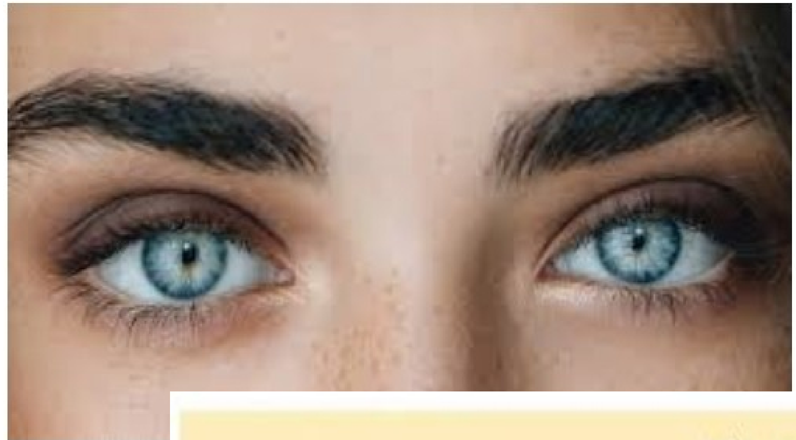
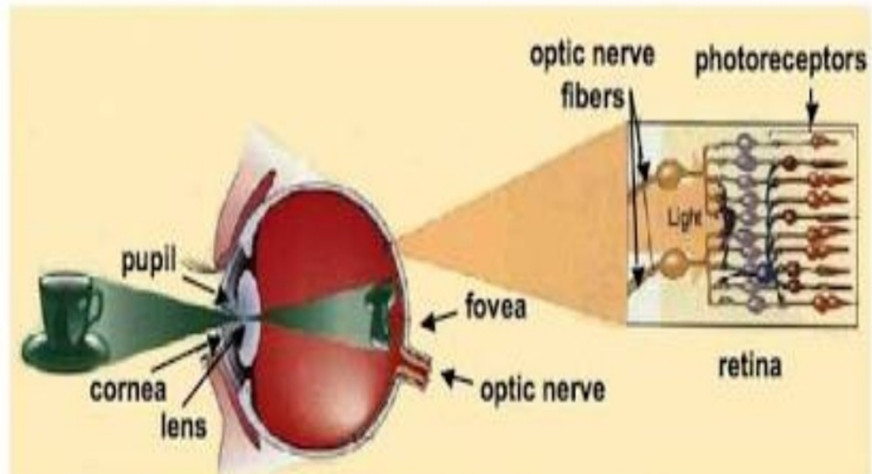
CHAPTER:11

The Human Eye and the Colourful World





Period-1

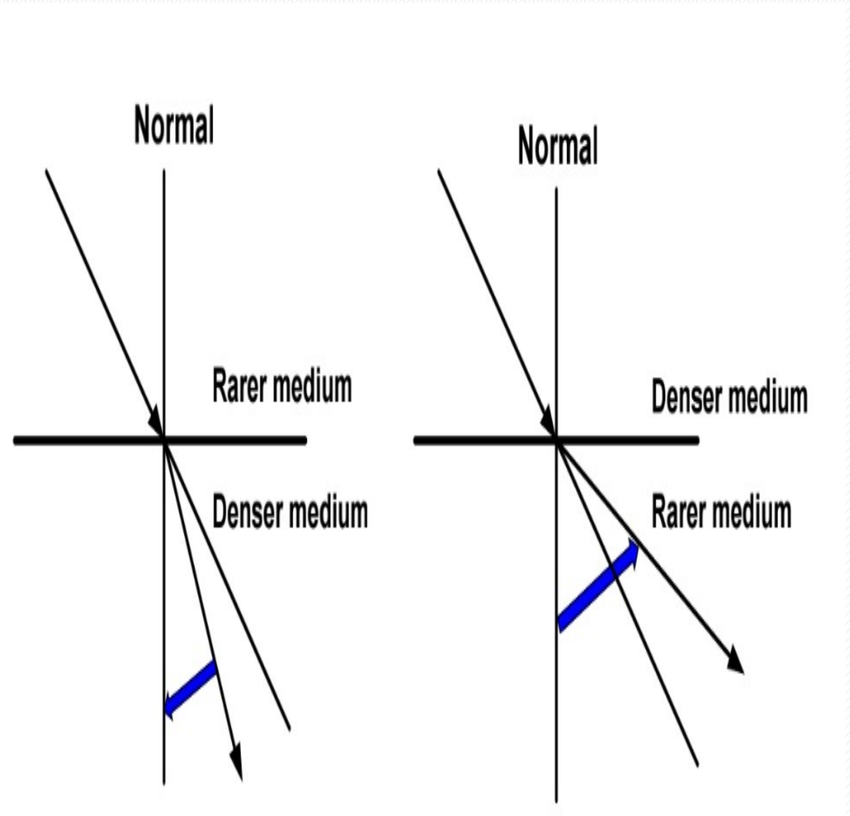
Check your Previous Knowledge

Key Points:

- Refraction
- Lens
- Refractive Index
- Convergent Lens & Divergent Lens
- Optic Centre, Centre of Curvature, Principal Axis, Radius of Curvature
- Principal Focus, Focal Length, Object Distance, Image Distance
- Real Image & Virtual Image
- Magnified Image & Diminished Image
- Inverted Image & Erect Image
- Lens Formula
- Sign Convention

Refraction

- When light travels obliquely from one transparent medium into another, it bends at the Interface. This bending of light is called Refraction of light.
- When light travels from a rarer medium to a denser medium, it bends towards the normal.
- When light travels from a denser medium to a rarer medium, it bends away from the normal.



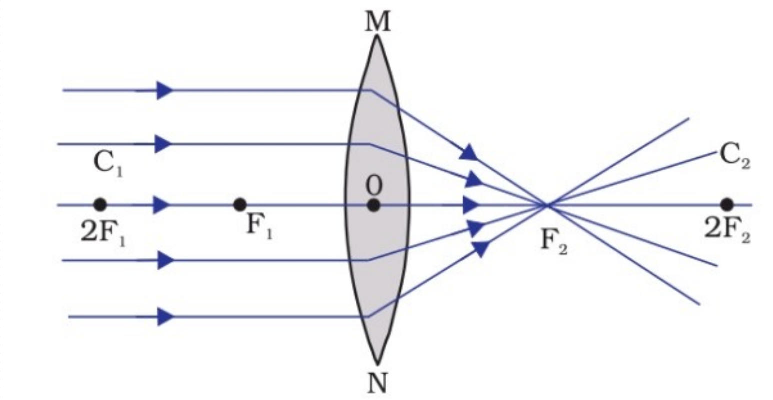
Spherical Lenses

- A spherical lens is a transparent material bounded by two surfaces, one or both of which are spherical.
- Spherical lenses are of two main types. They are convex and concave lenses.
- (i) Convex lens : A Convex lens is thicker in the middle and thinner at the edges.

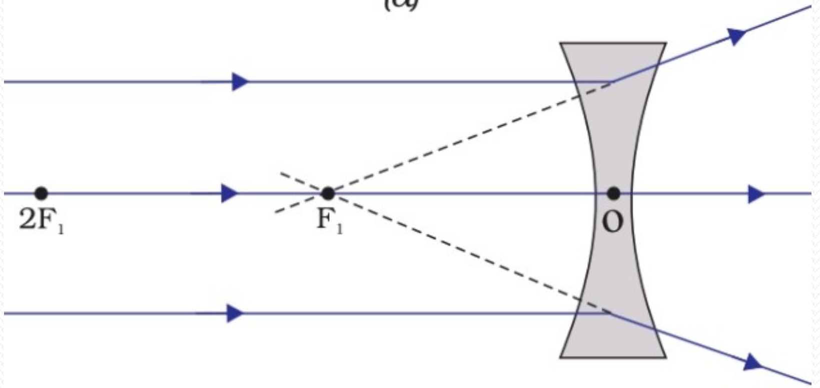
  Rays of light parallel to the principal axis after refraction through a convex lens meet at a point (converge) on the principal axis.

- (ii) Concave lens : A Concave lens is thinner in the middle and thicker at the edges.

  Rays of light parallel to the principal axis after refraction get diverged and appear to come from a point on the principal axis on the same side of the lens.



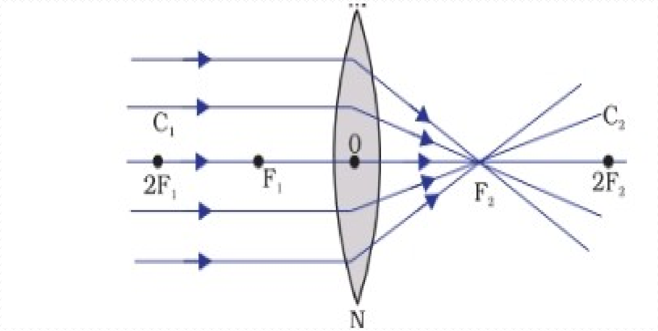
(a)



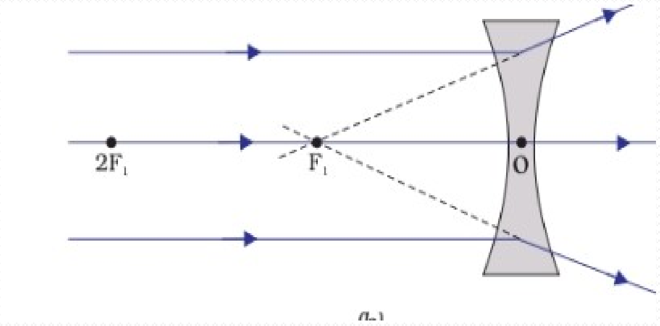
(b)

Convergent and Divergent lenses

- Convergent Lens:
- If the distance of separation amongst the incident parallel rays of light decreases after refraction through a lens, then the lens is called a Convergent lens. e.g. Convex lens



- Divergent Lens:
- If the distance of separation amongst the incident parallel rays of light increases after refraction through a lens, then the lens is called a Divergent lens. e.g. Concave lens



Refractive Index

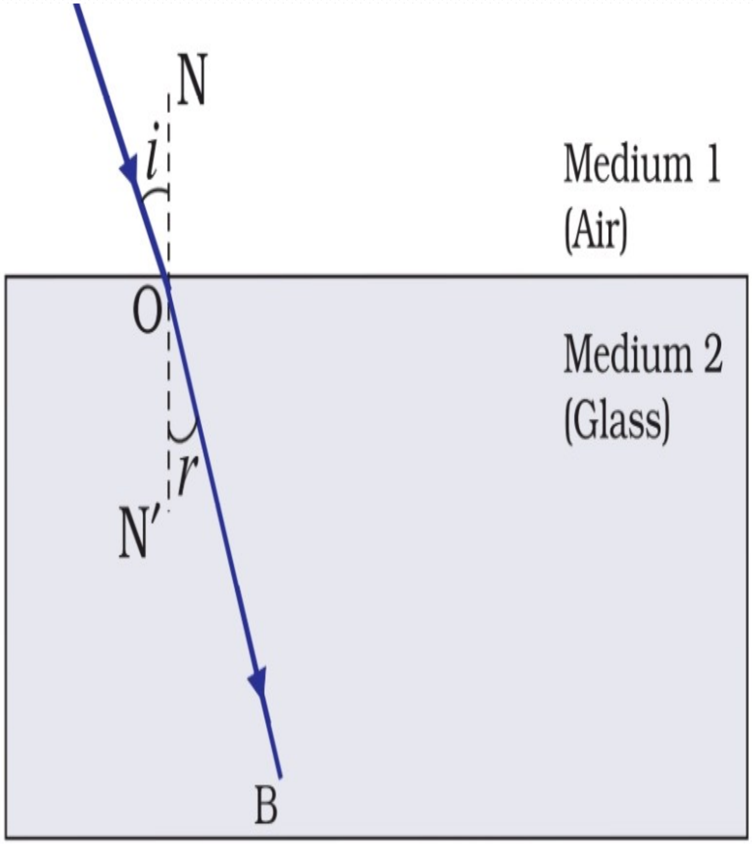
- Let v_1 be the speed of light in medium 1 and v_2 *be* the speed of light in medium 2.

