Introduction

This is a learning as well as an exam preparation video.

At the end of the video are practice assignments for you to attempt.

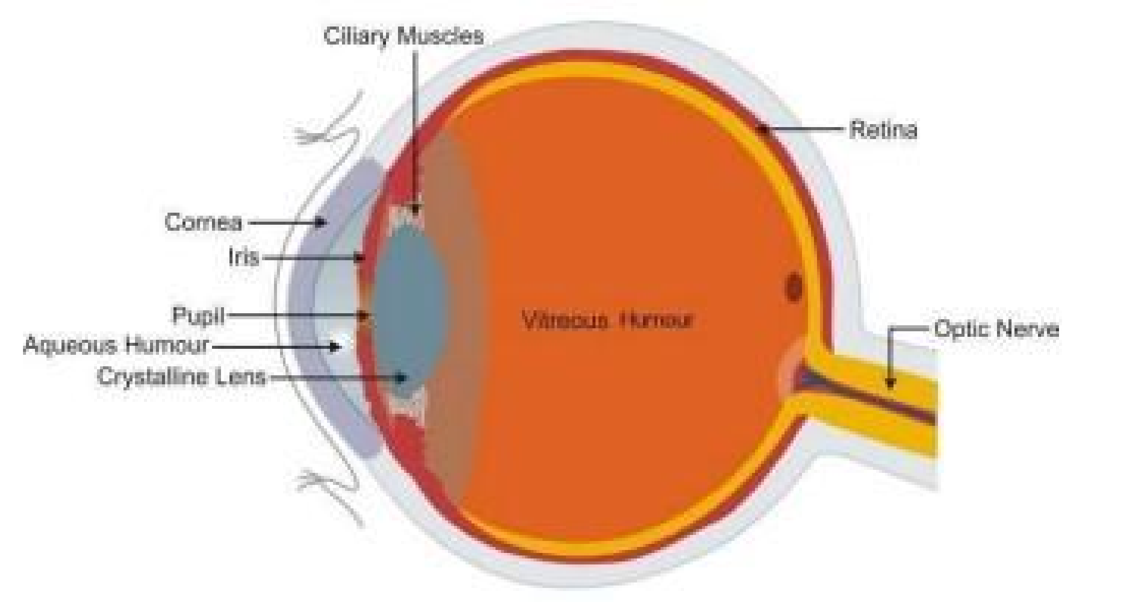
Please go to www.eastpoint.intemass.com/ or click on the link at the bottom of this video to do the assignments for this topic.

Chapter 2: Human Eye and the Colorful World

Chapter 2: Human Eye and the Colorful World

Human Eye

The human eye is an important and valuable sense organ which uses light and enables us to see the colourful world around us.



Chapter 2: Human Eye and the Colorful World

Human Eye

The various parts of the human eye and their respective functions include

Part	Function
Cornea	Protective layer of the eye Refraction of light rays entering the eye
Eye lens	Adjust the focal length and form an inverted image of the object on the retina
Pupil	Regulates the amount of light entering the eye
Iris	Controls the size of the pupil
Retina	Acts as a screen for forming the image
Ciliary muscles	Adjust the thickness of the lens
Optic nerves	Send signals to the brain

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Human Eye

- The image of any object seen persists on the retina for 1th/16 of a second, even after the removal of the object. This continuance of sensation on the eye for some time is called persistence of vision.
- The numerous light-sensitive cells contained in the retina of the eye are of two types:
  - Rod-shaped cells which respond to the brightness or intensity of light.
  - Cone-shaped cells which respond to the colour of light.

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Power of Accommodation of the Human Eye

- Power of accommodation of the eye is the ability of the eye to observe distinctly the objects, situated at widely different distances from the eye, on account of change in the focal length of the eye lens by the action of the ciliary muscles holding the lens.
- The farthest point up to which the eye can see objects clearly is called the far point (F) of the eye. It is ideally infinity for a normal eye.

