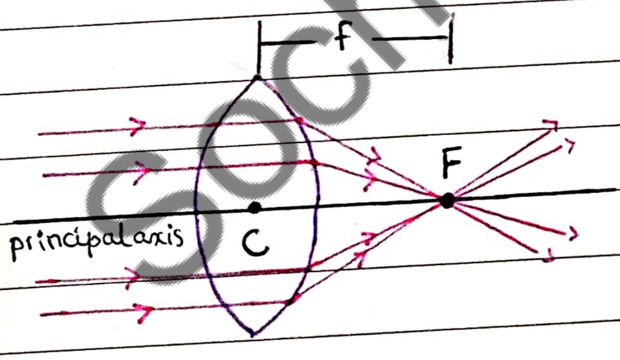
Optical Centre 'C' A point on the principal axis at the centre of lens is called optical centre.

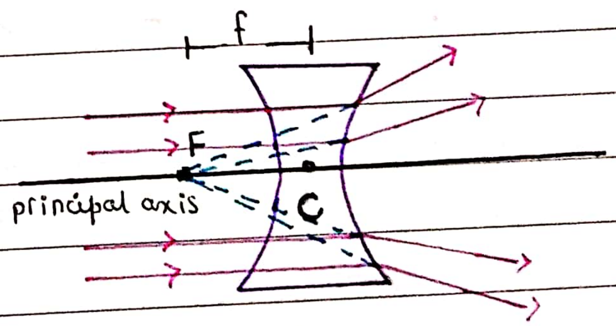
Focal Length 'f' The distance b/w optical centre and principal focus.

Principal Focus 'F'

Convex lens: The parallel rays of the light converge after refraction meet at a point on principal axis

Concave lens: The parallel rays of the light diverge after refraction from principal axis.





Power of a Lens

→ Power of the lens is the reciprocal of focal length

$$\text{Power} = \frac{1}{\text{focal Length}}$$

→ Mathematically can be Represented as

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

SI Unit

→ $P = \frac{1}{f}$

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

$P = m^{-1}$ = Diopter

Diopter is represented by 'D'

f of convex lens is +ive so the P is also +ive	f of concave lens is -ive so the P is also -ive

Image Formation by Lenses

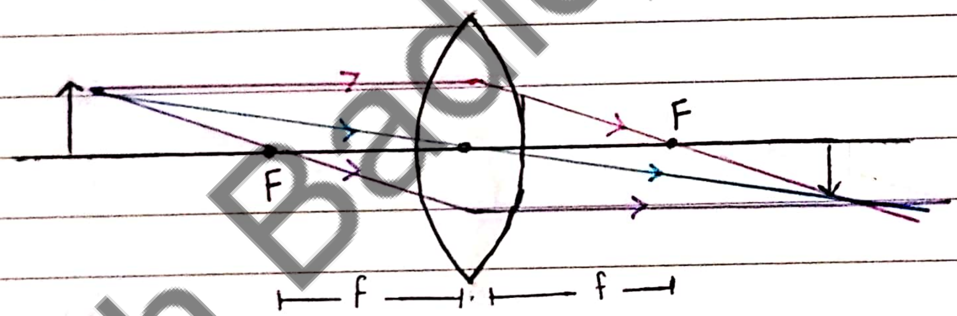
→ Lenses form image through refraction.

Image is formed in convex lens by the following three principal rays:

1. The light rays parallel to the principal axis passes through the focal point after refraction.

2. The light ray which is passing through the optical centre will pass straight without deviation.

3. The light ray passing through the focal point becomes parallel after refraction.



Concave lens

1. light ray which is parallel to principal axis after refraction diverge.
2. light ray which is passing throug the 'C' pass straight without deviation.
3. light ray directed to 'F' after refraction becomes ‖ to principal axis.

If we proceed the 2 rays, the point of intersection form an image which is virtual and erect.

