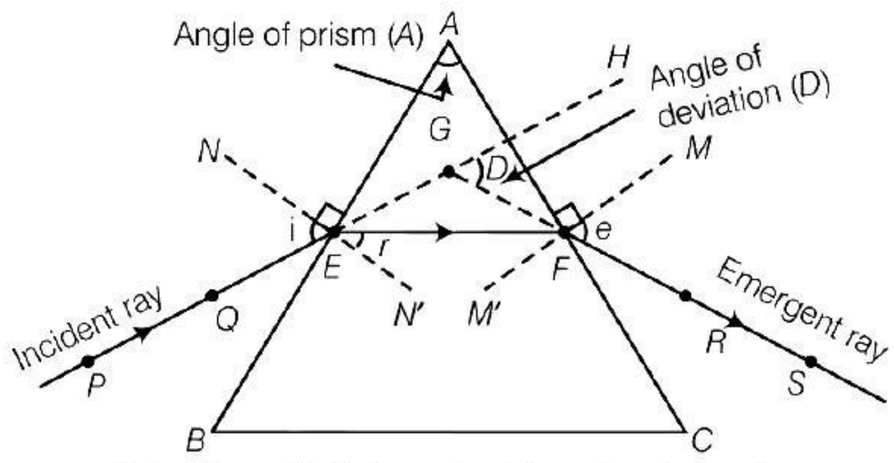
Human Eye and The Colourful World

Quick Revision

1. Refraction of Light through a Prism

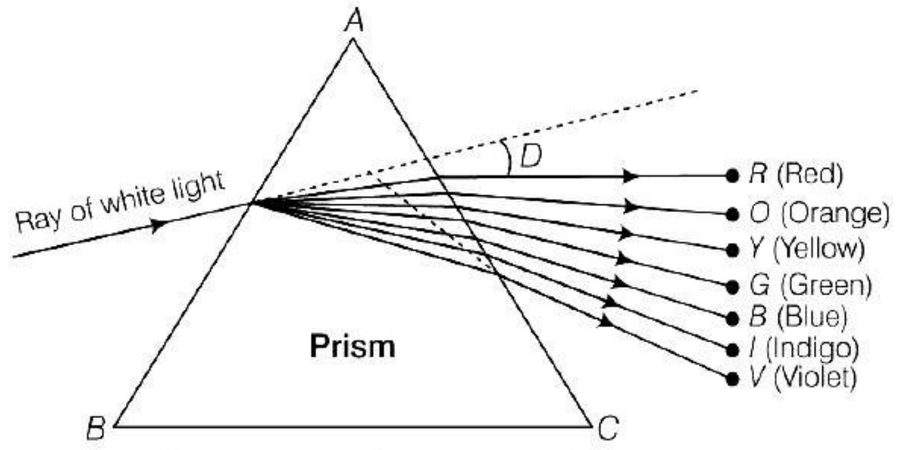
- Prism is a transparent refracting medium bounded by two plane surfaces, inclined to each other at a certain angle. It has one triangular base and three rectangular lateral surfaces.
- The angle between two lateral surfaces is called **angle of prism**.



Refraction of light through a triangular glass prism

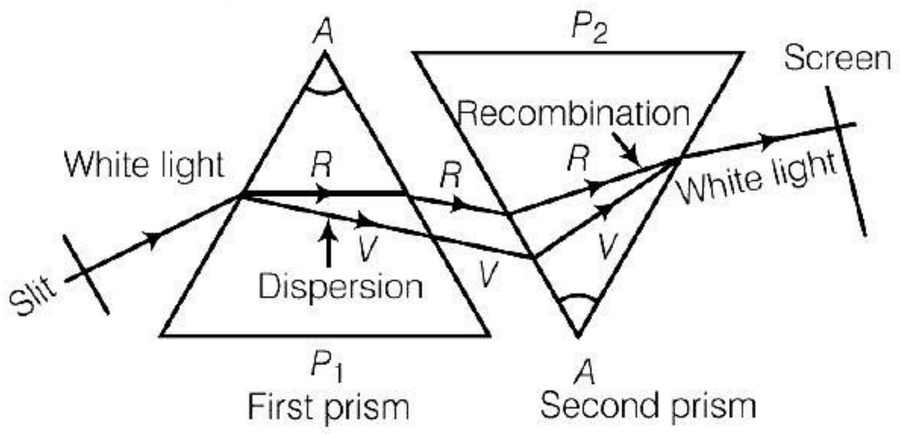
2. Dispersion of White Light by a Glass Prism

- The phenomenon of splitting of white light by prism into its constituent colours is called dispersion of white light.
- The group of different colours of light rays produced by the prism due to dispersion is called **spectrum**.
- Issac Newton was the first one to use a glass prism to obtain the spectrum of light.
- For red colour deviation is minimum and for violet colour deviation is maximum.



Dispersion of white light by a prism

- For violet colour, wavelength is minimum and for red colour wavelength is maximum, i.e. frequency for violet colour is maximum and for red colour frequency is minimum.
- **Recombination of White Light** Newton obtained while light by using similar prism in inverted position.