  The refractive index of medium 2 with respect to medium 1 is given by the ratio of the speed of light in medium 1 and the speed of light in medium 2. This is usually represented by the symbol n_{21}, which can be expressed in an equation form as

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

- By the same argument, the refractive index of medium 1 with respect to medium 2 is represented as n_{12}. It is can be expressed in an equation form as

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



Some Technical Terms related to Lenses

- **Optic Centre (O):**

  The geometrical Centre of the lens is called its Optic Centre.

  A ray of light passing through the Optic Centre goes undeviated.

- **Centers of Curvatures (C_1 & C_2):**

  Centre of Curvature of a surface of a lens is defined as the centre of that sphere of which that surface forms a part.

  There are two centers of curvature of a lens, one each belonging to both the surfaces. ($OC_1 = R_1$, $OC_2 = R_2$)

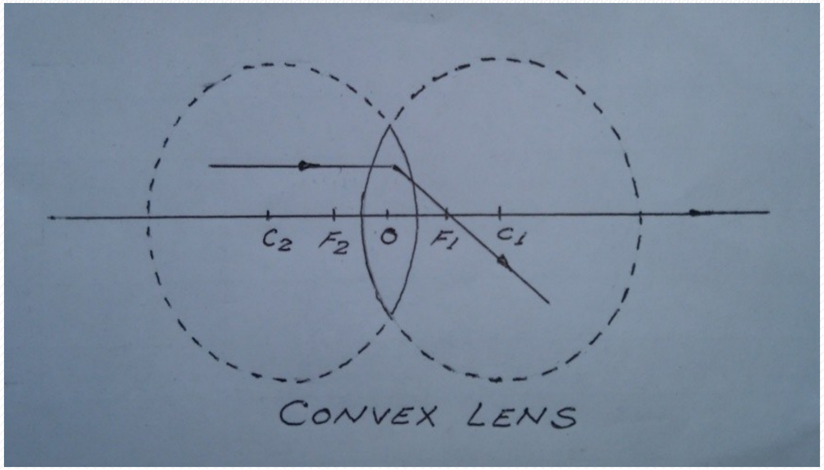
- **Principal Axis (C_1OC_2):**

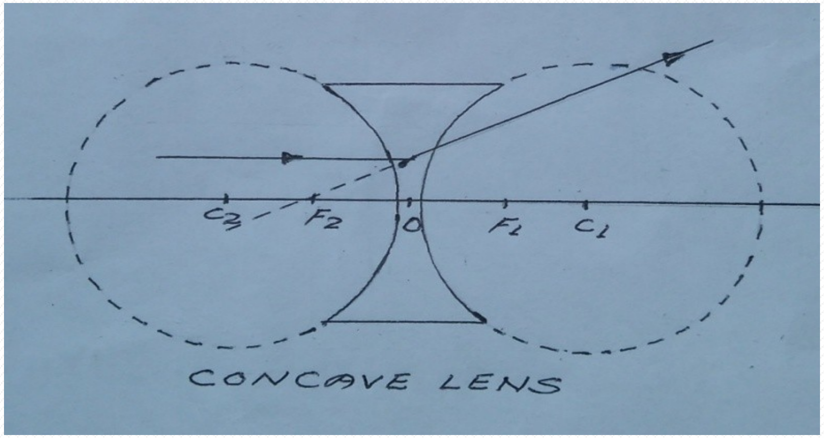
  A line joining the two centers of curvature and passing through the optical centre is called Principal Axis.

- **Radius of Curvature (R_1 & R_2):**

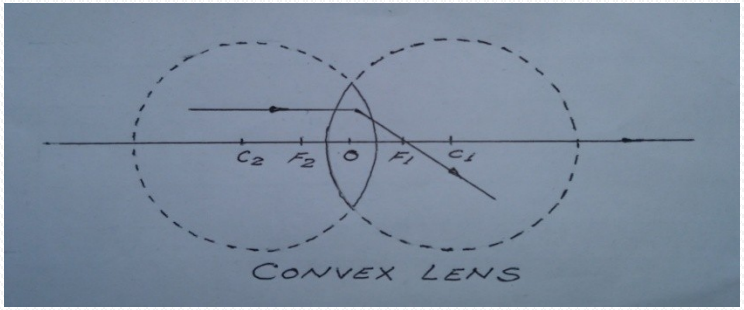
  Radius of curvature of a surface of a lens is defined as the radius of that sphere of which the surface forms a part.

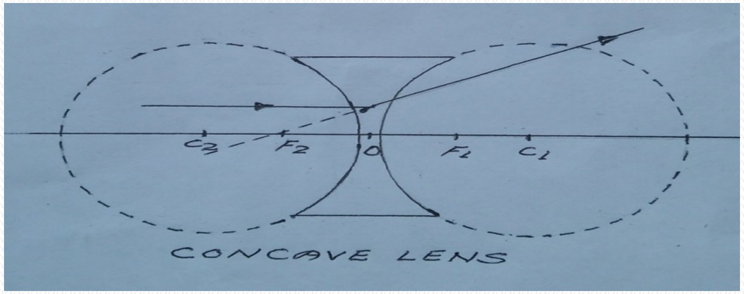
  There are two radii of curvature of a lens, one each belonging to both the surfaces.





Some Technical Terms related to Lenses





- **Principal Focus (F):**

  Principal focus of a lens is a point on the principal axis, at which a beam of light coming parallel to principal axis actually meets or appears to meet after refraction through the lens.

- **Focal Length (f_1 & f_2):**

  Focal Length of a lens is defined as the distance between principal focus and its optical centre.

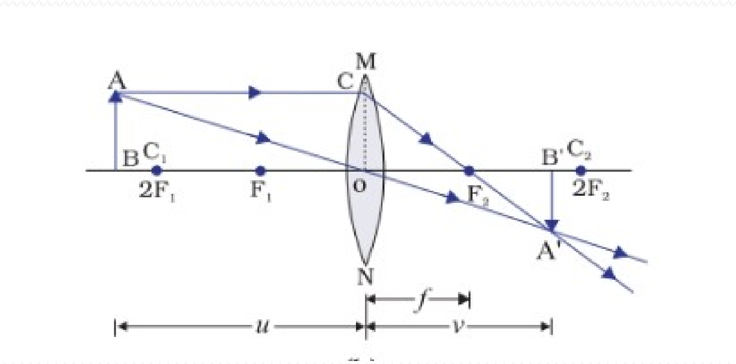
  A lens can be used from both sides. So, there are two focal lengths for a lens, one each belonging to both the surfaces. ($OF_1 = f_1$, $OF_2 = f_2$)

- **Object Distance**(u)**:**

  The distance of separation between the optic centre and the object, measured along the principal axis is called the Object Distance.

- **Image Distance**(v)**:**

  The distance of separation between the optic centre and the image, measured along the principal axis is called the Image Distance.

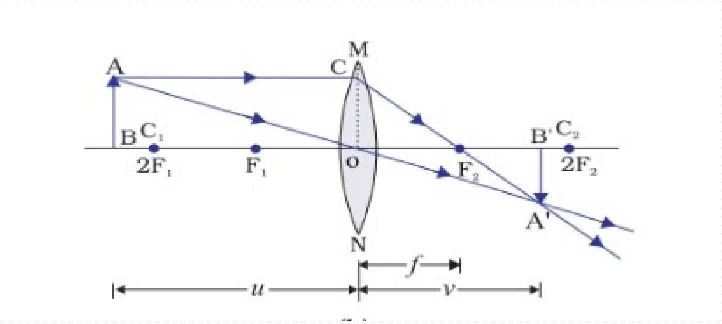


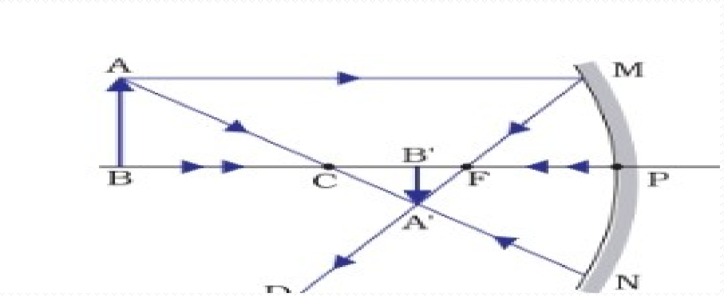
Real Image & Virtual Image

- Real Image:

The image formed by the actual intersection of reflected rays or refracted rays is known as Real Image.

Real images can be obtained on a screen.

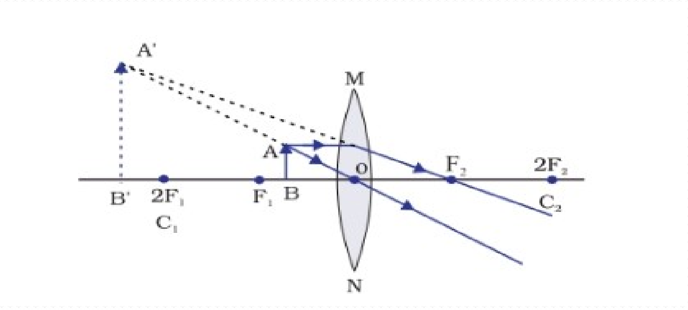


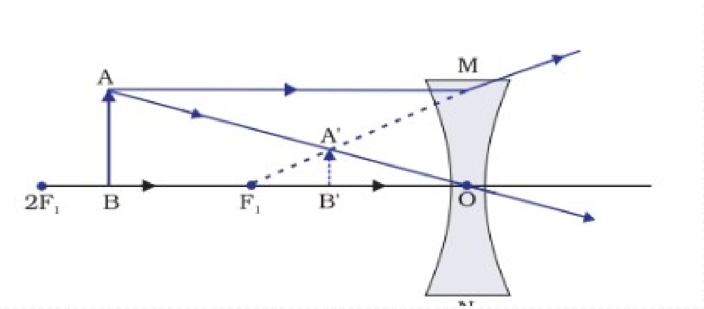


- Virtual Image:

The image formed by the intersection of extended reflected rays or extended refracted rays is known as Virtual Image.

