MAGNETISM AND MATTER

THE BAR MAGNET

magnet has two poles similar to the positive and negative charge of an electric dipole.

As mentioned in the introductory section, one pole is designated the North pole and the other, the South pole.

When suspended freely, these poles point approximately towards the geographic north and south poles, respectively.

A similar pattern of iron filings is observed around a current carrying solenoid.

The magnetic field lines

The magnetic field lines of a magnet (or a solenoid) form continuous The pattern suggests that the bar magnet **closed loops**.

This is **unlike** the **electric** dipole where these field lines is a magnetic dipole. begin from a positive charge and end on the negative charge or escape to infinity.

The tangent to the field line at a given point represents the direction of the net magnetic field B at that point.

The larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field B.

The magnetic field lines do not intersect, for if they did, the direction of the magnetic field would not be unique at the point of intersection.

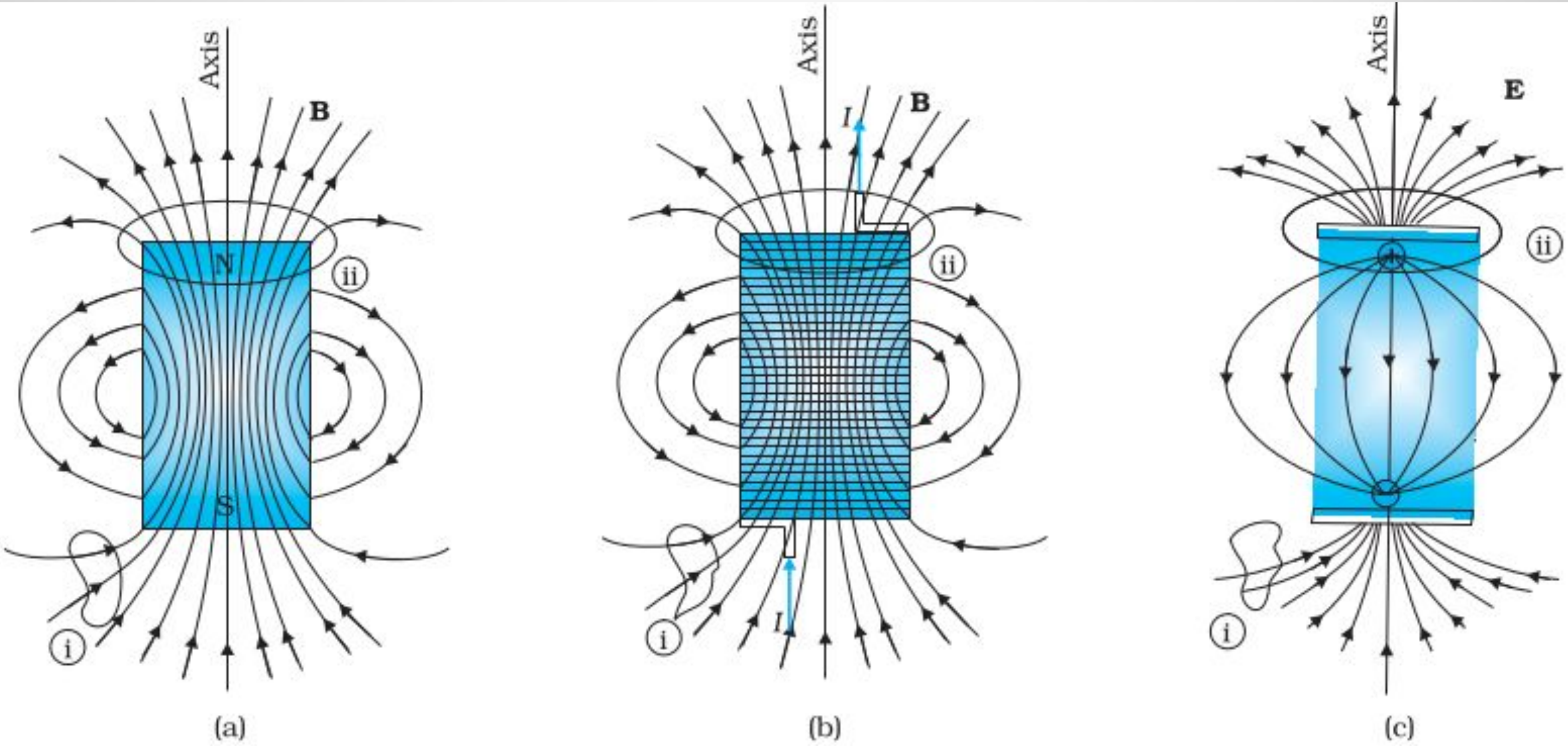


FIGURE 5.3 The field lines of (a) a bar magnet, (b) a current-carrying finite solenoid and (c) electric dipole. At large distances, the field lines are very similar. The curves labelled (i) and (ii) are closed Gaussian surfaces.

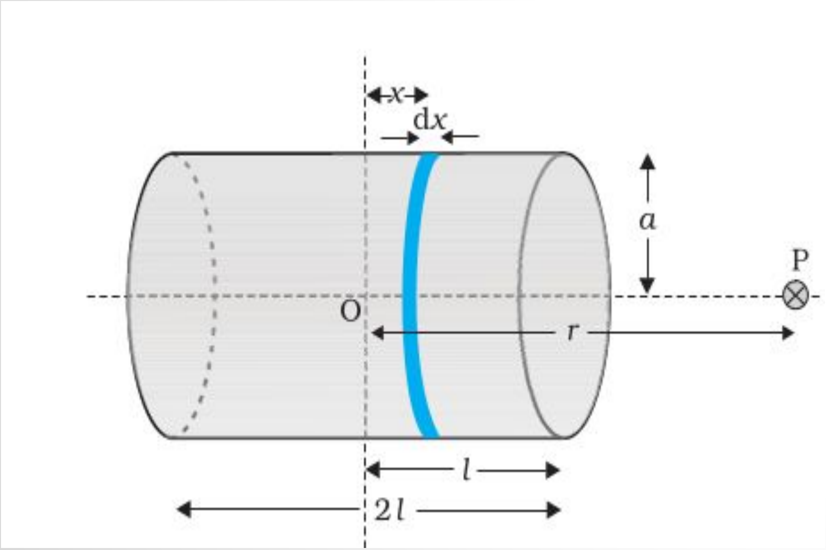
Bar magnet as an equivalent solenoid

We mentioned Ampere’s hypothesis that all magnetic phenomena can be explained in terms of circulating currents.

Recall that the magnetic dipole moment m associated with a current loop was defined to be **m = NI A** where N is the number of turns in the loop, I the current and A the area vector

The resemblance of magnetic field lines for a bar magnet and a solenoid suggest that a bar magnet may be thought of as a large number of circulating currents in analogy with a solenoid

We shall demonstrate that at large distances this axial field resembles that of a bar magnet



Consider a circular element of thickness **dx** of the solenoid at a distance **x** from its centre. It consists of (**n dx**) turns.

If current enclosed I_e = (ndxI)

the magnitude of the field at point P due to the circular element is

$$dB = \frac{\mu_0 n \, dx \, I a^2}{2[(r-x)^2 + a^2]^{3/2}}$$

The magnitude of the total field is obtained by summing over all the elements .

By integrating from x = – l to x = + l and by using trigonometric substitutions, we get

$$B = \frac{\mu_0 n I a^2}{2 r^3} \int_{-l}^{l} dx$$

$$= \frac{\mu_0 n I}{2} \frac{2 l a^2}{r^3}$$

the magnetic moment of the solenoid is equal to total number of turns × current × cross-sectional area

ie m = n (2ℓ) I (π a^2)

Therefore

$$B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$$

This is also the far axial magnetic field of a bar magnet which one may obtain experimentally