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Power of Accommodation of the Human Eye

- The point of closest distance at which an object can be seen clearly by the eye is called the near point (N) of the eye. For a normal eye, the near point is 25 cm, which is called the least distance of distinct vision (d) of a normal eye.
- The distance between the far point (F) and near point (N) is called the range of vision of the eye.

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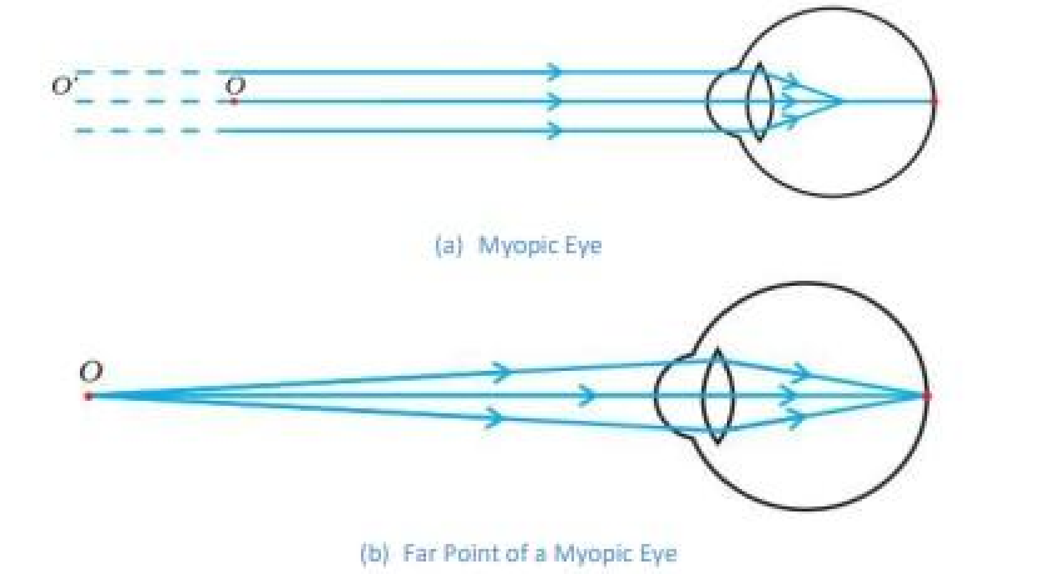
Defects of Vision

(a) Myopia or Short-Sightedness

A person with myopia can see nearby objects clearly but cannot see distant objects distinctly, as if the far point of the eye has shifted from infinity to some particular distance from the eye.



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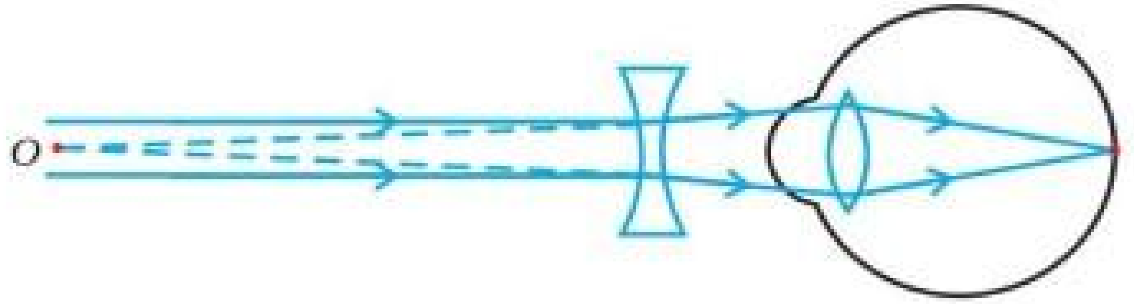
Defects of Vision

This defect may arise due to (i) excessive curvature of the eye lens or (ii) elongation of the eyeball.

To correct myopia, the person has to wear spectacles with a concave lens of focal length equal to the distance of far point of the myopic eye.



