

Chapter 6: Dispersion of Light

Sir Issac Newton, while working with the astronomical telescope, observed that the images of stars were coloured near the fringes. He then got the lenses of the telescope polished, but found that the colour still persisted. From these observations he suggested that the fault may not be with the lenses, but there is something in the nature of the light itself.

Sir Issac Newton found that the white light is a composed of a band of seven colours, resembling the rainbow formed after the rain, when he placed a glass prism in the path of light. The order of colours from the base of the prism was **violet, indigo, blue, green, yellow, orange and red**. The order of colours can be easily remembered by the word **VIBGYOR**.

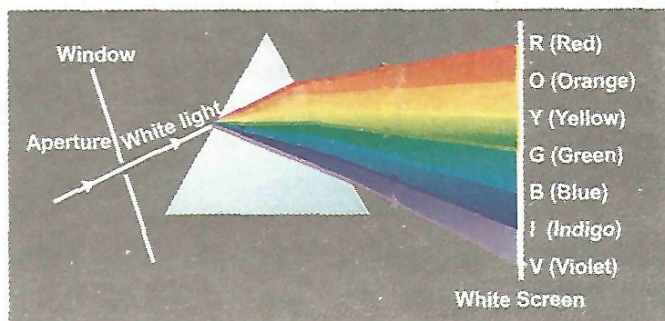


Fig. 2.13 : Dispersion of white light by a glass prism

Definitions

- 1) Dispersion of light:** The splitting up of a white light into seven colours on passing through a transparent medium like a glass prism.
- 2) Dispersion:** The phenomena due to which a white light splits into its component colours, when passed through a prism.
- 3) Spectrum:** The band of seven colours obtained on the screen, when a white light splits into its component colours.
- 4) Impure Spectrum:** A spectrum in which various bands of colours have no sharp well-defined boundaries, but merge in each other.
- 5) Pure Spectrum:** A spectrum in which various bands of colours have sharp well-defined boundaries, but do not merge in each other.

Note: The seven colours of spectrum **differ only in their frequencies**. These colours in the order of **increasing frequency** but **decreasing wavelengths** from **Red to violet**

Recombination of spectrum colours to a given white light

Newton showed that the seven coloured lights of the spectrum can be recombined to give back white light. **(See Figure 6.4 on page 210)**

What causes dispersion of white light?

White light is a mixture of several waves of electromagnetic radiations, whose wavelengths vary **from 700nm to 400nm**. The highest wavelengths produce red sensation in the eye, whereas the lowest wavelengths produce violet sensation. The wavelengths between the **700nm** and **400nm** produce the effect of **indigo, blue, green, yellow and orange**. These waves travel with same speed (3×10^8 m/s) in vacuum. **(See Figure 6.5 on page 211)**

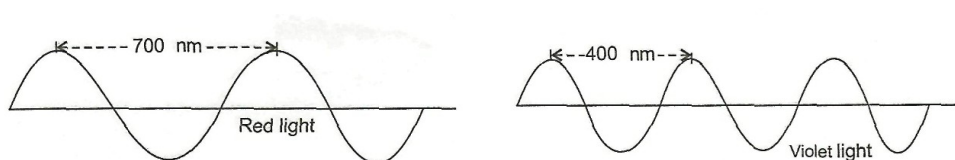


Fig. 2.17 : White light has wavelengths between 700 nm to 400 nm.

Monochromatic light: A light of a single colour or single wavelength. The word **Mono** means **one alone**, whereas the word **chrome** means **colour**.

Polychromatic light: A light which made of two or more colours. Sunlight is polychromatic as it is made of seven colours.

The word **Mono** means **one alone**, whereas the word **chrome** means **colour**. The word **Poly** means **many**.

RAINBOW

Rainbow is one of the most beautiful examples of spectrum formed due to the dispersion of light in nature. **The rainbow is produced due to the dispersion of sunlight by tiny droplets of water suspended in air, just after rain.** **(See Figure 6.6 on page 212)**

Note: Rainbow is always formed in the direction opposite to that of the sun. For example, if the sun is towards west, the rainbow is formed on the eastern horizon.

