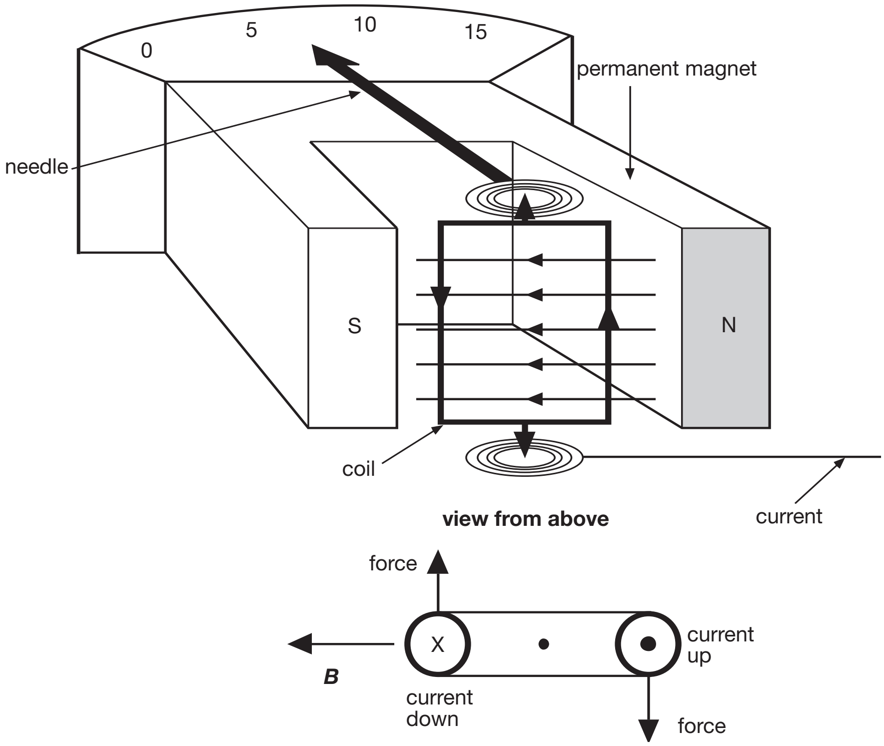


Figure 2.14
A galvanometer measures the current flowing through a coil in a magnetic field.

The coil usually freely moves around a fixed, soft iron cylinder. When used in conjunction with curved magnetic poles, this serves to increase the magnetic field passing through the coil and makes the galvanometer more sensitive. In addition, this arrangement produces a radial magnetic field. This ensures that some of the field always lies at right angles to the coil and that the turning force on the coil is almost independent of the position of the coil.

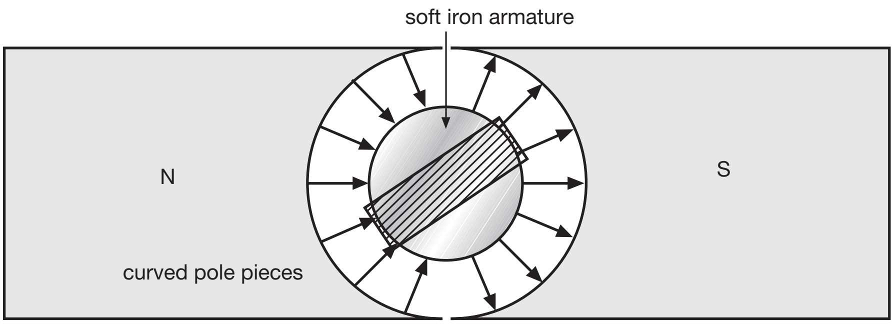


Figure 2.15
The soft iron cylinder inside the coil of a galvanometer increases the magnetic field in the coil.

Motors

Simple DC motors

Electrical meters use the turning force or torque on a current-carrying coil in a magnetic field to move a pointer. The turning force is opposed and balanced by a light spring. If the spring were removed, the meter would rotate past its mid point and come to a stop.

If the direction of the current were reversed at the instant the coil moved past its mid point, the coil would be dragged further. This principle is used in building motors.

In the simplest electrical motor, a fixed magnetic field is supplied by a horseshoe magnet or a pair of bar magnets. Within this, coils, supported by an armature, rotate. A current flows thought the coils causing the armature to rotate.

