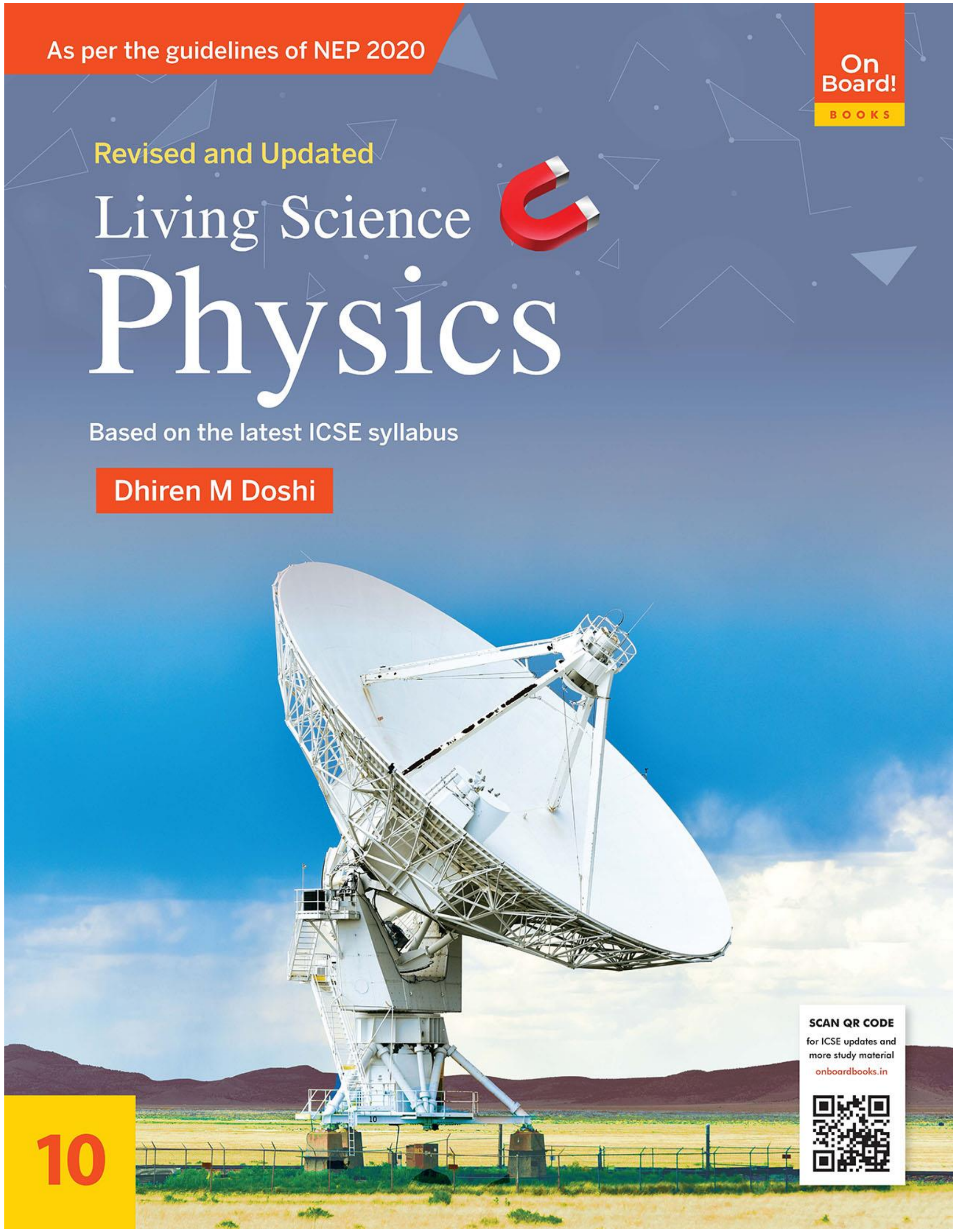
ICSE
Living Science
Physics

Class 10

Chapter 6 Spectrum

On Board! BOOKS



LEARNING OBJECTIVES

Deviation produced by a triangular prism

❖ Factors affecting the angle of deviation

Dispersion of light

❖ Causes of dispersion

Pure and impure spectrum

❖ Newton's experiment to show that the prism by itself produces no colours

Newton's experiments on dispersion and recombination of colour lights

❖ Two Prism experiment

❖ Newton's colour disc

Electromagnetic spectrum

❖ Visible spectrum and invisible spectrum

Infrared radiations

Ultraviolet radiations

❖ X-Rays