(c) Correction for Myopia

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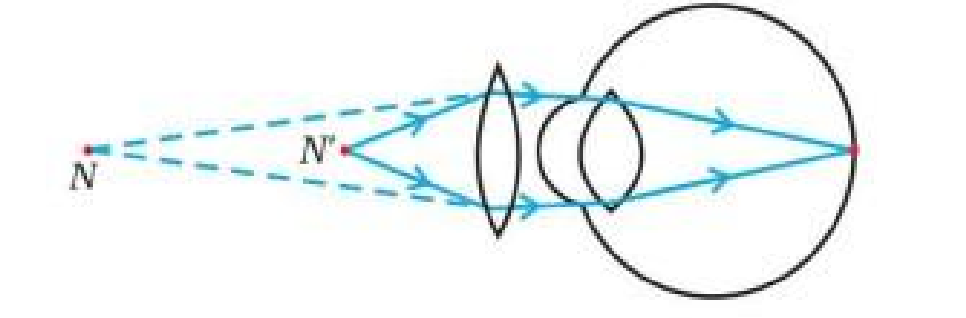
Defects of Vision

This defect may arise because (i) focal length of the eye lens is too long or (ii) the eyeball has become too small.

To correct hypermetropia, the person has to wear spectacles with a convex lens of focal length f, given by $f \; \frac{x' d}{x' - d}$

, where d is the least distance of distinct vision and x′ is the distance of near point N of the hypermetropic eye.



(c) Correction for Hypermetropia eye

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Defects of Vision

(c) Presbyopia

Presbyopia is a human eye defect because of which an old person cannot read and write comfortably.

It occurs in old age when the ciliary muscles holding the eye lens weaken and the eye lens loses some of its flexibility.

To correct presbyopia, an old person has to wear spectacles with a convex lens of suitable focal length (as in hypermetropia).

Sometimes, a person may suffer from both myopia and hypermetropia. Such a person requires bi-focal lenses. The upper part of a bi-focal lens consists of concave lens facilitating distant vision, and the lower part consists of convex lens facilitating nearby vision.

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Refraction through a glass prism

- If you take a glass prism, you can see that it has 2 triangular bases and three rectangular lateral surfaces, inclined at an angle. This angle is called the angle of the prism.
- Let’s look at a top view of a triangular prism with a ray of light entering it.

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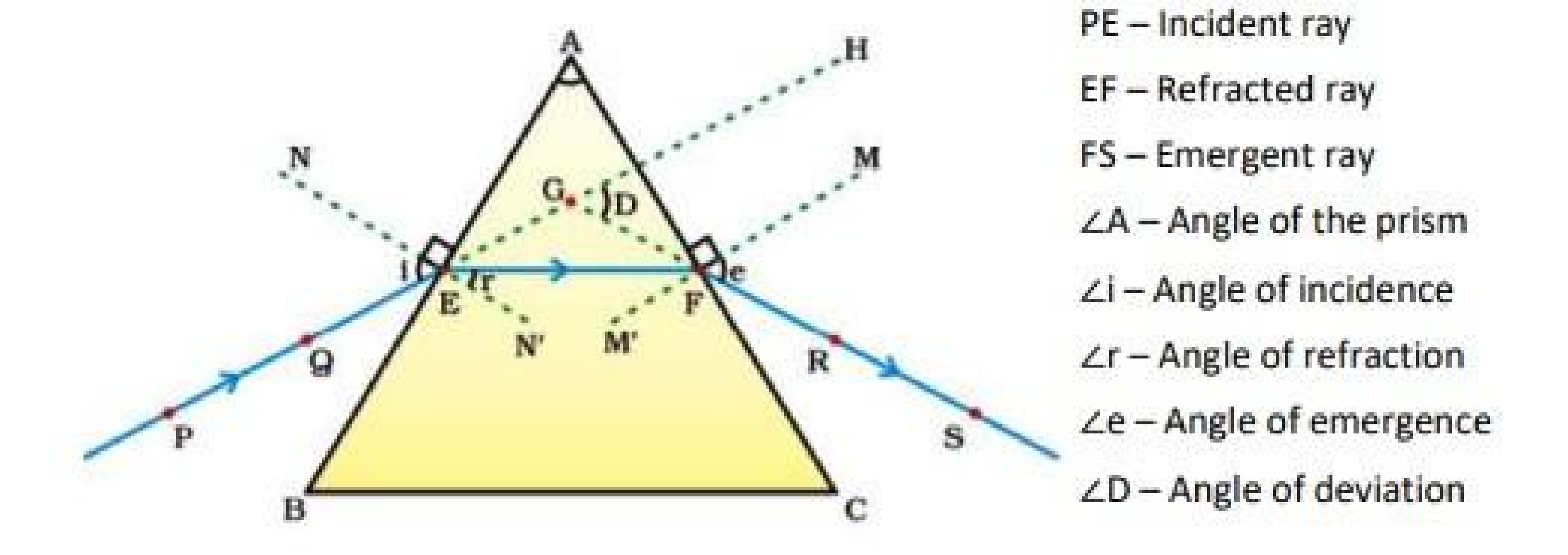
Refraction through a glass prism