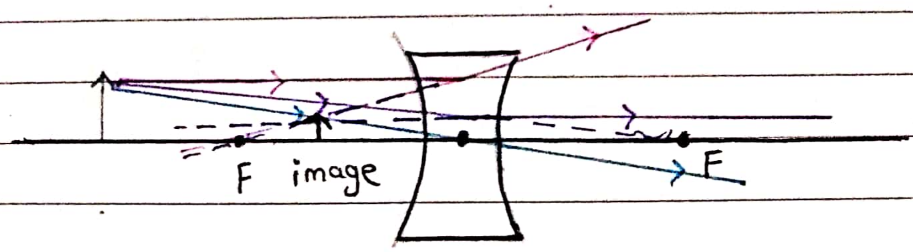
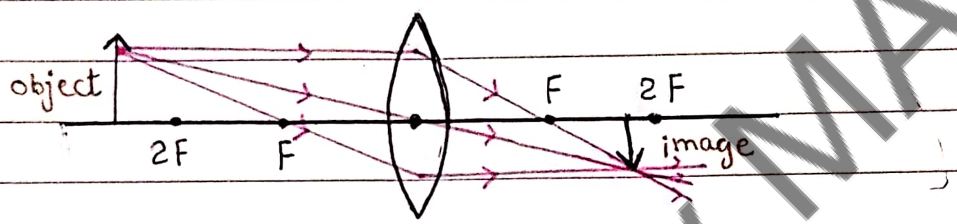
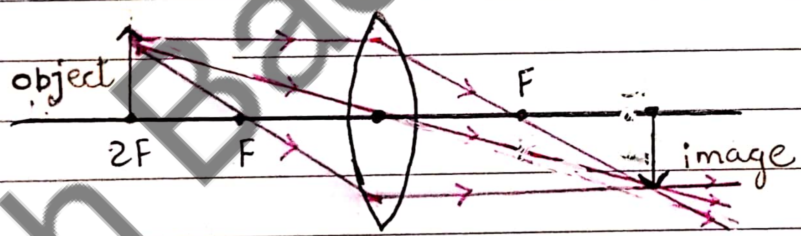


Image Formation in Convex Lens

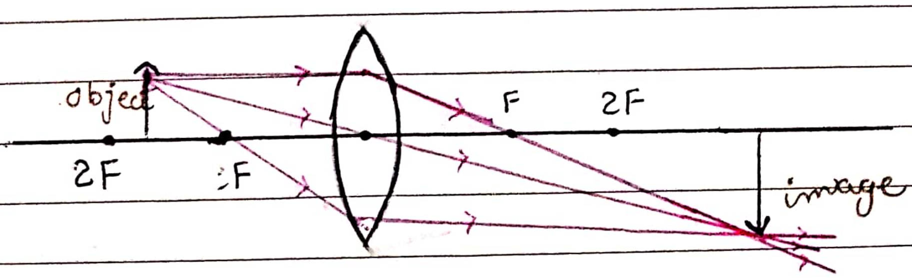
1. When object is placed beyond 2F, image is formed between F and 2F that is real, inverted and smaller than object



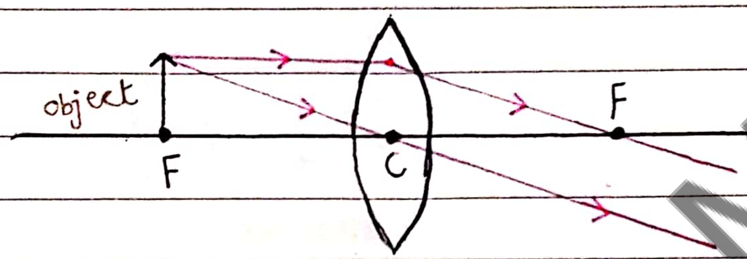
2. When object is placed at 2F, image is formed at 2F which is real inverted and same size as the object



3. When object is placed b/w F and 2F, image is formed beyond 2F which is real, inverted and larger than object



4. When object is placed at F, image will not form because parallel rays never meet.



5. When object is placed within focal length, image will be formed behind object which is virtual, erect and larger than object

