HUMAN EYE AND THE COLOURFUL WORLD

Eye: The human eye is the most important organ of the human body. It is used to see the beautiful nature and the natural phenomenon. The human eye is like a photographic camera.The human eye works on the principle of refraction of light. Just like optical instruments like camera, microscope, telescope, film projectors etc.

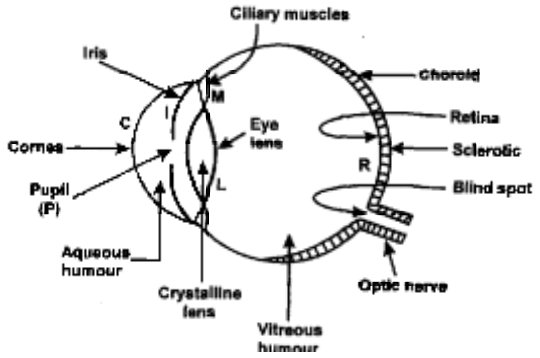


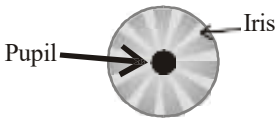
Figure Eye

Topic: Main Parts of Human Eye

1. **Eye Ball:** The eye ball is almost spherical in shape, having a diameter of about 2 - 3 cm.

2. **Cornea:** The front part of the eye bulging outside is covered by a transparent spherical membrane called cornea. The space between cornea and eye lens is filled with a clear liquid called aqueous humour.
   Note: The cornea and aqueous humour act as a lens and provide most of the refraction for the light rays entering the eye.

3. **Iris and Pupil:** Just behind the cornea a coloured diaphragm is called Iris. There is a hole in the middle of the iris which is called Pupil of the eye.
   Note: Iris consist of muscles and coloured pigment. The colour of the eyes of the person depends on the colour of these pigments.The pupil appears black because no light is reflected by it.



4. **Eye Lens:** Eye-lens is a convex lens made of a transparent, fiberous, soft and flexible material, like jelly made of protien. The eye lens is held in position by ciliary musels.

5. **Ciliary Muscles:** Ciliary muscles hold the eye lens in position, ciliary muscles controls the focal length of the eye lens.

   Explanation: If the amount of light is received by the eye in large amount then iris contracts and reduces the size of pupil, resulting pupil reduce the amount of light entering the eye and forms clear image of the object on the retina. On the other hand, if the amount of light received by the eye in small amount then the iris expands and increases the size of the pupil resulting pupil increases the amount of light enetring the eye and forms a clear image of the object on the retina.

6. **Retina:** The inside surface of the rear part of the eye ball is called retina. The retina is a delicate memberane having enormous number of light sensitive cells.When light falls on these cells, they become active and send electrical signals to the brain through the optic nerve. The brain interprets these signals and finally we see the erect image of the object.

7. **Optic Nerve:** The sensation of vision on the retina is carried to the brain by a nerve called optic nerve.

8. **Blind Spot:** The point where the optic nerve enters the eye ball is totally insensitive to light is known as blind spot.

9. **Vitreous humour:** First aqueous Human then vitress. It is a dense jelly like liquid slightly grey in colour filled in the posterior part (between eye lens and retina) of the eye ball. It has the following functions.

   (1) It prevents the eye ball from collapsing due to change in atmospheric pressure.
   (2) It partially helps in focussing the image clearly on the retina.

10. **Aqueous humor:** It is watery saline liquid, filled in the anterior portion (between cornea and eye lens) of the eye. It has the following functions:
    (1) It prevents the anterior portion of the eye from collapsing due to the change in atmospheric pressure.
    (2) It keeps the cornea moist, otherwise the cornea becomes opaque.
    (3) It helps in refraction of light rays entering the eye.

Working of eye: The light rays coming from an object enters the eye through cornea and pupil. The eye lens converges these light rays to form a real, inverted and highly diminished image of the object on the retina. The surface of the retina consists of a large number of light sensitive cells. When light falls on them, they get activated and generate electrical signals. These signals are sent to the brain by the optic nerve and the observer sees the actual - sized, erect image of the object.

Functions of iris and pupil: The iris regulate the amount of light entering the eye by adjusting the size of the pupil.

Persistence of vision: *The ability of an eye to see continue the image of an object for a very short duration of time even after the removal of the object in front of eye is called persistence of vision.* The image of an object persists (or remain) on the retina for about 1/16th of a second.

