34. DISPERSION OF LIGHT AND COLOURS

34.1 Colour of Light

White light is made up of different colours when viewed through some mechanisms. Rainbow is made of seven colours, but we can see only two or three colours. When the colour is viewed from the sky with the aid of some mechanism, we can see the other five or six colours.

When a white light is incidented on a glass prism, the light is refracted to different rays, when incidented on a screen to produce seven different colours. These colours are red, orange, yellow, green, blue, indigo and violet. This was first discovered by the great physicist, Sir Isaac Newton in 1666.

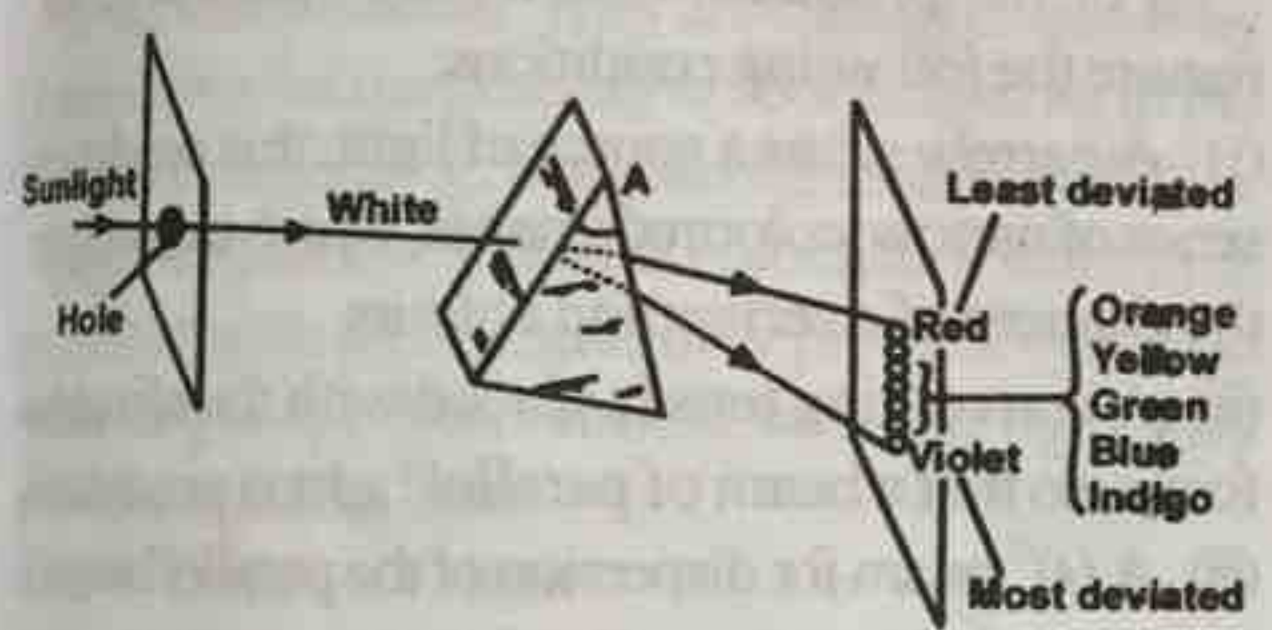

Fig. 34.1 Newton's prism experiment

The colours formed from the emergent rays after refraction are called *spectrum*, while *dispersion* can be defined as the process of separation of white light colour when it passes through a prism of a particular refractive index and the colour of different wavelength are deviated by different amount on a screen.

The colour which deviates most is violet, while the least deviated is the red. The colour can be drawn according to the increase in wavelength and refractive index.

R O Y G B I V

Increasing wavelength → R to V

Decreasing frequency → R to V

Increasing deviation → R to V

Increasing refractive index → R to V

34.2 Recombination of Spectrum

The spectrum of colours can be reversed to its original light [colour]. This follows a simple procedure: the emergent rays from the prism which serve as incident rays for the second prism B, the rays are refracted and combined before coming out as a single ray of light which can be focused on the screen as a wavelight.