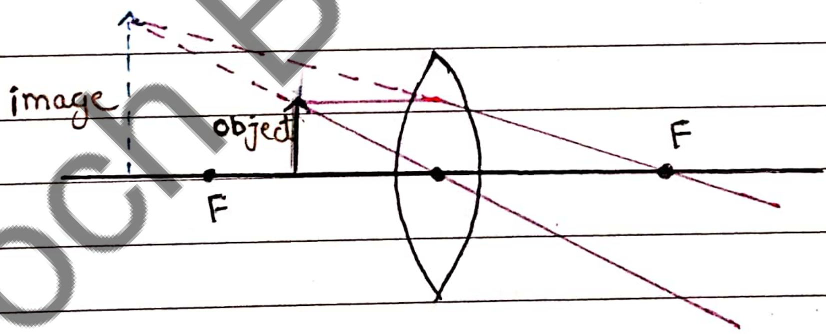


Image Location by Lens Equation

Definition

The Relation b/w object and image distance from the lens in terms of focal length of the lens is called lens formula

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

Sign Conventions

TYPE OF LENS	f	P	q	Formula
Convex	+	+ (toward left side of lens)	+ (real) − (virtual)	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$ $\frac{1}{f} = \frac{1}{p} - \frac{1}{q}$
Concave	−	+	−	$-\frac{1}{f} = \frac{1}{p} - \frac{1}{q}$

- The f of convex lens is taken +ive
- The f of concave lens is taken −ive

- The P of convex lens is taken +ive
- The P of concave lens is taken −ive

$p > f$
$q = +ive$

$p < f$
$q = -ive$

- 2 types of image are formed by convex lens
  1. real when q is +ive
  2. virtual when q is −ive
- The q of concave lens is taken −ive

Applications of Lenses

* Camera

Construction

- light proof box
- convex lens
- photographic film.

Working

The lens focuses images to be photographed onto the film. In simple lens camera, the distance b/w lens and film is fixed which is equal to the focal length of lens.

Position of object

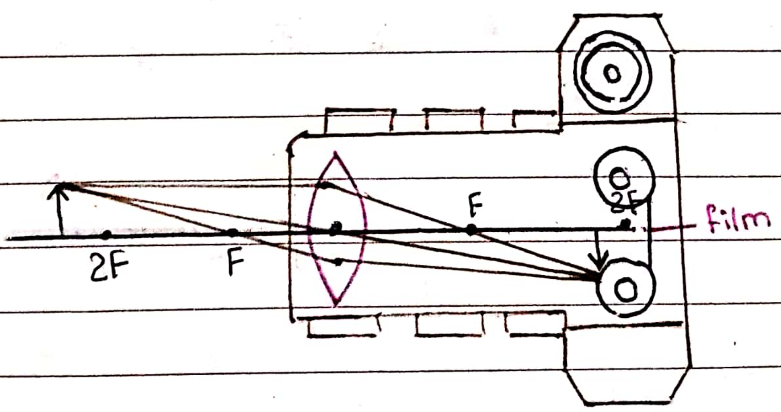
object is placed beyond 2F.

Position of image

Image is developed on the photographic film. and b/w F and 2F

Nature of image

Real, inverted and diminished image is formed.



* Slide Projecter

Construction
- concave mirror
- Light source (at the focus of concave mirror)
- condensor (2 plano convex lens)
- slide
- projection lens (converge or focus the image of slide on screen).

