CHAPTER 9

AC motors

Motors are used in industries and the home usually to convert electrical energy into more useful forms of energy

AC electric motors

9.1

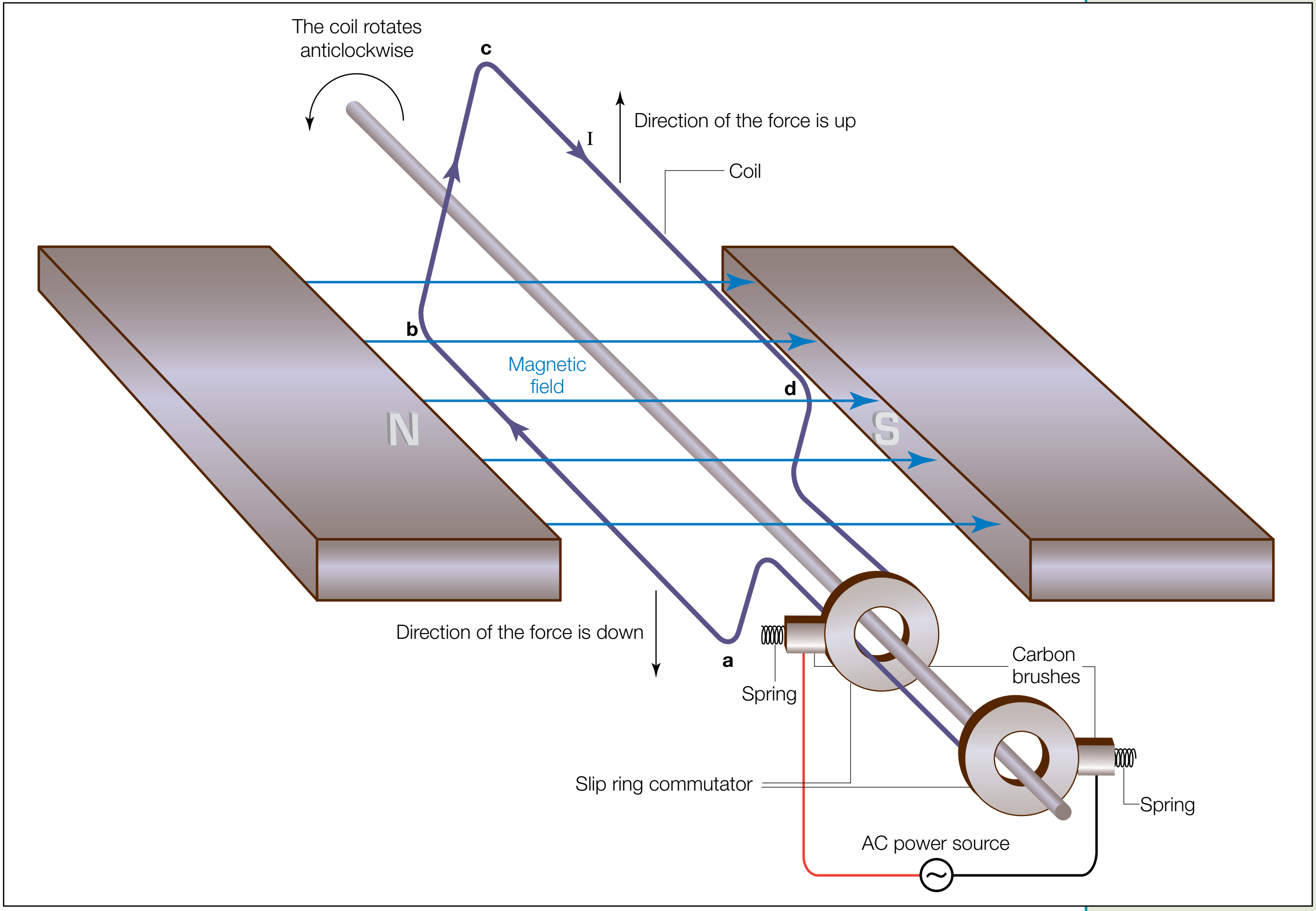
■ *Describe the main features of an AC electric motor*

Early in Chapter 5, we discussed the principle of DC electric motors. AC electric motors function in a similar way; however, there are a few subtle differences.