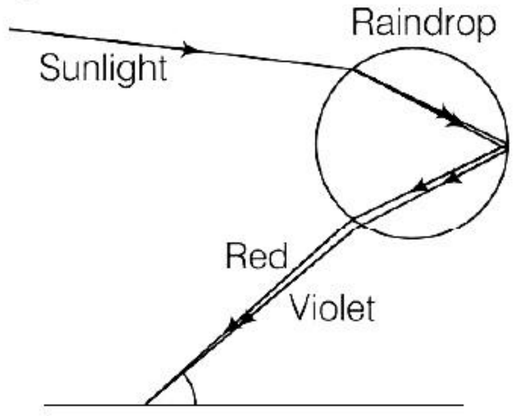


Recombination of the spectrum of white light

- **Rainbow** It is a natural spectrum appearing in the sky after a rain shower. It is caused by dispersion of sunlight by tiny water droplets, present in the atmosphere.
- Conditions for the formation of rainbow are

(i) The formation of rainbow involves a series of physical phenomena refraction, dispersion and internal i.e., reflection.

(ii) Rainbow is always formed in a direction opposite to that of the sun, i.e. sun is always behind the observer.



Rainbow formation

3. Atmospheric Refraction

The earth's atmosphere is not uniform throughout, its density goes on changing as we move up or down. It can be considered to be consisted of layers of different densities, which act as rarer or denser medium with respect to each other. The refraction of light due to these layers is called atmospheric refraction.

Some phenomena based on atmospheric refraction are

(i) **Twinkling of stars** is due to atmospheric refraction of star's light. As the light from the star enters the earth's atmosphere, it undergoes refraction due to varying optical densities of air at various altitudes. The continuously changing atmosphere refracts the light by different amounts. In this way, the star light reaching our eyes increases and decreases continuously and the star's appears to twinkle at night.

(ii) **Advance sunrise and delayed sunset** This is because of atmospheric refraction. When the sun is slightly below the horizon, the sun's light coming from less dense to more dense air, is refracted downwards. Because of this, the sun appears to be raised above the horizon and so the rising sun can be seen about 2 min before actual sunrise.

Similarly, due to atmospheric refraction the sun can be seen for about 2 min even after the sun has set below horizon.

4. 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. Very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelengths. Some phenomena based on scattering of light are given below

(i) **Tyndall effect** The path of a beam of light 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 due to suspended particles of dust and molecules of air. Tyndall effect becomes visible due to scattering of light.

(ii) **Colour of the 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 scatter the light of shorter wavelengths (blue end of spectrum) and hence, 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.

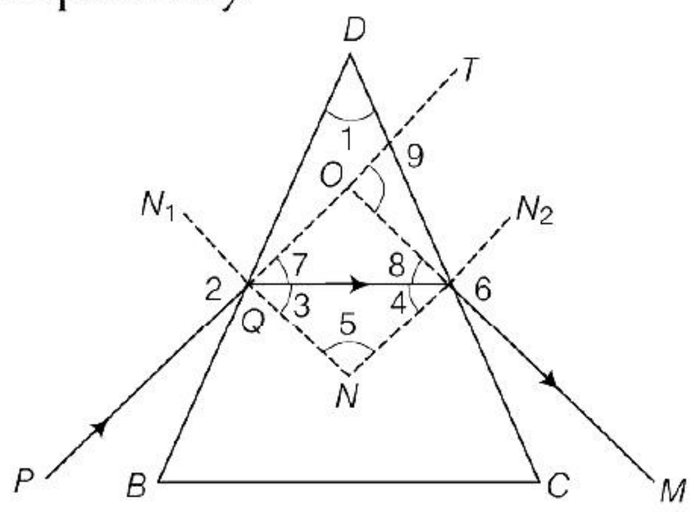
(iii) **Colour of sun at sunrise and sunset** At sunrise and sunset, the sun appear reds. Light from the sun near the horizon passes through thicker layers of air and covers larger distance in the atmosphere before reaching our eyes.

Near the horizon most of the blue light and shorter wavelength is scattered away by the particles. Therefore, the light that reaches our eyes is of longer wavelength. This give rise to the reddish appearance of the sun and the sky.

Objective Questions

Multiple Choice Questions

01. A ray diagram of refraction through prism is shown. Locate the angle of prism and angle of deviation, respectively.



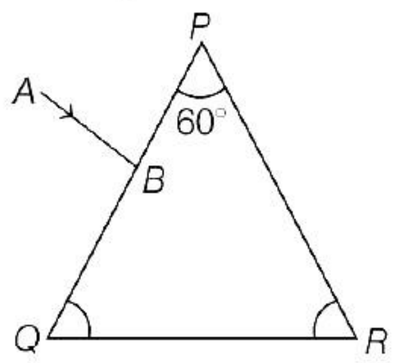
(a) 9, 1 (b) 5, 8
(c) 1, 9 (d) 9, 8

02. Prism is a homogeneous transparent medium consisting of two rectangular and three triangular faces.

(a) True (b) False
(c) Can't say (d) Partially true/false

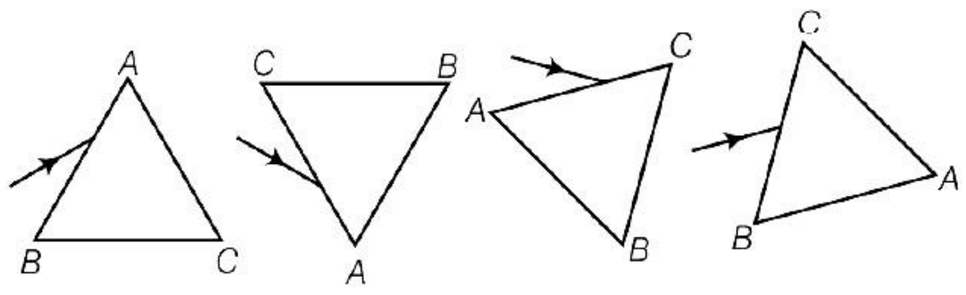
03. In given figure, a light ray AB is incident normally on one face PQ of an equilateral glass prism.