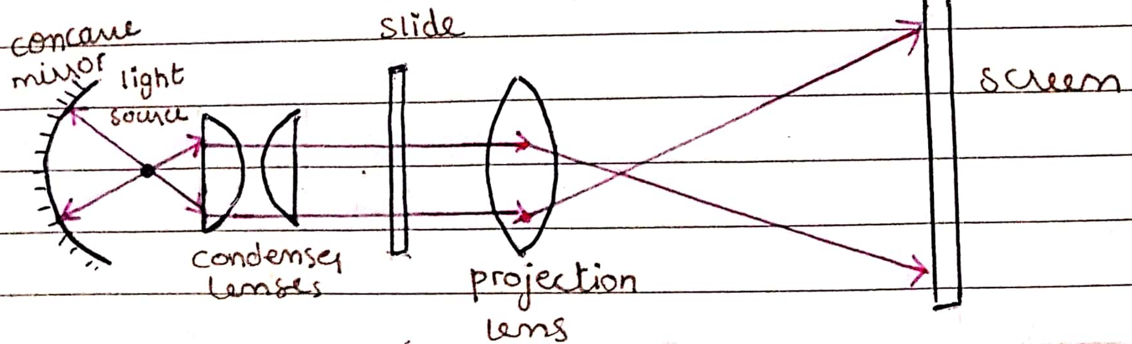
Working
When object is placed at the focus of (light) concave mirror, light rays after converging becomes parallel to condenser lenses. Condenser lenses direct the light through the slide to the projection lens. The projection lens is adjusted a magnified image is focused on the screen.

Position of object
The object is placed b/w F and 2F.

Position of image
The image is formed beyond 2F

Nature of image
real, inverted and large image will be formed.

Condition
The slide must be placed upside down so we can see erect q.



Simple Microscope

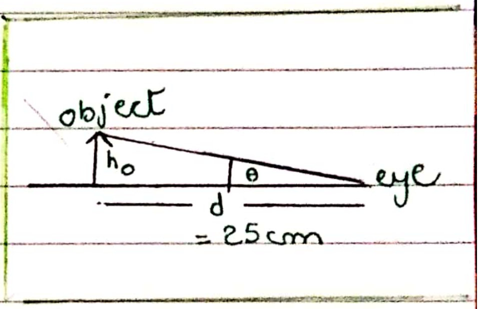
→ A microscope that is made up of only one convex lens used to magnify small objects.

Angular Magnification

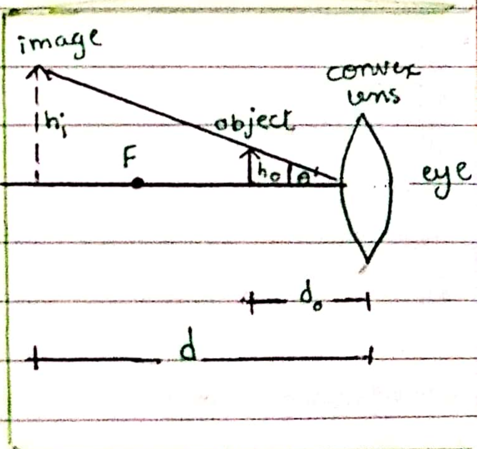
θ = Angle substended by the object on eye
θ' = Angle substended by the image on added eye.

Angular magnification can be defined as : "The ratio of the angle substended by image on added eye to the angle substended by the object on eye.

$$M = \frac{\theta'}{\theta}$$



When the object is placed within the f then its erect, virtual and magnified image can be seen by the convex lens at the "least distance of distinct vision = d"



Magnificatation of Simple Microscope

According to lens formula:

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

As image is virtual, so,

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

$$\frac{1}{f} = \frac{1}{p} - \frac{1}{d} \quad (d = -q)$$

multiplying both sides by d

$$d \times \frac{1}{f} = d \times \frac{1}{p} - d \times \frac{1}{d}$$

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

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

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

$$1 + \frac{d}{f} = M$$

$$\boxed{M = 1 + \frac{d}{f}}$$

Resolving Power

The resolving power of an instrument is its ability to distinguish b/w 2 closely placed objects or point source. For example we use high resolving power microscope to see tiny organisms and telescope to view distant stars.

Compound Microscope

→ Whenever high magnification is required we use 2 convex lens. This is called compound microscope

Eye piece lens It is placed near the eye.

objective lens It is placed near the object.