Structurally, the essential difference between AC and DC motors is that AC motors have **slip ring commutators**, in contrast to split ring commutators used in DC motors. It is essential to note that, unlike split ring commutators, which are responsible for reversing current direction, slip ring commutators simply have the role of conducting electricity from the power source without interfering with the rotation of the coil.

The structure of a simple AC motor is shown in Figure 9.1.

Figure 9.1 The structure of an AC motor



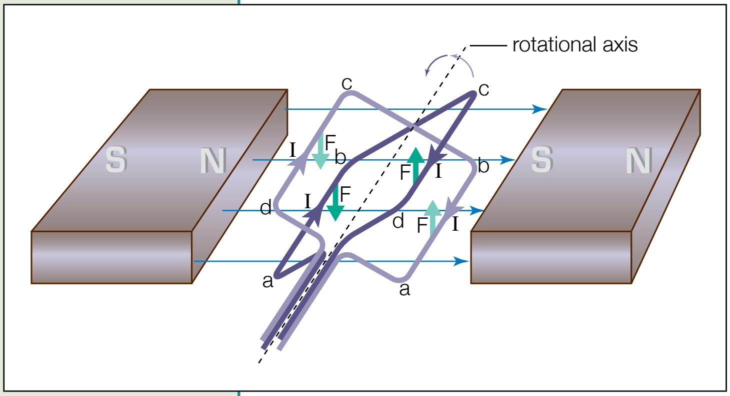


Figure 9.2 The functional principle of an AC motor

In Figure 9.1, the clockwise direction of the current in the coil will result in an upward force on 'cd' and a downward force on 'ab', consequently the coil rotates in an anti-clockwise direction. As the coil rotates past the vertical position, one would expect it to be pushed back and consequently oscillate about the vertical axis, since there is no action of the 'split ring commutator' (see Chapter 5). However, this is not the case if we examine the nature of AC: *the voltage, hence the current, of AC power constantly changes polarity.* Consequently, the current direction changes by itself without the split ring commutator at the vertical position, which allows the force to also reverse direction. This then enables the coil to rotate in a constant direction (see Fig. 9.2).

Not surprisingly, however, how fast an AC motor can spin will not only depend on the factors that will determine the torque of the coil, but also how fast the polarity of the AC power can change. Hence the speed of an AC motor is often limited by the frequency of the AC power.

NOTE: The frequency of the AC power determines how many times the AC power changes its polarity in one second.

9.2 AC induction motors

Structure

The AC induction motor, just like any other motor, consists of a stator and a rotor. Input current is fed into the stator and is responsible for creating magnetic fields. The rotor is made up of parallel aluminium bars that have their ends embedded in a metal ring at each terminal, forming a cage structure called the **squirrel cage** (although it resembles a bird cage). The rotor is usually covered by laminated soft iron and is embedded inside the stator. A schematic drawing of an AC induction motor is shown in Figures 9.3 (a) and (b).

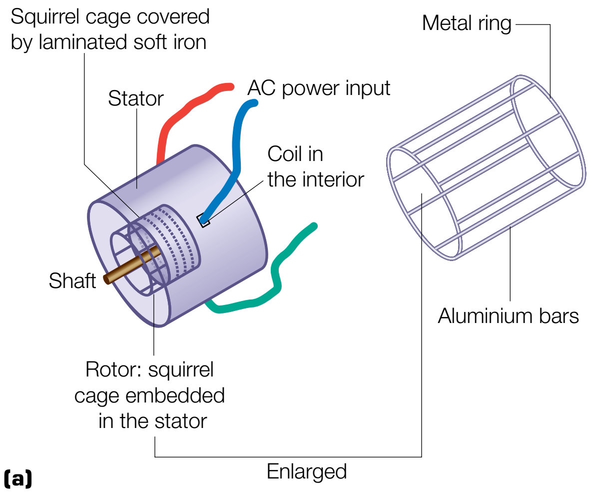


Figure 9.3 **(a)** A schematic drawing of an AC induction motor **(b)** A close up of a squirrel cage covered by a sheet of laminated soft iron

Functional principle

Based on its structure, you might wonder: If there is no current fed into the rotor, how does it actually create a torque and consequently rotate? The fundamental principle upon which the induction motor operates is shown through the example below. Study it carefully.

Example 1

Consider the set-up shown in Figure 9.4. An aluminium disk is mounted so that it is free to rotate. Suppose it is stationary to start with. Describe the subsequent motion of the disk when a magnet is brought nearby and is made to rotate about the disk as shown.

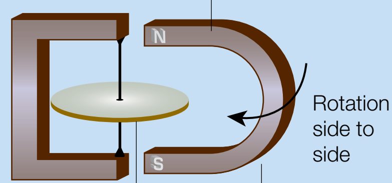


Figure 9.4 Simplified illustration of induction motor mechanisms

Solution

The disk will spin in the same direction as the direction the magnet is moved, that is, it follows the magnet.

This is because as the magnet is made to move next to the disk, there will be a changing magnetic flux created. This changing magnetic flux is linked with the disk, which results in an EMF being induced in the disk.

The EMF induced will result in eddy currents flowing inside the disk in such a way that they oppose the cause of the induction (Lenz's law), and in this case, the movement of the magnet. Since it is not possible to stop the moving magnet (as the magnet is forcibly moved), it follows that the disk will have to follow the motion of the magnet in order to minimise the relative movement between it and the magnet.

NOTE: For all motions, minimising the relative movement is equivalent to making something stationary.

In a sense, the interaction between the induced eddy currents and the external magnetic field allows the magnetic field to drag along the disk.

Returning to the AC induction motor: AC current is fed into the multiple coiled stator to create magnetic fields. The current is fed in such a way that there will be a rotating magnetic field created inside the stator. This rotating magnetic field will induce eddy currents within the squirrel cage rotor. The eddy current will flow in such a way that the rotor will rotate in the direction of the rotating magnetic field created by the stator, similar to how the disk spins in the direction of the rotating magnet. It is important to emphasise that for the AC induction motor, no current is fed into the rotor; current is *induced* inside the rotor, which then interacts with the external magnetic field of the stator to result in rotation, hence its name **induction motor**.

NOTE: The detail of how the rotating magnetic field is created is not required by the HSC course.

Energy transformation

SECONDARY SOURCE INVESTIGATION

PFAs

H3

PHYSICS SKILLS

H13.1A, B, C, E
H14.1E, G, H

■ *Gather, process and analyse information to identify some of the energy transfers and transformations involving the conversion of electrical energy into more useful forms in the home and industry*

You are required to identify some conversions and transformations of electrical energy into other forms of useful energies.

It is important to re-emphasise the **law of conservation of energy**: *energy cannot be created or destroyed, it can only be transformed*. Hence, electrical energy can be converted into other, different forms of energy through various electronic devices. This is summarised in Figure 9.5.

It should be noted that none of these energy conversions is perfectly efficient. During the energy conversion, it is inevitable that portions of the original energy are converted into other forms of undesirable energies (e.g. heat) and are often dissipated into the environment; they are therefore a 'waste' of energy. Unfortunately, this can only be minimised, not completely avoided.