❖ Gamma Rays

❖ Radio waves

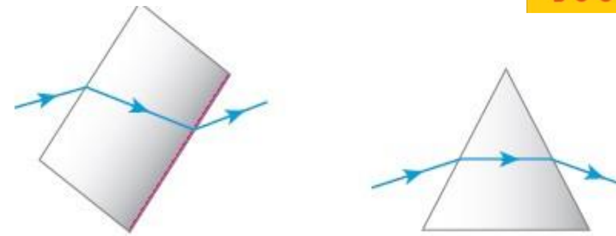
❖ Microwaves

Scattering of light

❖ Applications of scattering

Deviation Produced by a Prism

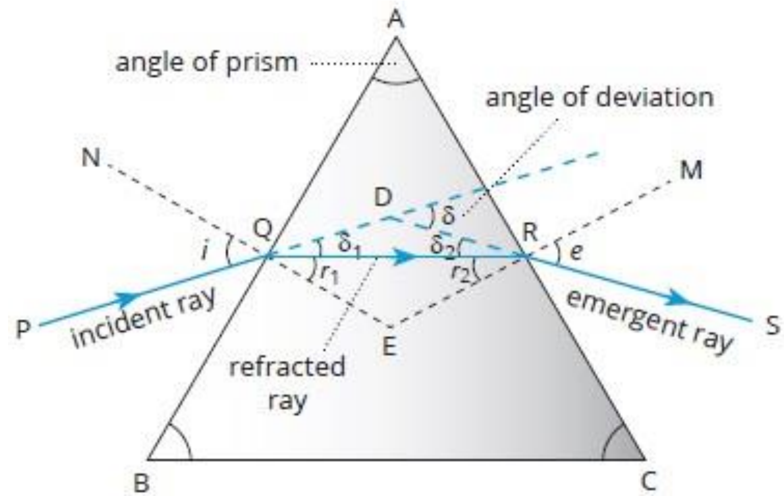
A light ray passing through a glass slab is displaced but its direction is not changed.



But a light ray passing through a prism is deviated.

The total deviation through which the incident ray is turned by the prism while passing through it is δ, where

$$\delta = \delta 1 + \delta 2$$



Factors affecting the angle of deviation

The total angle of deviation, δ , depends on the following four factors:

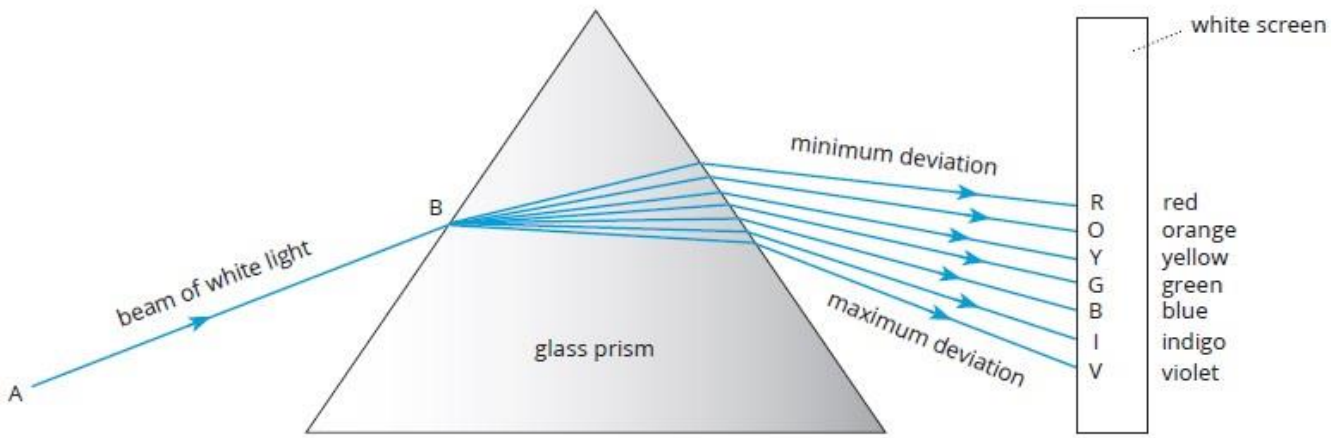
1. Angle of incidence
2. Angle of prism
3. Refractive index of the prism material
4. Wavelength of light

Dispersion of Light

The phenomenon of splitting of white light into its constituent colours on passing through a glass prism is called dispersion of light.

The band of colours obtained on a white screen, when white light splits into its constituent colours, on passing through a prism, is called the **spectrum**.

Based on this experiment, Newton discarded the theory that white light is uniform or homogeneous. He concluded that **white light is a mixture of seven different colours**.

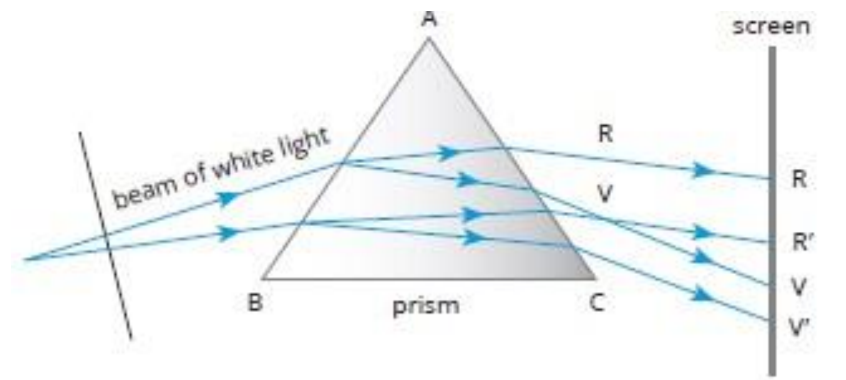


Cause of dispersion

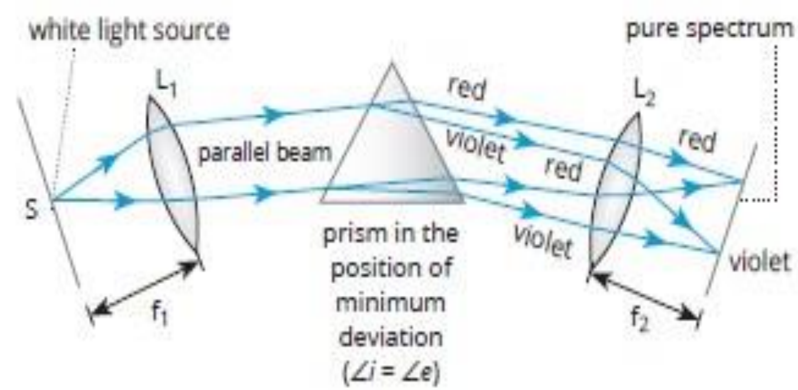
The angle of deviation (δ) decreases with the increase in the wavelength of light. Since the wavelength of violet light is smaller (4000 Å) than that of red light (8000 Å), therefore, on entering the prism the violet light is deviated more than the red light ($\delta v > \delta r$).