Find out the angle at face PR.



(a) 60° (b) 30°
(c) 45° (d) 90°

04. A prism ABC (with BC as base) is placed in different orientations. A narrow beam of white light is incident on the prism as shown in figure. In which of the following cases, after dispersion, the third colour from the top corresponds to the colour of the sky? *(NCERT Exemplar)*



(a) (b) (c) (d)

05. Splitting of white light into seven colours on passing through a glass prism is due to

(a) dispersion (b) refraction
(c) scattering (d) reflection

06. The colour of the white light deviated through the largest angle by a prism is ..... .

(a) Red (b) Yellow
(c) Violet (d) Green

07. Which of the following statements is correct regarding the propagation of light of different colours of white light in air? *(NCERT Exemplar)*

(a) Red light moves fastest
(b) Blue light moves faster than green light
(c) All the colours of the white light move with the same speed
(d) Yellow light moves with the mean speed as that of the red and the violet light

08. When white light is incident on a thin walled hollow glass prism, the colour of the emergent light will be

(a) red (b) green
(c) yellow (d) white

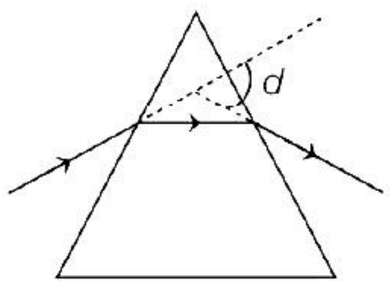
09. To recombine the spectrum to obtain white light, the dispersive prism and recombination prism should be in same position.

(a) True (b) False
(c) Can't say (d) Partially true/false

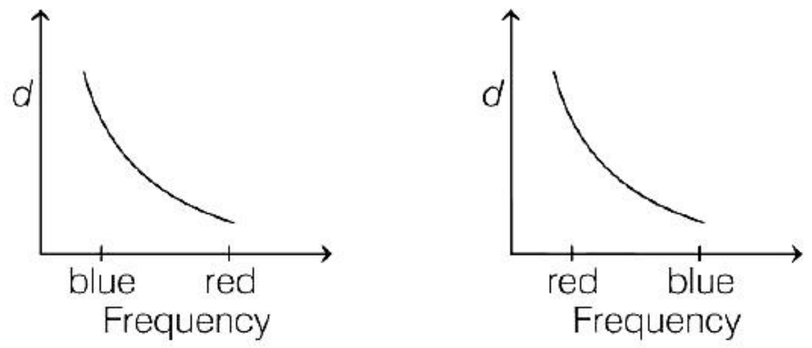
10. Which of the following phenomena of light are involved in the formation of a rainbow?

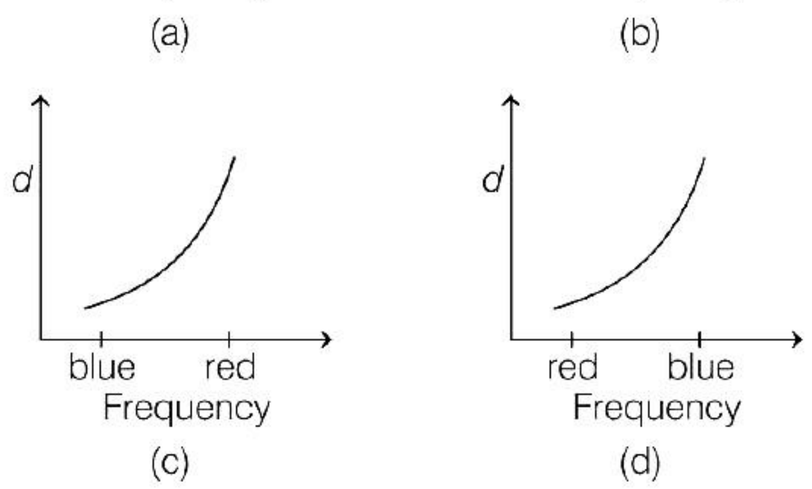
(a) Reflection, refraction and dispersion
(b) Refraction, dispersion and outer reflection
(c) Refraction, dispersion and internal reflection
(d) Dispersion, scattering and total internal reflection

11. Light rays are deviated by a prism



The deviation angle d is measured for light rays of different frequencies, including blue light and red light. Which graph is correct?





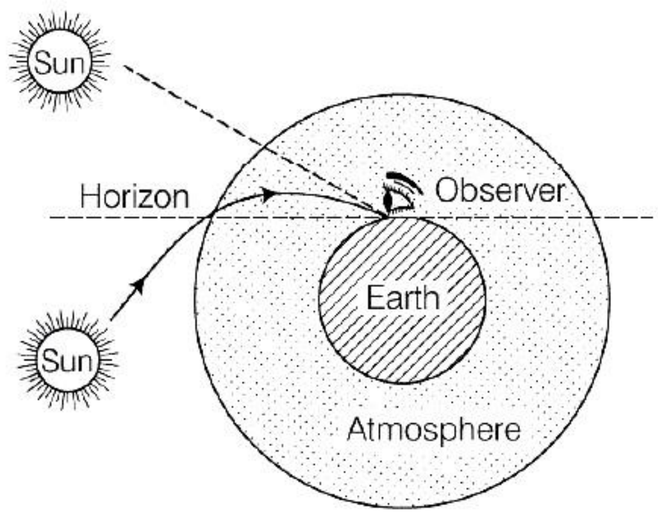
12. Twinkling of stars is due to atmospheric *(NCERT Exemplar)*

(a) dispersion of light by water droplets
(b) refraction of light by different layers of varying refractive indices
(c) scattering of light by dust particles
(d) internal reflection of light by clouds

13. Is it really true or a myth that stars appear higher than they actually are? If yes, then which phenomenon is responsible for it?