In the figure above, A is the angle of the prism.

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Refraction through a glass prism

- As per Snell's law, light travelling from a rarer medium to a denser medium bends towards the normal, and vice versa. Glass is denser than air, and thus, when a ray of light falls on the surface of the prism, it bends towards the normal. According to the diagram, ray PE falls on the surface of the prism and bends towards the normal NE.
- Then, while moving from the glass to air, the emergent ray FS bends away from the normal.

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Refraction through a glass prism

- ∠HDS is the angle of deviation which tells us how much the emergent ray has deviated from the incident ray. When the angle of incidence is equal to the angle of emergence, the angle of deviation is minimum.
- According to the figure, ∠PEN = ∠MES and ∠HDS is thus the angle of minimum deviation. The refracted ray EF is parallel to side BC in this case.

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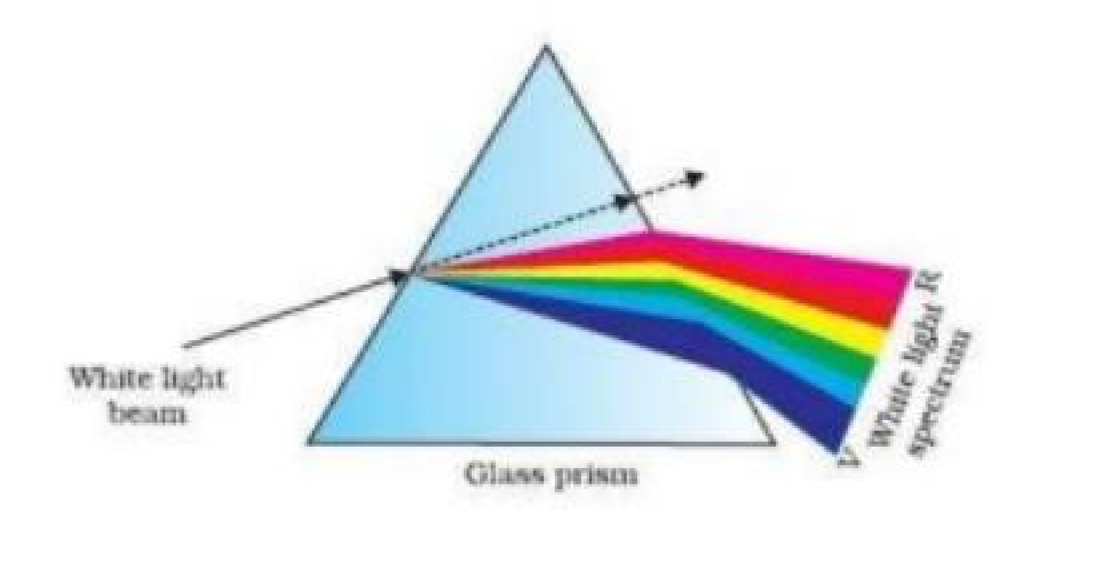
Dispersion of Light

- **Dispersion of light is the phenomenon of splitting of a beam of white light into its seven constituent colours on passing through a glass prism.**



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Dispersion of Light

- The band of coloured components of a light beam is called its spectrum.
- The sequence of colours given by the prism is Violet, Indigo, Blue, Green, Yellow, Orange and Red. VIBGYOR is the acronym for this sequence.
- The cause of dispersion is that different colours of white light with different wavelengths undergo different deviations on passing through a glass prism.