Pure and Impure Spectrum

A spectrum in which various bands of colours have no sharp well-defined boundaries, but merge with each other is called an impure spectrum.



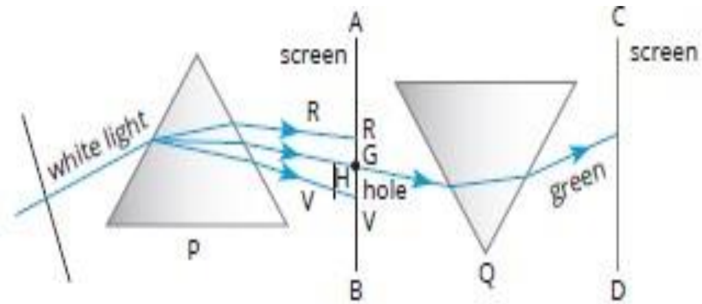
A spectrum in which various bands of colours have sharp well-defined boundaries, and do not merge with each other is called a pure spectrum.
Each colour occupies a distinct position on the screen. When a beam of light rays is passed through an instrument called **spectrometer**, it gives a pure spectrum .



Newton's Experiment to show that the prism by itself produces no colours

White light from a cardboard slit S is made to fall on an equilateral prism P, in a dark room . The prism P forms the spectrum RV on the screen AB. A narrow hole H is made in the screen AB to allow light of a particular colour to pass through it. Let us say green light is made to pass through this hole.

This green light is made to pass through another prism Q, placed in an inverted position. The green light after passing through the second prism Q is received on another screen CD. It is observed that green light is obtained on the screen CD. This proves that **the prism by itself produces no colours**.



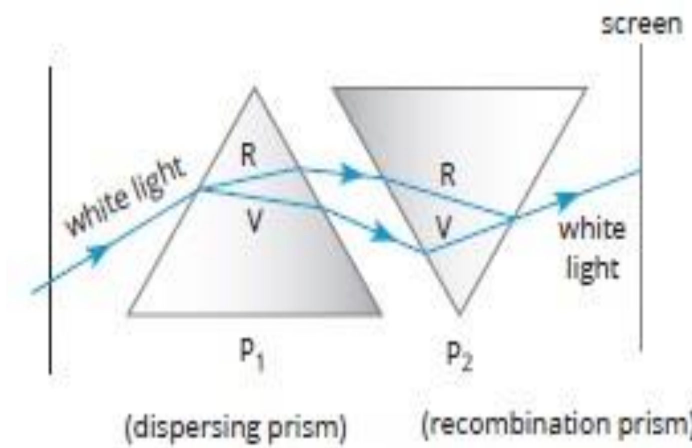
Newton's Experiments on Dispersion and Recombination of Colour Lights

Two Prisms Experiment

The prism P_1 dispersed the white light into its constituent colours. Hence this prism was called the dispersing prism. The second prism P_2 recombined the seven constituent colours to form white light. Hence the prism was called the recombination prism. This experiment proved that

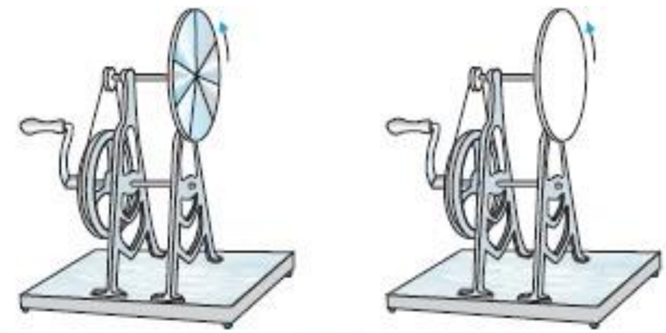
1. the prism by itself produces no colours.

2. the recombination of the seven constituent colours forms white light.