Virtual images cannot be obtained on a screen.





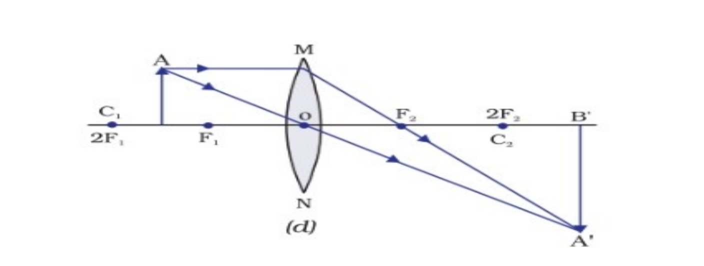
Magnified and Diminished Image:

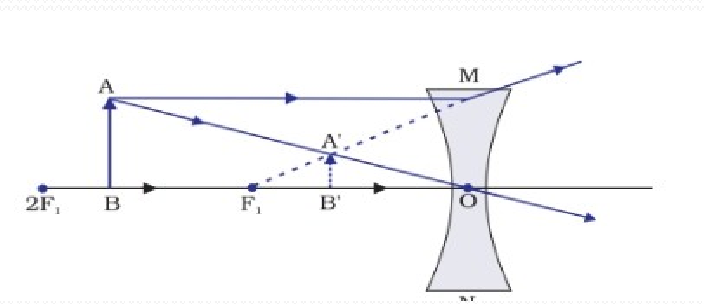
Magnified Image:

If the size of the image is bigger than the size of the object then the image is called a Magnified Image.

Diminished Image:

If the size of the image is smaller than the size of the object then the image is called a Diminished Image.





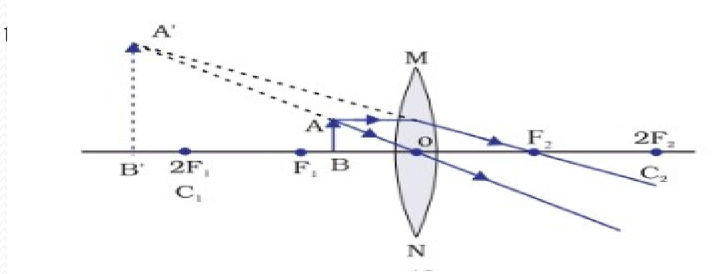
Inverted and Erect Image:

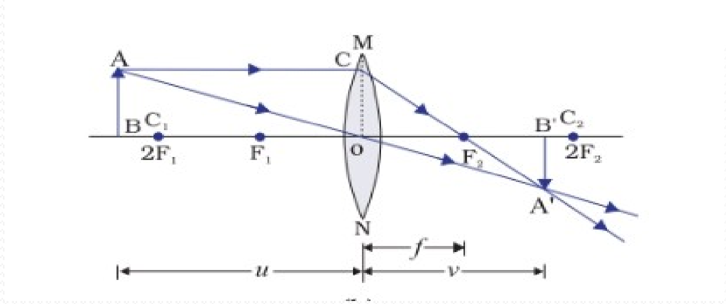
Inverted Image:

The image which is up side down as compared to the object is known as Inverted Image.

Erect Image:

The image in which the directions are the same as





Lens Formula & Magnification
Sign Convention for Lenses

Lens Formula:

- The lens formula for spherical lenses is the relationship amongst the Object Distance (u), Image Distance (v) and the Focal Length (f). The lens formula is expressed as:

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

Magnification (m):

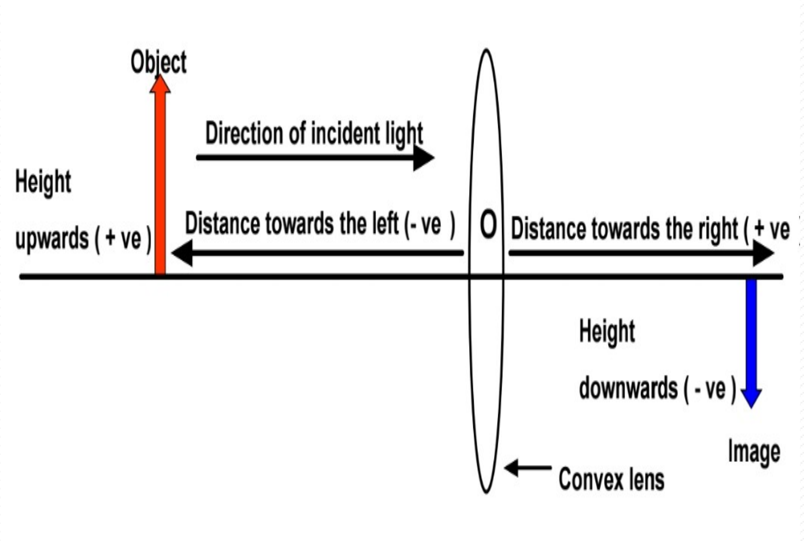
- Magnification for a Spherical Lens is the ratio of the height of the image (h_i) to the height of the object (h_o).
- Magnification for a Spherical Lens is also the ratio of the Image Distance (v) to the Object Distance (u)

$$\text{Magnification} = \frac{\text{Image Height } (h_i)}{\text{Object Height } (h_o)} = \frac{\text{Image Distance } (v)}{\text{Object Distance } (u)}$$

$$m = \frac{h_i}{h_o} = \frac{v}{u}$$

Sign Convention for Lenses:

- All distances are to be measured from the Optical Centre (O) of the lens.
- All distances measured along the direction of the incident ray are taken as positive.
- All distances measured opposite to the direction of the incident ray are taken as negative.
- Distances measured along the vertically upward direction from the Principal Axis is taken as positive.
- Distances measured along the vertically downward direction from the Principal Axis is taken as negative.



Period-2

Introduction

- Human Eye is the window through which we can see the beautiful World around us.
- The Human eye uses light and enables us to see objects
- We shall discuss:

(a) The parts of Human Eye

(b) How does the Eye help us to see objects around us?

(c) How do the lenses used in spectacles correct defects of vision?

(d) Refraction of light through a glass prism.

(d) Study of some Optical Phenomena like

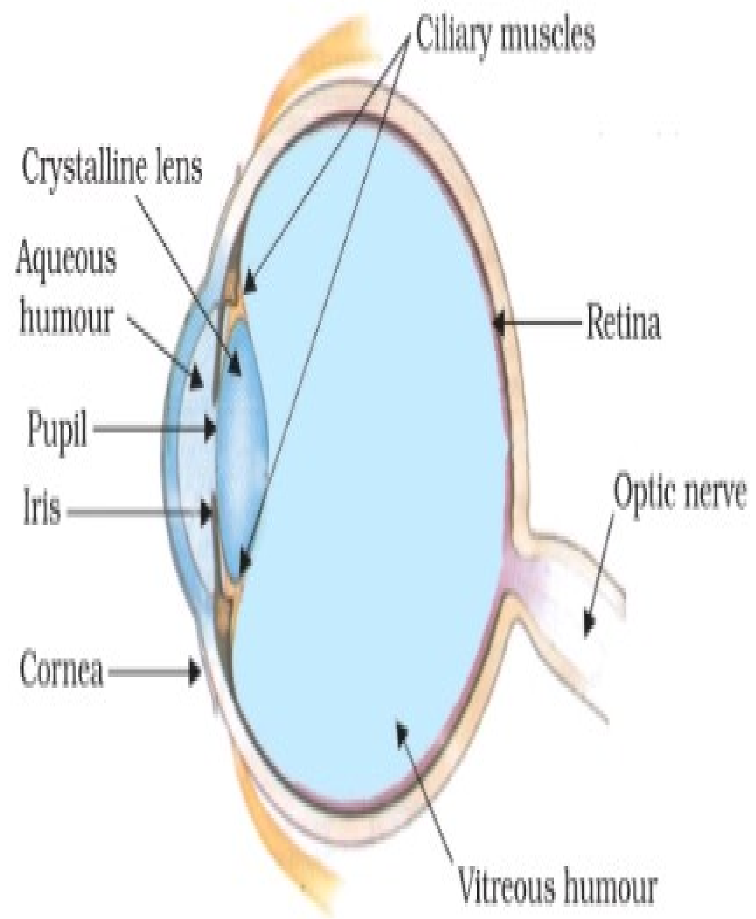
(i) Rainbow Formation

(ii) Splitting of White Light

(iii) Blue Colour of the Sky.

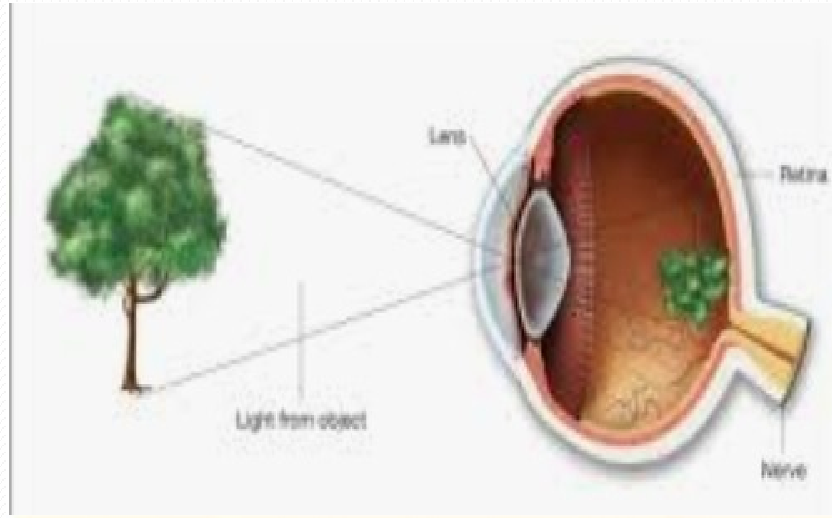
The Human Eye

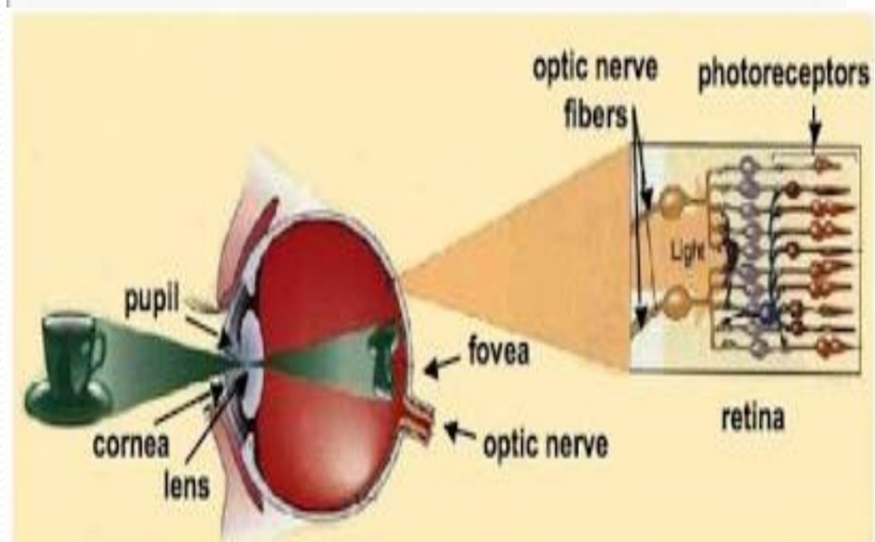
- Optically the eye is like an exceptionally fine camera with an elaborate lens system on one side and a sensitive screen on the other.
- Its lens system forms an image on a light-sensitive screen called the retina. Light enters the eye through a thin membrane called the Cornea. It forms the transparent bulge on the front surface of the eyeball.
- The eyeball is approximately spherical in shape with a diameter of about 2.3 cm.
- Most of the refraction for the light rays entering the eye occurs at the outer surface of the cornea. The refractive index of cornea is about 1.376.
- The crystalline lens which is made of a gelatinous material ,merely provides the finer adjustment of focal length required to focus objects at different distances on the retina. The eye lens forms an inverted real image of the object on the retina.
- The refractive index of eye lens varies from approximately 1.406 in the central layers down to 1.386 in less dense layers of the lens.
- A structure called Iris is present behind the cornea. Iris is a dark muscular diaphragm that controls the size of the pupil.
- The Pupil regulates and controls the amount of light entering the eye. The colour of pupil varies from black to blue to brown from person to person.