ATMOSPHERIC REFRACTION

- 1. When we sit around a campfire, the face of a person sitting opposite to you appears to shimmer:** This happens due to refraction of light since the hot air is rapidly moving and its optical density the path of refracted rays also changes. This gives rise to shimmering effect.
- 2. Apparent position and twinkling of stars:** Atmosphere consists of a number of parallel layers of air of varying densities, such that the densest layer is near the surface of the earth and the least dense layer is far away from the surface of the Earth. Thus **it appears to twinkle.**
- 3. Why does sun appear bigger during sunset or sunrise?**
During sunset or sunrise, **the rays of light travel through maximum length of atmosphere**, therefore refraction is also maximum. Hence, apparent image of sun is very much closer to eye. Thus, it appears bigger.
Note: It has been found that sun is visible to us about 2 minute before the actual sunrise and 2 minutes after the actual sunset, **because of refraction.**

SCATTERING OF LIGHT

Is the phenomenon due to which a particular wave (colour) of light is absorbed by a particle, which is greater in diameter than the wavelength of the light and then transmits it in all possible directions.

SOME COMMON PHENOMENA OF ATMOSPHERIC SCATTERING

1. Why does sky appear blue?

When the white sunlight passes through upper atmosphere, the violet, indigo and blue colours scatter which makes the sky to appear blue.

2. Why is the sunlight reaching the earth yellowish?

The white light gets deficient in violet, indigo and blue colour on account of scattering. Thus, it appears yellowish instead of white.

3. Why does the sun appears yellowish?

When the violet, indigo and blue colours scatter in the upper atmosphere, the resultant sunlight is yellowish in colour. When this light enters our eyes, then the sun appears yellowish.

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

In space, no particles are present. Thus, no scattering of light takes place. Hence, the sky appears dark as light by its own nature is invisible.

5. Why do the sun and the horizon appear reddish during sunset or sunrise?

Not only the violet, indigo or blue, but yellow, orange and red wavelengths of white light scatter. As the red light scatters last of all and is nearest to the eye, therefore, the sun and the horizon appear reddish.

6. Why do the distant hills appear blue?

In the thick growth of trees on the hills there are always present some amount of tiny droplets of water in the air. When the white light passes through this moisture laden air, the blue light is scattered. When this scattered light reaches our eyes, the hills appear blue.

7. Why does smoke coming out of coal fired chimney appear blue on a misty day?

The tiny particles of smoke and moisture scatter blue colour of the white light passing through it. When this scattered blue light reaches our eyes, the smoke appears blue.

8. Why do motorists use orange lights, rather than normal white light on a foggy day?

If a motorist uses white light while driving in fog, then the tiny droplets of water scatter large amount of blue light. This scattered blue light on reaching the eyes, decreases visibility, and hence, driving becomes extremely difficult. However, when orange lights are used, they don't get scattered on account of their longer wavelengths, and hence, the driver can

see ahead clearly. It is for the same reason that rescue workers wear orange coloured suits. Similarly, children's buses are painted orange, so that they are easily visible in the foggy conditions, smoke or rain.

9. Why is red light used as a universal danger signal?

The red light has largest wavelength among the spectral colours, and hence, is least scattered. Thus, red light can easily pass through fog or mist or smoke without getting scattered, and hence, is visible from a long distance.

(Answer the lesson exercises 1-10 on page-218)

Colours and pigments

Pigments: Is colouring material, which may be mineral, animal, vegetable or synthetic origin

Colour of opaque object in white light: The colour of the object depends upon the **wave bands it absorbs, reflected or transmits** when white light is incident on it.

Colour of transparent object in white light

The colour of transparent object depends upon:

a) Which colours of white light are absorbed. b) Which colours of white light are transmitted.

Colours of opaque objects in coloured light

The colour of an opaque object in coloured light depends upon **pigment present in the object**. It is the pigment which selectively absorbs or reflects coloured light falling on it.

Using filters of primary colours

- 1) **Red filters** absorb all except **red light**.
- 2) **Blue filters** absorb all except **red light**.