(a) Myth
(b) Yes, refraction of light
(c) Yes, atmospheric refraction of light
(d) Yes, dispersion of light

14. Which phenomenon is depicted in the diagram given below?



(a) Early sunrise and late sunset
(b) Change in shape of the sun during sunrise and at moon
(c) Both (a) and (b)
(d) Neither (a) nor (b)

15. Stars near the horizon twinkle more than those that are overhead.

(a) True (b) False
(c) Can't say (d) Partially true/false

16. At noon the sun appears white as

(a) its light is least scattered *(NCERT Exemplar)*
(b) all the colours of the white light are scattered away
(c) blue colour is scattered the most
(d) red colour is scattered the most

17. Emergency signals and danger signals are red because red can travel long distance without being scattered.

(a) True
(b) False
(c) Can't say
(d) Partially true/false

18. The clear sky appears blue, because *(NCERT Exemplar)*

(a) blue light gets absorbed in the atmosphere
(b) ultraviolet radiations are absorbed in the atmosphere
(c) violet and blue lights get scattered more than lights of all other colours by the atmosphere
(d) light of all other colours is scattered more than the violet and blue colour lights by the atmosphere

19. Match Column I with Column II and choose the most appropriate option from the codes given below

	Column I		Column II
A.	Twinkling of stars	p.	Dispersion
B.	Rainbow formation	q.	Internal reflection
C.	White colour of clouds	r.	Atmospheric refraction
D.	Glittering of diamond	s.	Scattering

Codes

(a) A → s, B → r, C → q, D → p
(b) A → p, B → s, C → r, D → q
(c) A → r, B → p, C → s, D → q
(d) A → p, B → q, C → r, D → s

20. The orange-reddish appearance of the sun during sunrise and sunset is because of ..... . *(NCERT Exemplar)*

(a) dispersion of light
(b) scattering of light
(c) total internal reflection of light
(d) reflection of light from the earth

21. The bluish colour of water in deep sea is due to *(NCERT Exemplar)*

(a) less the presence of algae and other plants found in water
(b) reflection of sky in water
(c) scattering of light
(d) absorption of light by the sea

22. The colour of head lights suitable for vehicle in foggy weather is

(a) yellow
(b) red
(c) green
(d) violet

23. To observe Tyndall effect, the size of the scatterer must be smaller than the wavelength of light.

(a) True
(b) False
(c) Can't say
(d) Partially true/false

24. The sky appears dark to passengers flying at very high altitudes mainly because *(CBSE 2020)*

(a) scattering of light is not enough at such heights
(b) there is no atmosphere at great heights
(c) the size of molecules is smaller than the wavelength of visible light
(d) the light gets scattered towards the earth

Assertion-Reasoning MCQs

Direction (Q.Nos. 25-29) For given questions two statements are given-one labeled Assertion (A) and the other labeled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is correct explanation of the A.
(b) Both A and R are true but R is not the correct explanation of the A.
(c) A is true but R is false.
(d) A is false but R is true.

25. **Assertion** Higher the refractive index of prism, lower will be the angle of deviation.

Reason The angle of deviation is inversely proportional to the angle of prism.

26. **Assertion** Refraction of white light through prism gives rise to dispersion.

Reason Both the refracting surfaces of glass slab are parallel to each other. But the refracting surfaces of prism are inclined to an angle called angle of prism.

27. Assertion The rainbow is seen when the sun is behind the observer.

Reason Rainbow is produced due to dispersion of white light by small rain drops hanging in the air after rain.

28. Assertion The stars twinkle while the planet do not.

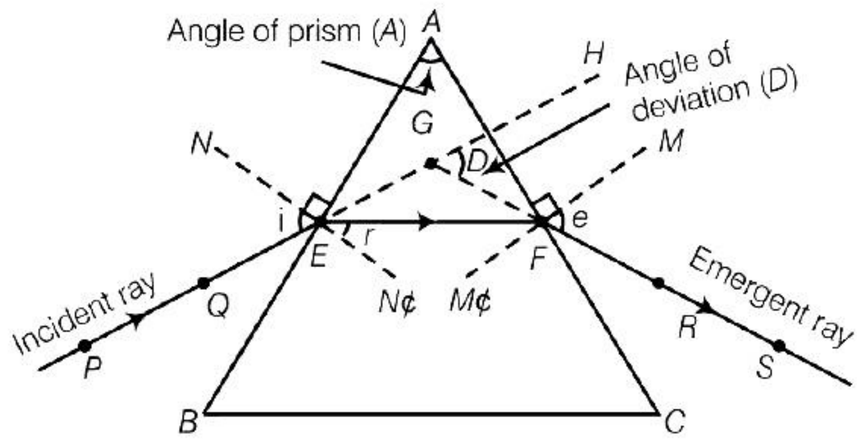
Reason The stars are much bigger in size than the planets.

29. Assertion Blue colour of sky appears due to scattering of blue colour.

Reason Blue colour has shortest wavelength in visible spectrum.