Newton's Colour Disc

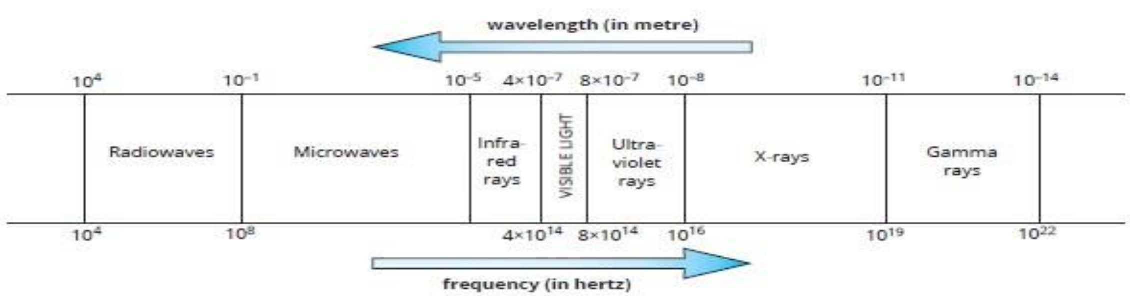
When the speed of rotation of the disc is high, the whole disc appears dull white in colour indicating that a mixture of lights from the seven painted colours yields white light. If the disc is rotated at high speed, the eye perceives all the colours at one time so as a result the total effect gives a sensation of dull white colour.



a. Newton's colour disc b. Rotating disc appears dull white

Electromagnetic Spectrum

The orderly classification of electromagnetic waves according to their wavelength or frequency is called the electromagnetic spectrum. The speed (c), frequency (f) and wavelength (λ) of the electromagnetic waves are related as $c = f\lambda$.



Note: Refer to the Table 6.2 P-117 for Electromagnetic spectrum

Visible Spectrum and Invisible Spectrum

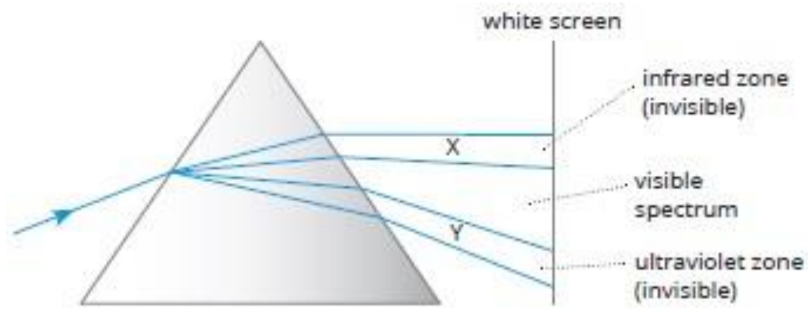
If we pass sunlight through a triangular glass prism, we get a band of seven colours; violet, indigo, blue, green, yellow, orange and red (VIBGYOR). The human eye can detect a very small segment of the spectrum with wavelength ranging from about 4×10^{-7} m to 7×10^{-7} m. This is called **visible spectrum.** The ultraviolet radiation and infrared radiation do not sensitise our eyes, so we cannot see it. It lies in the **invisible spectrum**.

Infrared Radiations

The electromagnetic radiations whose wavelength is longer than that of the visible red light are called infrared radiations and the spectrum is called infrared spectrum. Their wavelength ranges from 4×10^{-7} m to 7×10^{-4} m.

Detection of Infrared Radiations

This part of spectrum was discovered by William Herschel in 1800. He obtained a spectrum by passing solar light through glass prism. He placed a thermometer with a blackened bulb in the dark part X beyond the red rays of the visible spectrum.



It showed sudden rise in temperature indicating the existence of some invisible rays there, having the heating effect. From this he concluded that the sun emitted some invisible rays which could not be seen by the eyes but heated the objects on which they fell. These rays which exist beyond the red-end of the spectrum are called **infrared rays**.

Sources of Infrared Radiations

Infrared radiations sometimes are called **heat radiations**. Infrared radiations are produced by hot bodies such as fire, heated iron ball, etc. **Sun is the natural source of infrared radiations**.

Uses of Infrared Radiations

1. Infrared rays produce heating effect, as a result of this property they are used by doctors to treat muscular strains (medical therapy).
2. Infrared rays have a high penetrating power and are least scattered by fog and mist (as it has a long wavelength). So they can penetrate thick columns of fog and smoke. Therefore, they can be used for taking photographs over long distances even in foggy weather. For the same reason, they are used in photography at night.
3. They are used for producing dehydrated fruits.
4. They are used in greenhouses to keep the plants warm.

Ultraviolet Radiations

The electromagnetic radiations whose wavelength is shorter than that of the visible violet light are called ultraviolet radiations and the spectrum is called ultraviolet spectrum. Their wavelength ranges from 4×10^{-7} m to 6×10^{-10} m. Ultraviolet radiations destroy bacteria. Thus, they are used for sterilising surgical instruments.

Sources of ultraviolet radiations

They are produced by electric spark, discharge tube, mercury vapour lamp with quartz envelop very hot bodies and the Sun. The Sun produces a large amount of ultraviolet radiations, most of which is absorbed by the ozone layer in the upper atmosphere.

X-Rays

The X-rays were discovered by German physicist **W Roentgen** in 1895. Their wavelength ranges from 1×10^{-10} m to 3×10^{-8} m. They are produced when very fast moving electrons are stopped by a heavy metal target of high melting point. They are used for diagnostic purposes in medical science for detection of fractures, foreign bodies like bullets and stones in the human body.

Gamma Rays

Gamma rays were discovered by Rutherford. These are the most energetic electromagnetic radiations of very short wavelength (6×10^{-13} m to 1×10^{-10} m). These rays are emitted from the nuclei of radioactive elements. They are used to kill cancerous cells in human body, thus help in the treatment of cancer and tumours.

Radio Waves

These are the waves of longest wavelength amongst all the electromagnetic waves. They have wavelength between 0.3 m to 6×10^{2} m. They show all the properties of the electromagnetic waves. Radio waves are used in radio and television communication. They are also used in radar communication and cellular phones communication.

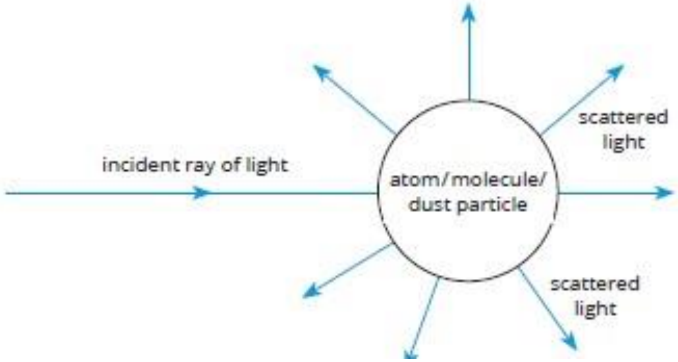
Microwaves

Microwaves are the electromagnetic waves of wavelength in the range of 1×10^{-3} m to 3×10^{-1} m. They are produced by special vacuum tubes such as klystron tube and Gunn diode. They show all the properties of the electromagnetic waves. Microwaves are used in the radar systems for aircraft navigation and for cooking purposes.

Note: Refer to **Table 6.3, P-118** for Difference between ultraviolet radiation, visible light and infrared radiation.

Scattering of Light

Scattering of light is a phenomenon of change in the direction of light on striking particles like an atom, a molecule, dust particle, water droplet, etc.