The Human Eye

- The Ciliary Muscles helps to change the curvature of the lens and to change its focal length.
- Portion of the eye in between cornea and eye lens is filled with a liquid (Refractive Index = 1.336) called Aqueous Humor. It nourishes the cornea and eye lens by supplying Amino Acids and Glucose.
- Portion of the eye in between retina and eye lens is filled with a liquid (Refractive Index = 1.337)called Vitreous Humor. It helps eye to hold its Spherical shape.
- The retina is a delicate membrane having enormous number of light-sensitive cells. The light-sensitive cells are called Cones and Rods. Each cone and rod is connected with an individual nerve which conducts the electricity through the nerve canal to the brain.
- Just opposite to the eye lens, on the retina there is a depressed spot called Yellow Spot. This is the most sensitive part of the retina. The most depressed portion of Yellow Spot is called Fovea Centrallis.
- Blind spot is a spot on the retina present at the point of origin of the optic nerve. Rods and Cones are absent here.
- Experiments seem to indicate that cones respond only to bright light and are particularly responsible for detection and distinction of colours.
- Rods are sensitive to feeble light. Rods are responsible for detection of motion and slight variation in intensity.
- The rod and cones get activated upon illumination and generate electrical signals. These signals are sent to the brain via the optic nerves. The brain interprets these signals, and finally, processes the information so that we perceive objects as they are.





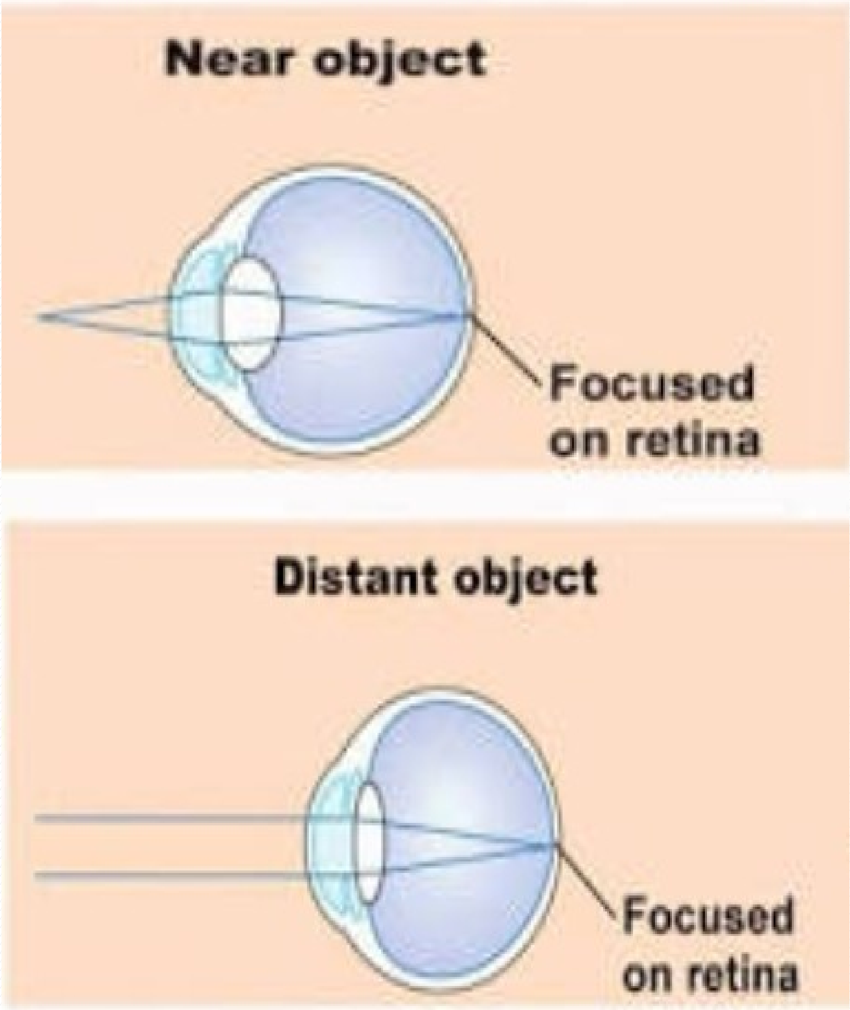
Self Assessment-1

1. Name the type of lens present in human eye.
2. What role does Ciliary Muscles play?
3. Name the part where most of the refraction for the light rays entering the eye occurs.
4. Which part does partially cover the front side of the eye lens?
5. What is the function of Pupil?
6. What is Aqueous Humor?
7. What is Vitreous Humor?
8. What is Yellow Spot?
9. Where does the eye lens form image?
10. What type of image does the eye lens form?
11. Name the connector that connects Retina and Brain.
12. Who changes light into corresponding electric signals in the Retina?
13. What are the functions of Rods?
14. What are the functions of Cones?
15. What is Blind Spot?
16. Draw a neat diagram of Human Eye and label (i) Cornea (ii) Aqueous Humor (iii) Iris (iv) Pupil (v) Blind spot.
17. Draw a neat diagram of Human Eye and label (i) Ciliary Muscles (ii) Vitreous Humor (iii) Retina (iv) Yellow Spot

Period-3

Power of Accommodation

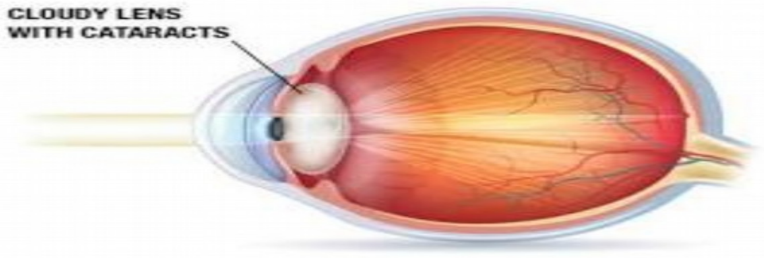
- The ability of the eye lens to adjust its focal length is called Accommodation.
- The curvature of eye lens can be modified to some extent by the ciliary muscles. The change in the curvature of the eye lens can thus change its focal length.
- When the muscles are relaxed, the lens becomes thin. Thus, its focal length increases. This enables us to see distant objects clearly.
- When the ciliary muscles contract, the curvature of the eye lens increases. The eye lens then becomes thicker. Consequently, the focal length of the eye lens decreases. This enables us to see nearby objects clearly.
- However, the focal length of the eye lens cannot be decreased below a certain minimum limit.
- The minimum distance, at which objects can be seen most distinctly without strain, is called the least distance of distinct vision. It is also called the near point of the eye.
- For a young adult with normal vision, the near point is about 25 cm.
- The farthest point up to which the eye can see objects clearly is called the far point of the eye.
- For a young adult with normal vision, the far point is infinity.
- A young adult with normal vision can see objects clearly that are between 25 cm and infinity.

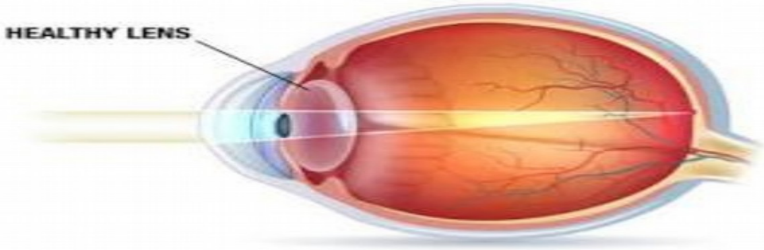


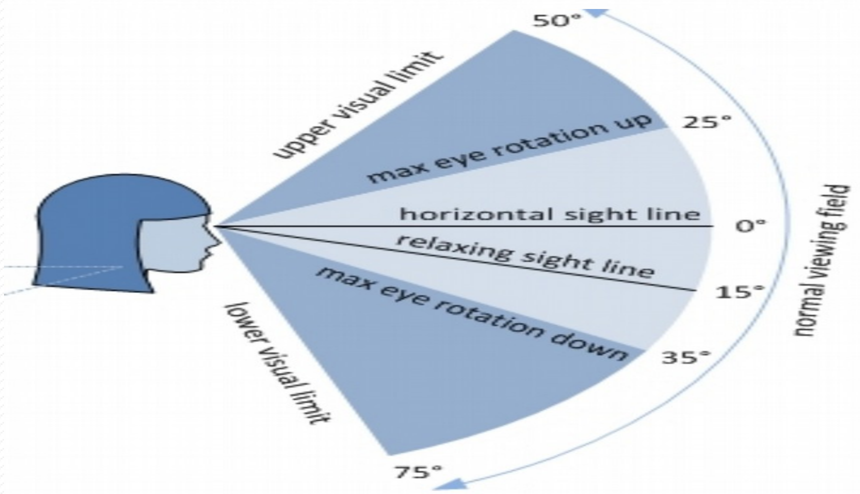
Power of Accommodation

- Sometimes, the crystalline lens of people at old age becomes milky and cloudy. This condition is called Cataract. This causes partial or complete loss of vision. It is possible to restore vision through a cataract surgery.
- There are several advantages of our having two eyes instead of one. It gives a wider field of view. A human being has a horizontal field of view of about 150° with one eye and of about 180° with two eyes. The ability to detect faint objects is, of course, enhanced with two detectors instead of one.
- Some animals, usually prey animals, have their two eyes positioned on opposite sides of their heads to give the widest possible field of view. But our two eyes are positioned on the front of our heads, and it thus reduces our field of view in favour of what is called **Stereopsis** (the perception of depth and three dimensional structure obtained by the brain on the basis of visual information derived from two eyes).
- If we shut one eye and the world looks flat i.e. two-dimensional. Let us keep both eyes open and the world takes on the third dimension of depth.
- Because our eyes are separated by a few centimetres, each eye sees a slightly different image. Our brain combines the two images into one, using the extra information to tell us how close or far away things are.
- The degree of convergence or divergence of light rays achieved by a lens is expressed in terms of its power. The power of a lens is defined as the reciprocal of its focal length. It is represented by the letter *P*. The power P of a lens of focal length f is given by

$$P = \frac{1}{f\ (meter)}\ Dioptre\ (D)$$







Self Assessment -2

1. What do you mean by 'Accommodation of Human Eye?
2. How can the focal length of eye be changed?
3. How do we see the nearby objects clearly?
4. What is Near Point?
5. How do we see the distant objects clearly?
6. What is Far Point?
7. What do you mean by 'Least distance of distinct vision'? What is its value?
8. What is the range of clear vision for a young adult with normal vision ?
9. What is Cataract? What harm can it cause? What is its remedy?
10. Mention two advantages of having two eyes instead of one.
11. What is Stereopsis ?
12. What is the dis-advantage of vision with only one eye?
13. What are the values of horizontal field of view with one eye and with two eyes respectively?
14. What do you mean by 'Power of a lens' ?
15. Mention the relationship between power of a lens and its focal length.
16. Calculate the power of a convex lens with focal length 10 cm.
17. Calculate the power of a concave lens with focal length 20 cm.
18. Why is a normal eye not able to see clearly the objects placed closer than 25 cm?