Case Based MCQs

30. Read the following and answer questions from (i) to (v).



Refraction of light through a triangular glass prism

After tracing the path of ray of light through a glass prism, a student measures the angle of incidence $\angle i$, angle of refraction $\angle r$, prism angle $\angle A$, angle of emergence $(\angle e)$ and angle of deviation $(\angle D)$.

Observation table based on the above experiment done by student is as follows

Number of observations	Angle of incidence $(\angle i)$	Angle of emergence $(\angle e)$	Angle of deviation $(\angle D)$
(1)	30°	60°	30°
(2)	35°	55°	30°
(3)	40°	50°	30°
(4)	45°	45°	30°
(5)	50°	40°	30°

(i) From the given ray diagram, the ray that are represented by the (i) PQ (ii) QM, respectively,

(a) incident ray, reflected ray
(b) reflected ray, incident ray
(c) incident ray, refracted ray
(d) refracted ray, incident ray

(ii) The phenomena associated with the splitting of white light into band of seven colours or spectrum is ..... .

(a) dispersion of light (b) scattering of light
(c) refraction of light (d) reflection of light

(iii) Select the correct option from the following, based on the analysis of his measurements:

(a) $\angle A + \angle D = \angle i$
(b) $\angle A + \angle D = \angle i + \angle e$
(c) $\angle A + \angle e = \angle i + \angle D$
(d) $\angle i + \angle D = \angle A + \angle e$

(iv) Which of the following is the correct set-up of protractor for tracing the path of ray of light through a glass prism, for measuring the angle of incidence?

(v) The angle of deviation depends on

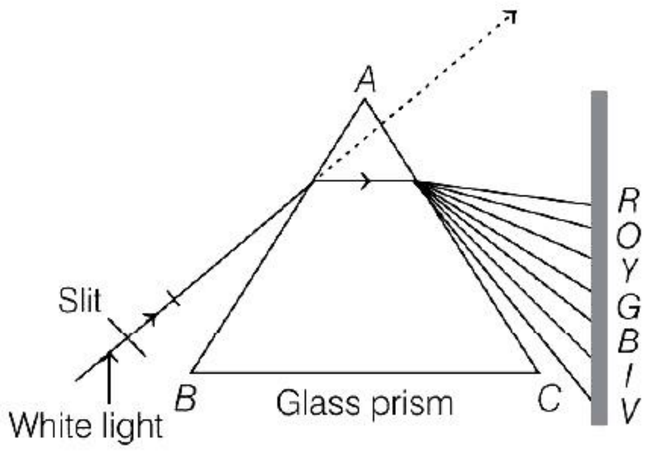
(a) refractive index of prism
(b) angle of incidence
(c) angle of emergence
(d) All of the above

31. Read the following and answer questions from (i) to (v).

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.

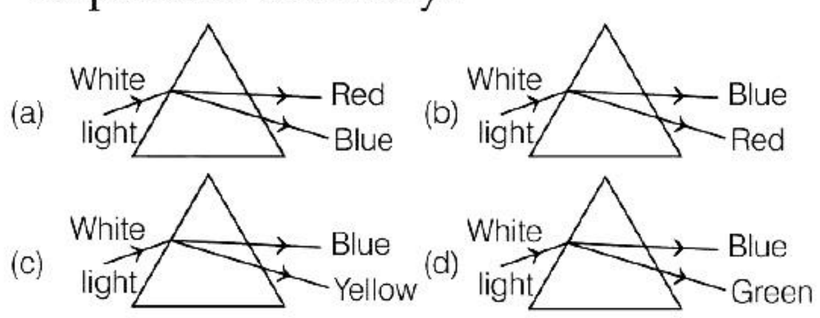
Isaac Newton was the first one to use a glass prism to obtain the spectrum of light.



(i) The splitting of white light can be done by

(a) lens (b) prism
(c) water drop (d) Both (b) and (c)

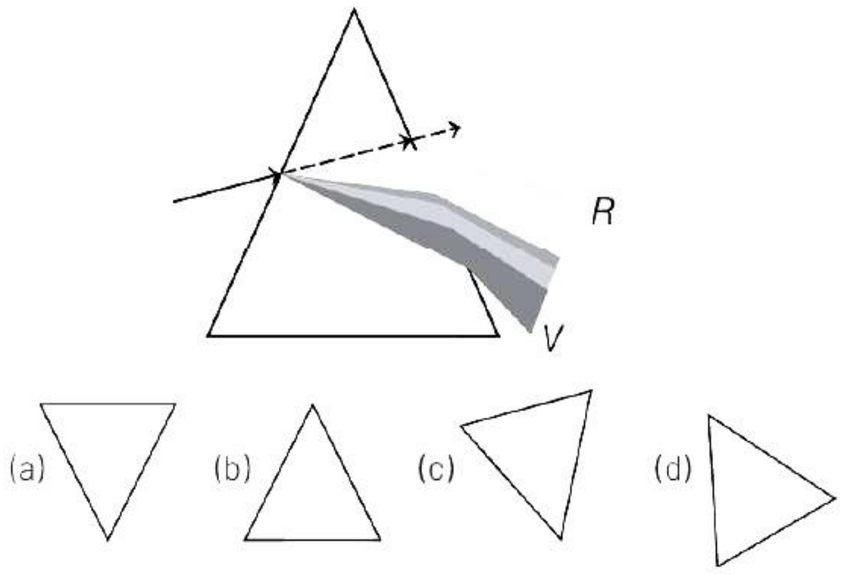
(ii) Which of the following diagram shows dispersion correctly?