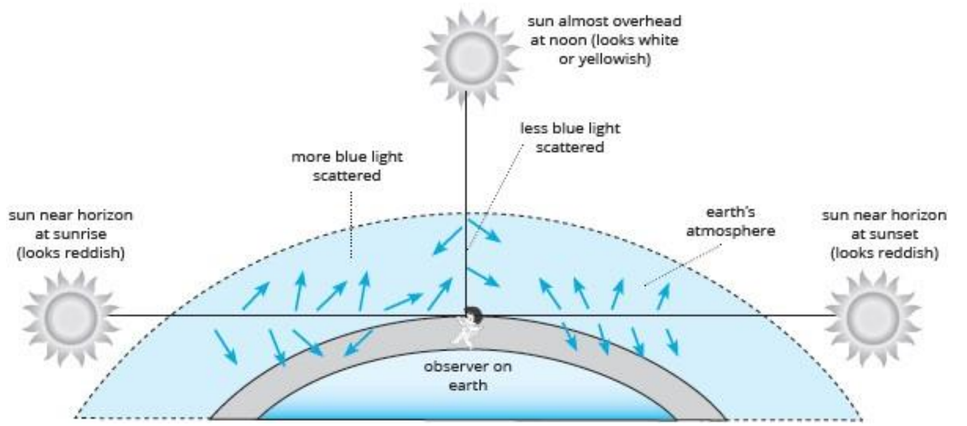
Some Applications of Scattering

Blue colour of sky

the finer particles in air scatter the blue-coloured light (shorter wavelength) more strongly and effectively than the red-coloured light. The scattered blue light enters our eyes. Hence, the sky looks blue.

The reddening of the sun at sunrise and sunset

The red colour which has the largest wavelength is scattered the least. Among the colours of sunlight, the colour scattered least, i.e. red colour enters our eye. This gives rise to reddish appearance of the sun, both at the time of sunrise and sunset.



Danger signals are red
Among the colours of visible light, red colour has the largest wavelength and hence, is least scattered. Thus, red light can easily pass through fog or mist or smoke without getting scattered. It can be seen from maximum distance. That is why, red colour is used as universal danger signal.

Motorist use orange light on a foggy day rather than normal white light
On a foggy day, the air has large amount of water droplets. If a motorist uses white light while driving in fog, then the water droplets present in the air scatter large amount of the blue light. This on reaching our eyes decreases visibility and hence driving becomes extremely difficult. The orange light has longer wavelength and hence, it is least scattered. Thus, orange light can easily pass through fog without getting scattered and hence, is visible from maximum distance.

Smoke coming out of coal fired chimney appears blue on a misty day
On a misty day, the air has large amount of tiny particles of water droplets, dust and smoke. These tiny particles present in the air scatter blue colour of the white light passing through it. When this scattered blue light reaches our eyes, the smoke appears blue.

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SUMMARY

1.**Dispersion:** The phenomenon of splitting of white light into its constituent colours on passing through a glass prism is called dispersion.

2. **Impure spectrum:** A spectrum in which various bands of colours have no sharp well-defined boundaries, but merge with each other.

3. **Pure spectrum:** A spectrum in which various bands of colour have sharp well-defined boundaries and do not merge with each other.

4. **Deviation:** The red colour (with minimum refractive index value of the seven visible light colours) suffers the least deviation and the violet colour (with maximum refractive index) suffers the maximum deviation produced by the prism.

5. **Electromagnetic spectrum:** An orderly classification of electromagnetic waves according to their wavelength or frequency.

6. **Visible spectrum:** The spectrum of seven colours of light having the wavelength range from 4 × 10–7 m (violet) to 7 × 10–7 m (red) that we can see.

7. **Infrared radiations:** The electromagnetic radiations whose wavelength is longer than that of visible light.

8. **Ultraviolet radiations:** The electromagnetic radiations whose wavelength is shorter than that of the visible violet light.

9. **Scattering of light:** It is a phenomenon of change in the direction of light on striking a particle like an atom, a molecule, dust particles, water droplets, etc. It explains the phenomenon like ‘blue colour of the sky’, ‘the reddening of the sun at sunrise and the sunset’, etc.