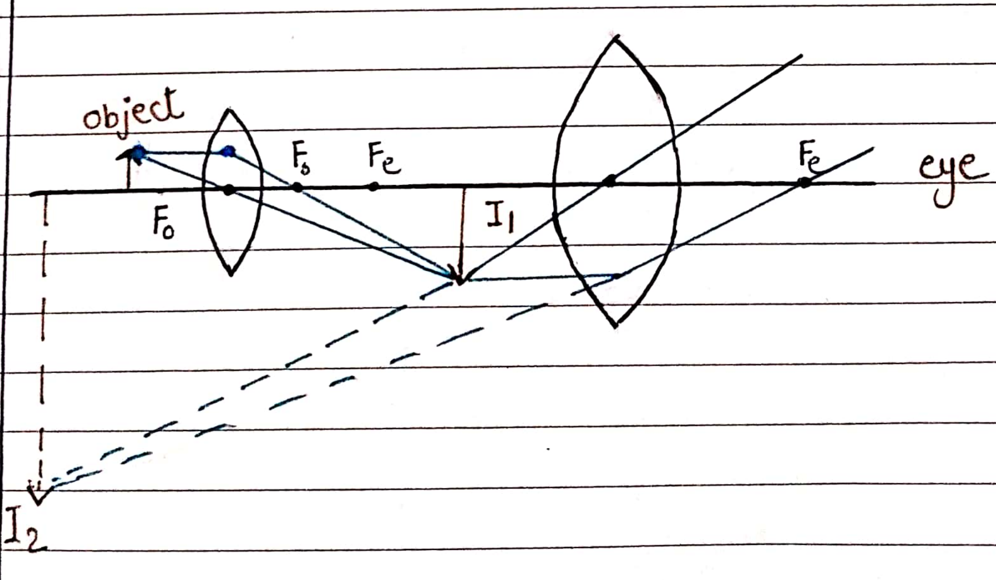
Features of compound Microscope

- It gives greater magnification than a single lens
- The objective lens has short focal length $f_o < 1cm$.
- The eye piece has larger focal length of a few cm.

Working

When object is placed beyond F so it will form real, inverted and magnified image as I_1 which act as virtual object. Eye piece will form virtual, erect and magnified image as I_2 at least distance of distinct vision. $f_e > f_o$.

Ray Diagram



Uses

* used to study bacteria
* used to study micro objects
* used for research in fields of science like botany, microbiology etc.

Magnification of Compound Microscope

magnification of compound microscope is given by

$$M = \frac{L}{f_o}\left(1 + \frac{d}{f_o}\right)$$

Derivation

$M = M_1 M_2$ — (i)

M_1 = magnification by objective lens

$M_1 = \frac{q}{p}$

$M_1 = \frac{L}{f_o}$ — (ii)

$f_o + f_e = L$

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

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

$M = \frac{L}{f_o}$

M_2 = Magnification by eye piece

$M_2 = \frac{1}{f} = \frac{1}{p} + \frac{1}{q}$

$\frac{1}{f} = \frac{1}{p} - \frac{1}{q}$ (virtual image)

Now,

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

$\frac{1}{f} \times d = \frac{1}{p} \times d - \frac{1}{d} \times d$

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

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

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

Put value of M_1 and M_2 in eq (i)

$M = M_1 M_2$

$M = \frac{L}{f_o}\left(1 + \frac{d}{f_o}\right)$

Telescope

An instrument which is used to observe distant object.

Refracting Telescope

A telescope that uses 2 converging lenses.

Objective Lens

The lens which focuses object. It forms real image.