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Dispersion of Light

- If a second identical prism is placed in an inverted position with respect to the first prism, all the seven colours recombine to form white light.
- The rainbow is a beautiful example of dispersion of light in nature. Sunlight gets dispersed on passing through tiny droplets of water suspended in air during or after a shower.

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Dispersion of Light

Isaac Newton was the first to use a glass prism to obtain the spectrum of sunlight. Hetried to split the colours of the spectrum of white light further by using another similarprism. However, he could not get any more colours. He then placed a second identicalprism in an inverted position with respect to the first prism, allowed all the colours of the spectrum to pass through the second prism. He found a beam of white light emerging from the other side of the second prism. This observation gave Newton the idea that the sunlight is made up of seven colours.

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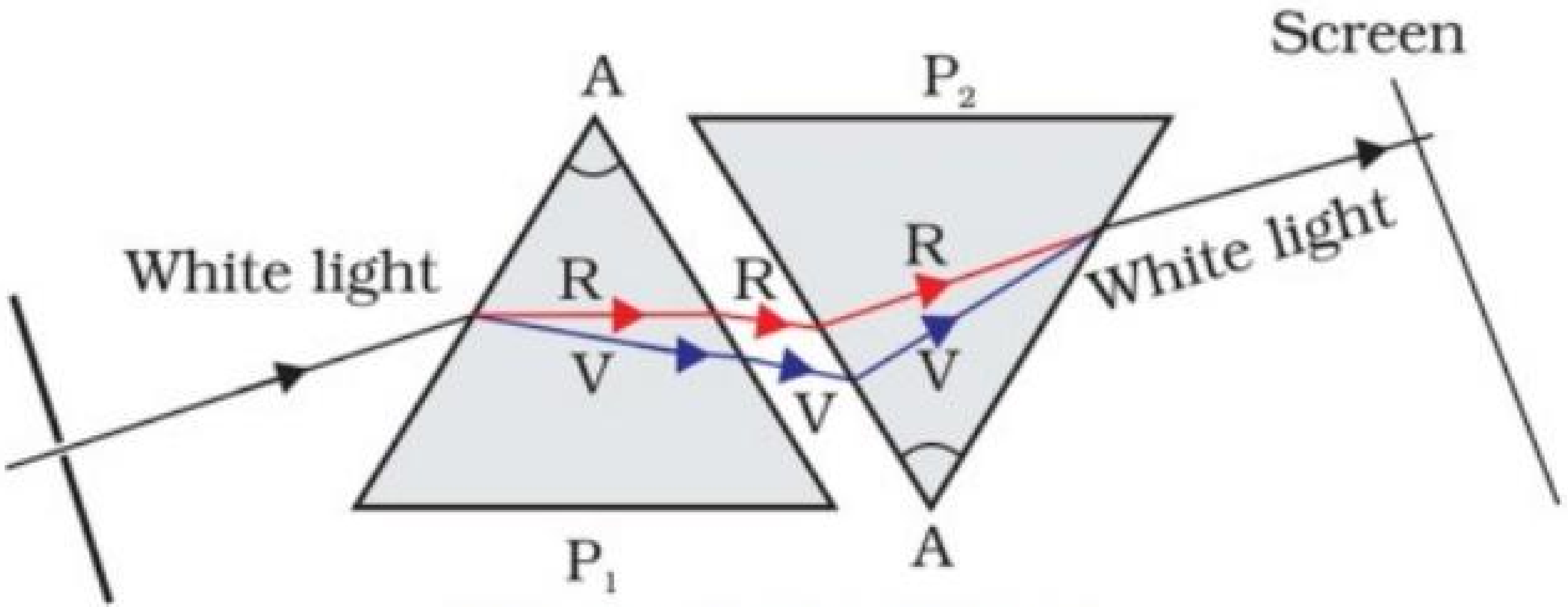
Dispersion of Light



