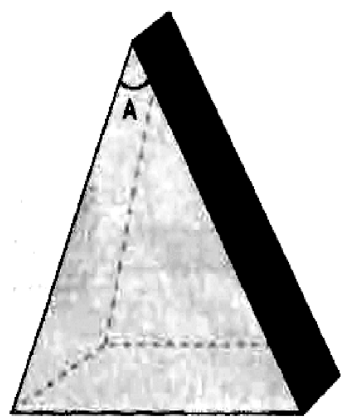
HUMAN EYE AND COLOURFUL WORLD

REFRACTION THROUGH A GLASS PRISM

REFRACTION OF LIGHT THROUGH A PRISM

Prism is a homogenous transparent refracting
medium bounded by at least two non – parallel surfaces inclined at some angle.
It is made of glass and having three rectangular faces and two triangular faces.A commonly used prism is shown in figure. The two non – parallel plane surface participating in the refraction of light are called refracting surfaces.
The angle between two non – parallel
refracting surfaces is called angle of prism or refracting angle. It is denoted by A.

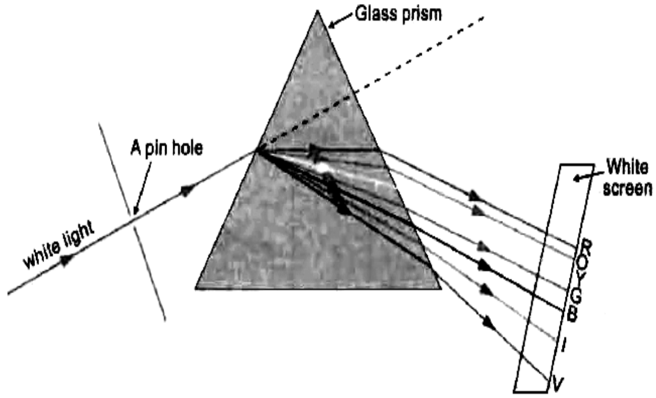


A PRISM

Dispersion of white light through a glass prism

Q. What is Dispersion?

Ans. Spliting of white light into seven colours is called dispersion.
When white light passes through a glass prism, we get a band of seven colours on the white screen as shown in figure. The colour obtained on the screen are violet, indigo blue, green, yellow, orange and red. These colours can be remembered as VIBGYOR. From this observation, we can conclude that white light is a mixture of seven colours. The phenomenon of spliting white light into seven colours is known as dispersion.



Note: The spliting of white light into seven colours when it passes through a prism was investigated by Sir Issac Newton, a great physicist.

Composition of white light: White light is a mixture of seven colours i.e. violet, indigo, blue, green, yellow, orange and red. Every colour has its own characteristic wavelength. Different colours with their wavelengths are given below in the Table.

S No	Colour	Wavelength
1	Red	7900 Å
2	Orange	6000 Å
3	Yellow	5800 Å
4	Green	5400 Å
5	Blue	4800 Å
6	Indigo	4500 Å
7	Violet	4000 Å

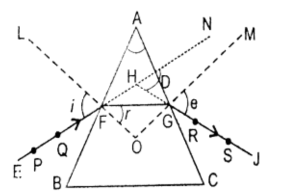
CAUSE OF DISPERSION:

White light consists of seven colours: red, orange, yellow, green, blue, indigo and violet. Each colour has its own wavelength. The wavelength of red colour is the longest and the wavelength of violet colour is the shortest. The speed of light or colour depends upon the wavelength. If wavelength of a colour is large, the speed of the colour is also large. Thus, each colour of light travels with different speed in a given medium. The speed of red colour is more than the speed of orange in a medium. The speed of orange colour is more that the speed of yellow colour and so on. Therefore, the speed of red colour is a medium is the highest and the speed of violet colour is the least.

Hence, all colours of white light are refracted by different amounts while passing through the glass prism. Therefore when a white light passes through a glass prism, different constituent colours come out the prism at different angles. This gives rise to the dispersion of white light.

In figure, ABC is the principal section of the prism. For drawing ray diagrams only principal section is used Refraction of light through an equilateral glass prism is shown below :

EF	—	Incident ray
FG	—	Refracted ray
GJ	—	Emergent ray
$\angle A$	—	Angle of prism
$\angle i$	—	Angle of incidence
$\angle r$	—	Angle of refraction
$\angle e$	—	Angle of emergence
$\angle D$	—	Angle of deviation



Refraction of light through an equilateral glass prism

(i) Angle of deviation - The angle between the incident ray and emergent ray is called angle of deviation.

(ii) Angle of prism : The angle of a prism or the refracting angle of a prism is the angle between the plane on which light is incident and the plane from which light emerges.

(iii) Angle of incidence - It is the angle that the incident ray makes with the normal to the plane where the ray first strikes the prism.

(iv) Angle of Emergence - It is the angle made between the emergent ray and the normal to the plane from which the ray emerges out.

stration

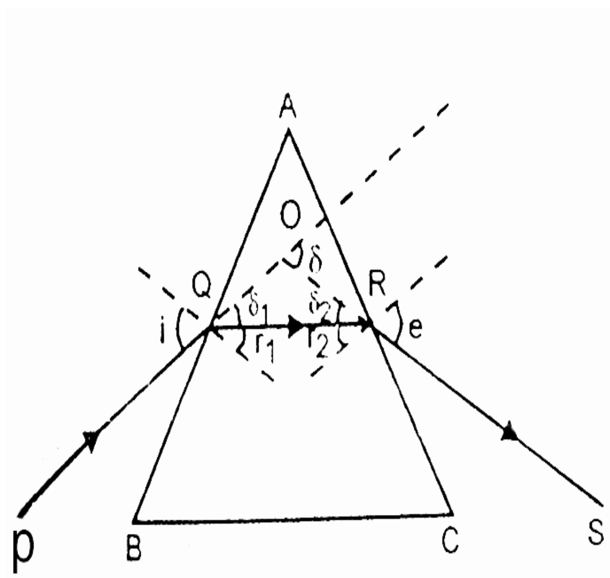
What happens to a light ray that obliquely falls on the transparent side of a prism?