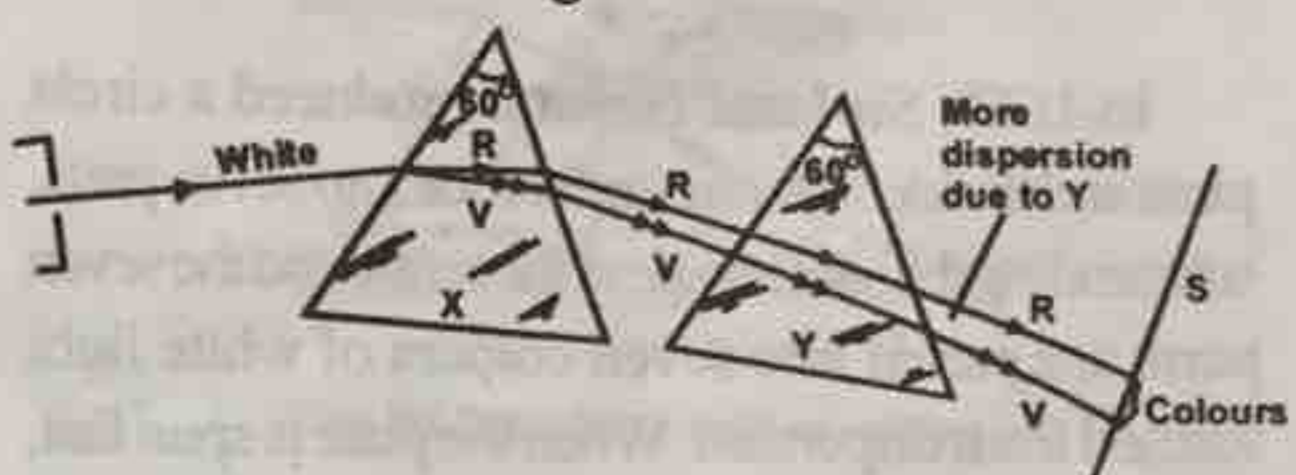

Fig. 34.2 Dispersion

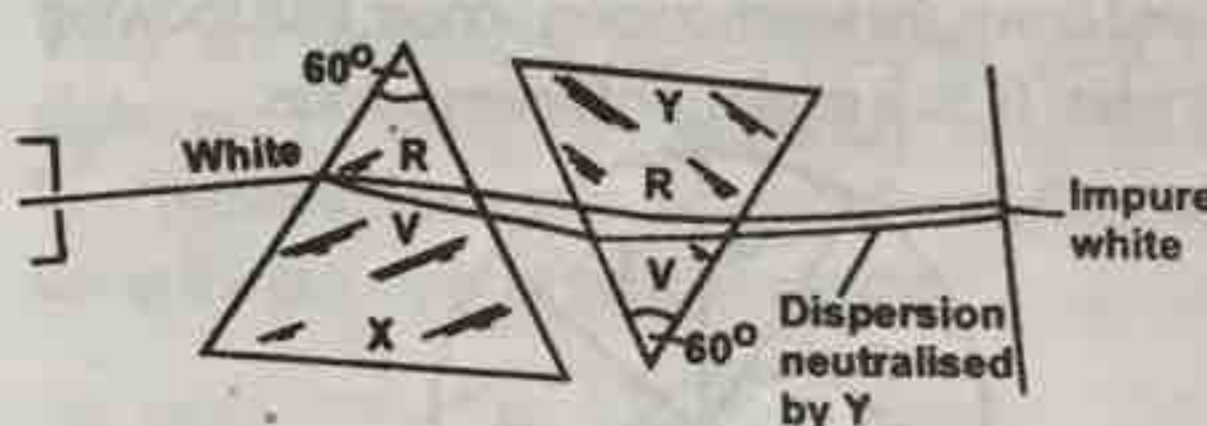

Fig. 34.3 No dispersion

34.3 Dispersion Power

The refractive index of the material of a prism is given by:

$$\mu = \frac{\sin\left(\frac{A + D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Where A is the acute angle of the prism, D is the minimum deviation for small angle prism.

$$\mu = 1 + \frac{D}{A}$$

$D = [\mu - 1] A$

for small prism $A = \alpha$ acute angle

$D = d =$ minimum deviation

Then, $d = [\mu - 1]\alpha$

$d = [\mu - 1]\alpha$

The dispersion power (w) of the material of a small angle prism for blue and red rays is defined as the angular dispersive difference between blue and red to its minimum deviation.

w = angular dispersive difference between red and blue

$$w = \frac{n_b - n_r}{\mu - 1}$$

34.4 Newton's Colour Disc

In 1669, Sir Isaac Newton produced a circle plate and divided the circumference into seven parts, substending the same angle at the centre and the seven parts are parted into seven colours of white light formed from dispersion. When the plate is spun fast, these colours seem to be grey-white, and when it is slowed down, the seven colours appear, thus showing that white light is made up of seven colours.