Recombination of the spectrum of white light

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Atmospheric Refraction

- Atmospheric refraction is the phenomenon of bending of light on passing through the Earth’s atmosphere. This reason for this occurrence is that the upper layers of the Earth’s atmosphere are rarer compared to the lower layers.
- On account of atmospheric refraction of light,
  - The stars seem higher than they actually are.
  - The Sun appears to rise 2 minutes before and set 2 minutes later, increasing the apparent length of the day by 4 minutes.
  - The Sun appears oval at sunrise and sunset, but appears circular at noon.
  - The stars twinkle and planets do not.

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Scattering of Light

The scattering of light is one of the most important phenomena in daily lives. This phenomenon has been seen by everyone from their childhood like the blue colour of the sky, the colour of the rainbow, etc. The scattering of light is completely different from the reflection and refraction of light. In reflection of light, the light goes in a straight line whereas in the scattering of light the light ray gets scattered in different directions by the medium through which it passes.

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Scattering of Light

The process by which small particles are present in the atmosphere causes the scatter in the light which in turn gives rise to optical phenomena such as the blue colour of the sky in which we term as the scattering of light.

Example: When light strikes the particles in the air, the particles absorb some light and radiate the rest in all directions except the incident direction. This is called "scattering of light". The wavelength of the light and the size of the particle which scattered the light assists in determining the strength of the scattering.

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Scattering of Light

Let p be considered as the probability of scattering and λ is the wavelength of radiation, then it is given as:

$$P = \frac{1}{\lambda^4}$$

The probability for scattering will give a high rise for shorter wavelength and it is inversely proportional to the fourth power of the wavelength of radiation.

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Tyndall Effect

The Tyndall effect is the phenomenon in which the particles in a colloid scatter the beams of light that are directed at them. This effect is exhibited by all colloidal solutions and some very fine suspensions. Therefore, it can be used to verify if a given solution is a colloid. The intensity of scattered light depends on the density of the colloidal particles as well as the frequency of the incident light.

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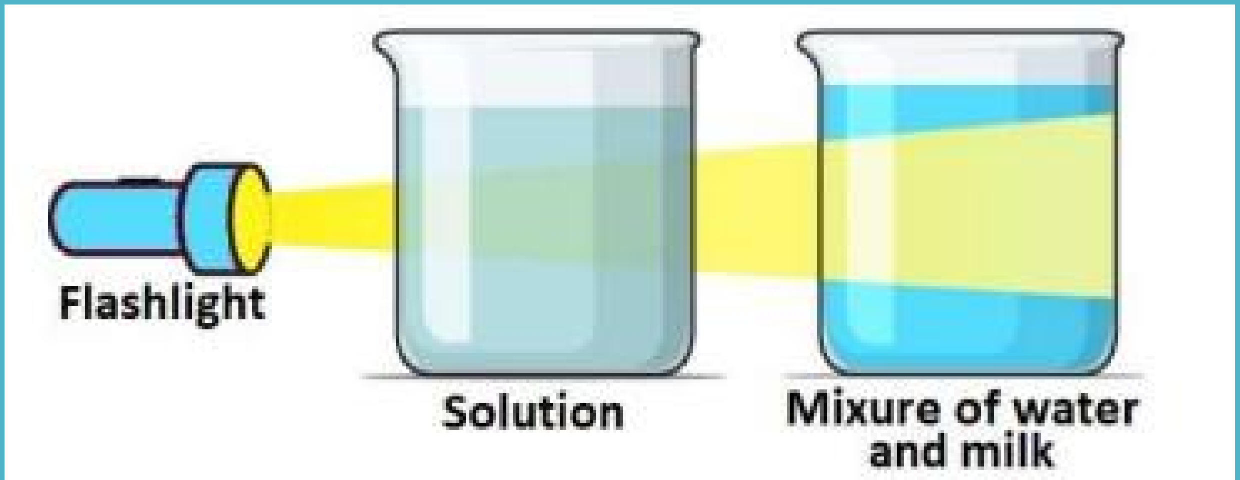
Tyndall Effect

When a beam of light passes through a colloid, the colloidal particles present in the solution do not allow the beam to completely pass through. The light collides with the colloidal particles and is scattered (it deviates from its normal trajectory, which is a straight line). This scattering makes the path of the light beam visible, as illustrated below.