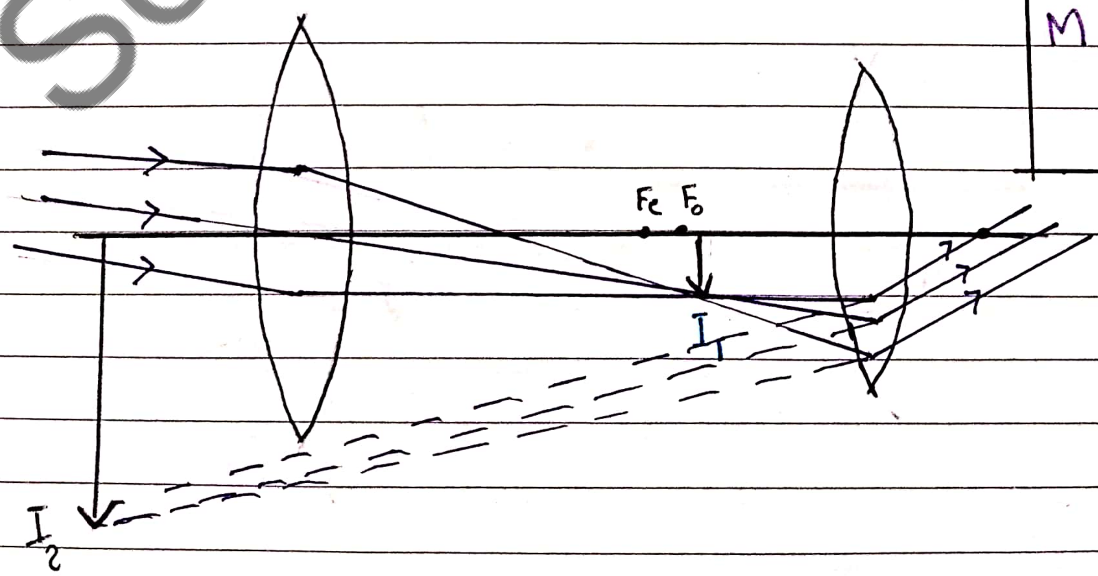
Eyepiece Lens

It is placed near the eye. It forms virtual image.

Working

Telescope consists of 2 lenses. One is objective and other is eyepiece. $f_o > f_e$, that's why it will collect more light from distant object. The parallel rays coming from object will form real and inverted image as I_1 which act as object for eyepiece. Eyepiece will form virtual, erect and magnified image as I_2 at infinity.

Ray Diagram



$$M = \frac{f_o}{f_e}$$

Eye	Camera
Image is formed on retina	Image is formed on photographic film.
focal length can be changed	focal length is fixed
distance b/w eye lens and retina is fix	distance b/w lens and photographic film is not fix
light enters through cornea.	light enters through apurture
Amount of light is controlled by iris	light enters when shutter is open in camera
Lens of eye is flexible	lens of camera is not flexible

Accommodation

→ "The variation of focal length of eye lens to form a sharp image on retina is called accommodation"

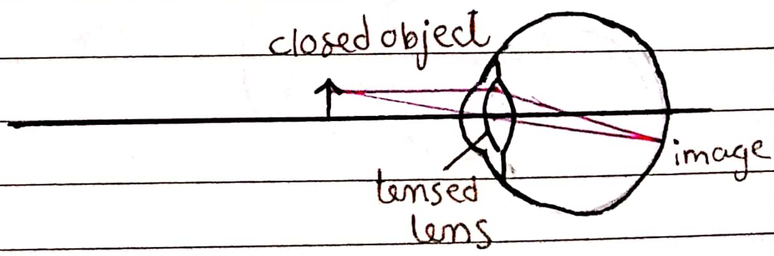
Case-1 When object is far away from the eye

1. deviation of light will be less.
2. cilliary muscles will relax
3. curvature of lens will decrease
4. focal length will increase.

$$\text{curvature} \propto \frac{1}{f}$$

Case-2 When object is close to the eye

1. deviation of light will be more.
2. ciliary muscles will contract.
3. curvature of lens will increase.
4. focal length will decrease.



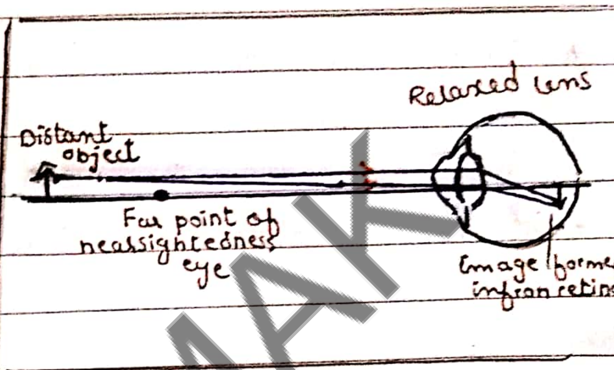
Near Point	Far point
* The minumum distance of an object from the eye at which it produces sharp image on retina.	* The maximum distance of a distant object from the eye on which the fully relaxed eye can focus.
* The minumum distance is also called "least distance of distinct vision"	* The maximum distance also called "infinity point".
Nearpoint or d = 25cm d = 50 cm for 40yrs d = 500 cm for 60 yrs	* Far point is located at infinity.