Figure 2.16**a** shows a current passing through a coil that lies along the magnetic field. The sections of the coil that are at right angles to the field are acted upon by a turning force, which pulls the coil around until it is at right angles to the field (Figure 2.16**b**). At this point,

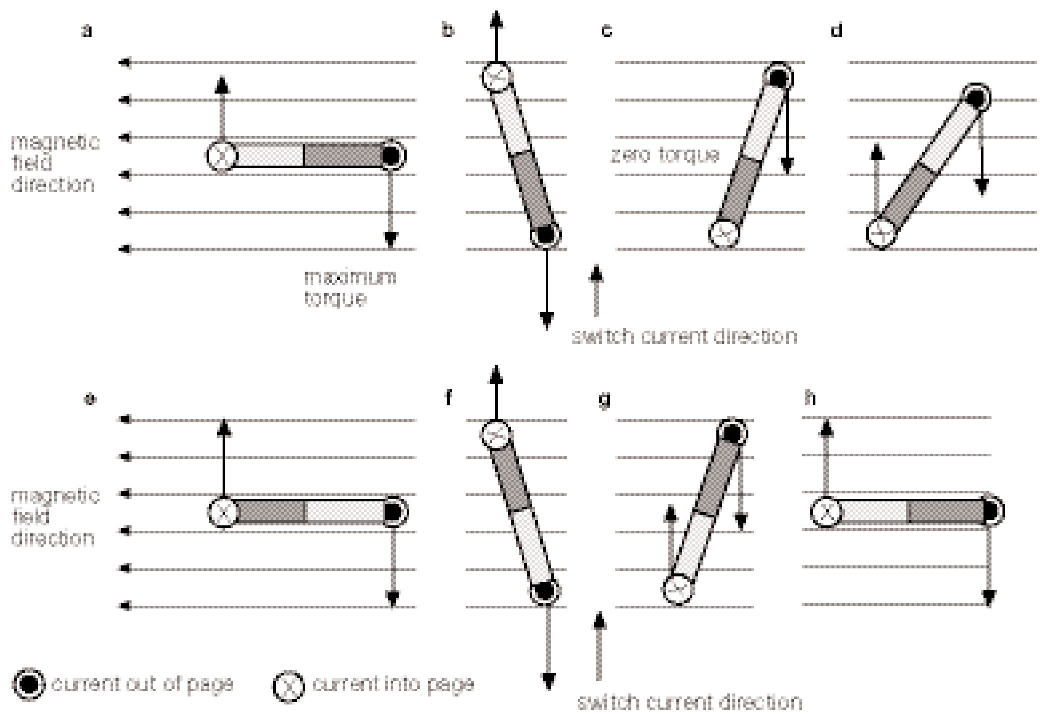


Figure 2.16
a Coil lies along the magnetic field. **b** Turning force pulls coil around until it is at right angles to field. **c** The current direction is switched. **d**, **e** The coil is pulled around until it again lies along the field. **f** It continues until at right angles to field. **g** The current direction is again reversed. **h** The coil passes through its original position.

the forces on each side of the coil balance. If the direction of the current flowing through the coil is reversed (Figure 2.16**c**), the coil will now continue to be dragged around until it is again lying along the field (Figure 2.16**e**) and continue on until it again lies at right angles to the field (Figure 2.16**f**). The current direction is again reversed (Figure 2.16**g**) and the coil is pulled over the top of its rotation and back to its starting position (Figure 2.16**h**).

The art of building a DC motor lies in switching the current direction at exactly the right time. This is achieved by using a simple switch connected to the shaft of the motor itself. The switch is known as a **commutator**. This commutator consists of two semicircular contacts mounted on the motor shaft. These contacts are soldered to each end of the coil. Current passes into the coil through a stationary carbon brush pushed up against one of the commutator half rings. After passing through the coil the current leaves through the other commutator half ring and the second stationary carbon brush.

As the motor rotates through the position where the coil lies across the field, each brush loses contact with the split ring and almost immediately reconnects to the other half of the split ring. This occurs twice in every rotation at which time the current reverses and the motor continues to be pulled around.

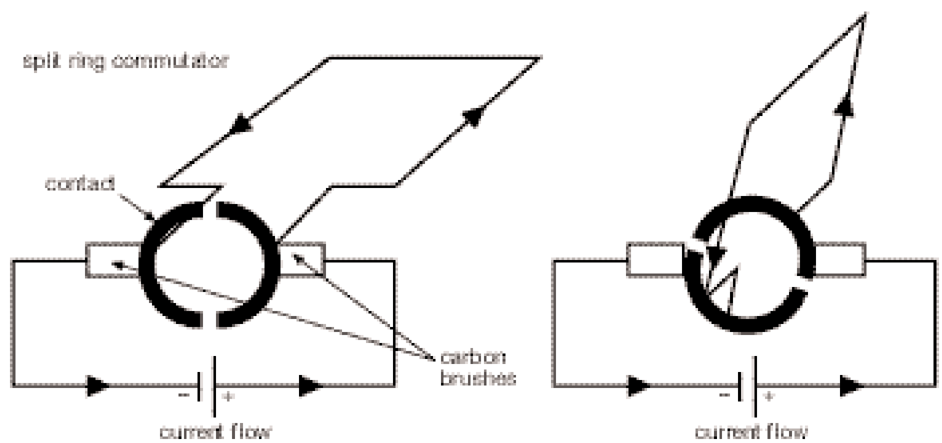
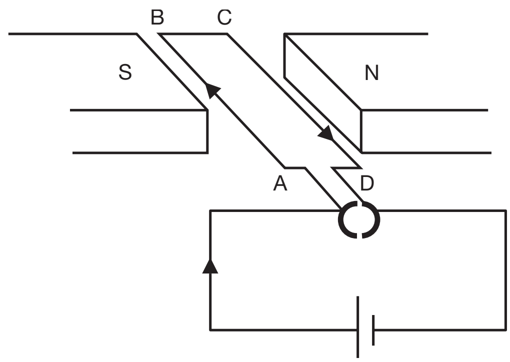


Figure 2.17
The split-ring commutator used in DC motors and generators.

Example

Problem

A rectangular loop of wire carrying a current of 10 A is in a uniform magnetic field of 1.0×10^{-2} T.
AB = CD = 0.075 m
BC = 0.016 m



a Calculate the magnitude of the force on CD.
b Calculate the magnitude of the force on BC.
c Calculate the maximum torque experienced by the coil.

Solution

a $F = BIl = 1.0 \times 10^{-2}\ \text{T} \times 10\ \text{A} \times 0.075\ \text{m} = 7.5 \times 10^{-3}\ \text{N}$
b 0 N
c $\tau = nIBA = 1\ \text{turn} \times 10\ \text{A} \times 1.0 \times 10^{-2}\ \text{T} \times (0.0750\ \text{m} \times 0.016\ \text{m}) = 1.2 \times 10^{-4}\ \text{N m}$

Improvements to DC motors

Such DC current motors are found mainly in battery-operated toys and tools etc.

As we have seen the torque delivered by such a motor is not smooth, but varies as a cosine curve.

DC motors are used in a wide variety of applications, from driving rail engines or golf buggies, to operating a compact disc player. Their design reflects their differing uses.

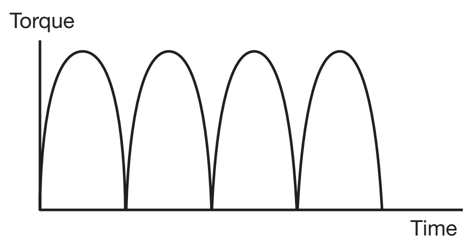


Figure 2.18 The torque produced by a simple DC motor is not constant.

They can be designed to produce a more constant torque by using several coils set at different angles to each other, and each connected via its own commutator to the current supply. Each coil delivers its maximum torque at a different time, smoothing the rotation of the motor.

The torque delivered by the motor can be increased by making some simple improvements.

- Make the coil from several hundred turns of thin wire.
- Use a soft iron centre to the coil or armature. This increases the number of field lines passing through the coil, and provides radial magnetic field lines, which ensure that the turning force on the coil is almost independent of the coil's position.
- Replace the permanent magnets by electromagnets, which can produce higher magnetic field strengths. These electromagnets are called stators and remain fixed, while the armature coils rotate inside them.