CHAPTER

6

Spectrum of Light

In the previous chapters, we have learnt that when a ray of light travels from one medium to another, it gets deviated from its path. It is because of the difference in the speeds of light in two media. This deviation will not occur if the angle of incidence becomes zero.

Since, the deviation always occurs at the boundary of the two media. Therefore, the magnitude of the deviation depends on the angle of incidence at the interface of two media and the refractive index of the second medium with respect to the first medium. In this chapter, we will study about the refraction of light through prism, which constitutes the phenomenon of dispersion.

Chapter Objectives

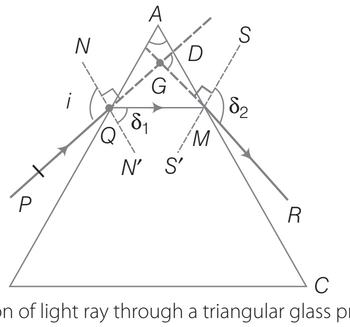
- Deviation Produced by a Triangular Prism
- Dispersion of White Light by a Glass Prism
- Scattering of Light
- Electromagnetic Spectrum

Prism

Prism is a transparent refracting medium bounded by at least two lateral surfaces, inclined to each other at a certain angle. It has two triangular bases and three rectangular lateral surfaces. The angle between two lateral surfaces is called **angle of prism** (A).

Deviation Produced by a Triangular Prism

In the figure given alongside, a ray of light PQ is entering from air to glass at the first surface AB. The light ray on refraction get bent toward the normal by an angle δ_1. At the second surface AC, the light ray enters from glass to air, so it bent away from the normal by an angle δ_2. The diagram shows refraction through a prism.



Deviation of light ray through a triangular glass prism

where,

$PQ =$ incident ray, $QM =$ refracted ray, $MR =$ emergent ray, $\angle A =$ angle of prism, $\angle i =$ angle of incidence and $\angle D =$ angle of deviation.

This represents the deviation of light rays produced by a prism.

Note When a ray of light passes through a prism, it bends towards the thicker part of the prism.

Therefore, the net deviation produced in the emergent ray *MR* w.r.t. the incident ray *PQ* can be given as,

$$D = \delta_1 + \delta_2$$

In chapter 4, we have already discussed the dependence of angle of deviation on various factors in details.

Dependence of Angle of Deviation on the Colour (or Wavelength) of Light

As, for light of different colours, the refractive index of a given transparent medium is different, it decreases with increase in the wavelength of the light. Therefore, the refractive index of the material of prism is maximum for the violet colour and least for red light. As a result, a given prism deviates the violet light most and the red light least.

Also, from the definition of refractive index,

i.e., $$\mu = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

As, speed of violet light is minimum and red is maximum in a medium, so

$$\mu_{\text{violet}} > \mu_{\text{red}}$$

As, $$\mu = \frac{\sin i}{\sin r}$$

where, r is the angle of refraction.

$\Rightarrow$ $$\sin r = \frac{\sin i}{\mu}$$

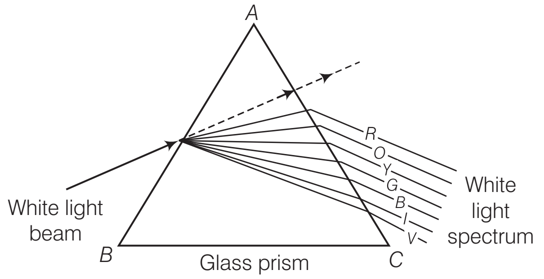
So, for a particular value of i, $r_{\text{violet}} < r_{\text{red}}$.

Hence, $\delta_{\text{violet}} > \delta_{\text{red}}$

Dispersion of White Light by a Glass Prism

The phenomenon of splitting of white light into its constituent colours, when it passes through a prism is called **dispersion.** This band of seven colours so obtained, the VIBGYOR (V = violet, I = indigo, B = blue, G = green, Y = yellow, O = orange and R = red) is called **spectrum**.

Isaac Newton was the first one to use a glass prism to obtain the spectrum of light.



Dispersion of white light by a glass prism

White light gets dispersed only at one surface of prism *AB*. But the deviation occurs at both the surfaces of prism i.e., *AB* and *AC*. Also, prism never produce any colour, rather it just helps in splitting the components of white light.

Note A similar band of seven colours is produced when a beam of white light from an electric bulb falls on a triangular glass prism.

Cause of Dispersion

Light rays of different colours, travel with the same speed in vacuum and air but in any other medium, they travel with different speeds and bend through different angles, which leads to the dispersion of light.