(iii) When a red light passes through a prism, it will

(a) not split
(b) split into seven colours
(c) split into white colour
(d) split into many different colours

(iv) Dispersion of white light by a prism is shown in the diagram below. What should be the position of second prism in order to recombine the spectra and yield white light?



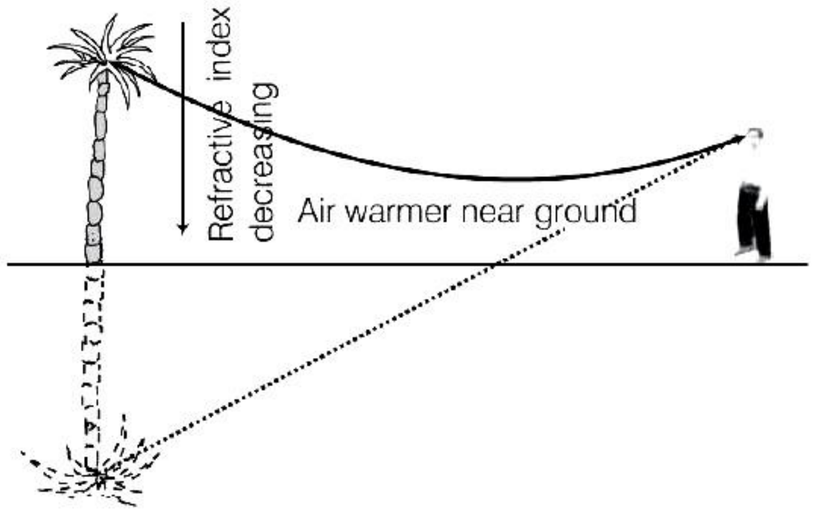
(v) A glass slab is placed over a page on which the word VIBGYOR is printed with each letter in corresponding colour. Then, which of the following is correct?

(a) The images of all the letters will be in the same place as that on paper
(b) Letter V is raised more
(c) Letter R is raised more
(d) None of the above

32. Read the following and answer questions from (i) to (v).

A mirage is a naturally occuring optical phenomenon in which light rays are bent to produce a displaced image of distant objects on the sky.

The fluctuations in the refractive index of the earth's atmosphere is responsible for atmospheric refraction. Mirage is one of the example of atmospheric refraction.



In contrast to hallucination, a mirage is a real optical phenomenon that can be captured on camera, since light rays are actually refracted to form the false image at the observer's location, e.g. inferior images on land are very easily mistaken for the reflections from a small water body. Heat-haze, also known as heat swimmer, refers to the inferior which can be experienced when viewing objects through a mirage layer of heated air. A superior mirage occurs when the air below the line of sight is colder than the air above it.

(i) When light travels from hot air to cold air, then it bends

(a) towards the normal
(b) away from the normal
(c) towards the normal and scatter
(d) away from the normal and scatter

(ii) Mirage is formed due to

(a) bending of light because of multiple layers of atmosphere having different densities
(b) bending of light because of temperature difference of air
(c) dispersion of light because of temperature difference of air
(d) scattering of light because of temperature difference of air

(iii) Due to atmospheric refraction, apparent length of day

(a) increases (b) decreases
(c) remains the same (d) All of these

(iv) The sun appears oval shaped or flattened due to

(a) scattering of light (b) dispersion of light
(c) atmospheric refraction
(d) None of the above

(v) Choose the wrong statement related to refraction of light.

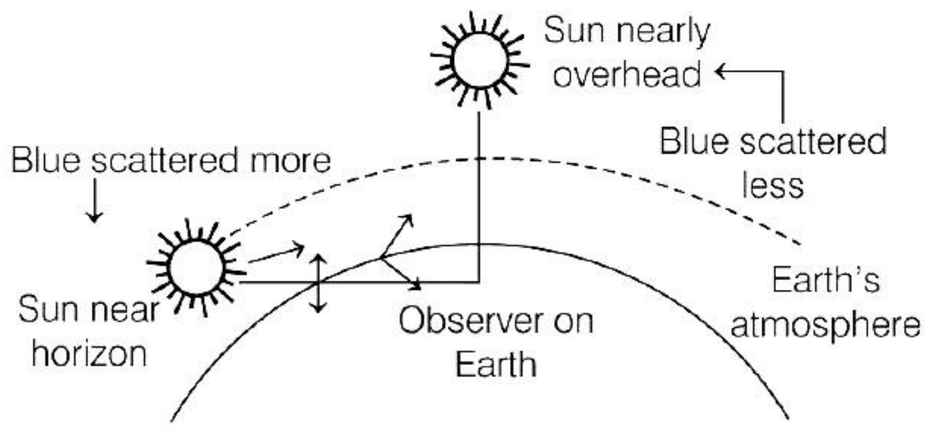
(a) Twinkling of stars
(b) Early sunrise and delayed sunset
(c) Object in water appears bigger in size
(d) Red light undergoes dispersion, while passing through prism

33. Read the following and answer questions from (i) to (v).

At sunrise and sunset, the Sun and the sky appear red. Light from the Sun near the horizon passes through thicker layers of air and covers larger distance in the atmosphere before reaching our eyes.

Near the horizon, most of the blue light and shorter wavelengths light rays are scattered away by the particles. 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.