How do we see colours and objects: The retina of our eye has a large number of light sensitive cells. These cells are of two types:

(i) Rods shaped cells (ii) Cones shaped cells

Rods shaped cells: Rods shaped cells are sensitive to dim light. We can see things to some distance in a dark room due to the presence of rod shaped cells on the retina Noctural (निशाचर) animals like owl have a large number of rod shaped cells in their retina due to this. They can see properly during the night. A hen has small amount of rod shaped cells on their ratina which are sensitive to brightness of light due to this they wakes up with the rising of the sun and goes to sleep by sunset of light.

Cones shaped cells: Cones shaped are sensitive to bright light (or normal light). The cone shaped cells of the retina make us see colours and also make us distinguish between various colours. The cones shaped cells do not function in dim light.

Note: A bee has some cone shape cells on their retina, which are senestive to ultra violet light, whereas human eye cannot see the ultraviolet light.

Colour Blindness: It is that defect of the eye due to which a person is unable to distinguish between certain colours, this is because the retina of such person does not possess some specific cone shaped cells, for example a person who is blind to red - green colour it means ratina of such person does not contain green and red pigments. It is genetic disorder.

Power of accommodation of eye: *The ability of an eye to focus the distant object as well as the near object on the retina by changing the focal length of eye lens by the action of ciliary muscles is called accomodation of eye.*

Explanation: While observer seeing the far object, the ciliary muscles are completely relaxed, so the eye lens become thin, hence the converging power of eye lens decreases and focal length of eye lens increases. Thus the image of the far object is clearly focussed on the retina. When the same eye sees the nearby object the ciliary muscles contract, so the eye lens becomes thick, hence the converging power of eye lens increases and focal length of eye lens decreases. Thus the image of nearby object is clearly focussed on the retina.

Note: The maximum "accommodation" of a normal eye is about 25 cm from the eye if an object placed at a distance of less than 25 cm can not be seen clearly because all the power of accommodation of the eye already has been used. The power of accommodation of a normal eye is 4D.

Far Point: The farthest point from the eye which can be seen clearly is know as the "far point" of the eye the far-point of a normal human eye is at infinity.

Near Point: The nearest point upto which an eye can see the object clearly without any strain is called the "Near Point" (or least distance of distinct vision). The near point of a normal human eye is at a distance of 25 cm from the eye.

Range of vision: The distance between far point and near point is called range of vision. The range of vision of a normal human eye is from infinity to about 25 cm i.e., a normal human eye can see the objects clearly lying between infinity to 25 cm.

Note: The least distance of distinct vision for Babies is 7 cm and for Adults is 25 cm.

Topic: Defects of eye and their remedies

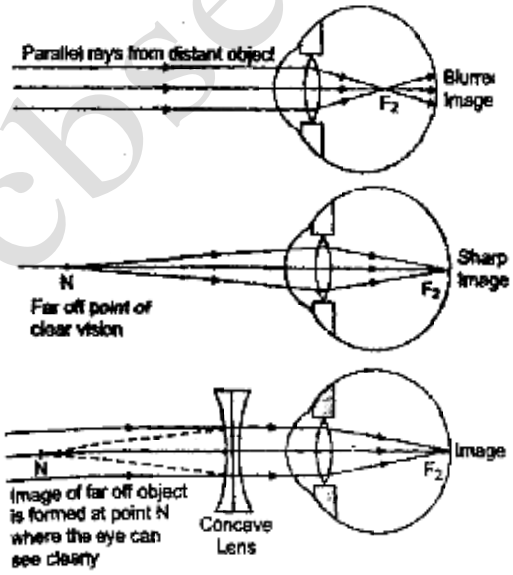
The most common defects of the eye are

1. Myopia (Short sightedness or near sightedness)
2. Hypermetropia (long sightedness or far sightedness)
3. Presbyopia and 4. Cataract

1. Myopia: Myopia is that defect of eye due to which an eye cannot see the distant objects clearly. There are two reasons of myopia.

1. Converging power of eye lens increase.
2. Eye ball being too long.

Note: In the case of myopia, image is formed before the retina myopia can be corrected by using concave lens.



Correction of Myopia: When a concave lens of suitable power is placed in front of the myopic eye, concave lens forms a virtual and erect image of the distant object at the far point of myopic eye. The virtual & erect image formed at far point of myopic eye act as object for eye lens and finally, eye lens form real and inverted image of the object on the retina.

Note: In the case of myopia The concave lens reduces the converging power of the eye lens.

Focal Length and Power of a concave Lens used to correct Myopia: Let **'d'** be the distance of the far point from myopic eye, and object lies at infinity. So the distance of the object for concave lens is infinity and distance of the image for concave lens is equal to the distance of far point i.e. **'d'**. So the focal length of concave lens can be calculated by using lens formula

$\therefore u = -\infty$ and $v = -d$.