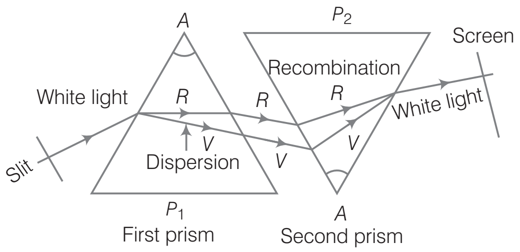
Red light has the maximum wavelength and **violet light** has the minimum wavelength. So in any medium, red light travels fastest and deviates least, while violet light travels slowest and deviates maximum, i.e.,

$$\text{Wavelength} \propto \text{Velocity} \propto \frac{1}{\text{Deviation}}$$

Note
- If δ_r, δ_y and δ_v are the deviations for red, yellow and violet components, then mean deviation is measured by δ_y as yellow light falls in between red and violet, $\delta_v - \delta_r$ is called angular dispersion.
- The dispersive power of a material is defined as the ratio of **angular dispersion** to the mean deviation when a white beam of light is passed through it. It is given by, $\omega = \frac{\delta_v - \delta_r}{\delta_y}$.

Recombination of White Light

Newton showed that the reverse of dispersion of light is also possible. He kept two prisms close to each other one in erect position and the other in an inverted position. The light gets dispersed when passes through the first prism. The second prism receives all the seven coloured rays from first prism and recombines them into original white light. This observation shows that sunlight is made up of seven colours. Any light that gives spectrum similar to that of sunlight is called **white light**.



Recombination of the spectrum of white light

Rainbow

A natural spectrum appearing in the sky after a rain shower is called rainbow. It is caused by dispersion of sunlight by tiny water droplets, present in the atmosphere. It 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. It can also be seen on a sunny day by looking at the sky through a waterfall or through a water fountain, with the Sun behind you.

Note Red colour appears on the upper side of the rainbow and violet on the lower side, in case of primary rainbow.

CHECK POINT 01

1. When a monochromatic beam of light undergoes minimum deviation through equilateral glass prism, state how does the beam pass through the prism with respect to the base?
2. Among seven constituents colours of white light, which colour travels
   (i) fastest (ii) slowest in glass?
3. What do you understand by the term of dispersion of light?
4. Name the subjective property of light related its wavelength.
5. Name the phenomenon which is responsible for the formation of rainbow.

Scattering of Light

The reflection of light from an object in all directions is called scattering of light. The colour of scattered light depends on the size of scattering particles and wavelength of light. Very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelength (red light). If the size of the scattering particles is large enough, then the scattered light may even appear white.

Note
- The blue light present in sunlight is scattered 10 times more than the red light.
- Scattering $\propto d^6$ (where, d = diameter of particle)
- According to Rayleigh,
  amount of scattering $\propto \frac{1}{\lambda^4}$ (where, λ = wavelength of light)

Some Phenomena Based on Scattering of Light

Some phenomena based on scattering of light are

Tyndall Effect

The path of a beam of light passing through a true solution is not visible. However, its path becomes visible when it passes through a colloidal solution, where the size of the particles is relatively larger.

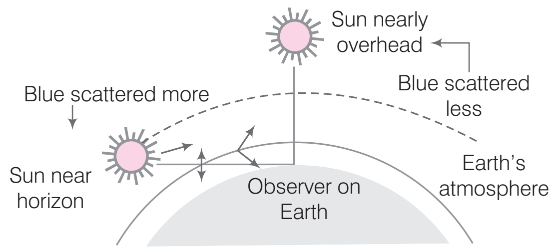
This scattering of light when it passes through a colloidal solution is called Tyndall effect. The Earth's atmosphere is a heterogeneous mixture of minute particles of smoke, tiny water droplets, suspended particles of dust and molecules of air which becomes visible due to scattering of light.

Blue Colour of Sky

During the day time, sky appears blue. This is because the size of the particles in the atmosphere is smaller than the wavelength of visible light. So, they are more effective in scattering the light of shorter wavelengths (blue end of spectrum). Hence, when sunlight passes through the atmosphere, the fine particles scatter the blue colour more strongly than red. This scattered blue light enters our eye. Hence, during the day time, the sky appears blue. It should be noted that the sky appears black to the passengers flying at higher altitudes because scattering of light is not prominent at such height due to the absence of particles.

Colour of Sun at Sunrise and Sunset

Light from the Sun near the horizon passes through thicker layers of air and covers larger distance in the atmosphere before reaching our eyes. Due to this, most of the blue light and shorter wavelengths are scattered away by the particles near the horizon. Therefore, the light that reaches our eyes is of longer wavelengths. This gives rise to the reddish appearance of the Sun and the sky. However at the noon, the light from the Sun overhead would travel relatively shorter distance. So, it appears white as only a little of the blue and violet colours are scattered.



Reddening of the Sun at sunrise and sunset

Note If the Earth had no atmosphere, then sky would have looked dark and black.