(i) To an astronaut in a spaceship, the colour of earth appears

(a) red (b) blue
(c) white (d) black

(ii) At the time of sunrise and sunset, the light from the sun has to travel

(a) longest distance of atmosphere
(b) shortest distance of atmosphere
(c) Both (a) and (b)
(d) Can't say

(iii) The colour of sky appears blue, it is due to the

(a) refraction of light through the atmosphere
(b) dispersion of light by air molecule
(c) scattering of light by air molecule
(d) All of the above

(iv) At the time of sunrise and sunset
(a) blue colour scattered and red colour reaches our eye
(b) red colour scattered and blue colour reaches our eye
(c) green and blue scattered and orange reaches our eye
(d) None of the above

(v) The danger signal is made red in colour, because
(a) the red light can be seen from farthest distance
(b) the scattering of red light is least
(c) Both (a) and (b)
(d) None of the above

ANSWERS

Multiple Choice Questions

1. (c)	2. (b)	3. (a)	4. (b)	5. (a)	6. (c)	7. (c)	8. (d)	9. (b)	10. (c)
11. (d)	12. (b)	13. (c)	14. (a)	15. (a)	16. (a)	17. (a)	18. (c)	19. (c)	20. (b)
21. (c)	22. (a)	23. (b)	24. (a)						

Assertion-Reasoning MCQs

25. (d) 26. (b) 27. (b) 28. (b) 29. (a)

Case Based MCQs

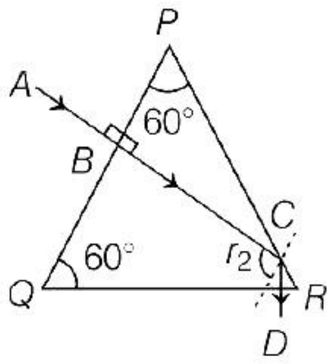
30. (i)-(c), (ii)-(a), (iii)-(b), (iv)-(d), (v)-(d)
31. (i)-(d), (ii)-(a), (iii)-(a), (iv)-(a), (v)-(b)
32. (i)-(a), (ii)-(b), (iii)-(a), (iv)-(c), (v)-(d)
33. (i)-(b), (ii)-(a), (iii)-(c), (iv)-(a), (v)-(c)

EXPLANATIONS

1. According to the diagram, in prism *BDC*,
$\angle D = \angle 1$ = angle of the prism
$\angle 9$ = angle of deviation.

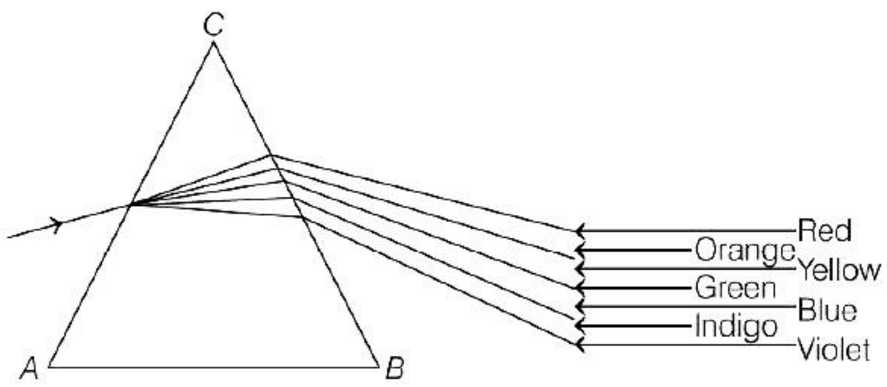
2. False; Prism is a homogeneous transparent medium consisting of three rectangular and two triangular faces.

3. The ray traces path inside prism as shown

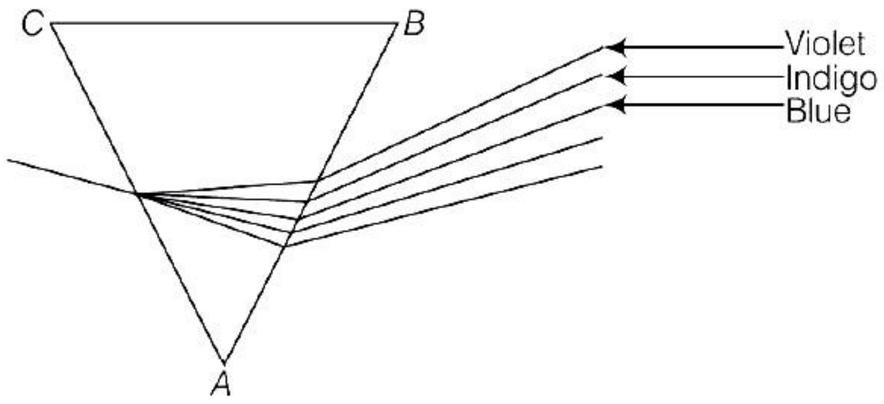


Here, $i = 0° \Rightarrow r_1 = 0°$ and $A = 60°$
Also, $\angle P = r_1 + r_2$
$60° = 0° + r_2$ or $r_2 = 60°$

4. Generally, in case of a prism, the formation of spectrum is shown below



In the above figure, from top the third colour is yellow. But we can see that from bottom the third colour is blue which is the colour of sky. So, we can obtain the correct situation by inverting the prism. Thus the required orientations can be found in case (b).



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

6. When white light passes through prism, then violet colour has maximum deviation and red has minimum deviation.

7. All the colours of white light in air or vacuum move with the same speed but different wavelengths and frequencies.

8. The emergent light will be white, because the outer faces of the prism behave like hollow plates.

9. False; To recombine the spectrum to obtain white light, the recombination prism should be in inverted position with dispersive prism.

