Electromagnetism

Before we deal with this major subject, it would be sensible to discuss basic magnetism briefly.

Magnetism
We are all familiar with simple magnets and have probably all seen the lines of force traced on paper with iron filings. The quantity of lines of force that come out from a magnet is called the *flux* and is measured in *Webbers* (Wb). **Wilhelm Edward Weber (1804–91)**German scientist famous for his work in the measurement of electrical quantities.

Flux density: symbol, *B*; unit, tesla (T)
Just as population densities are measured in people per km^2, flux density is measured in flux per m^2 or Wb/m^2. This unit, however, is known as the *tesla* (T).

$$B(\text{T}) = \varphi(\text{Wb}) / a\ (\text{m}^2)$$

Nickola Tesla (1856–1943) Yugoslavian electrical engineer renowned for his work on a.c. generation and distribution.

Example
A motor field pole has an area of 60 cm^2. If the pole carries a flux of 0.3 Wb, calculate the flux density.

$$B =;\ ?\_ = 0.3\ \text{Wb};\ a = 60\text{cm}^2 = 0.006\text{m}^2$$

B = 0.3/.006 = 50T

<u>Electromagnetism</u>

This is the principle of producing a magnet using an electric current and ferromagnetic material.

Field around a conductor carrying a current

When a conductor carries a current, a magnetic field is produced around that conductor. This field is in the form of concentric circles along the whole length of the conductor Fig.1

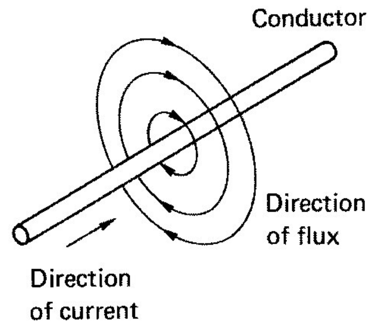

Fig 1

The direction of the field depends on the direction of the current – clockwise for a current flowing away from the observer and anticlockwise for a current flowing towards the observer. In order to show these directions, certain signs are used (Fig. 2).

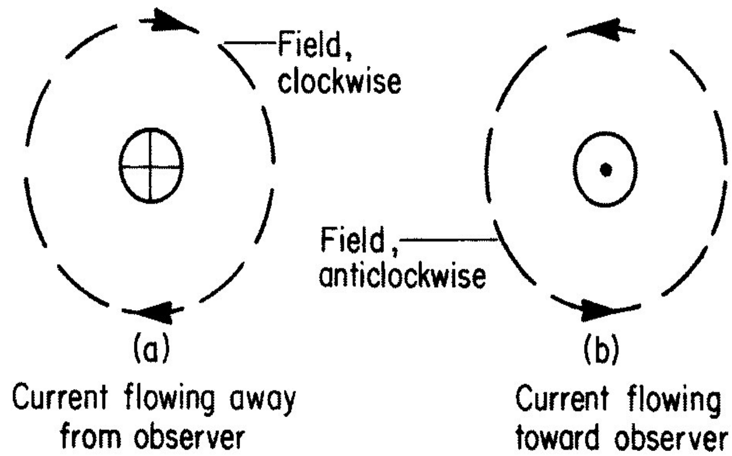

Fig.2

The screw rule

In order quickly to determine the direction of the magnetic field around a current-carrying conductor, the screw rule may be applied (Fig. 3). Imagine a screw being twisted into or out of the end of a conductor in the same direction as the current. The direction of rotation of the screw will indicate the direction of the magnetic field.

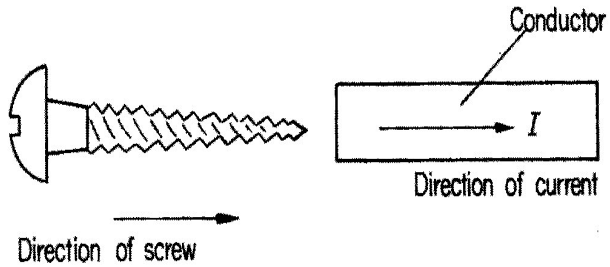

Fig.3

Force between current-carrying conductors

If we place two current-carrying conductors side by side there will exist a force between them due to the flux. The direction of this force will depend on the directions of the current flow (Fig. 4).
In Fig. 4a there is more flux between the conductors than on either side of them, and they will be forced apart.

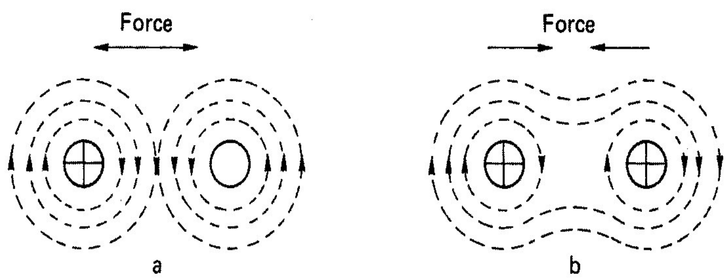

Fig.4

In Fig. 4b, the flux between the conductors is in opposite directions and tends to cancel out leaving more flux on the outside of the conductors than in between them, so they will be forced together. The direction of movement can be found using Fleming's left-hand rule.

Fleming's left-hand rule

If the thumb, first and second fingers of the left hand is placed at right angles to one another (Fig. 5), they indicate: First finger Field, second finger Current, thumb Motion

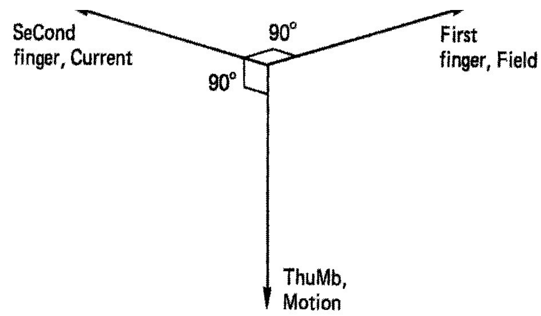

Fig. 5

Force on a conductor carrying a current in a magnetic field

If we arrange for a current-carrying conductor to be placed at right angles to a magnetic field, a force will be exerted on that conductor (Fig. 4.6). This force is measured in newtons.

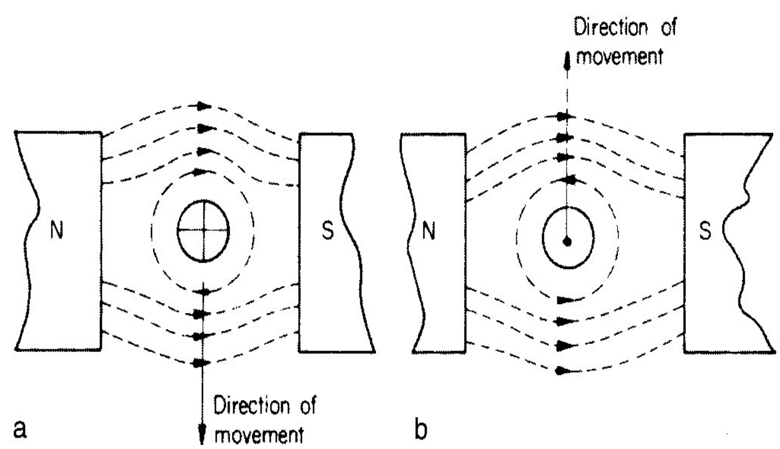

Fig. 6

Sir Isaac Newton (1642–1727)
English scientist of considerable fame, known especially for his work on force, mass, motion and momentum. In Fig. 6a the flux above the conductor is greater than the flux below, and the conductor is forced downwards. In Fig. 6b the current and hence the field around the conductor is opposite to that in Fig. 4.6a and the conductor is forced upwards.
The magnitude of this force is dependent on three things:

i. the current flowing in the conductor (I);
ii. the density of the magnetic field (B); and
iii. The length of the conductor in the magnetic field (l).

F (newtons) = B (teslas) · l (metres) · I (amperes)

Example

Calculate the force exerted on a conductor 40 cm long carrying a current of 100 A at right angles to a magnetic field of flux density 0.25 T.

F = ?; B = 0.25 T; l = 40 cm = 0.4 m; I = 100A
$F = B \cdot l \cdot I$
$= 0.25 \cdot 0.4 \cdot 100$
F = 10N

Example
A circular magnetic field has a diameter of 20 cm and a flux of 149.6 mWb. Calculate the force exerted in a conductor 21 cm long lying at right angles to this field if the current flowing is 15 A.

$B = \Phi/a$

But $a = \pi d^2/4$

Complete the problem