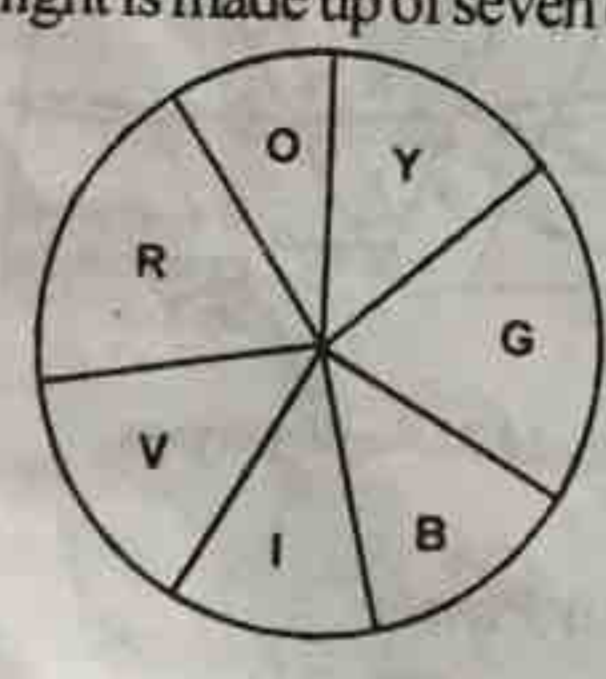

Fig. 34.4 Newton's colour disc

34.5 Pure Spectrum

Spectrum produced so far is impure because the rays overlap and the position of the spectrum also changes as the colour is not separated. A pure spectrum can be produced using a triangular prism–two converging lenses and a narrow slit of white light. The narrow slit is used to produce series of narrow coloured images, which minimizes the chances of overlapping colours, when incident rays are incidented on the converging lens which refract the rays into a parallel beam and focus it on angle 60 triangular prism. The emergent rays are then focused on another converging lens to produce parallel of different colours on the screen at its focus. This produces a spectrum which does not overlap.