Period-4

Defects of Vision and their Correction

Sometimes, the eye may gradually lose its power of accommodation. In such conditions, the person cannot see the objects distinctly and comfortably. The vision becomes blurred due to the refractive defects of the eye.

Short Sightedness or Myopia:

- Myopia or Short Sightedness is a defect of vision by which a person can see objects situated nearby and cannot see objects situated far away.
- Rays starting from object situated nearby meet on retina, after refraction through the eye lens. Eye is able to exert accommodation up to O only. So, O is called the Far Point of the eye.
- Rays coming from infinity meet a point short of retina so that only a diffused impression is formed on retina.

Causes:

Elongation of Eye Ball:

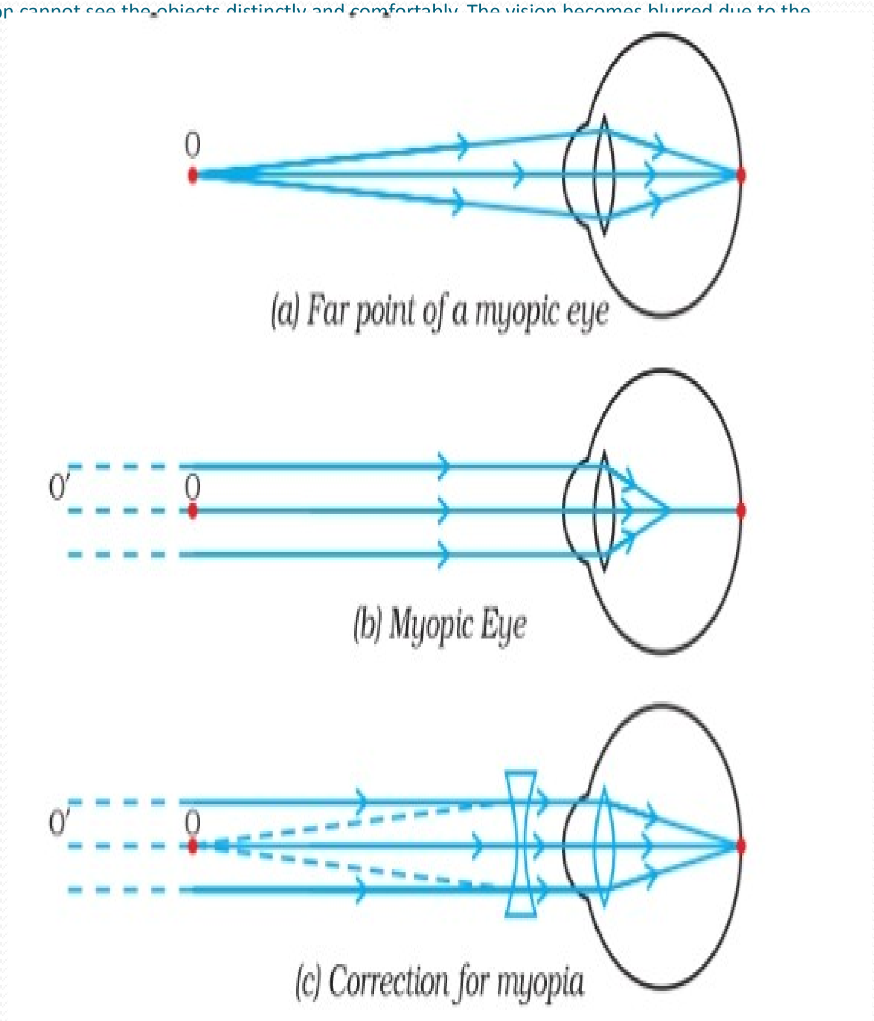
If the eye ball gets elongated, retina gets drifted away. Principal focus of the eye lens falls short of retina.

Shortening of Focal Length of the Eye Lens or Excessive Curvature of the Eye Lens:

It may be caused due to a change in density of eye lens or due to deformation of ciliary muscles.

Remedy:

Myopia can be removed by putting a Concave Lens of suitable focal length before the eye. Light rays from infinity, after refraction through concave lens, follow such a path that they appear to come from the far point O. For any other object situated in between infinity and O, eye exerts its accommodation power.



Defects of Vision and their Correction

- Long Sightedness or Hypermetropia:

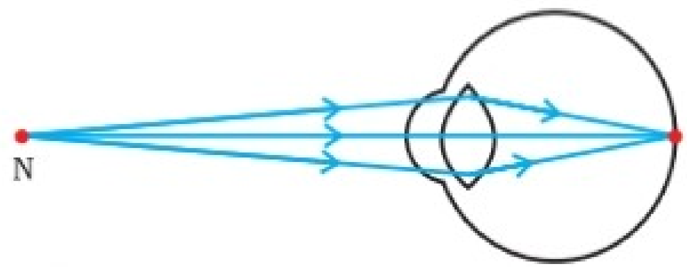
- Hypermetropia or Long Sightedness is a defect of vision by which a person can see objects situated at greater distances from the eye and cannot see objects situated nearby.
- Starting from infinity, the objects are visible due to the accommodation of eye up to the point N, which is called the near point of the eye.
- Rays coming from least distance of distinct vision (**N′**) meet a point away from retina so that only a diffused impression is formed on retina.

- **Causes:**
- **Shortening of Eye Ball:**

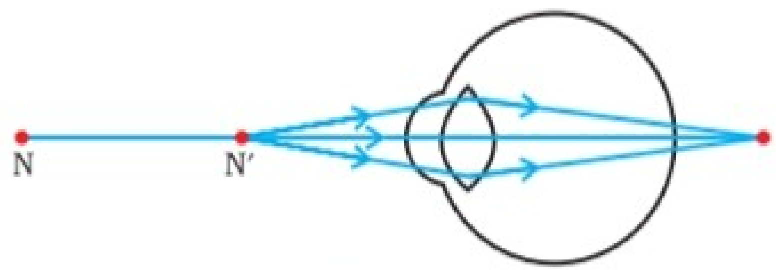
  It may happen due to some accident in which face gets a blow from front or back.
- **Elongation of Focal Length of the Eye Lens or Less Curvature of the Eye Lens:**

  It may be caused due to a change in density of eye lens or due to deformation of ciliary muscles.
- **Remedy:**

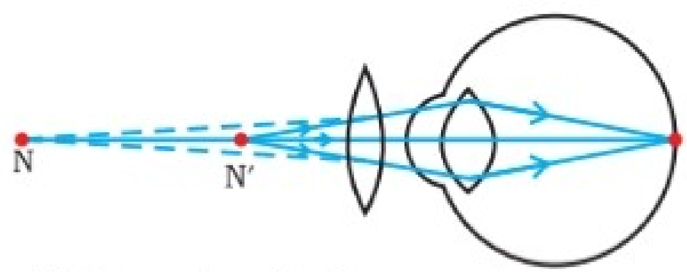
  Myopia can be removed by putting a Convex Lens of suitable focal length before the eye. Light rays from the least distance of distinct vision (**N′**) after refraction through convex lens, follow such a path that they appear to come from the near point N. For any other object situated in between least distance of distinct vision (**N′**) and N, eye exerts its accommodation power.



(a) Near point of a Hypermetropic eye



(b) Hypermetropic eye



(c) Correction for Hypermetropic eye

Self Assessment -3

1. What do you mean by ‘Defects of Vision?
2. What is Myopia?
3. What are the causes of Myopia?
4. What is the remedy for Myopia?
5. What is Hypermetropia ?
6. What are the causes of Hypermetropia?
7. What is the remedy for Hypermetropia ?
8. Draw a neat labeled diagram to explain Myopia and its remedy.
9. Draw a neat labeled diagram to explain Hypermetropia and its remedy.

Period-5

Numerical on Myopia and Hyper-Metropia

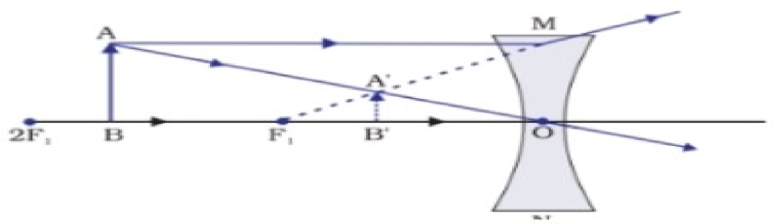
Question No.1:

A short sighted person who can see most clearly at a distance of 15 cm requires spectacles enabling him to see clearly objects at a distance of 60 cm. Calculate the nature and the power of the lens required.

Answer:

The person can see clearly if rays of light starting from an object situated at a distance of 60 cm appear to him to come from a point situated at a distance of 15 cm.

Given, u = - 60 cm, v = - 15 cm, f = ?



Sign Convention:

Object distance = OB = u = -ve

Image distance = OB´ = v = -ve

Focal Length = OF_1 = f = -ve

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

$$\Rightarrow \frac{1}{f} = \frac{1}{-15} - \frac{1}{-60}$$

$$\Rightarrow \frac{1}{f} = \frac{(-4+1)}{60}$$

$$\Rightarrow \frac{1}{f} = \frac{(-3)}{60}$$

$$\Rightarrow f = \frac{-60}{3}$$

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

Again, $P = \frac{100}{f\,(cm)}$

$$\Rightarrow P = \frac{100}{(-20)}$$

$$P = -5 \text{ D}$$

As the power of the lens is negative, the person requires a Concave lens of power 5D.

Numerical on Myopia and Hyper-Metropia

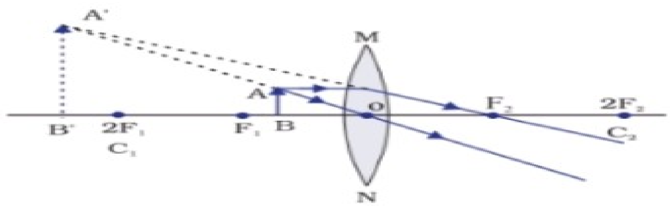
Question No.2:

A person cannot see objects distinctly at a distance less than 1m. Calculate the nature and power of the lens that he should use in order to read a book at a distance of 25 cm.

Answer:

The distance of near point of the person is 1m (= 100 cm).He will be able to read the book clearly if rays of light starting from a distance of 25 cm appears to come from a distance of 100 cm.

Given, u = - 25 cm, v = - 100 cm, f = ?



Sign Convention:

Object distance = OB = u = -ve

Image distance = OB´ = v = -ve

Focal Length = OF_2 = f = +ve

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

$$\Rightarrow \frac{1}{f} = \frac{1}{(-100)} - \frac{1}{(-25)}$$

$$\Rightarrow \frac{1}{f} = \frac{(-1+4)}{100}$$

$$\Rightarrow \frac{1}{f} = \frac{3}{100}$$

$$\Rightarrow f = \frac{100}{3}$$

f = 33.33 cm

Again, $P = \frac{100}{f\,(cm)}$

$$\Rightarrow P = 100 \times \frac{1}{f}$$

$$\Rightarrow P = 100 \times \frac{3}{100}$$

P = 3 D

As the power of the lens is positive, the person requires a Convex lens of power 3D.

- # Presbiopia:

- The power of accommodation of the eye usually decreases with ageing. For most people, the near point gradually recedes away. They find it difficult to see nearby objects comfortably and distinctly without corrective eye-glasses. This defect is called Presbyopia.

Causes:

- It arises due to the gradual weakening of the ciliary muscles and diminishing flexibility of the eye lens.

Remedy:

- Sometimes, a person may suffer from both myopia and hypermetropia. Such people often require bifocal lenses.
- A common type of bi-focal lenses consists of both concave and convex lenses. The upper portion consists of a concave lens. It facilitates distant vision. The lower part is a convex lens. It facilitates near vision.
- Now a days, it is possible to correct the refractive defects with contact lenses or through surgical interventions.

Important Information

- Do you know that our eyes can live even after our death?
- By donating our eyes after we die, we can light the life of a blind person.
- About 35 million people in the developing world are blind and most of them can be cured.
- About 4.5 million people with corneal blindness can be cured through corneal transplantation of donated eyes.
- Out of these 4.5 million, 60% are children below the age of 12.

So, if we have got the gift of vision, why not pass it on to somebody who does not have it?

- Eye donors can belong to any age group or sex. People who use spectacles, or those operated for cataract, can still donate the eyes. People who are diabetic, have hypertension, asthma patients and those without communicable diseases can also donate eyes.
- Eyes must be removed within 4-6 hours after death. Inform the nearest eye bank immediately.
- The eye bank team will remove the eyes at the home of the deceased or at a hospital.
- Eye removal takes only 10-15 minutes. It is a simple process and does not lead to any disfigurement.
- Persons who were infected with or died because of AIDS, Hepatitis B or C, Rabies, Acute Leukaemia, Tetanus, Cholera, Meningitis or Encephalitis cannot donate eyes.

Self Assessment -4

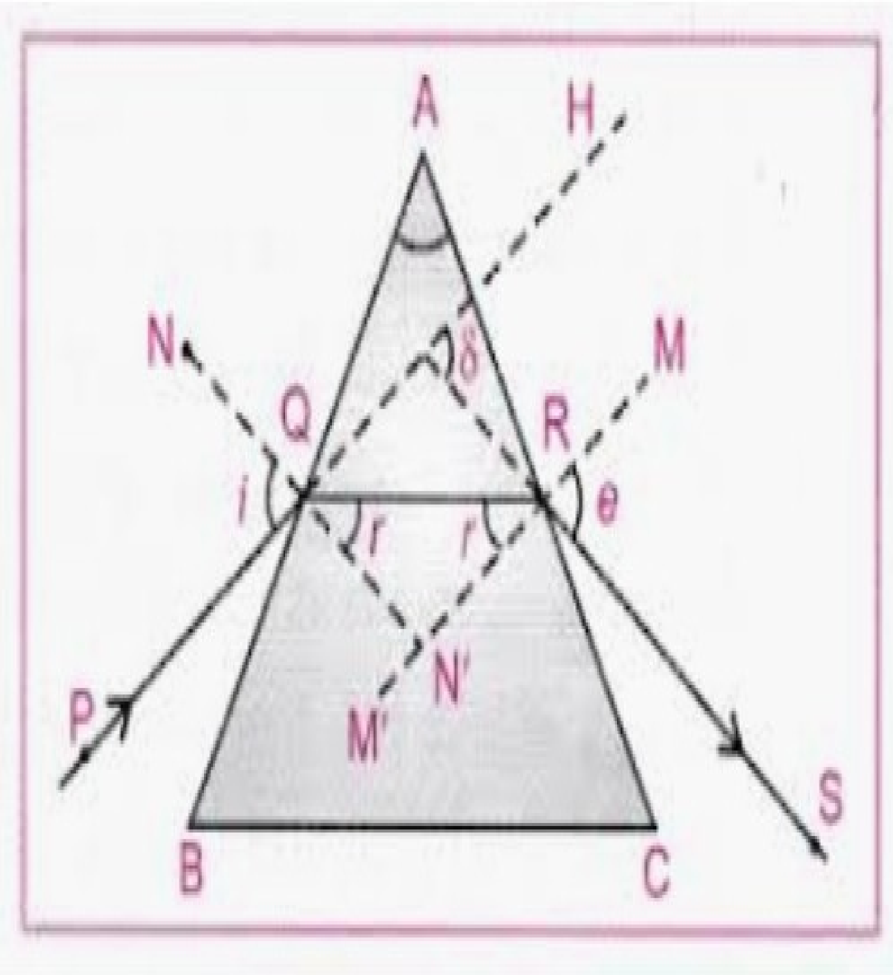
1. What is Presbiopia?
2. What are the causes of Presbiopia?
3. How can Presbiopia be removed?
4. A person with defective vision can see an object clearly when it is not beyond 40 cm from the eye. What should be the nature and power of the lens to correct the eye for objects at infinity?
5. A short sighted person who can see most clearly at a distance of 75 cm requires spectacles to enable him to see objects at a distance of 400 m. Calculate the focal length and power of the lens required.
6. A person suffering from hypermetropia can see clearly beyond 100 cm. Find the power of the lens required to read a newspaper placed at a distance of 30 cm from the eye.
7. A student has difficulty reading the blackboard while sitting in the last row. What could be the defect the child is suffering from? How can it be corrected?
8. A person needs a lens of power –5.5 dioptres for correcting his distant vision. For correcting his near vision he needs a lens of power +1.5 dioptre. What is the focal length of the lens required for correcting (i) distant vision, and (ii) near vision?
9. Make a diagram to show how hypermetropia is corrected. The near point of a hypermetropic eye is 1 m. What is the power of the lens required to correct this defect? Assume that the near point of the normal eye is 25 cm.
10. What happens to the image distance in the eye when we increase the distance of an object from the eye?
11. The far point of a myopic person is 80 cm in front of the eye. What is the nature and power of the lens required to correct the problem?

Period-6

Refraction through a Prism

- **Prism:** A Prism is a transparent optical object with flat, polished surfaces that refract light. At least two of the polished surfaces must have an angle between them.
- **Bending of light:** Light changes its speed when it moves from one medium to another medium having difference in optical density. This speed change causes the light to be refracted and to enter the new medium at a different angle. The degree of bending of the light's path depends on the angle that the incident ray of light makes with the surface, and on the ratio of the refractive index of the two media.
- **Angle of incidence (∠i):** It is the angle between the incident ray (PQ) and the normal (NN') at the point of Incidence (Q).
- **Angle of Emergence (∠e) :** It is the angle between the emergent ray (RS) and the normal (MM') at the point of emergence (R).
- **Angle of Prism (∠A) :** It is the angle between two refracting surfaces of the prism.
- **Angle of Deviation (∠D or ∠∂) :** It is the angle made between the incident ray of light entering the first surface of the prism and the refracted ray of light that emerges from the second face of the prism.

  We have, **∠A + ∠D = ∠i + ∠e**



Refraction through a Prism

- **Factors of dependence of Angle of Deviation:**
- Angle of deviation depends upon—
  (i) Angle of Prism
  (ii) Nature of material of the prism
  (iii) Angle of incidence
- The amount of overall refraction of the ray of light passing through the prism is often expressed in terms of angle of deviation.
- When the angle of incidence increases, angle of deviation decreases, till it becomes minimum at a particular angle of incidence {Dm = (n21 – A)}.

The refracted ray becomes parallel to the base of the prism for the angle of minimum deviation.

If v_1 and v_2 are the velocities of light in air and in glass medium respectively

Then, $n_{21} = \frac{n2}{n1} = \frac{V1}{V2}$

$\Rightarrow n_{21} = \frac{n2}{n1} = \frac{V1}{v\lambda 2}$ $(v_2 = v\lambda_2)$

i.e. $n_{21} \propto \frac{1}{\lambda 2}$

The refractive index of the prism is $n_{21} = \frac{n2}{n1} = \frac{\sin\frac{(A+Dm)}{2}}{\sin(\frac{A}{2})}$

For small angle of prism, <A << and <Dm< <

So, $\sin\frac{(A+Dm)}{2}$ can be written as $\frac{A+Dm}{2}$

and $\sin(\frac{A}{2})$ can be written as $\frac{A}{2}$

$\therefore n_{21} = \frac{n2}{n1} = \frac{\sin\frac{(A+Dm)}{2}}{\sin(\frac{A}{2})}$

$\Rightarrow n_{21} = \frac{\frac{(A+Dm)}{2}}{(\frac{A}{2})}$

$\Rightarrow n_{21} = \frac{(A+Dm)}{A}$

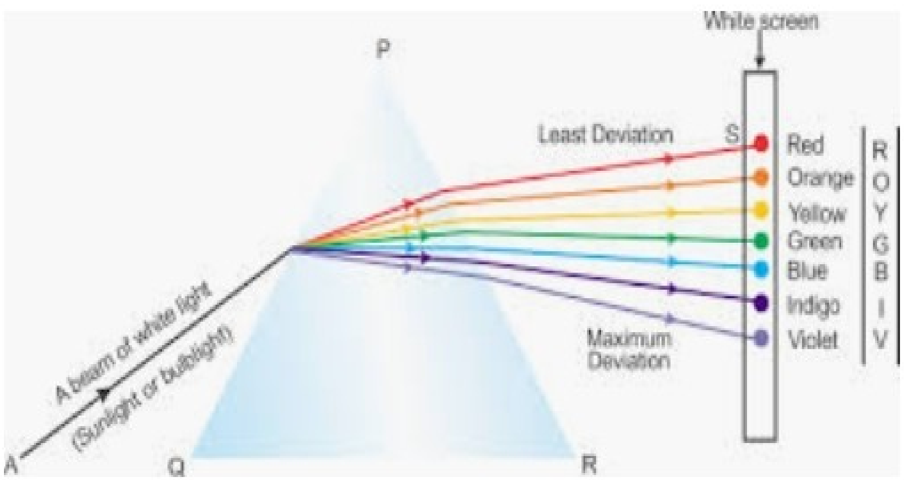
$\Rightarrow n_{21} = \frac{(A+Dm)}{A}$

$\Rightarrow n_{21} = 1 + \frac{Dm}{A}$

$\therefore Dm = (n_{21} - 1) A$

Dispersion of White Light by a Glass Prism

- The constituent colours of white light are Violet, Indigo, Blue, Green, Yellow, Orange and Red.
- If white light is incident on a glass prism, the emergent light is seen to be consisting of seven colours.
- The phenomenon of splitting of white light into its constituent colours is known as Dispersion.
- Red light having the maximum wavelength suffers least dispersion.
- Violet light having the minimum wavelength suffers maximum dispersion.
- The band of the coloured components of a light beam is called its spectrum.
- Isaac Newton was the first to use a glass prism to obtain the spectrum of sunlight.



Now, $D_m = (n_{21} - 1)\,A$ and $n_{21} \propto \frac{1}{\lambda^2}$

λ_v (Violet) = 450 nm , λ_r (Red) = 700 nm

Since, $\lambda_r > \lambda_v$

Therefore, $n_r < n_v$ $\left(n_{21} \propto \frac{1}{\lambda^2}\right)$

Again, $D_r = (n_r - 1)\,A$ and $D_v = (n_v - 1)\,A$

Angular Dispersion

$D_v - D_r = (n_v - 1)\,A - (n_r - 1)\,A$

$\Rightarrow D_v - D_r = (n_v - n_r)\,A$

$\Rightarrow D_v > D_r$

Self Assessment -5

1. What is Spectrum?
2. What is Dispersion of light?
3. Name the constituent colours of white light.
4. What is a Prism?
5. What is Angle of Prism?
6. What is Angle of Emergence?
7. What is Angle of Deviation?
8. What is Angle of Minimum Deviation?
9. On what factors does the Angle of Deviation depend?
10. Name the sequence of emergent light, when white light refracts through a prism.
11. Mention the relationship between Refractive Index and Wavelength.
12. What is the wavelength of Violet light?
13. What is the wavelength of Red light?
14. Mention the relationship amongst Angle of Deviation, Refractive Index and Angle of Prism.
15. What is Angular Dispersion?

Period-7

Practical:
To Study Refraction of White Light through a Glass Prism

Aim:

To trace the path of rays of light through a glass prism.

Materials Required:

A white Paper, Soft Board, Thumb Pins, Glass Prism, Needle Pins, Pencil, Scale and Protractor

Theory:

- **Prism:** A Prism is a transparent optical object with flat, polished surfaces that refract light. At least two of the polished surfaces must have an angle between them.
- **Bending of light:** Light changes its speed when it moves from one medium to another medium having difference in optical density. This speed change causes the light to be refracted and to enter the new medium at a different angle. The degree of bending of the light's path depends on the angle that the incident ray of light makes with the surface, and on the ratio of the refractive index of the two media.
- **Angle of incidence (∠i):** It is the angle between the incident ray (PQ) and the normal (NN') at the point of Incidence (Q).
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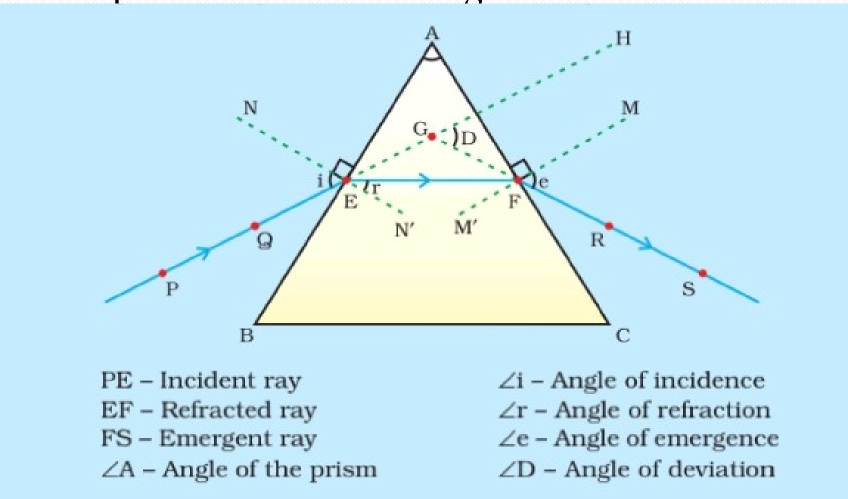
  We have, **∠A + ∠D = ∠i + ∠e**

- **Factors of dependence of Angle of Deviation:**
- Angle of deviation depends upon—
  (i) Angle of Prism
  (ii) Nature of material of the prism
  (iii) Angle of incidence
- The amount of overall refraction of the ray of light passing through the prism is often expressed in terms of angle of deviation.



Practical:

To Study Refraction of White Light through a Glass Prism

Procedure:

- Let us fix a sheet of white paper on a drawing board using drawing pins.
- Let us place a glass prism on it in such a way that it rests on its triangular base.
- Let us trace the outline of the prism using a pencil.
- Let us draw a straight line PE inclined to one of the refracting surfaces, say AB, of the prism.
- Let us fix two pins, say at points P and Q, on the line PE .
- Let us look for the images of the pins, fixed at P and Q, through the other face AC.
- Let us fix two more pins, at points R and S, such that the pins at R and S and the images of the pins at P and Q lie on the same straight line.
- Let us remove the pins and the glass prism.
- The line PE meets the boundary of the prism at point E. Similarly, let us join and produce the points R and S.
- Let these lines meet the boundary of the prism at E and F, respectively.
- Let us Join E and F.
- Let us draw perpendiculars to the refracting surfaces AB and AC of the prism at points E and F, respectively.
- Let us mark the angle of incidence ($\angle i$), angle of refraction ($\angle r$) , angle of emergence ($\angle e$) and angle of deviation ($\angle D$).

Observation:

- A ray of light is entering from air to glass at the first surface AB. The light ray on refraction has bent towards the normal. At the second surface AC, the light ray has entered from glass to air. Hence it has bent away from normal.
- Measured value of angle of incidence ($\angle i$) =
- Measured value of angle of refraction ($\angle r$) =
- Measured value of angle of emergence ($\angle e$) =
- Measured value of angle of deviation ($\angle D$) =

Table of Measurement:

Sl No.	Value of Angle of Incidence $\angle i^\circ$	Value of Angle of Refraction $\angle r^\circ$	Value of Angle of Emergence $\angle e^\circ$	Value of Angle of Deviation $\angle D^\circ$	Value of Angle of Minimum Deviation $\angle Dm^\circ$
1					
2					
3					

Practical:
To Study Refraction of White Light through a Glass Prism

Precautions:

- A sharp pencil should be used for drawing the boundary of the prism.
- Soft board and pointed pins should be used.
- The pins should be fixed at a distance of at least 5 cm or more.
- The pins should be fixed vertically and immediately encircled after they are removed.
- While viewing the co-linearity of pins and images, the eye should be kept at a distance from the pins so that all of them can be seen simultaneously.
- The co-linearity of all the four pins can be confirmed by moving the heads slightly to either side while viewing them. They all appear to move together.
- The angle of incidence should be between 30^0 and 60^0.
- Proper arrows should be drawn for incident ray, refracted ray and emergent ray.

- **Self Assessment – 6 (Viva-Voce):**

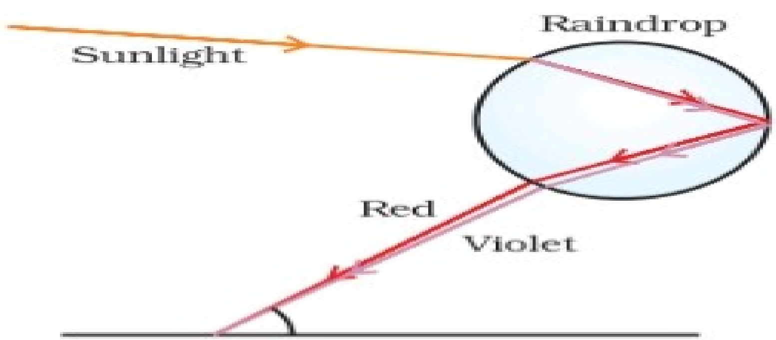
1. What is Refractive Index?
2. What is the unit if Refractive Index?
3. What is absolute Refractive Index?
4. What is Spectrum?
5. What is Dispersion of light?
6. What is a Prism?
7. What is Angle of Prism?
8. What is Angle of Emergence?
7. What is Angle of Deviation?
8. What is Angle of Minimum Deviation?
9. On what factors does the Angle of Deviation depend?
10. Name the sequence of emergent light, when white light refracts through a prism.
11. Mention the relationship between Refractive Index and Wavelength.
12. What is the wavelength of Violet light?
13. What is the wavelength of Red light?
14. Mention the relationship amongst Angle of Deviation, Refractive Index and Angle of Prism.
15. What is Angular Dispersion?

Period-8

Dispersion of White Light in Nature

❑ Rainbow:

- A rainbow is a natural spectrum appearing in the sky after a rain shower .
- It is caused by dispersion of sunlight by tiny water droplets, present in the atmosphere.
- A rainbow is always formed in a direction opposite to that of the Sun.
- The water droplets act like small prisms. They refract and disperse the incident sunlight, then reflect it internally, and finally refract it again when it comes out of the raindrop.
- Due to the dispersion of light and internal reflection, different colours reach the observer's eye.

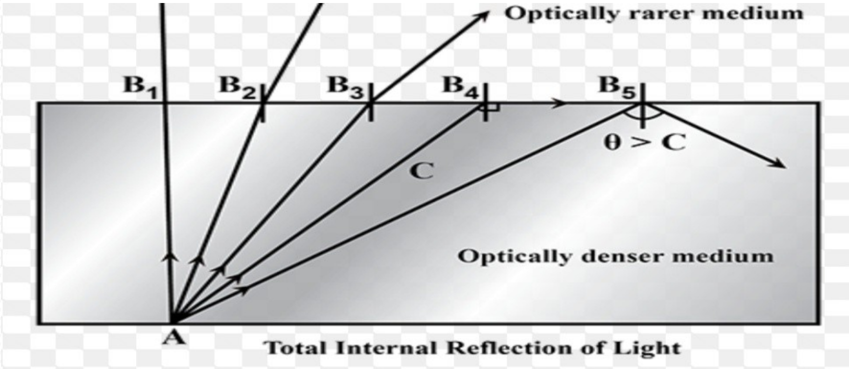


❑ Critical Angle:

The angle of incidence corresponding to which the value of angle of refraction is 90 ^{0} ,when light refracts from denser medium to rarer medium is known as Critical Angle.

❑ Total Internal Reflection:

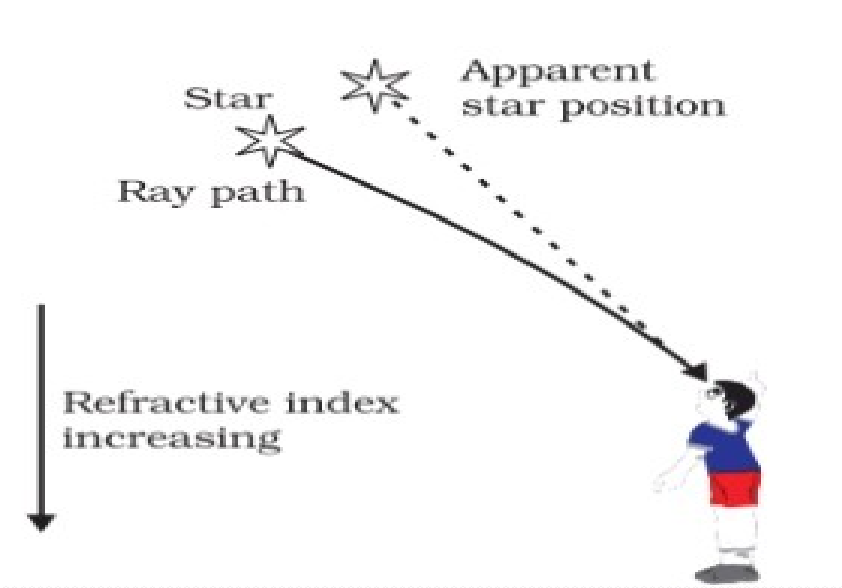
When light ray moves from a denser medium to a rarer medium and the value of the angle of incidence is more than the critical angle, then the refracted ray comes back to the denser medium. This phenomenon is known as Total Internal Reflection.



Atmospheric Refraction

Twinkling of Stars:

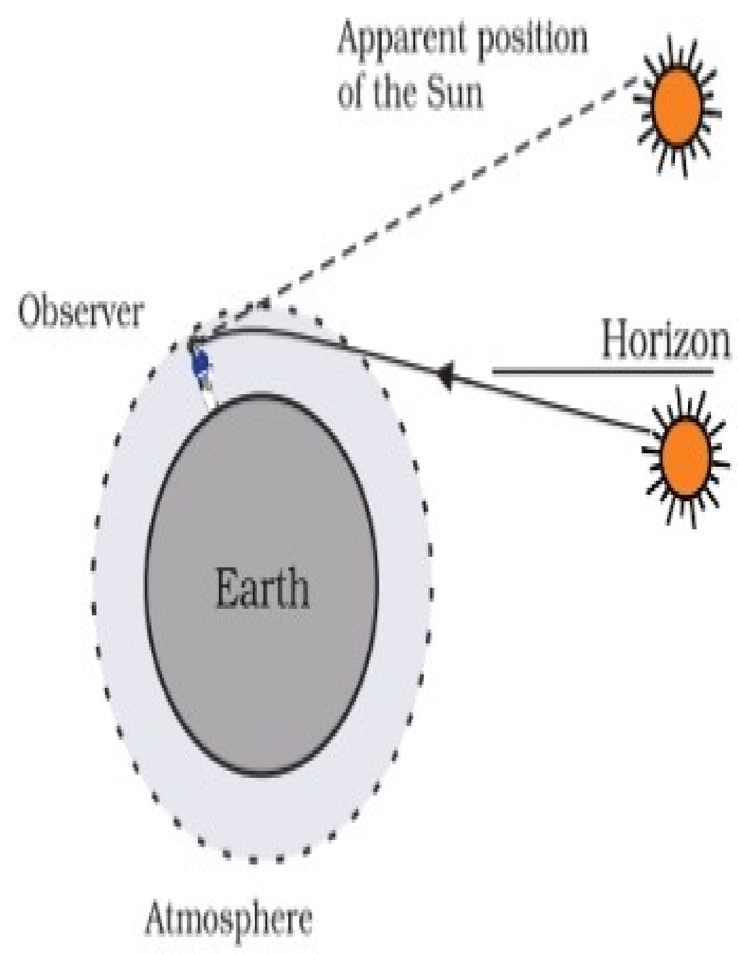
- The twinkling of a star is due to atmospheric refraction of starlight.
- The starlight, on entering the earth's atmosphere, undergoes refraction continuously before it reaches the earth.
- The atmospheric refraction occurs in a medium of gradually changing refractive index. As the height decreases, the density increases. As a result, the speed of light decreases and refractive index increases.
- Since the incident beam of light keep on bending towards the normal at different interfaces, the apparent position of the star is slightly different from its actual position.
- The star appears slightly higher (above) than its actual position when viewed near the horizon .
- Further, this apparent position of the star is not stationary, but keeps on changing slightly, since the physical conditions of the earth's atmosphere are not stationary.
- Since the stars are very distant, they approximate point-sized sources of light. As the path of rays of light coming from the star goes on varying slightly, the apparent position of the star fluctuates and the amount of starlight entering the eye flickers
- The star sometimes appears brighter and at some other timefainter, which is the Twinkling Effect.
- The planets are much closer to the earth, and are thus seen as extended sources. If we consider a planet as a collection of a large number of point-sized sources of light, the total variation in the amount of light entering our eye from all the individual point-sized sources will average out to zero, thereby nullifying the twinkling effect.



Atmospheric Refraction

Advanced Sunrise and Delayed Sunset:

- The Sun is visible to us about 2 minutes before the actual sunrise, and about 2 minutes after the actual sunset because of atmospheric refraction.
- By actual sunrise, we mean the actual crossing of the horizon by the Sun.
- The atmospheric refraction occurs in a medium of gradually changing refractive index. As the height decreases, the density increases. As a result, the speed of light decreases and refractive index increases.
- Since the incident beam of light keep on bending towards the normal at different interfaces, the apparent position of the Sun is slightly different from its actual position.
- The Sun appears slightly higher (above) than its actual position when viewed near the horizon .
- The diagram on the right shows the actual and apparent positions of the Sun with respect to the horizon.
- We see the Sun before it is actually coming to the horizon in the morning, leading to Advanced Sunrise.
- We keep on seeing the Sun even after it has moved below the horizon in the evening,leading to Delayed Sunset.



Self Assessment -7

1. What is Rainbow?
2. What is the cause of formation of Rainbow?
3. Under what condition a Rainbow is formed?
4. What is Critical Angle?
5. What is Total Internal Reflection?
6. Obtain the expression for the Snell's Law for Critical Angle.
7. Why do Stars twinkle?
8. Explain why the Planets do not twinkle.
9. Draw a neat labeled diagram explaining the twinkling of a star.
10. Why do we see an early Sunrise?
11. Why do we see a delayed Sunset?
12. Draw a neat labeled diagram explaining the early Sunrise.
13. Draw a neat labeled diagram to explain the emergence of an incident white light from a water droplet.

Period-9

Scattering of Light

Scattering of Light:

- The interplay of light with objects around us gives rise to several spectacular phenomena in nature.
- The blue colour of the sky, colour of water in deep sea, the reddening of the sun at sunrise and the sunset are some of the wonderful phenomena we are familiar with.
- When light passes from one medium to any other medium, then a part of the light is absorbed by particles of the medium preceded by its subsequent radiation in a particular direction. This phenomenon is termed as Scattering of Light.
- The colour of the scattered light depends on the size of the scattering particles.

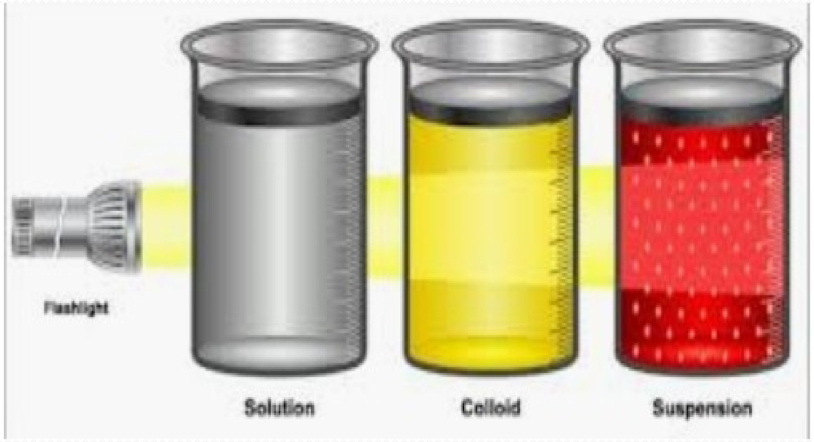
(a) Very fine particles scatter mainly blue light.

(b) Particles of larger size scatter light of longer wavelengths.

(c)If the size of the scattering particles is large enough then the scattered light may even appear white.

Tyndall Effect:

- The earth's atmosphere is a heterogeneous mixture of minute particles. These particles include smoke, tiny water droplets, suspended particles of dust and molecules of air.
- When a beam of light strikes the heterogeneous mixture of minute particles, the path of the beam becomes visible. The light reaches us, after being reflected diffusely by these particles.
- The phenomenon of scattering of light by the colloidal particles gives rise to Tyndall effect.
- This phenomenon is seen when a fine beam of sunlight enters a smoke-filled room through a small hole. Thus, scattering of light makes the particles visible.
- Tyndall effect can also be observed when sunlight passes through a canopy of a dense forest. Here, tiny water droplets in the mist scatter light.



Scattering of Light

Why is the Colour of the Clear Sky Blue?

- The molecules of air and other fine particles in the atmosphere have size smaller than the wavelength of visible light.
- These are more effective in scattering light of shorter wavelengths at the blue end than light of longer wavelengths at the red end.
- The red light has a wavelength about 1.8 times greater than blue light. Thus, when sunlight passes through the atmosphere, the fine particles in air scatter the blue colour (shorter wavelengths) more strongly than red. The scattered blue light enters our eyes.
- If the earth had no atmosphere, there would not have been any scattering. Then, the sky would have looked dark.
- The sky appears dark to passengers flying at very high altitudes, as scattering is not prominent at such heights.
- The red is least scattered by fog or smoke. Therefore, it can be seen in the same colour at a distance. That is why 'danger' signal lights are red in colour.

Colour of the Sun at Sunrise and Sunset:

- Light from the Sun near the horizon passes through thicker layers of air and larger distance in the earth's atmosphere before reaching our eyes
- However, light from the Sun overhead would travel relatively shorter distance.
- At noon, the Sun appears white as only a little of the blue and violet colours are scattered.
- Near the horizon, most of the blue light and shorter wavelengths are scattered away by the particles.
- Therefore, the light that reaches our eyes is of longer wavelengths. This gives rise to the reddish appearance of the Sun.
- The scattering of light by molecules was intensively investigated by C.V. Raman in the 1920s. Raman was awarded the Nobel Prize for Physics in 1930 for his work.

Self Assessment -8

1. What is Scattering of Light?
2. On what factors does the scattering of white light depend?
3. What is Tyndall Effect?
4. Why is the colour of the clear sky blue?
5. Why does the Sun appear reddish early in the morning?
6. Why does the sky appear dark instead of blue to an astronaut?
7. Why do 'danger' signal lights are red in colour?
8. Why does the Sun appear reddish in the evening?