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{-d} - \frac{1}{-\infty}$$

$$\frac{1}{f} = -\frac{1}{d} + \frac{1}{\infty} \Rightarrow \frac{1}{f} = -\frac{1}{d} + 0 \left(\because \frac{1}{\infty} = 0 \right)$$

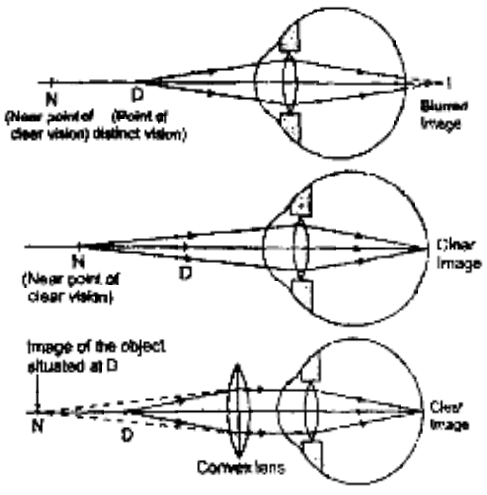
$$\therefore \quad f = -d \qquad \text{(i)}$$

Thus, using eqn. (i) we can find the focal length of a concave lens to correct myopia. The power of concave lens is given by:

$$P = \frac{1}{f(\text{inm})} \text{ or } \Rightarrow P = \frac{100}{f(\text{incm})}$$

2. Hypermetropia: Hypermetropia is that defect of eye due to which an eye cannot see the nearly objects clearly. There are two reasons of hypermetropia.

1. Converging power of eye lens decreases
2. Eye ball being too short



Note: In the case of Hypermetropia the image is formed behind the retina and it is corrected by using convex lens.

Correction of Hypermetropia: When a convex lens of suitable power is placed infront of the hypermetropic eye, the convex lens forms a virtual & erect image of the nearby object (25 cm) at the near point of the hypermetropic eye. The virtual & erect image formed at near point of Hypermetropic eye act as object for eye lens, finally eye lens forms real and inverted image of the object on the retina.

Note: In the case of hypermetropia, the convex lens increases the converging power of the eye lens.

Focal Length and Power of a convex Lens used to correct Hypermetropia: In the case of Hypermetropia the least distance of distinct vision is 25cm. Let **'d'** be distance of the near point of Hypermetropic eye. So in the case of Hypermetropia. Take u = 25 cm and v = d. So the focal length of convex lens can be calculated by using lens formula.

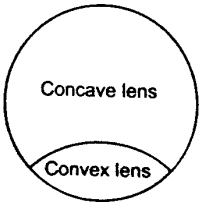
$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \qquad \Rightarrow \qquad \frac{1}{f}=\frac{1}{-d}-\frac{1}{-25}$$

$$\frac{1}{f}=\frac{-1}{d}+\frac{1}{25}$$

The power of convex lens can be calculated by using power formula or

$$P=\frac{1}{f(\text{inm})} \Rightarrow (P)=\frac{100}{f(\text{in cm})}$$

Note: When a person suffers from both the myopia as well as hypermetropia, then his spectacles have bi-focal lens, the upper half is a concave lens for distinct vision and lower half is a convex lens for reading purpose.



3. **Presbyopia:** This is an old age related Hypermetropia. In old age the elasticity of the eye lens decreases. Due to this ciliary muscles are unable to change effectively the focal length of eye lens. Hence near point of person shifts away from the eye. This defect can be corrected by using convex lens of suitable focal length.

   Note: The cause of hypermetropia is decreased in length of eye ball or decrease in conversing power eye lens but in the case of presbyopia there is only increase in focal length of eye lens. The eye ball in presbyopia has normal length.

4. **Cataract:** This problem arises in old age in old age an opaque membrane formed over the eye lens. This membrane reduces the intensity of light falling on the eye lens. Hence eye cannot see anything. Normal vision of eye can be restored only after the effected lens is removed by surgery and an artificial lens is planted at that place.

Why do we have two eyes: There are two advantages of two eyes.

1. **Two eyes gives a wider field of view**. A human can see a horizon view of about 150° with one eye with two eyes, the field of view becomes 180°.

   Note: The prey animals of (like rabbit, dear, chicken, fish etc.,) have their eyes the opposite side of their head. So, they can see very large area around them and try to escape from predators. Horse is a only domestic animals who has two eyes on the opposite sides of the head. The human being have two eyes infront of their head.