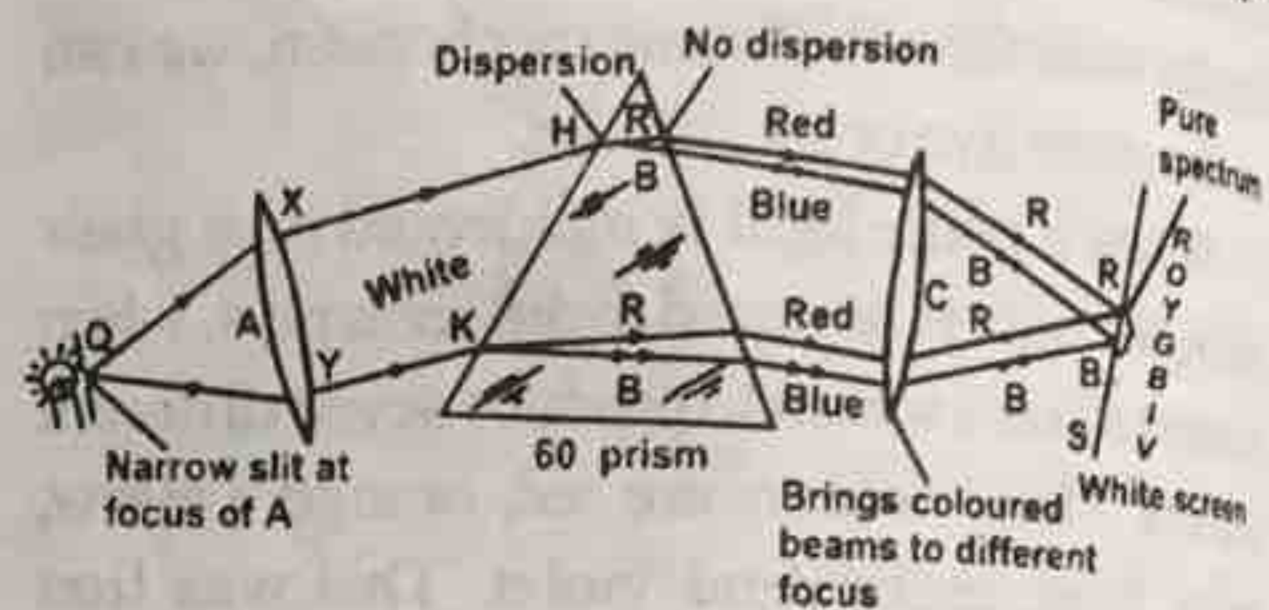

Fig. 34.5 Production of a pure spectrum

For the production of a pure spectrum, we require the following conditions:

(i) A narrow slit as a source of light; this produces series of narrow, coloured images, which minimizes the chances of overlapping colours.

(ii) A converging lens is placed with the slit at its focus, so that a beam of parallel light is produced.

(iii) A 60° prism for dispersion of the parallel beam.

(iv) A second lens for collecting the parallel beams of different colours, but this is not essential.

(v) A screen at the focus of the second lens on which the pure spectrum can be projected.

34.6 Impure Spectrum

Impure spectrum can be produced if only one converging lens is available. The image produced on the screen will not be pure since there is absence of final converging lens to produce a parallel beam as that of pure spectrum. The converging lens focuses the refracted beam parallel to the prism which in turn is refracted and dispersed by focusing them on a screen. The prism must be placed at minimum deviation position to obtain a fairly impure spectrum.

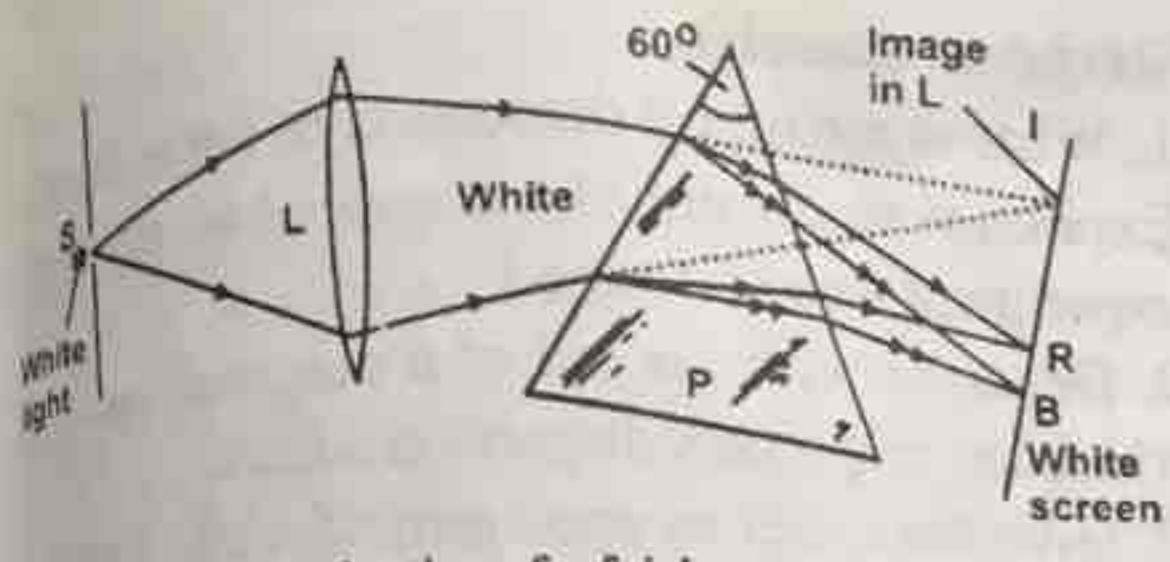

Fig. 34.6 **Production of a fairly pure spectrum**

34.7 Forms of Colours

There are three forms of colours:

1. **Primary colours:** These are colours or spectrum which cannot be produced by mixing any colour together. The primary colours are red, green and blue. They occur naturally from the spectrum and they can form other colours when mixed in the same proportion.