Electromagnetic Spectrum

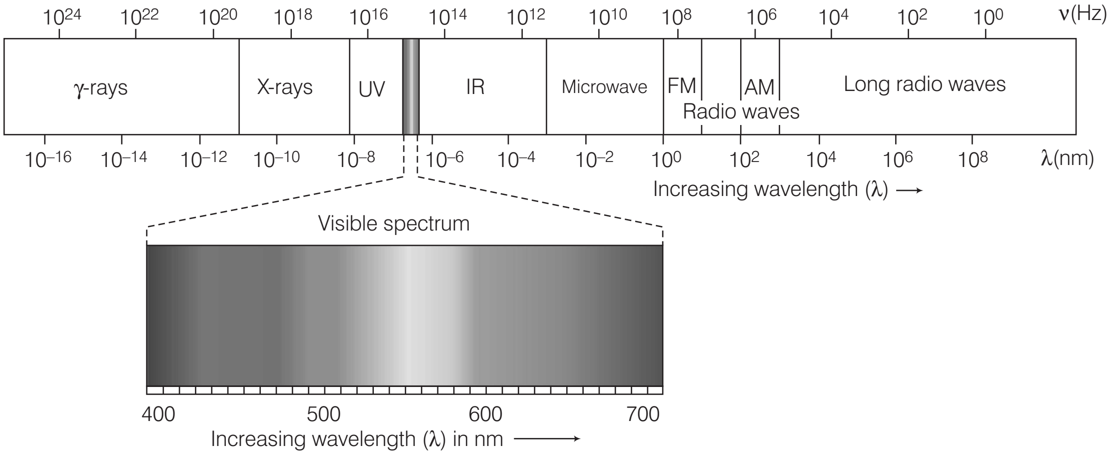
The orderly arrangement of electromagnetic waves in increasing or decreasing order of wavelength λ or frequency ν is called electromagnetic spectrum. The range varies from 10^{-12} m to 10^4 m, i.e., from γ-rays to radio waves.

Note
- A spectrum which has defined boundaries i.e., various bands of colours do not overlap with each other is called pure spectrum whereas the spectrum which do not have defined boundaries is called **impure spectrum**.

- The region in the spectrum beyond red and before violet is called **invisible spectrum**.

Broad Classification of Spectrum in the Increasing Order of Wavelength

The figure shown below shows the various parts of the electromagnetic spectrum with approximate wavelength range.



Properties of Different Electromagnetic Waves

Type	Wavelength range	Production	Detection	Effect on photographic plate	Penetrating power	Applications	Discover
Radio wave	> 0.1 m	Rapid acceleration and decelerations of electrons in aerials	Receiver's aerials	Do not affects	High	In amplitude modulation, ground wave propagation, TV waves and cellular phones	Marconi
Microwave	0.1 m to 1 mm	Klystron valve or magnetron valve	Point contact diodes	Do not affects	High	In RADAR's, microwave oven, study of atomic and molecular structures	Hertz
Infrared wave	1 mm to 700 nm	Vibration of atoms and molecules	Thermopiles bolometer, infrared photographic film	Do not affects	Passes through rock salt but absorbed by prism	In physical theraphy and weather forecasting	William Hershell
Visible light	700 nm to 400 nm	Electrons in atoms emit visible light when they move from higher energy level to a lower energy level	The eye, photocells, photographic film	Affects	Reflects by human body, but passes through glass prism	To see things	Newton
Ultraviolet rays	400 nm to 1 nm	Inner shell electrons in atoms moving from higher energy level to a lower energy level	Photocells, photographic film	Strongly affect	Only passes through quartz	In burglar alarms, sterlise surgical instruments	Prof. J. Ritter
X-rays	1 nm to 10^{-3} nm	X-ray tubes or inner shell electrons	Photographic film, strongly affect Geiger tubes, ionisation chamber	Strongly affect	High	To detect the fracture, diseased organs, stones in body, etc, for scientific research	Rontgen
Gamma rays	$< 10^{-3}$ nm	Radioactive decay of the nucleus	Geiger tubes, films	Affects	High	In nuclear reaction, treatment of tumour and cancer, kill pathogenic microorganisms	Rutherford

General Properties of Electromagnetic Spectrum

The properties common to all electromagnetic spectrum are as follows

(i) The electromagnetic waves of entire wavelength range do not require any material medium for their propagation.

(ii) They all travel with the same speed in vacuum which is same as the speed of light in vacuum, i.e., 3×10^8 m/s.

(iii) They exhibit the properties of reflection and refraction.

(iv) These waves are not deflected by the electric and magnetic fields.

(v) These waves are transverse waves.

Properties and Uses of Infrared Waves

These waves were discovered by **Herschell**. These waves are also called **heat waves**. These waves are produced from the heat radiating bodies and molecules.

They have high penetration power. Its frequency range is from 3×10^{11} Hz to 4×10^{14} Hz.

Uses of infrared waves are given below

(i) These are used in physical therapy.

(ii) These are used in satellite for army purpose.

(iii) These are used in weather forecasting.

(iv) These are used for producing dehydrated fruits.

(v) These are used in solar water heater, solar cells and cooker.

Properties and Uses of Ultraviolet Rays

These rays were discovered by **Ritter** in 1801. These are produced by special lamps and very hot bodies. The sun is an important source of UV-rays but fortunately absorbed by ozone layer. Its frequency range is from 10^{14} Hz to 10^{16} Hz.

Uses of ultraviolet rays are given below

(i) These are used in burglar alarm.

(ii) These are used in checking mineral sample.

(iii) These are used to study molecular structure.

(iv) To kill germs in water.