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Tyndall Effect

Generally, blue light is scattered to a greater extent when compared to red light. This is because the wavelength of blue light is smaller than that of red light. This is the reason why the smoke released by motorcycles sometimes appears blue.

The Tyndall effect was first discovered by (and is named after) the Irish physicist John Tyndall. The diameters of the particles that cause the Tyndall effect can range from 40 to 900 nanometers (1 nanometer = 10-9 meter). In comparison, the wavelength of the visible light spectrum ranges from 400 to 750 nanometers.

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Tyndall Effect

Examples of Tyndall Effect

We get to see Tyndall effect in our surroundings very often, some of the examples are

- When a beam of sunlight enters the dark room through small hole or window then its path become visible due to scattering of light by the dust particles present in the room.
- When a beam of light is projected on a screen from a projector in the cinema hall, it becomes visible.
- When sunlight passes through the canopy of a dense forest it get scattered by tiny water droplets.

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Tyndall Effect

The colour of the clear Sky Blue

The molecules of air and other fine particles in the atmosphere have smaller size than the wavelength of visible light. These are more effective in scattering light of shorter wavelengths at the blue end than the light of longer wavelength at the red end. Thus, the blue colour is due to the scattering of sunlight through fine particles in air.

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Tyndall Effect

Why does the sky appear dark instead of blue to an astronaut?

The sky appears dark instead of blue to an astronaut because there is no atmosphere in the outer space that can scatter the sunlight. As the sunlight is not scattered, no scattered light reach the eyes of the astronauts and the sky appears black to them.

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Tyndall Effect

Colour of Sunrise and Sunset

While sunset and sunrise, the colour of the sun and its surrounding appear red. During sunset and sunrise, the sun is near to horizon, and therefore, the sunlight has to travel larger distance in atmosphere. Due to this, most of the blue light (shorter wavelength) is scattered away by the particles. The light of longer wavelength (red colour) reaches our eye. This is why sun appears red in colour.

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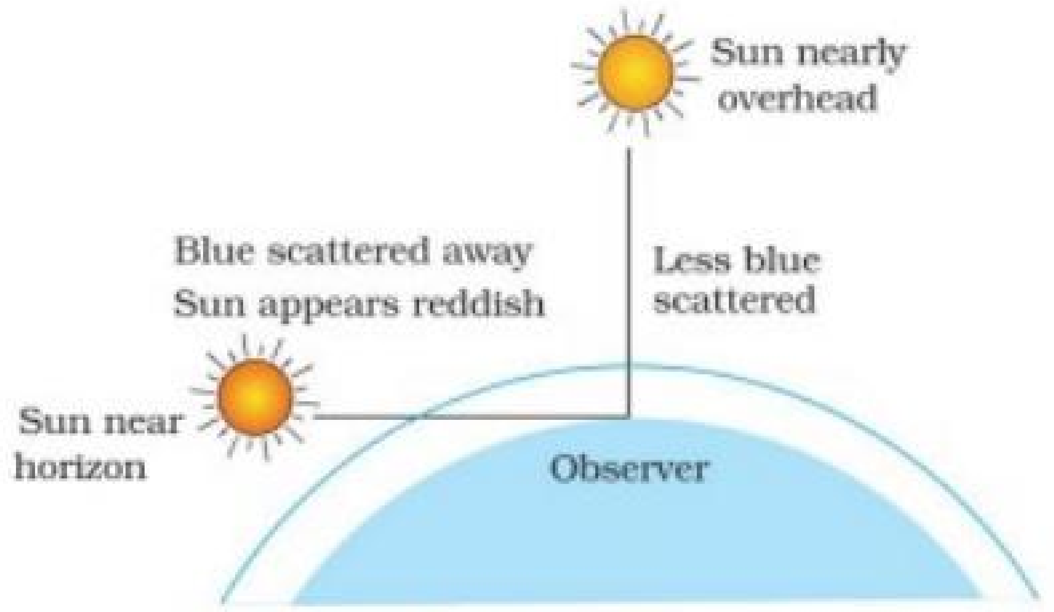
Tyndall Effect