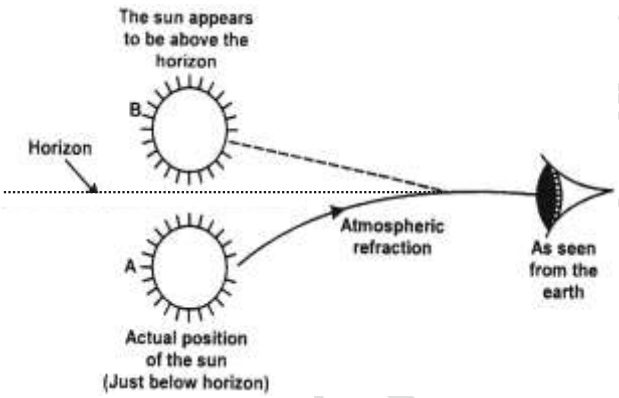
2. **Two eyes enables us to judge distance more accurately:** This is because two eyes see the same object from two slightly different angles and send two slightly different images of the same object to the brain. The brain combines these two images to form a three dimensional picture of the object which enables us to judge the accurate distance of the object.

   Note: All the predators have their eyes infront of head, so that they can judge accurate distance of their prey and catch them easily.

TOPIC : ATMOSPHERIC REFRACTION

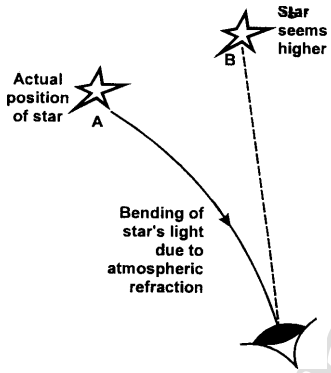
Definition: The refraction of light caused by the earth's atmosphere is called atmospheric refraction. Some examples of atmospheric refraction are given below.

Example 1: We can see the sun about 2 minutes before the actual sunrise and 2 minutes after the actual sunset this is because as we go up in the atmosphere. The density of layers of air decrease. We know that when light rays travel from rarer to denser medium then light rays bend toward the normal. The light rays coming from sun keeps on bending towards normal till it enters the eye of the observer. But our eyes always follow a straight path of light. Due to this, the sun appears above horizon although it is below the horizon. Thus the sun appears about two minutes earlier than actually when it should be.



For the same reason it keeps on appearing two minutes after sunset. Hence the day becomes four minutes longer.

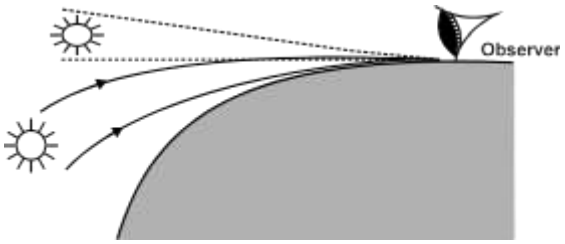
Example 2: Due to atmospheric refraction, the stars appears to be higher in the sky. This is because as we go up in the atmosphere. The density of larger of air decreases. We know that when light rays travel from rarer to denser medium then light rays bends towards the normal. The rays of light coming from a star keeps on bending towards normal. Till it enters the eyes of the observer, but our eyes always follow a straight path of light. Due to this star appears higher in the sky.



Example 3: The star appears twinkle at night, this is because the light rays coming from a star enters the earth's atmosphere, it undergoes refraction due to the different densities of layers of air. The densities of layers of air is continuously changing when the densities of layer of air decrease them atmosphere refracts more star - light towards us, the star appears to be bright and when the density of larger of air increases then atmosphere refracts less star - light towards us, then the star appears to be dim. In this way, the star - light reaching our eyes increases and decreases continuously. Due to this star appears to twinkle at night.

☞ **Why moon and planets do not twinkle at night:** This is because, the planets are very close to us, so they appear to be quite big to us. So, a planet or moon can be considered to be a collection of a very large number of point sources of light. The dimming effect produced by some of the point sources of light in one part of the planet or moon is nullified by the brighter effect produced by the point sources of light in its other part. Thus, on the whole, the brightness of a planet or moon always remains the same and hence it does not appear to twinkle.

Example 4: Sun appears bigger during sunset and sunrise, this is because at sunset and sunrise, the sun is near to the horizon. The rays of light coming from the upper and lower edge of the sun bend unequally while travelling through the atmosphere. As a result of this phenomenon, the sun appears bigger, oval or flattened.



At noon, the sun is overhead. The rays of light coming from the sun enter the atmosphere normally, hence they do no bend at all while passing through the atmosphere. Therefore, the sun appears circular at noon.

Topic: Scattering of Light

Scattering of light means to throw of light in various random direction. Light is scattered when it falls on various types of suspended particles in its path. The intensity of scattering of light is inversely proportional to the wave length of light colour. When the size of scatters is less than or nearly equal to the wavelength of light colour.