Solution

Light ray is partially reflected and partially refracted at the refracting surface where the light ray strikes. The refracted light ray bends towards the base of the prism and finally suffers second refraction at the opposite surface from where it emerges out of the prism.

The Prism Equation

Let ABC be the principal section of the prism with base BC and angle of the prism at A as shown in figure.



The incident ray PQ after suffering refraction at a front face AB goes along QR, and finally emerges on the second refracting surface AC along RS. In this process the light ray deviates from its original path by an angle .

Let i, r_1, be the angle of incidence, angle of refraction and angle of deviation respectively at the first face AB. Let e, r_2 and be the angle of emergence, angle of incidence and angle of deviation respectively at the second face.

From =

$$\delta=\delta_1+\delta_2$$

$$\delta=(i-r_1)+(e-r_2)$$

$$\delta=i+e-(r_1+r_2) \quad ...(i)$$

From

QAR +AQR + ARQ = 180º, $A + (90 - r_1) + (90 - r_2) = 180°$

$A = r_1 + r_2$ ...(ii)

Substituting this value in equation (i),

$d = i + e - A$ ...(iii)

$A + d = i + e$

$i + e = A + d$ ...(iv)

This is the prism Equation.

Angle of minimum deviation

The angle 'e' is determined by the angle of incidence 'i'. Thus, the angle of deviation 'd' is also determined by :

(i) For a particular value of angle of incidence, the angle of deviation is minimum. In this situation, the ray passes symmetrically through the prism.

Hence for minimum deviation i = e and if i =e we can get $r_1 = r_2$.

From eqn. (iii) , we have

$d_m = i + i - A$

$$i=\left(\frac{A+\delta_m}{2}\right) \quad ....(v)$$

From eqn. (ii), we have

$A = r + r$

$r = A/2$

Using snell's law,

$$\mu=\frac{\sin i}{\sin r}=\frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} \quad ....(vi)$$

Deviation produced by a thin prism :

According to the prism equation,

A + d = i + e

d = i + e – A ....(vii)

Using snell's law at face AB

i & r are very small

$$\mu = \frac{\sin i}{\sin r} = \frac{i}{r_1}$$

i = m r_1

Similarly , e = m r_2

Substituting these values in eqn. (vii)

d = m r_1 + m r_2 – A

d = m(r_1 + r_2) – A ....(using eqn. (iv))

d = m A - A

d = (m - 1) A

Hence deviation produced by a thin prism is independent of the angle of incidence.

Illustration

If a thin prism given a deviation of 3º for violet colour, deviation of 2.5° for red colour, Then find deviation for *mean* colour of light . m_v = 1.60 , m_r = 1.50

Solution

Using the formula -

d = (m – 1) A

dv = (m_v– 1) A

3 = (1.60 – 1) A

Þ A = 3/0.60 = 5º

Also , $\mu = \frac{\mu_v + \mu_r}{2} = \frac{1.60+1.50}{2} = 1.55$

m = = = 1.55

d = $(\mu - 1)A$

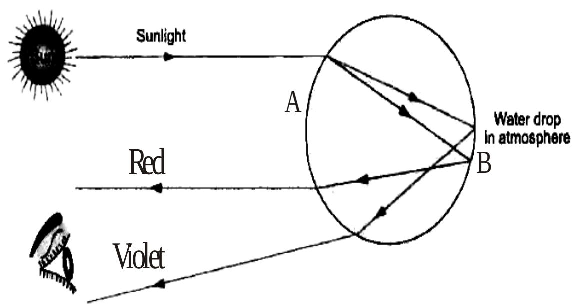
$d = 0.55 \times 5^{\circ} = (2.75)^{\circ}$

Dispersion of light in Nature

You must have seen a beautiful rainbow in the sky after rainfall. This rainbow is formed due to the dispersion of sunlight. When sunlight falls on the water drops suspended in the atmosphere after rainfall, rainbow is formed due to the dispersion of sun light. The waterdrops suspended in air (or atmosphere) act as prisms.

Rainbow :

Rainbow is the example of dispersion of sunlight. The formation of rainbow after rainfall is shown in figure.



When sunlight falls on a water drop suspended in air, then the sunlight is refracted. The refracted sunlight splits (or dispersed) into its constituent colour (i.e. seven colours). Thus water drop suspended in air behave as a glass prism. The red colour deviates the least and the violet colour deviates the most. Different colours of refracted sunlight fall upon the opposite face of the water drop. Now each colour is partly reflected back into the drop. The reflected colours on reaching the lower surface of water drop are refracted again into the air. Thus, we get a spectrum of seven colours, which is known as rainbow.

Rainbow is one of the most beautiful example 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 the rain.**

You can also see rainbow on a bright sunny day, in the mist created by a waterfall or a water fountain.

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.

Conditions for Observing a Rainbow:

Rainbow is observed during a rainfall or after the rainfall or when we look at a water fountain provided the sun is at the back of the observer.