2. **Secondary colours:** These are colours formed from primary colours. They are colours obtained by mixing two of the primary colours together in the same proportion, e.g. when red light mixes with blue light, they produce magenta colour, also when blue is mixed with green light, they produce cyan and when a green light is mixed with red light they produce a yellow light.

Red + Green → Yellow
Green + Blue → Cyan
Blue + Red → Magenta

3. **Complementary colours:** These are two colours which give a white colour when mixed together. Complementary colours are obtained when a secondary colour is mixed with a colour that's not in its component. Complemetary colours can be obtained by

(i) mixing a primary colour with a secondary colour.
(ii) mixing two secondary colours.
(iii) mixing the primary colours.

34.8 Colour Triangles and Circles

The colour triangles and circles are obtained from the additive colour mixing of primary colours with other colours which are secondary and tertiary colours [complementary]. The colour obtained can be summarized as,

R + B → magenta
R + G → yellow
B + G → cyan
Complementary
R + B + G → white
B + Y → white
R + cyan → white
G + magenta → white

These colours of bodies can be represented on an equilateral triangle for easy remembrance.

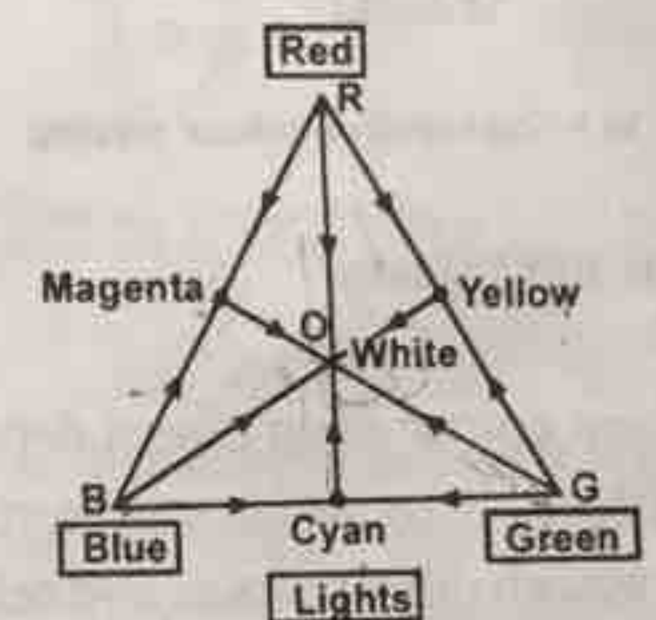

Fig. 34.7 Additive colour mixing

M - magenta, C - cyan, Y - yellow, W - white
They are sometimes represented by their first alphabet to avoid appearing clumsy. They can also be represented in circles, as a set of venn diagrams, using the principle of set to resolve it.

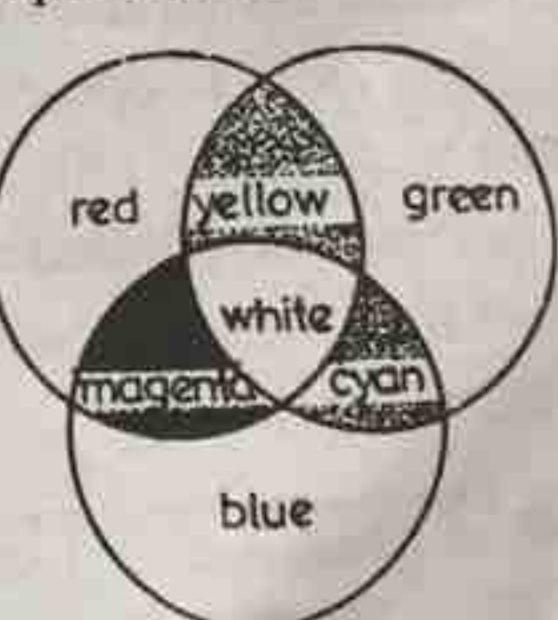

Fig. 34.8 Additive coloured light

34.9 Subtractive Colour Mixing

The mixture of blue and yellow pigments (paints) produces a green colour. This is due to a subtractive process.

Blue paint absorbs all light except blue and

5. MAGNETISM AND MAGNETIC FIELDS

5.1 Magnetism

Certain materials, when brought near iron are found to be attracted to it. Such materials are called *magnets* and the phenomenon is known as *magnetism*. A magnet in the shape of a needle or rod has two poles, the ***north pole*** on one end and the ***south pole*** on the other. If two such magnets are brought close together it would be observed that :

Like poles repel and unlike poles attract

The earth behaves like a big (though weak) magnet with its north magnetic pole close to the geographic south pole while its south magnetic pole is located near the geographic north pole. ***The angle of declination*** is the angle between the earth's geographic N-S axis and the magnetic N-S axis. This varies from place to place on the earth's surface and it also varies with time. The ***angle of dip*** is the angle which the earth's magnetic N-S axis makes with the horizontal.

5.2 Magnetic Lines of Force

If a compass is placed near a magnet, the compass needle is oriented in such a way that its north pole points away from the magnet's north pole and toward the magnet's south pole. By placing the compass at various points around the magnet, imaginary lines can be mapped out with arrows indicating the direction to which the north pole of the compass will point at each location (Fig. 5.1a). These lines are referred to as the magnetic lines of force. The lines go from the north pole of the magnet into its south pole.

The magnetic lines of force around a magnet can also be established by placing the magnet on a cardboard and sprinkling iron filings (fine iron particles) around it. By gently tapping on the board, the iron filings will orient themselves along visible lines which run from the north pole to the south pole of the magnet. The lines of force around two magnets with like poles placed close to each other are shown in Fig. 5.1b and with unlike poles placed close together in Fig. 5.1c.

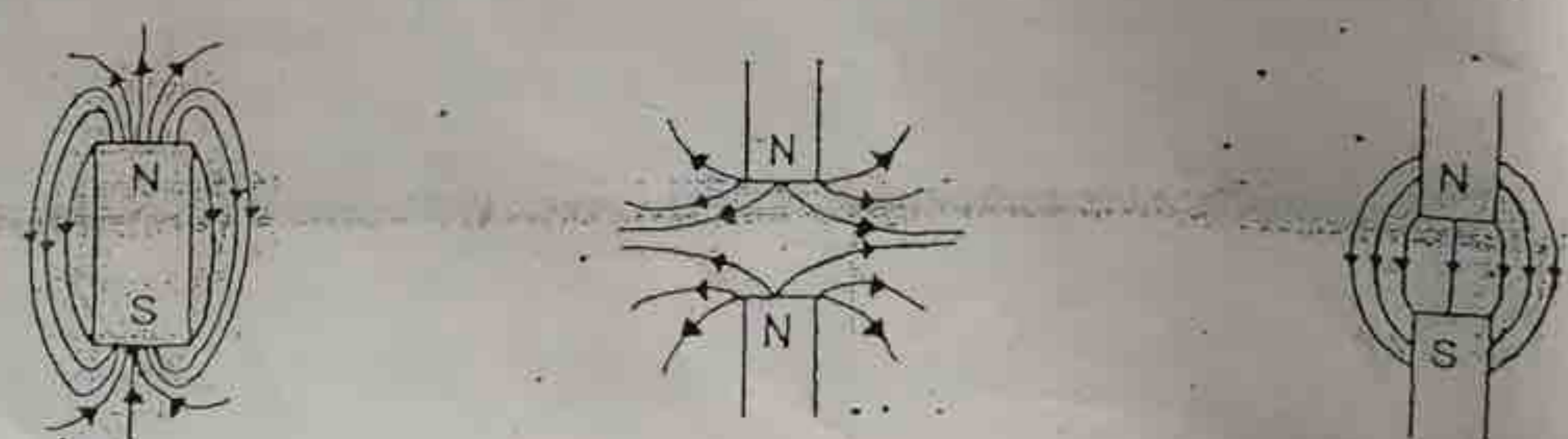

Fig. 5.1 (a) (b) (c)