If the size of scatterer is greater then the size of the wavelength of visible light then each colour scatter almost in equal amount. We know that the wavelength of red light is greater than the wavelength of other colours. So, the intensity of scattered red light is less than the other colours. Since the wavelength of violet colour is smaller then the other colours. So intensity of scattered violet light is larger than the other colours.

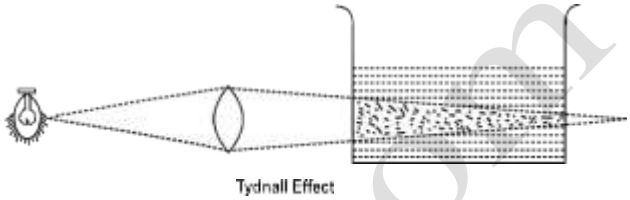
$$I \alpha \frac{1}{\lambda}$$ { When I is the intensity of light colour and λ is the wavelength of light colour.

Scatters: Dust particles, Fog, Smoke, Water droplets Atoms, Molecules of gases present in the atmosphere are called scatters.

☞ The blue colour of sky, greenish blue colour of sea water, red colour of sunset and sunrise and white colour of clouds are due to the scattering of the sun light by the particles present in the atmosphere.

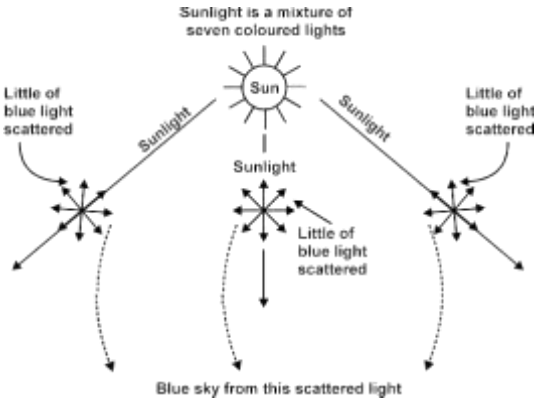
Topic: Tyndall Effect

When a strong beam of light is passed through a colloidal solution kept in a dark room the path of light being through the colloidal solution becomes visible. This occurs due to scattering of light by the colloidal particles. **Definition:** The scattering of light by particles in its path is called Tyndall effect.



Applications of Scattering of Light

Ex1. **Why is Sky Blue:** The sky appears blue. This is because, when sunlight enters the earth's atmosphere, The wavelengths of violet, indigo and blue colours are smaller than the wavelengths of other colours. We know that intensity of scattered light is inversely proportional to the wavelength light colour. So violet, indigo and blue colours are scattered in more amount than the other colours. But our eyes are very sensitive to the blue colour than the violet and indigo due to this clear sky appears blue.

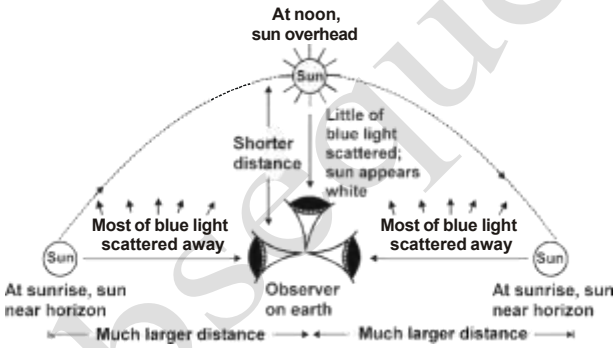


Ex2. **Sky appears grayish over cities:** This is because the smoke and dust particles in the atmosphere over such cities scatter mainly red, orange and yellow colours more than the other colours of smaller wavelengths. When these colours combine they give the shade of grey colour.
Note: Sky would appears black in daytime if earth had no atmosphere: This is because no scatterer present in the atmosphere. The sky appears dark for astronauts far from the

atmosphere of the earth. This is because no scatterer present in the space. When the earth had no atmosphere, sunlight would be visible only if we look directly towards the sun. Even the stars will be visible in daytime.

Ex3. **The sunset and sunrise appear red:** At the time of sunrise or sunset, the position of the sun is very far away from us. So, sunlight travels longer distance through the atmosphere. We know that intensity of scattering light inversely proportional to the wavelength of light colour. Since the wavelength of red colour is more than the other colours. So red colour scatter in small amount, then other colours. As a result of this, more red light reaches to eyes of the observer then other colour due to this sunset and sunrise appear red.