3) **Green filters** absorb all except **green light**. (See Figure 6.13 on page 221)

Mixing Colours: They are primary and secondary colours

Primary colours are **red, green and blue** because they produce the rest of the colours and cannot be obtained by mixing of two or more colours. The secondary colours are **yellow, cyan and magenta**. The tertiary colour is **white**.

Note: Black is not colouring at all.

Pair of complementary colours: The complementary colours are two colours (one primary and the other secondary) whose combination is white.

- ✓ Yellow = Red + Green
- ✓ Cyan = Blue + Green
- ✓ Magenta = Red + Blue
- ✓ White = Yellow + Blue
- ✓ White = Cyan + Red
- ✓ White = Magenta + Green

(See Figure 6.15 on page 223)

Colour of mixing as an additive process: Colour mixing is an additive process, i.e., the retina is simultaneously excited for two or more colours, thus the optical message mix in brain to form a new colour.

Primary Pigments: Cyan, yellow and magenta form primary pigments. In away primary pigments are the secondary spectral colours.

- ✓ Yellow pigment + Cyan pigment = Green pigment
- ✓ Yellow pigment + magenta pigment = Red pigment
- ✓ Cyan pigment + magenta pigment = blue pigment
- ✓ Yellow pigment + Cyan pigment + magenta pigment = Black pigment

(Answer the lesson exercises 1-10 on page-226)

Invisible Spectrum

Are the regions of spectrum which do not excite the retina and hence are not visible are collectively.

Infrared Spectrum

Are the electromagnetic radiations beyond red of visible spectrum, called infrared radiations and the spectrum.

Their wavelength extends $8000 \times 10^{-10}\text{m}$ to $400000 \times 10^{-10}\text{m}$, and this part of spectrum discovered by **William Herschel** in **1800**.

Source of infra-red radiations: As a matter of fact, any substance which radiates out heat energy.

Properties of infra-red radiations

- 1) Being electromagnetic waves they are not effect by electric or magnetic field.
- 2) They travel with velocity of light of $3 \times 10^8\text{m/s}$.
- 3) They obey laws of reflection and refraction.
- 4) Their wavelength is between $8000 \times 10^{-10}\text{m}$ to $400000 \times 10^{-10}\text{m}$.
- 5) They can be detected by a thermopile or a thermometer.
- 6) They do not effect ordinary photographic film.
- 7) They are least scattered by fog, mist, owing to their long wavelength.

Uses of infra-red rays

- 1) They are used by doctors for therapeutic purposes, such as swollen joints and muscles.
- 2) They can be used for taking photographs.
- 3) Specially prepared devices can see the objects in darkness. These devices are generally called night vision.

Ultra violet spectrum: Is the region of spectrum which extends beyond violet colour of visible spectrum. The portion of spectrum was discovered by **Professor J.Ritter** in **1801**.

Source of ultra-violet radiation

- 1) Any source of light at the temperature more than 2500°C
- 2) The electric sparks or electric lamp arc
- 3) Mercury vapour lamps
- 4) Sunlight

Properties of ultra-violet radiations

- 1) Being electromagnetic waves they are not effect by electric or magnetic field.
- 2) They travel with velocity of light of $3 \times 10^8 \text{m/s}$.
- 3) Their wavelength is between $400\text{\AA}$ to $1000\text{\AA}$. ($\text{\AA} = 10^{-10}\text{m}$)
- 4) They obey laws of reflection and refraction.
- 5) They produce florescence in substances, like zinc sulphate, barium sulphate.
- 6) They produce chemical effect in silver salts.
- 7) They are absorbed by the atmosphere and convert oxygen to ozone.

Uses of ultra-violet radiations

- 1) Ultra-violet radiations produce a vitamin D which is very good for growth of strong bones and teeth.
- 2) Ultra-violet radiations have lethal effect on microorganisms.
- 3) Ultra-violet radiations are used to detect forgery of cheques important documents, by erasing original writing.
- 4) Ultra-violet radiations are used to detect adulteration in ghee because of its property of florescence.
- 5) Ultra-violet radiations are used to detecting original diamonds from fake diamonds.

(Answer the lesson exercises 1-10 on page-232)