5.3 The Magnetic Field

Magnetic forces of attraction or repulsion are believed to be due to moving electric charges. A stationary charge exerts a coulombic force on any other charge placed near it. In addition, a *moving* electric charge exerts a force (magnetic force) on another *moving* charge close to it. A *magnetic field* is said to exist within the region in which a moving charge experiences a magnetic force. The magnetic field is characterized by a vector B, which is sometimes called the *magnetic flux density* or the *magnetic induction*. The direction of the magnetic field (or the B - vector) is defined as the direction along which a moving electric charge experiences no force. The unit of B is the *Tesla* (T)

Consider a magnetic field of flux density B which cuts across a surface of area A. The field makes an angle θ with the normal to an element of the surface of area dA (Fig. 5.2). The *magnetic flux* across the surface is the product of the normal component of the magnetic flux density and the area through which the flux passes. For the elemental area dA, the magnetic flux is

$$d\Phi = B_n dA = B \cos\theta \, dA$$

where B_n is the normal component of B. The total magnetic flux across the whole surface is

$$\Phi = \int B_n dA \qquad (5.1)$$

If B does not vary across the surface ,

$$\Phi = B_n A = BA \cos\theta \qquad (5.1a)$$

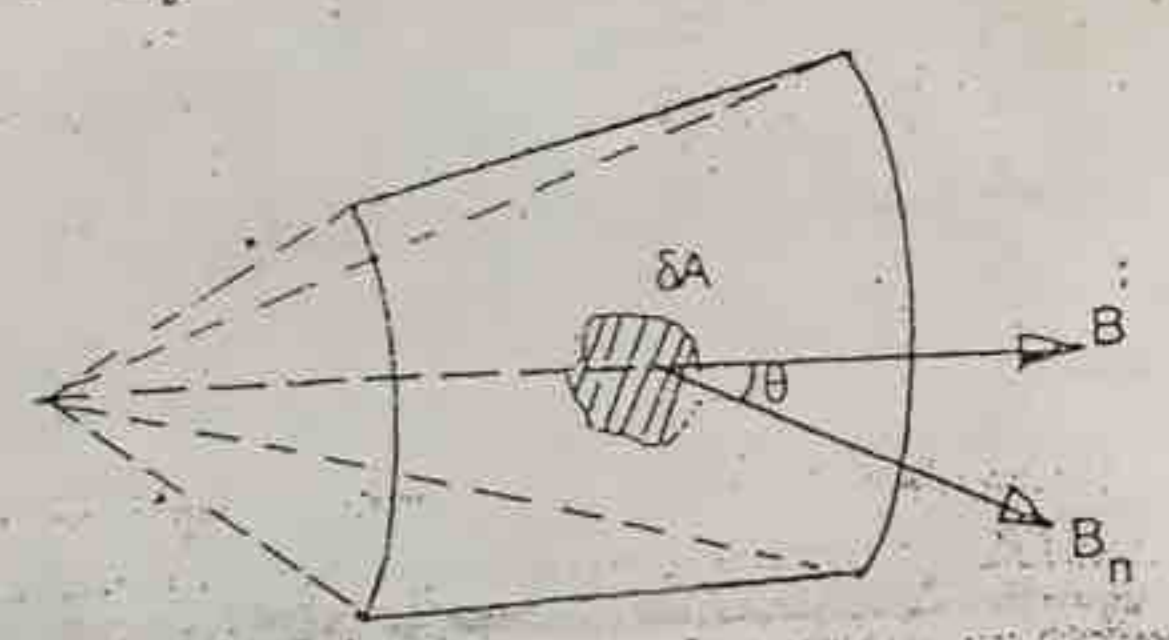

Fig. 5.2

The unit of Φ is [T.m²], also called the *weber* (Wb), i.e. 1 T = 1 Wb/m²

5.4 Magnetic Field of an Electric Current

Since a moving charge sets up a magnetic field around it, it is to be expected that a magnetic field would exist around a current-carrying conductor. The magnetic field generated by an electric current can be imagined as being made up of the sum of the contributions from short segments, each of length dl along the conductor. The magnetic field dB due to a segment dl of the conductor at a point P which is located at a distance r away from the segment (Fig. 5.3) is

$$dB = \frac{\mu_0 I dl \sin\theta}{4\pi r^2} \qquad (5.2)$$