Ex4. **The sun appears white during noon:** This is because the sun is overhead and sunlight travels less distance through the atmosphere. So all colours of visible light scatter in small amount, hence large percentage of each colour reaches on the eyes of the observer due to this, the sun appears white at noon.



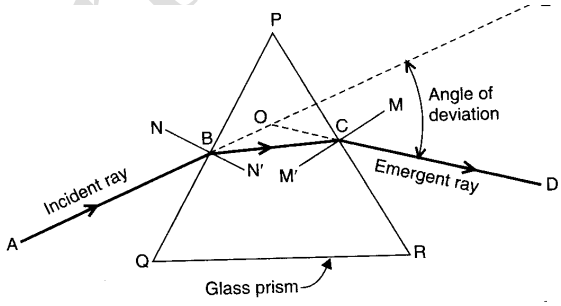
Ex5. **Why clouds appear white:** The clouds are at much lower height. They are seen due to scattering of light from lower parts of the atmosphere, which contains dust particles, water droplets, ice particles etc. as the size of these particles, more than the wavelength of all visible colours. So all colours of white lights are scattered nearly equal. When these scattered colours combine they give white light. Hence clouds generally appears white.

Ex6. **Why Danger Signals are red:** The danger signals are red this is because the wavelength of red colour is longer then the other colours. We have know that intensity of scattered light is inversely proportional to the wavelength of light colour. So red light scattered by atmosphere in small amount. Due to this large amount of red light reaches on the eye of the observer. Hence, red light can be seen even from a longer distance.

Topic: Refraction of light through glass prism

Prism: Prism is a homogenous transparent refracting medium bounded by atleast two non - parallel surface inclined at some angles.

Angle of Deviation: The angle between incident ray and emergent ray is called angle of deviation.



ACTIVITY-1

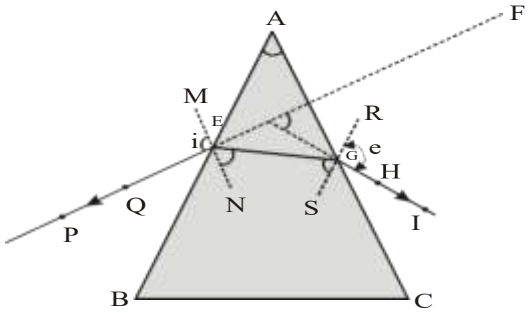
Aim: To find the angle of deviation of a ray of light passing through the prism

Procedure:

Step 1. Place a glass prism on a sheet of white paper

Step 2. Mark its boundary with H.B. Pencil.

Step 3. Now fix two pins at points P and Q as shown in fig.



Step 4. Look through the refracting face AC and fix two pins at point H and I such that the pins H and I and the image of pins P and Q lies in a straight line.

Step 5. Now remove the prism and all pins.

Step 6. Join the points P and Q and extend this line so that it touches the refracting surface AB at point E.

Step 7. Also join the points H and I and extend this line so that it touches the refracting surface AC at point G and join point E and G.

Step 9. Draw perpendiculars MN' and RS at the point E and G.

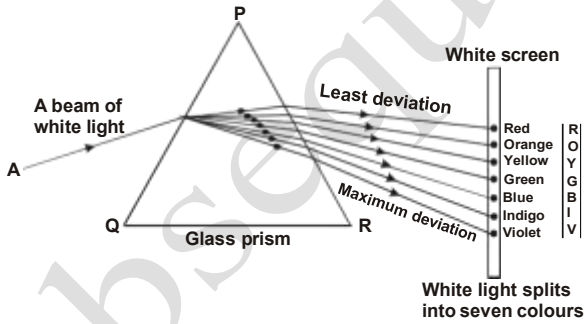
Step 10. Produce the emergent ray GHI backward so that it intersects the incident ray produced forward at point J.

Step 11. $\angle FJG$ is the angle of deviation which is required angle.

Topic: Dispersion & Spectrum

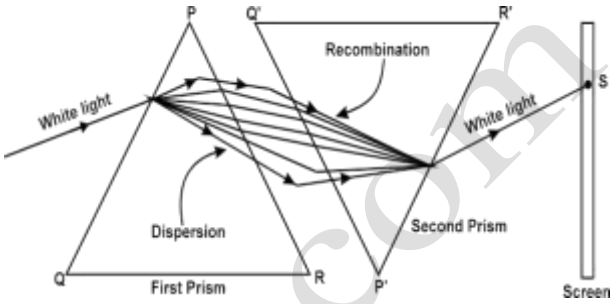
Despersion: The phenomenon due to which white light splits into seven colours when passed through a glass prism is called dispersion.

Spectrum: The band of seven colour formed on a white screen when a beam of white light is passed through a glass prism is called spectrum.