(v) To sterilise surgical instruments.

Relation between Frequency, Speed and Wavelength of Electromagnetic Waves

All electromagnetic waves move with same velocity (v) $(3 \times 10^{-8}\text{ m/s})$ in vacuum but their frequencies (ν) and wavelength (λ) are different.

The relation between frequency (ν), speed (v) and wavelength (λ) of electromagnetic waves is

$$\text{Frequency}\,(\nu) = \frac{\text{Speed of elecromagnetic wave}\,(v)}{\text{Wavelength}\,(\lambda)}$$

Example 1. An electromagnetic wave of frequency 40 MHz travel in free space in the *x*-direction. Determine the wavelength of the wave.

Sol. Given, frequency, $\nu = 40$ MHz

Speed of wave, $v = 3 \times 10^8$ m /s

Using the relation,

$$\text{wavelength of wave, } \lambda = \frac{\text{speed of wave } (v)}{\text{frequency } (\nu)}$$

Substituting the given values, we get

$$\lambda = \frac{3 \times 10^8}{40 \times 10^6} = 7.5 \text{ m}$$

Example 2. What is the wavelength of an electromagnetic wave whose frequency is 10^{15} Hz? Name this electromagnetic wave.

Sol. Given, frequency, $\nu = 10^{15}$ Hz,

speed of wave, $v = 3 \times 10^8 \text{ ms}^{-1}$

Using the relation,

$$\text{wavelength of wave, } \lambda = \frac{\text{speed of wave } (v)}{\text{frequency } (\nu)}$$

Substituting the given values, we get

$$\lambda = \frac{3 \times 10^8}{10^{15}} = 3 \times 10^{-7} \text{ m} = 300 \text{ nm}$$

Such a wave is infrared wave, whose wavelength varies from 10 nm to 400 nm.

Note This EM spectrum and its properties have been frequently asked in previous years 2014, 2013, 2012, 2011, 2010.

CHECK POINT 02

1 Which characteristic property of light is responsible for the blue colour of the sky?

2 The backlight of a motor is red, why?

3 Arrange the electromagnetic waves in the descending order of their wavelength.
(a) Microwaves (b) Infrared rays
(c) Ultravoilet (d) γ- rays

4 Write the equation for the relation between the frequency and wavelength of light in vacuum.

5 Name the region beyond the violet end of the spectrum.

6 Calculate speed of EM wave in a glass slab in which frequency of EM wave is 4×10^{14} Hz and wavelength is 500 nm. ***Ans.*** 2×10^{14} m/s

SUMMARY

- Prism is a portion of a transparent refracting medium bounded by two plane surfaces inclined each other at a certain angle.
- Angle of Deviation It is the angle between incident and emergent ray. It depends on angle of prism, angle of incidence and angle of emergence, refractive index of the material of the prism.
- Deviation of light caused by a prism is inversely proportional to its wavelength.
- Dispersion It is a phenomenon of splitting of light into its constituents colours. It is caused because of the different velocities of light in same medium.
- Red light deviates the least whereas violet light deviates maximum.
- Spectrum It is the band of colours obtained on the screen when a white light splits into component colours by the prism. It is of two type, pure spectrum and empure spectrum.
- Rainbow It is a natural phenomenon due to the dispersion of light formed by the rain drop, when sunlight falls on it. It is formed due to refraction, dispersion and total internal reflection of light.
- Scattering of Light It is the reflection of light from an object in all directions. It only takes place when the size of the scattering object is very small as compared to the wavelength of the light.
- Blue colour of the sky, reddish appearence of sun at sunrise and sunset, etc are due to scattering of light.
- Electromagnetic Spectrum It is the orderly distribution of electromagnetic radiations according to their wavelength or frequency.
- All the electromagnetic radiations travel with the same speed in vacuum which is same as the speed of light in vacuum, i.e., 3×10^8 m/s.
- Ultraviolet radiations wavelength range varies from 1 nm to 400 nm and infrared radiations wavelength range varies from 700 nm to 1 mm.

EXAM PRACTICE

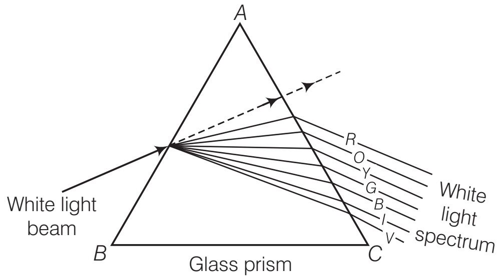
a 2 Marks Questions

1. Briefly mention, how does the deviation produced by a triangular prism depend on the colours (or wavelengths) of light incident on it?

Sol. Since, the refractive index of glass increases with decrease in wavelength of light. So, the deviation caused by a prism also increases with decrease in the wavelength of light, e.g., as λ of violet less than λ of red, hence $\delta_{red} < \delta_{violet}$. ***[2]***

2. Draw a ray diagram showing the dispersion through a prism when a narrow beam of white light is incident on one of its refracting surfaces. Also indicate the order of the colours of the spectrum obtained.

Sol. Ray diagram showing the dispersion of white light through a prism is shown below,



[1]

The order of the colours of the spectrum are given below

V = violet, I = indigo, B = blue,

G = green, Y = yellow, O = orange and R = red. ***[1]***

3. Explain the cause of dispersion of white light through a prism.

Sol. The speed of light for different colours is same in air but it is different for different colours in any other transparent medium. The speed of light in a transparent medium decreases with the decrease in the wavelength of light. ***[1]***

Since, the refractive index of the medium depends on the wavelength of the light. So, different colours of different wavelengths are deviated through different angles of deviation through a glass prism. This causes the dispersion of white light. ***[1]***

4. Is it possible that a glass slab disperse the light? If not, why?

Sol. No, it is not possible that a glass slab disperse the light, because it has parallel rectangular faces. ***[1]***

When a white light is incident on the glass slab, it gets dispersed into different colours but these different colours combine to form white light on emerging from the other parallel face. ***[1]***

5. Name the four colours of the spectrum of white light which have wavelength longer than the blue light. Also, name the light amongst the given, which shows maximum deviation.

Sol. The four colours of the spectrum of white light which have wavelength longer than the blue light are green, yellow, orange, red. ***[1]***

Green shows the maximum displacement amongst the given lights. ***[1]***

6. If the wavelengths for the light of red and blue colours are approximately 7.8×10^{-7} m and 4.8×10^{-7} m respectively, mention

(i) which colour has a greater speed in vacuum?

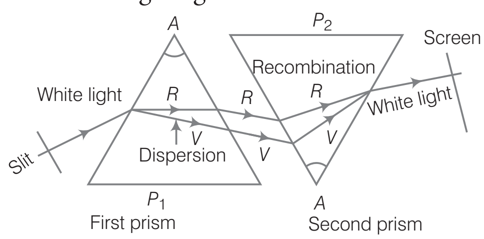
(ii) which colour has a greater speed in glass?

Sol. (i) In vacuum, both the colours (i.e., red and blue) will have the same speed. ***[1]***

(ii) In glass, red light has a greater speed because its deviation is least. ***[1]***

7. How will you use two identical prisms so that a narrow beam of white light incident on one prism emerges out of the second prism as white light? Draw the diagram.

Sol. A narrow beam of white light incident on one of the prisms emerges out of the identical prism placed in an inverted position with respect to the first prims, as shown in the figure given below. ***[1]***



[1]

8. What do you understand by term "spectrum of light"? Name one natural spectrum formed by sunlight after rain.

Sol. The band of seven colours formed on the screen when a white light passes through a glass prism, is known as spectrum of light. ***[1]***

Rainbow is a natural spectrum formed by the sunlight after rain. ***[1]***

9. (i) Define scattering.

(ii) The smoke from a fire looks white. Which of the following statements is true?

1. Molecules of the smoke are bigger than the wavelength of light.
2. Molecules of the smoke are smaller than the wavelength of light. ***[2018]***

Sol. (i) The process of absorption and then reemission of light energy is called scattering of light. When sunlight passes through the Earth's atmosphere, much of the light gets scattered (i.e., the light spreads in all directions) by the fine dust particles and air molecule in it ***[1]***

(ii) As molecules of the smoke are bigger than the wavelength of light, as a result they scatter all wavelengths which overlaps to give white colour. ***[1]***

10. Why is it difficult to drive on a foggy day?

Sol. On a foggy day, most of the light gets scattered by the particles in the fog. Due to this visibility reduces. Hence, it becomes difficult to see and is difficult to drive also on a foggy day. ***[2]***

11. Briefly mention, why does the sky at noon appear white?

Sol. During the time of noon, the sun is directly above our head. Due to which the sunlight travels relatively shorter distance as compare to the time when sun is at the horizon. So, we get light rays directly from the sun without much scattering. Therefore, the sky at noon appears white. ***[2]***

12. (i) Why is white light considered to be polychromatic in nature?

(ii) Give the range of wavelength of these electromagnetic waves which are visible to us. ***[2009]***

Sol. (i) Since, polychromatic light consists of many colours each having its characteristic wavelength. Therefore, white light is also a polychromatic light because it is made up of seven colours, containing different wavelengths. ***[1]***

(ii) 400 nm to 700 nm is the range of visible spectrum. ***[1]***

13. Mention two properties of infrared radiations that are not true for visible light.

Sol. *Two properties are*

(i) they are absorbed by glass. ***[1]***

(ii) they do not affect the ordinary photographic film. ***[1]***

14. Why are infrared radiations preferred over ordinary visible light for taking photographs in fog?

Sol. For taking photographs in fog, infrared radiations are preferred over ordinary visible light

(i) because of their long wavelengths, they are scattered less by the earth's atmosphere. As, intensity of scattered radiation $\propto \frac{1}{\lambda^4}$. ***[1]***

(ii) also, they can penetrate deep inside the atmosphere even in fog. ***[1]***

15. Explain the following statement.

"The photographic dark rooms are provided with infrared lamps". Write any other use of infrared radiations.

Sol. Since, infrared lamps do not affect the photographic film due to this reason, the dark rooms are provided with infrared lamps. ***[1]***

Infrared radiations are used for producing dehydrated fruits. ***[1]***

16. (i) Name the radiations which are absorbed by green house gases in earth's atmosphere.

(ii) A radiation X is focussed by a particular device on the bulb of a thermometer and mercury in the it shows a rapid increase. Name the radiation.

Sol. (i) Infrared radiations are low energy radiations, which are absorbed by CO_2, present in Earth's atmosphere. ***[1]***

(ii) Infrared radiations trapped by the bulb of the thermometer increases the mercury level. ***[1]***

b 3 Marks Questions

17. It is seen that the white light splits into bands of seven colours when passed through the glass prism. With reference to this observation, answer the following questions.

(i) State the conclusion that you draw about the white light.

(ii) Name the sequence of colours from the base of the prism.

(iii) Do all the bands are of same width? If not, then why?

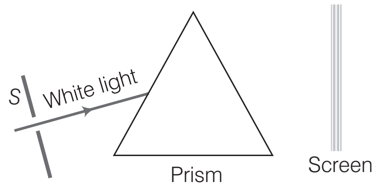
Sol. (i) After reading the given observation, it is concluded that white light is polychromatic due to which refraction and dispersion of white light takes place.

(ii) The sequence of colours from the base of prism is violet, indigo, blue, green, yellow, orange and red.

(iii) Bands of colours will be of different width. As, their widths are depends on the range of frequency or wavelength of a colour.

As, the range of colour increases, its bandwidth also increases. So, red colour has maximum and yellow has minimum bandwidth. **[1 + 1 + 1]**

18. The figure given below shows a thin beam of white light from a source *S* striking on one face of prism.

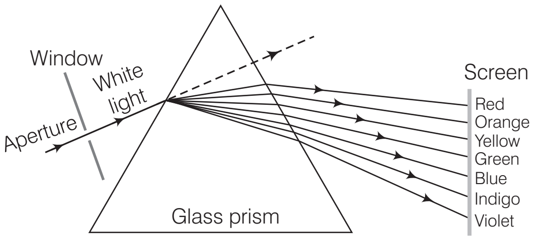


(i) In order to show the effect of the prism on the beam, complete the diagram so that, it can represent what is seen on the screen.

(ii) Assume if a slit is placed between the prism and the screen to pass only the light of green colour, then what observation will you get on the screen.

(iii) State the conclusion that you draw from the observation in part (ii) above?

Sol. (i) As we can see in the figure (below), a pattern of seven colours is formed on the screen with red on the top and violet at the bottom. **[1]**



(ii) Since, a green filter transmits only green light. Therefore, it is placed between the prism and the screen, the spectrum on the screen will appear dark except for the region near the green part in the original spectrum. **[1]**

(iii) It proves that the prism by itself produces no colour. **[1]**

19. (i) A glass slab is placed over a page on which the word VIBGYOR is printed with each letter in its corresponding colour.

(a) Will the image of all the letters be in the same place?

(b) If not, state which letter will be raised to the maximum. Give a reason for your answer.

(ii) What will be the colour of an object which appears green in white light and black in red light?

Sol. (i) (a) No, the image of all the letters are not in the same place, because the letter of each colour have different frequency or wavelength. **[1]**

(b) The letter V for violet is raised more because λ is least for violet colour, hence deviation is most. **[1]**

(ii) The colour of an object which appears green in white light and black in red light will be green. **[1]**

20. Why do we see a rainbow in the sky only after rainfall?

Sol. We see a rainbow in the sky only after rainfall due to dispersion of sunlight by tiny water droplets, present in the atmosphere. These droplets act like small prism. They refract and disperse the incident sunlight, then reflect it internally and finally refract it again when it comes out of the raindrop. Hence, due to dispersion of light and internal reflection, different colours are seen by the observer's eye. **[3]**

21. Explain how scattering of light depends upon particle size.

Sol. Since, scattering of the light is proportional to diameter of particle and inversly proportional to the wavelength of light. So, very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelength. If the size of the scattering particles is very large, the scattered light may appear white. **[3]**

22. State three properties common to all type of electromagnetic radiations.

Sol. *Three properties common to all electromagnetic radiations are*

(i) they do not require any material medium for their propagation. **[1]**

(ii) they all travel with the same speed in vacuum, which is same as the speed of light in vacuum, i.e., 3×10^{8} ms^{-1}. **[1]**

(iii) they exihibit the properties of reflection and refraction. **[1]**

23. Which type of rays exist beyond visible red end of the electromagnetic spectrum? State one property and one use of these rays.

Sol. Beyond visible red end of electromagnetic spectrum, infrared rays exist. They have frequency less than and wavelength greater than that of red light. **[1]**

Property They are detected by their heating property. **[1]**

Use They are used in photography at night and also in mist and fog. **[1]**

24. (i) Suggest one way in each case by which we can detect the presence of
(a) infrared radiations and
(b) ultraviolet radiations.
(ii) Give one use of infrared radiations.

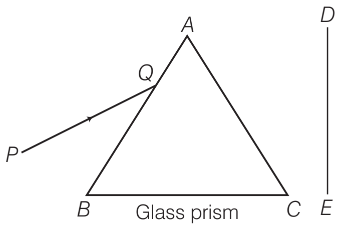
Sol. (i) (a) We can detect infrared radiation by using a thermopile or a blackened bulb thermometer. ***[1]***

(b) We can detect the presence of ultraviolet radiation by using silver chloride solution. ***[1]***

(ii) Infrared radiations are used in muscular therapy and for taking photographs in fog. ***[1]***

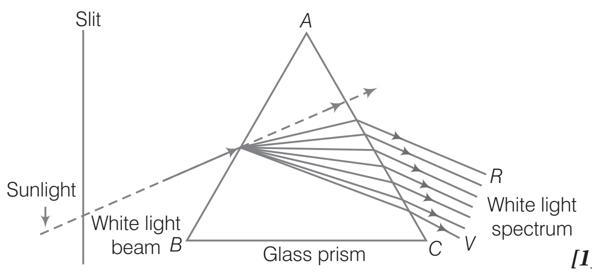
C *4 Marks Questions*

25. A narrow beam of white light is passing through a glass prism *ABC* as shown in the diagram.



Trace it on your answer sheet and show the path of the emergent beam as observed on the screen *DE*.
(i) Write the name and cause of the phenomenon observed.
(ii) Where else in nature is this phenomenon observed?
(iii) Based on this observation state the conclusion which can be drawn about the constituents of white light.

Sol. *The path of the light incident on the prism is shown below*



[1]

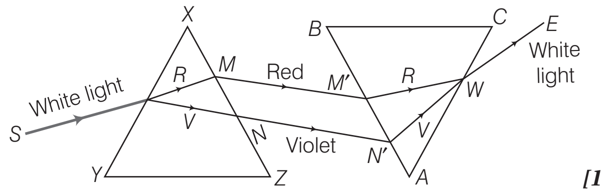
(i) The phenomenon of splitting of white light into its constituent colours is called dispersion of light. It is caused because different constituent colours of light travel with different speeds in the medium other than air/vacuum and bend through different angles. ***[1]***

(ii) This phenomenon is observed as formation of rainbow. ***[1]***

(iii) Based on phenomenon of dispersion, we can conclude that
(a) white light consists of seven colour and ***[½]***
(b) violet light suffers maximum deviation and red light suffers minimum deviation. ***[½]***

26. Explain, how can you produce deviation with dispersion?

Sol. First of all, take two prisms *XYZ* and *ABC* of same material and same refracting angles (here, we can also take different material and different refracting angles prisms).



[1½]

Both prisms are placed inverted as shown in the figure above. When a ray of white light passes through prism *XYZ*, the emergent rays *MM′* and *NN′* bends towards the base *YZ* of prism *XYZ* with colour red or violet respectively and form the band of seven colours between red and violet rays. The seven colours enter into prism *ABC* and bends towards base *BC* of prism. ***[1½]***

Since, $\mu_V > \mu_R$, so violet $N'W$ ray bends the most and $M'W$ (red) bends the least and overall colours meet at *W* and emerges out as a white light *WE* as shown in the figure. ***[1]***

27. What is meant by scattering of light? Mention the factor on which it depends. Explain why
(i) the colour of the clear sky is blue and
(ii) for astronauts sky appears darker?

Sol. The reflection of light from an object in all directions is called scattering of light.

The colour of scattered light depends on the size of scattering articles and wavelength of light.

i.e., Scattering $\propto d^6$ (where, d = diameter of particle)

and scattering $\propto \frac{1}{\lambda^4}$ (where, λ = wavelength of particle) ***[2]***

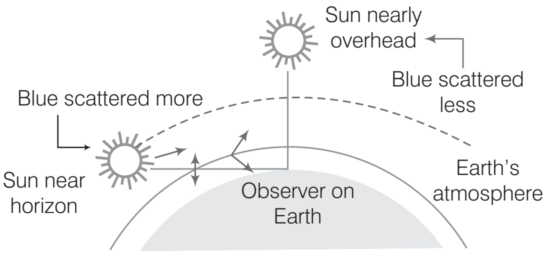
(i) During the day time sky appears blue. This is because the size of particles in the atmosphere is smaller than the wavelength of visible light. So, they are more effective in scattering the light of shorter wavelengths i.e., blue light. ***[1]***

(ii) Since, at such a height there is no atmosphere i.e., no particles. Therefore, no scattering of light takes places. Hence, for astronauts the sky appears dark. **[1]**

28. How can we explain the reddish appearance of the sun at sunrise or sunset? Why does it not appear red at noon?

Sol. The reddish appearance of the sun at sunrise or sunset is due to the scattering of light by the molecules of air and other fine particles in the atmosphere having size smaller than the wavelength of visible light. A light from the sun near the horizon passes through thicker layers of air and covers larger distance in the Earth's atmosphere before reaching our eyes.