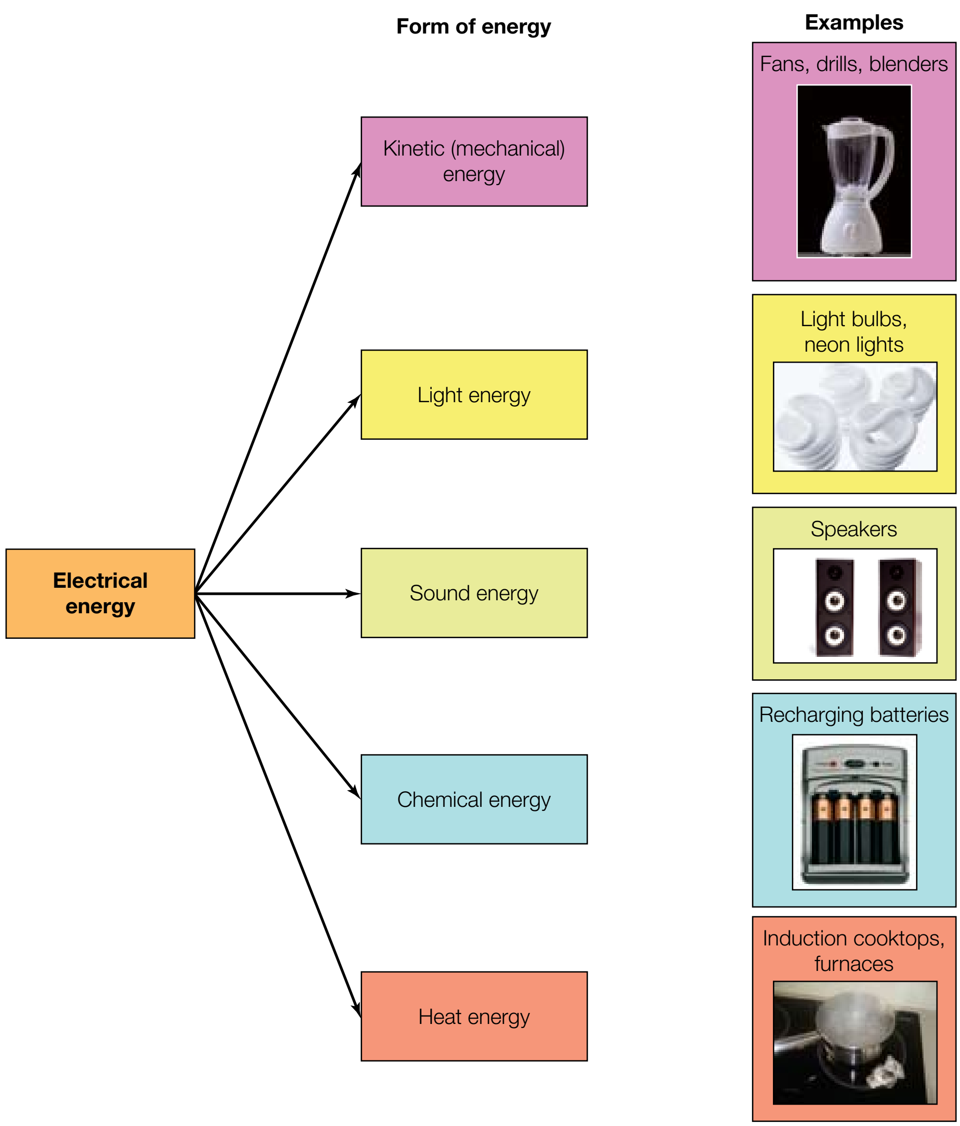


Figure 9.5 The conversion of electrical energy by various electrical devices

Demonstrating the principle of an AC induction motor

FIRST-HAND INVESTIGATION

PHYSICS SKILLS

H12.1B, D
H14.1E, G

■ *Perform an investigation to demonstrate the principle of an AC induction motor*

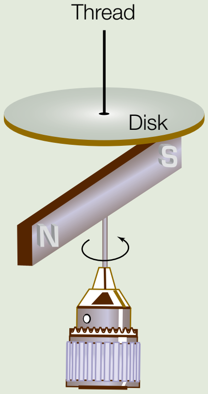
This investigation does not necessarily need to be planned by students. It should demonstrate how a changing magnetic field can cause motion in another object not in physical contact with the source of the magnetic field.

Such a demonstration can be made using the following apparatus:

- an old CD
- aluminium foil
- cotton
- blu-tack
- a strong bar magnet
- a dowel stick or pencil (about 10 cm long)
- an electric drill

Method

1. Wrap the CD in aluminium foil so that the foil is smooth (the aluminium base of a drink can could also be used here).
2. Pack the centre of the CD with blu-tack and pass a piece of cotton through it so that the CD can be suspended evenly and is able to spin smoothly.
3. Drill a hole in the exact centre of the bar magnet (the diameter of the hole should match the diameter of the dowel stick or pencil).
4. Using a suitable glue, insert the dowel stick or pencil into the hole in the magnet. If a hole cannot be drilled, use araldite or a similar glue to glue the dowel stick to the magnet.
5. Insert the other end of the pencil or dowel stick into the chuck of an electric drill.
6. With the CD suspended horizontally, hold the drill so that the magnet can rotate in a horizontal plane underneath the CD (but not touch it).
7. Observe the motion of the aluminium disk as the magnet rotates in a horizontal plane beneath it.
8. By applying Lenz's law, describe the eddy currents produced in the disk.



The changing magnetic field causes motion

CHAPTER REVISION QUESTIONS

1. What is a squirrel cage? Briefly describe its structure.
2. What type of power source must be used in AC induction motors? Account for this.
3. List two advantages of an AC induction motor. Relate these properties to its structure.
4. List two advantages of an AC induction motor.
5. Name one appliance at home that employs an AC induction motor.

SR

Answers to chapter revision questions