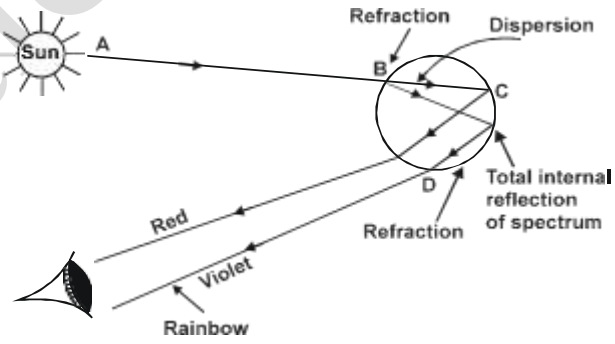
Cause of Dispersion: The main cause of dispersion is that the speeds of light of every colour are different in same medium due to their different wavelengths. So, every colour deviated with different angles in same medium. We know that the angle of deviation is inversely proportional to the wavelength of colour. Since the wavelength of the red colour is higher than the other colours so red colour is deviated with smaller angle and the violet colour is deviated with largest angle.

Recombination of spectrum: We know when white light passes through a glass prism then it is splits into seven colours. If another similar prism is placed alongside it in the inverted position. The first prism splits the white light into seven colours. The second prism all the seven colours and recombine them into original white beam of light.



Dispersion of light in Nature

Rainbow is a natural example of dispersion of white light in nature which is produced by the dispersion of sun's light by rain drops in the atmosphere.



Formation of a rainbow

Explanation: The rain drops in the atmosphere act like many small prism. The formation of rainbow can be explained with the help of a diagram as shown in the above fig. A ray of white sunlight AB enters the raindrops at point B and undergoes refraction and dispersion to form a spectrum. This spectrum when strike opposite face of rain drop at point C then it takes total internal reflection and finally refracted out of the raindrops at point D. The red colour of spectrum appears at the top of the rainbow whereas violet colour appears at its bottom.

• Rainbow is due to refraction, dispersion and reflection of light.

Condition for Rainbow: There are two conditions to see the rainbow. These are:

1. The Sun must be behind the observer.
2. During a rainfall or after the rainfall and at fountains.

KNOWLEDGEBOOSTER

- Any person of any age or sex (male or female) can donate eyes. People who wear spectacles or have undergone cataract operations can also donate eyes. Even the persons having ailments such as diabetes (sugar), hypertension (blood pressure) and asthma can donate eyes. But they should not have any communicable disease. like AIDS, hepatitis B or C, rabies, leukaemia, tetanus, cholera, meningitis, or encephalitis, however, cannot donate eyes.

- After the death of the person the eyes must be removed within 4 to 6 hours of a person's death. It takes only 10 to 15 minutes to remove the eyes. There is no disfigurement of the face in this process.

- For a young person the power of accomodation is about 4 dioptre.

- In the retina there are 125 million rod and 7 million cone cells, which are sensitive to light.

Note:

Note:

ACTIVITY 2

AIM: To study the phenomenon of scattering of light through a colloidal solution.

MATREIALS REQUIRED: Strong source of white light, two converging lens, transparent glass tank, water, cardboard, 200 gram of sodium thiosulphate(hypo). 2ml of conc. sulphuric acid.

PROCEDURE:

Step 1 Place a convex lens of known focal length on a stand.

Step 2 Place the source of white light at the focus of the convex lens.

Step 3 Allow the parallel beam of light, obtained from the convex lens to pass through a transparent glass tank containing clear water.

Step 4 Pass the emergent parallel rays from the tank through a circular hole in the cardboard.

Step 5 Place a second convex lens infront of the hole.

Step 6 Place a screen MN at the focus of this second hole.

Step 7 Dissolve about 200 gram of sodium thisulphate (hypo) in about 2 L of clean water in the tank.

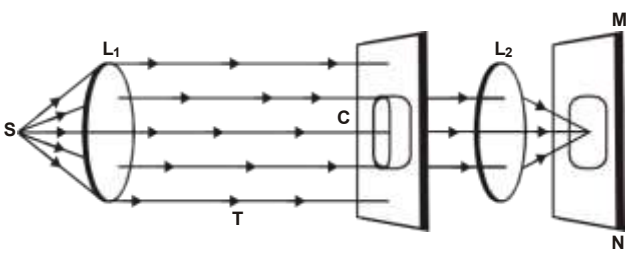
Step 8 Add 1- 2 ml of concentrated sulphuric acid to the water.

Step 9 Observe the colour from three sides of the glass tank.