Defects of Vision

The inability of eye to see image of objects clearly is called defect of vision.

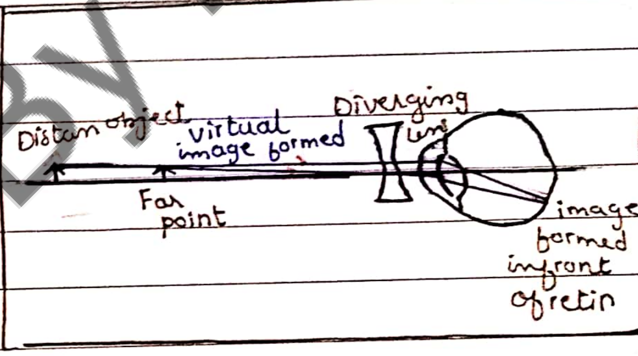
Nearsightedness (Myopia)

Some people cannot see far objects clearly, the image is formed infront of retina. This is known as Nearsightedness.



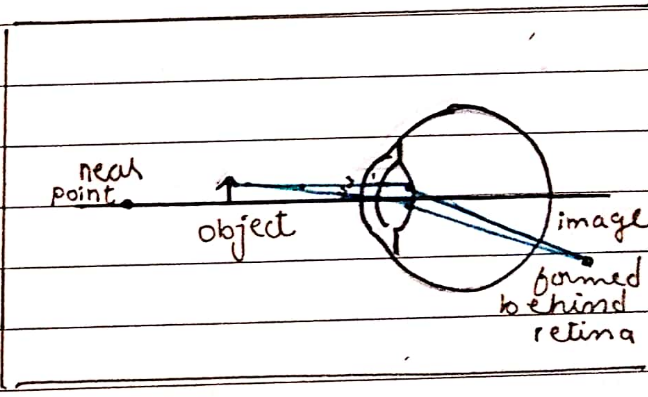
Correction

Nearsightedness can be corrected by concave lens. The light rays coming from distant object diverge and form virtual and erect image near the eye. It will be focused by convex lens and form real and virtual image.



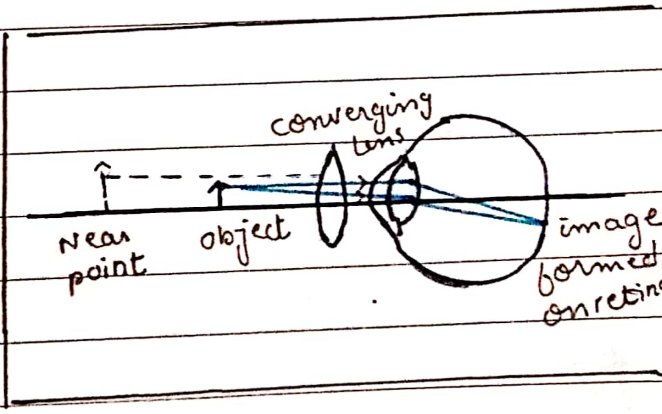
Farsightedness (Hypermetsopia)

Some people cannot see near objects clearly, image is formed behind retina. This is known as farsightedness.



Correction

Farsightedness can be corrected by artificial convex lens. The object lies within focal length which form virtual, erect and magnified image. This image act as virtual object for eye lens and it will form real image on retina.



Nearsightedness	Farsightedness
* People cannot see distant objects.	* People cannot see near objects.
* Image is formed infront of retina	* image is formed behind retina.
* It is corrected by diverging lens.	* It is corrected by artificial convex lens.