10. Rainbow is a phenomenon due to combined effect of dispersion, refraction and internal reflection of sunlight by spherical water droplets of rain.

11. In dispersion through a prism, the red deviates least while blue deviates more. Hence, the wavelength of red is more than blue light.
Also, frequency is related to wavelength by relation

$$f = \frac{1}{\lambda}$$

So, correct graph is shown in option (d).

12. The twinkling of a star is due to atmospheric refraction of light of stars. This light, on entering the earth's atmosphere, undergoes refraction continuously before it reaches the earth.
The path of rays of light coming from the distant star goes on varying slightly, the apparent position of the star fluctuates and the amount of starlight entering the eye flickers. The star sometimes appears brighter and at some other time fainter, which gives us the twinkling effect.

13. Star light coming from far undergoes atmospheric refraction due to gradually changing refractive index of the different layers of atmosphere and hence rays coming from stars refract downwards causing the appearance of the stars above than they actually are.

14. Diagram given depicts early sunrise and late sunset due to atmospheric refraction.

15. True; As the light from the stars have to cover more distance in horizon than from the stars overhead, hence have to cover more layers of atmosphere, having different optical densities and refractive index, hence more twinkling effects.

16. At noon the sun appears white because the light from the sun is directly over head and travels relatively shorter distance. So, only a little light is scattered.

17. True; Scattering depends on wavelength, hence red is scattered least as its wavelength is more.

18. The clear sky appears blue is due to scattering of sunlight. The molecules in the air scatter blue or violet light from the sun more than they scatter other colour's light.

19. A → r; Twinkling of stars is due to atmospheric refraction of light.
B → p; Rainbow is formed in sky due to dispersion of sunlight through rain drops.
C → s; White colour of clouds is due to least scattering of sunlight.
D → q; Glittering of diamond is due to multiple internal reflection of light entering it.

20. The orange-reddish appearance of the sun at sunrise or sunset is due to least scattering of red light as red light have the maximum wavelength and the rays of light have to travel a larger part of the atmosphere.

21. The bluish colour of water in deep sea is due to scattering of light as the very fine particles in water scatter mainly blue light.
The red, green, orange and yellow having longer wavelengths are absorbed more strongly by water than blue which has shorter wavelength. So, when white light from the sun enters the sea, it is mostly the blue that gets returned.

22. Yellow headlights are suitable for a vehicle in foggy weather, because wavelength of yellow colour of light is larger and it does not undergo large scattering.

23. False; The scattering of light when it passes through a colloidal solution is called Tyndall effect. And for scattering the size of the scatterer must be comparable to the wavelength of light.

24. At very high altitudes, the thickness of atmosphere is low. So, there are less number of particles present for scattering. Hence, the sky appears dark to the passengers.

25. Higher the refractive index of prism, greater will be the angle of deviation.

26. Both A and R are true, but R is not the correct explanation of A. Light rays of different colours travel with different speeds and bend through different angles when pass through different media which is the cause of dispersion.

27. Just after rain, the water drops are floating in the air. Each drop acts like a prism. So, when sun rays fall on them, dispersion of light takes place and we see a spectrum of light in the sky.

28. As planets are of larger size but not more than stars and much closer to the earth than stars, so, planets can be considered as a collection of large number of point sized sources of light.

The total variation in the amount of light entering our eye from all these individual point sized sources will average out to zero which nullify the twinkling effect of each other. Therefore, planets do not twinkle.

29. 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 scatter the light of shorter wavelengths, i.e. blue colour light is scattered.

30. (i) Incident ray of light is represented by *PQ*.
Refracted ray of light is represented by *EF*.

(ii) Dispersion of light.

(iii) From the given table, it is clear that

$$\angle A + \angle D = \angle i + \angle e$$

(iv) As angle of incidence is the angle between the incident ray and normal drawn on the refracting surface. So, correct setup of protractor is shown in (d).

(v) The angle of deviation is given by

$$\angle D = \angle i + \angle e - \angle A$$

Thus, it depends on angle of incidence, angle of emergence and angle of prism. It also depends on the refractive index of prism.

31. (i) The white light splits into its constituent colours on passing through a prism or water drops in case of rainbow.

(ii) The deviation is more for blue and minimum for red, so, correct diagram is in option (a).

(iii) As red light has a single wavelength and when it enters a prism, it will not split into other different colours.

(iv) To recombine the spectra to yield white light, the second prism should be kept inverted with respect to given prism as in option (a).

(v) The refractive index of a material depends on the wavelength of light used. Since, refractive index of glass is maximum for violet light, so, letter *V* is raised to the maximum.

32. (i) When light travels from hot air (rarer) to cold air (denser), then it bends towards the normal.

(ii) Mirage is formed due to bending of light because of temperature difference of different layers of air. Due to which the refractive index changes with height.

(iii) Due to atmospheric refraction, apparent length of the day increases by 4 minutes.

(iv) It is due to atmospheric refraction.

(v) The statement (d) is wrong as white light undergoes dispersion while passing through prism.

33. (i) As, light is scattered by the air molecules present in atmosphere and blue colour has shorter wavelength, so it is scattered most and the earth would appears blue.

(ii) As, the distance between us and sun is more at the time of sunrise and sunset. So, light has to travel longest distance during these times.

(iii) Sky appears blue due to more scattering of blue light by molecules of air.

(iv) Red light being of longest wavelength scatters least and reaches our eye while blue colour scatters most.

(v) As, scattering of red light is least, so, it can be seen from farthest distance.