Step 10 Observe the colour of the transmitted light from the side of the glass tank facing the circular hole.

OBSERVATION:

1. From three sides of the glass tank, we observe blue colour of light.
2. From the side of the glass tank facing the circular hole, first orange, red colour, then bright-crimson red colour us observed on the screen.



ACTIVITY 3

AIM: To study the dispersion of white light by a glass prism.

MATERIAL REQUIRED: Cardboard, glass prism, white screen.

PROCEDURE:

Step 1 Take the thick sheet of cardboard and make small hole in its middle.

Step 2 Allow sunlight to fall on the narrow slit.

Step 3 Take a glass prism and allow the narrow beam of white light emerging from the hole in the cardboard to fall on it.

Step 4 Turn the prism and allow the narrow beam of white light emerging from the hole in the cardboard to fall on it.

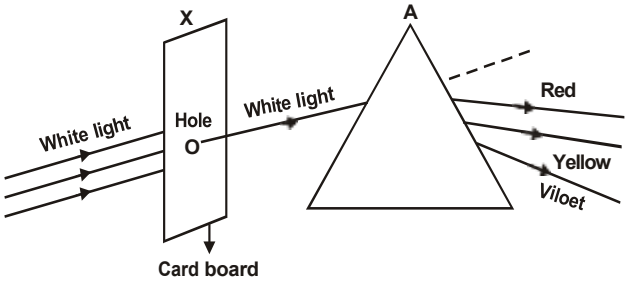
Step 5 Observe the sequence of colours on the screen.

OBSERVATION:

1. A coloured pattern is seen on the screen.
2. The colour sequence is – Violet, Indigo, Blue, Green, Yellow, Orange and Red, ordered from bottom to top.

CONCLUSION:

1. Ray of white light when passed through a prism disperses in seven constituent colours.
2. Different colours of light bend through different angles when passed through the prism.
3. Red light bends least while violet bends the maximum.
4. Dispersion occurs due to different degree of refraction, hence different degrees of bending of different colours of light.



ACTIVITY 4

AIM: Recombination of white light by glass prisms

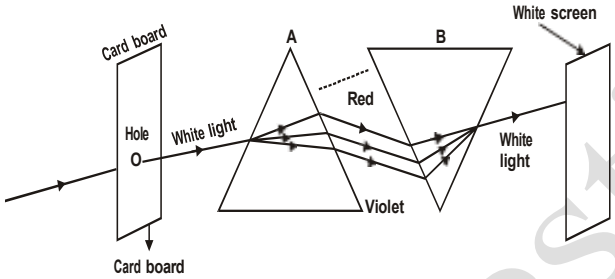
APPARTUS REQUIRED: Two glass prisms made of some kind of glass, a card board having a fine hole at its centre, a white screen.

PROCEDURE:

Step 1 Place a card board in front of a prism A. A ray of white light coming from the hole in the card board falls on the prism A.

Step 2 White light splits into seven colours by prism A is made to fall on another glass prism B placed with its base upward. Since prism A disperses white light, so it is known as dispersing prism.

Step 3 The prism B deviates colours of light towards its base. The various colours recombines at the opposite face of glass prism B.



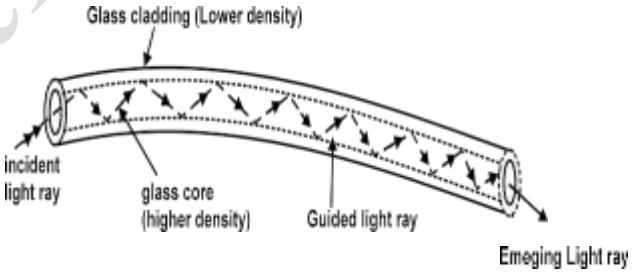
Step 4 The light received on the white screen placed of prism B is white. Since the prism B recombines the colours of light to produce white light, so glass prism B is known as recombination prism.

This activity was initially performed by the great scientist Issac Newton.

Notes:

KNOWLEDGE BOOSTER

✪ We use optical fibres nowadays to transmit voice, video and data signals in tele - communication networks. Optical fibres have the unique ability of transmitting signals without any loss of energy. We know that there is no loss of energy in total internal reflection. Optical fibres utilize this concept for transmission of signals through it. Optical fibres are as thin and flexible as human hair. It has a very thin core made of pure glass, surrounded by a cladding, also made of pure hair. It has a very thin core made of pure glass, surrounded by a cladding, also made of pure glass, having slightly lower refractive index. When light rays (signals) are passed through the core, the light rays suffer total internal reflection at the core - cladding surface. This reflection lets the signal travel through the fibre for as long as 200 kms.



Notes: