Cambridge

A2 Level

Physics

CODE: (9702)

Chapter 26

Chapter 26: Magnetic fields and electromagnetism

Producing and representing magnetic fields

We represent magnetic field patterns by drawing magnetic field lines

■ ■ The magnetic field lines come out of north poles and go into south poles. uniform field
■ ■ The direction of a field line at any point in the field shows the direction of the force that a 'free' magnetic north pole would experience at that point.
■ ■ The field is strongest where the field lines are closest together.

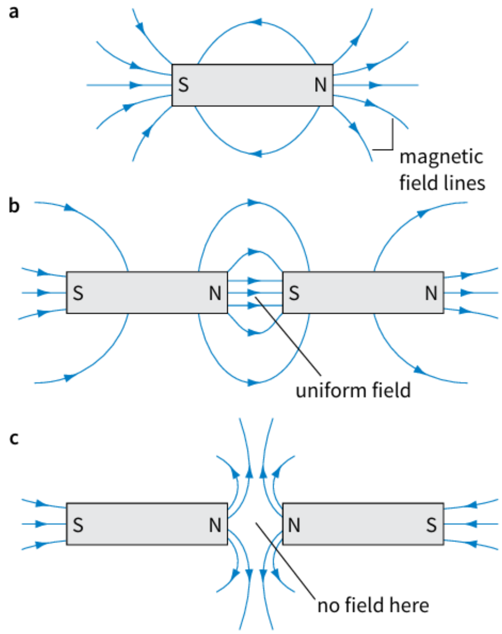

Figure 26.2 Magnetic field patterns: **a** for a bar magnet; **b** for two attracting bar magnets; **c** for two repelling bar magnets.

Field direction

The idea that magnetic field lines emerge from north poles and go into south poles is simply a convention. Figure 26.5 shows some useful rules for remembering the direction of the magnetic field produced by a current

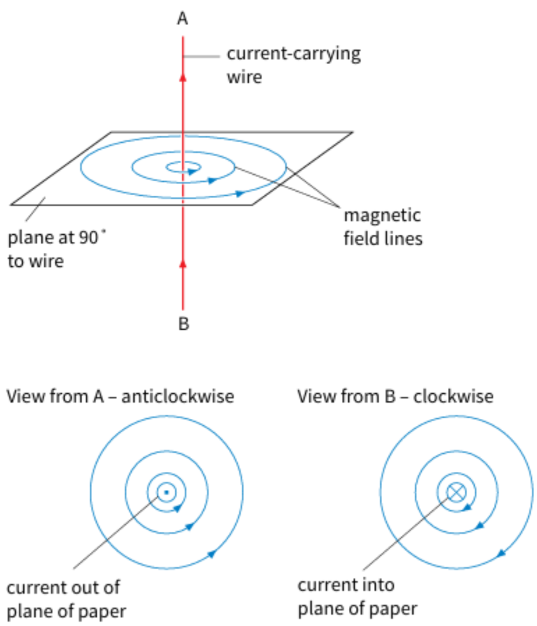

Figure 26.4 The magnetic field pattern around a current-carrying wire. The diagram also shows the convention used to indicate the direction of current.

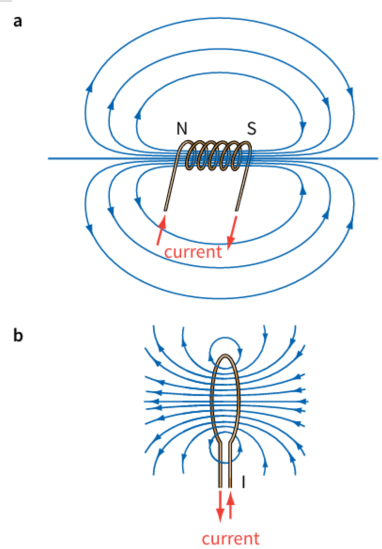

Figure 26.3 Magnetic field patterns for **a** a solenoid, and **b** a flat circular coil.

The right-hand grip rule gives the direction of magnetic field lines in an electromagnet. Grip the coil so that your fingers go around it is following the direction of the current. Your thumb now points in the direction of the field lines inside the coil, i.e. it points towards the electromagnet's north pole.

The circular field around a wire carrying a current does not have magnetic poles. To find the direction of the magnetic field you need to use another rule, the **right-hand rule.**

Magnetic force

A current-carrying wire is surrounded by a magnetic field. This magnetic field wil interact with an external magnetic field, giving rise to a force on the conductor, just like the fields of two interacting magnets. A simple situation is shown in Figure 26.8.

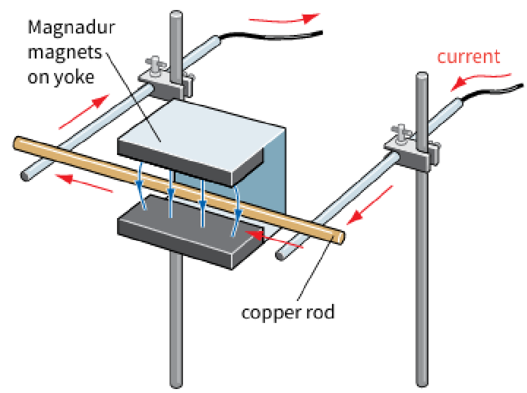

Figure 26.8 The copper rod is free to roll along the two horizontal aluminium 'rails'.

Explaining the magnetic force

We can explain this force by thinking about the magnetic fields of the magnets and the current-carrying conductor. These fields combine or interact to produce the force on the rod. Figure 26.10 shows:

- ■ ■ the external magnetic field of the magnets
- ■ ■ the magnetic field of the current-carrying conductor
- ■ ■ the combined fields of the current-carrying conductor and the magnets

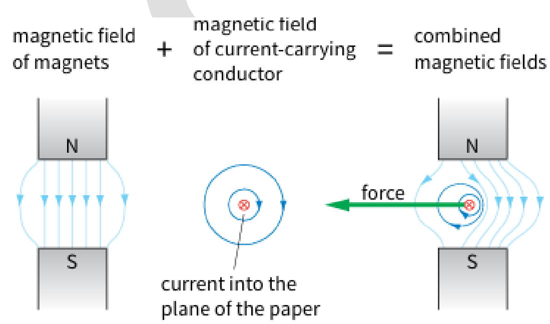

Figure 26.10 In the field of a permanent magnet, a current-carrying conductor experiences a force in accordance with Fleming's left-hand rule. The fields due to the permanent magnet and the current (left and centre) combine as shown on the right.

Magnetic flux density

In electric or gravitational field diagrams, the strength of the field is indicated by the separation between the f ield lines. The field is strongest where the field lines are closest together. The same is true for magnetic fields. The **strength** of a magnetic field is known as its **magnetic flux density,** with symbol B

> The magnetic flux density at a point in space is the force experienced per unit length by a long straight conductor carrying unit current and placed at right angles to the field at that point.

The tesla is defined as follows

> The magnetic flux density is 1 T when a wire carrying a current of 1 A placed at right angles to the magnetic field experiences a force of 1 N per metre of its length.

Measuring magnetic flux density

Box 26.2 looks at two practical methods for measuring magnetic flux density.

Measuring magnetic flux density

Box 26.2 looks at two practical methods for measuring magnetic flux density.

Whenever an electric current cuts across magnetic field lines (Figure 26.18), a force is exerted on the current-carrying conductor. This helps us to remember that a conductor experiences no force when the current is parallel to the field.

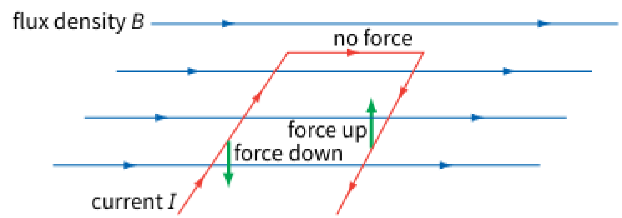

Figure 26.18 The force on a current-carrying conductor crossing a magnetic field.

Forces between currents

Any electric current has a magnetic field around it. If we have two currents, each will have its own magnetic field, and we might expect these to interact.

Explaining the forces

There are two ways to understand the origin of the forces between current-carrying conductors. In the first, we draw the magnetic fields around two current-carrying

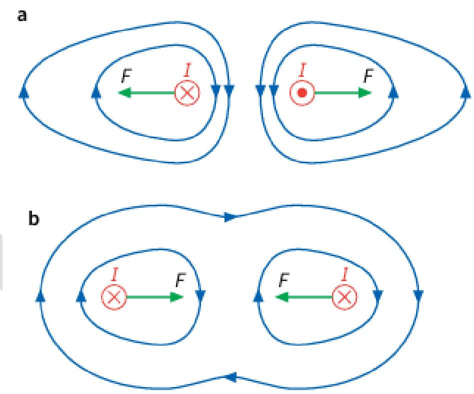

Figure 26.22 The forces between current-carrying wires.

The arrow shows the direction of the force, which is towards I1. Similarly, there will be a BIL force on I1, directed towards I2. T hese two forces are equal and opposite to one another. They are an example of an action and reaction pair, as described by Newton's third law of motion.

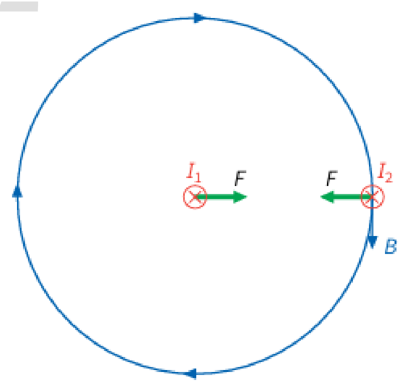

Figure 26.24 Explaining the force between two currents.

Relating SI units

In this chapter, we have seen how one SI unit, the tesla, is defined in terms of three others, the amp, the metre and the newton. It is an essential feature of the SI system that all units are carefully defined; in particular, derived units such as the newton and tesla must be defined in terms of a set of more fundamental units called **base units.**

The exact definition is not required, but you should know that the ampere is itself a base unit. Other units are known as **derived units,** and can be deduced from the base units.

Base units	Derived units	because
m, kg, s	newton $N = kg\,m\,s^{-2}$	$F = ma$
	joule $J = kg\,m^2\,s^{-2}$	$W = Fd$
	watt $W = kg\,m^2\,s^{-3}$	$P = \frac{W}{t}$
m, kg, s, A	coulomb $C = A\,s$	$Q = It$
	volt $V = kg\,m^2\,A^{-1}\,s^{-3}$	$V = \frac{W}{Q}$
	tesla $T = kg\,A^{-1}\,s^{-2}$	$B = \frac{F}{IL}$

Table 26.1 How derived units relate to base units in the SI system.

Comparing forces in magnetic, electric and gravitational fields

Other features that all fields share include:

■ ■ Action at a distance, between masses, between charges or between wires carrying currents.

■ ■ Decreasing strength with distance from the source of the field.

■ ■ Representation by field lines, the direction of which show the direction of the force at points along the line; the density of field lines indicates the relative strength of the field