Hence, most of the blue light and shorter wavelengths are scattered away by the particles. So, only red light being of higher wavelength reaches us which gives reddish appearance of the sun at sunrise or sunset. **[2]**



[1]

At noon, the sun appears white, not red, as only a little of the blue and violet colours are scattered as light from the sun overhead would travel relatively shorter distance. **[1]**

Numerical Based Questions

29. An electromagnetic wave has a frequency of 500MHz and a wavelength of 60 cm. Calculate velocity.

Sol. Given, frequency, $\nu = 500 \text{ MHz} = 500 \times 10^6$ Hz,

wavelength, $\lambda = 60$ cm

Velocity, $v = \nu\lambda = 500 \times 10^6 \times \frac{60}{100} = 3 \times 10^8 \text{ ms}^{-1}$ **[2]**

30. The wavelength of electromagnetic radiation is 900 nm. Find its frequency. (Take, speed of radiation = $3 \times 10^8 \text{ ms}^{-1}$)

Sol. Given, wavelength, $\lambda = 900\text{nm}$

$= 900 \times 10^{-9}$ m

$= 9 \times 10^{-7}$ m

Speed of radiation, $v = 3 \times 10^8 \text{ ms}^{-1}$

As we know,

$$\text{Frequency, } \nu = \frac{\text{Speed of electromagnetic radiation}}{\text{Wavelength}}$$

Substituting the given values, we get

$$\nu = \frac{3 \times 10^8}{9 \times 10^{-7}} = 0.34 \times 10^{15}$$

$= 3.4 \times 10^{14}$ Hz **[2]**

31. A radio can tune into any station in 7.5 MHz to 12 MHz band, what is the corresponding wavelength band?

Sol. Given, frequency range = 7.5 MHz to 12 MHz

$= 7.5 \times 10^6$ Hz to 12×10^6 Hz

Speed of radio waves, $v = 3 \times 10^8 \text{ ms}^{-1}$

From the relation,

speed of wave (v) = wavelength (λ) × frequency (ν)

$\Rightarrow \quad \lambda = \frac{v}{\nu}$

$\therefore \quad \lambda_1 = \frac{3 \times 10^8}{7.5 \times 10^6} = 40$ m

and $\quad \lambda_2 = \frac{3 \times 10^8}{12 \times 10^6} = 25$ m

$\therefore$ The corresponding wavelength band is 40 m – 25 m. **[2]**

32. An enemy plane is at a distance of 300 km from a radar. In how much time, the radar will be able to detect the plane? (Take, velocity of radiowaves as $3 \times 10^8 \text{ ms}^{-1}$). **[2017]**

Sol. As we know, speed $= \frac{\text{distance}}{\text{time}}$

Given, distance from the radar to the plane,

$d = 300 \text{ km} = 300000$ m

Velocity of radar, $v = 3 \times 10^8 \text{ ms}^{-1}$

According to the formula, $d = \frac{v \times t}{2}$

$$t = \frac{2 \times d}{v} = \frac{2 \times 300{,}000}{3 \times 100000000} = \frac{2}{1000} = 0.002\text{s}$$ **[2]**

CHAPTER EXERCISE

2 Marks Questions

1. What are the necessary conditions that are to be followed to obtain a pure spectrum on a screen?

2. Explain the reason for the given statement. "Light of different colours is deviated through different angles by a prism".

3. Write a note on the following terms:
(i) Monochromatic light
(ii) Polychromatic light

4. When a ray of light is passed through a hollow glass prism, it does not give spectrum. Explain why?

5. "Do the ratio of speed of red and blue radiation in glass is smaller than one, greater than one or equal to one"? Give reason.

6. State one harmful effect each of ultraviolet and infrared radiations.

7. Give reasons for the following:
(i) Smoke out of a chimney sometimes appears blue.
(ii) Infrared radiations are used to detect diseases in crops.

8. Briefly tell, how do the sky appears when seen from the moon (or outer space)? Give reason in support of your answer.

3 Marks Questions

9. Explain any three factors on which the deviation produced by a prism depends.

10. If a player is wearing a uniform consisting of a red shirt and a white short as seen in a white light, so state what will be the appearance of shirt and the short in
(i) red light and (ii) blue light?

11. Briefly mention the name and wavelength of electromagnetic wave whose frequency is 10^{12} Hz. Can you produce and use it in the kitchen?

4 Marks Questions

12. What do you mean by electromagnetic spectrum? Give the complete electromagnetic spectrum.

13. (i) "The sunlight appears yellow". Justify this statement along with a reason.
(ii) Name the extreme colours in pure spectrum of light.

Numerical Based Questions

14. An electromagnetic wave travels in vacuum along z-direction. If the frequency of the wave is 30 MHz, what is its wavelength?
Ans. 10 m

15. A certain electromagnetic wave has a wavelength of 625 nm.
(i) What is the frequency of the wave ?
(ii) What region of the electromagnetic spectrum is it found?
Ans. (i) 4.8×10^{14} Hz, (ii) Visible region