Colour of Sunrise and Sunset



Reddening of the Sun at sunrise and sunset

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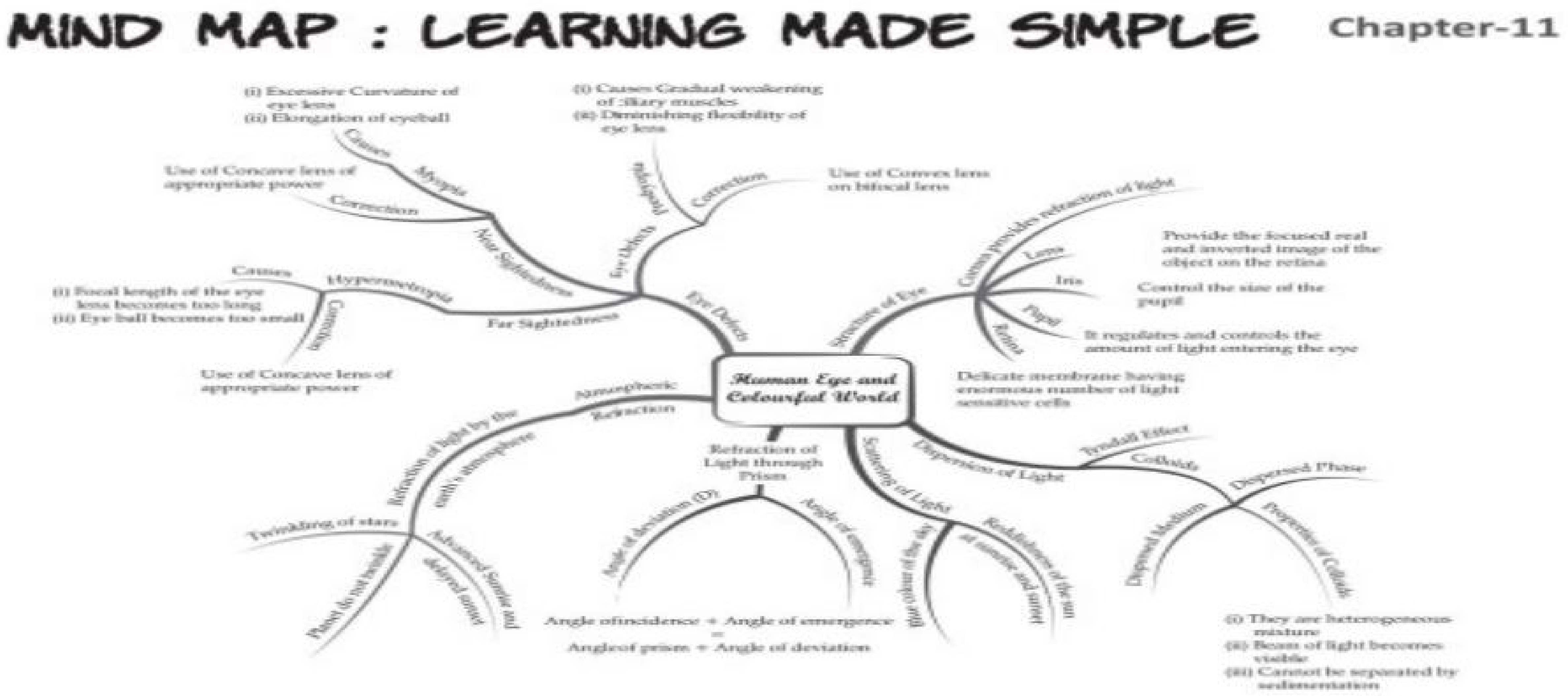

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