Cambridge

A2 Level

Physics

CODE: (9702)

Chapter 29

Chapter 29: Alternating currents

Sinusoidal current

The graph has the same shape as the graphs used to represent simple harmonic motion (see Chapter 19), and it can be interpreted in the same way. The electrons in a wire carrying a.c. thus move back and forth with s.h.m. The current varies like a sine wave and so it is described as sinusoidal.

Alternating voltages

Alternating current is produced in power stations by large generators like those shown in Figure 29.3.

An equation for a.c.

As well as drawing a graph, we can write an equation to represent alternating current. This equation tells us the value of the current I at any time t:

$$I = I_0 \sin \omega t$$

where ω is the angular frequency of the supply measured in rad s^{-1} (radians per second). This is related to the frequency f in the same way as for s.h.m.:

$$\omega = 2\pi f$$

and the frequency and period are related by:

$$f = \frac{1}{T}$$

Measuring frequency and voltage

An oscilloscope can be used to measure the frequency and voltage of an alternating current.

Power and a.c.

We use mains electricity to supply us with energy. If the current and voltage are varying all the time, does this mean that the power is varying all the time too? Th e answer to this is yes. You may have noticed that some fluorescent lamps flicker continuously, especially if you observe them out of the corner of your eye.

Figure 29.3 Generators in the generating hall of a large power station.

Root-mean-square values

There is a mathematical relationship between the peak value V0 of the alternating voltage and a d.c. voltage which delivers the same average electrical power

The root-mean-square value of an alternating current is that steady current which delivers the same average power as the a.c. to a resistive load.

Calculating power

The importance of r.m.s. values is that they allow us to apply equations from our study of direct current to situations where the current is alternating. So, to calculate the average power dissipated in a resistor, we can use the usual formulae for power:

$$P = I^2R = IV = \frac{V^2}{R}$$

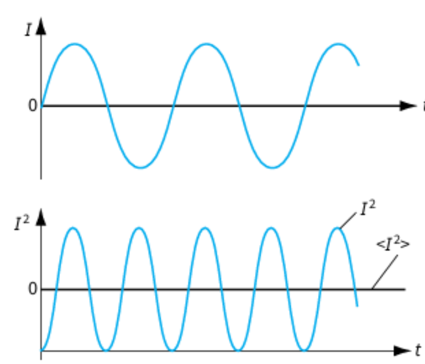

Figure 29.10 An alternating current I is alternately positive and negative, while I^2 is always positive.

Explaining root-mean-square

We will now briefly consider the origin of the term root-mean-square and show how the factor of √2 comes about. The equation P = I^2R tells us that the power P is proportional to the square of the current I.

Why use a.c. for electricity supply?

There are several reasons for preferring alternating voltages for a national electricity supply system. The most important reason is that a.c. can be transformed to high voltages, so that the current flowing is reduced, and this leads to lower power losses in the transmission lines.

Figure 29.11 Power lines carry electricity from power station to consumer.

Economic savings

The resistive heating of power lines is a waste of money, in two ways. Firstly, it costs money to generate power because of the fuel needed. Secondly, more power stations are required, and power stations are expensive. The use of transformers to transform power to high voltages saves a few per cent of a national bill for electrical power, and means that fewer expensive power stations are needed

Transformers

Figure 29.12 shows the construction of a simple transformer. T he primary coil of Np turns of wire is wound around an iron core. The secondary coil of Ns turns is wound on the opposite side of the core.

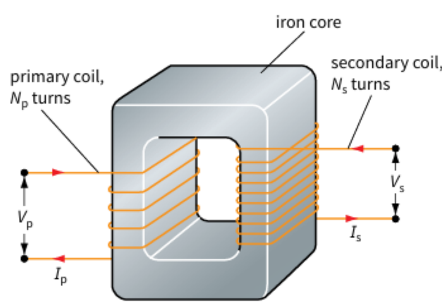

Figure 29.12 Defining quantities for a simple iron-cored transformer.

Note that there is no **electrical** connection between the primary coil and the secondary coil. Energy is transferred from one to the other via the magnetic field in the core.

Step-up, step-down

The transformer represented in Figure 29.12 has 5 turns on its primary coil and 10 on its secondary coil. It is described as a **step-up transformer** because the output voltage is greater than the input voltage (the voltage has been 'stepped up').

We can write an equation relating the voltages across the coils to the number of turns in each coil:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

The equation above is known as the **turns-ratio equation** for a transformer.

A transformer with fewer turns on the secondary coil than on the primary coil is described as a **step-down transformer.**

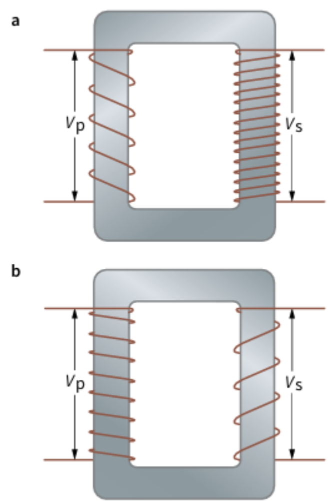

Figure 29.13 Two transformers: **a** step-up, and **b** step-down.

Voltage, current, power

If there is no power lost in a transformer, it follows that the quantity I × V is the same for both primary and secondary coils:

$$I_p V_p = I_s V_s \quad \text{or} \quad \frac{V_s}{V_p} = \frac{I_p}{I_s}$$

Rectification

Many electrical appliances work with alternating current. Some, like electrical heaters, will work equally well with d.c. or a.c. However, there are many appliances such as electronic equipment which require d.c. For these, the alternating mains must be converted to d.c. by the process of **rectification.**

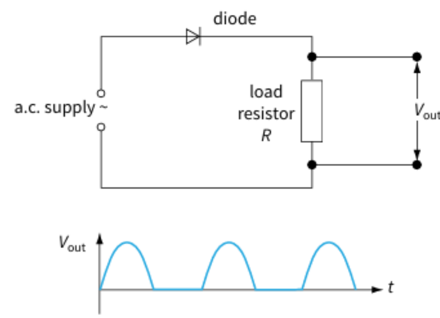

Figure 29.15 Half-wave rectification of a.c. requires a single diode.

The bridge rectifier To overcome this problem of reduced power, a bridge rectifier circuit is used. This consists of four diodes connected across the alternating voltage, as shown in Figure 29.16. The resulting output voltage across the load resistor R is full-wave rectified. The way in which this works is shown in Figure 29.17.

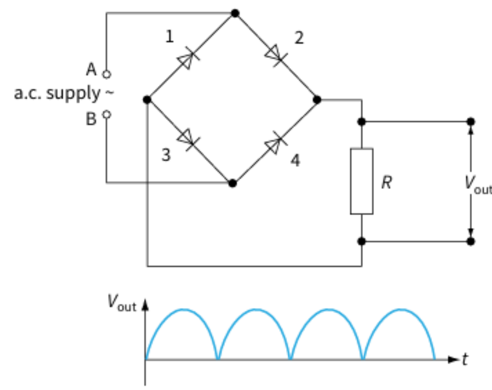

Figure 29.16 Full-wave rectification of a.c. using a diode bridge.

■ ■ During the first half of the a.c. cycle, terminal A is positive. Current flows through diode 2, downwards through R and through diode 3 to terminal B. In this half of the cycle, current cannot flow through diodes 1 or 4 because they are pointing the wrong way.

■ ■ In the second half of the cycle, terminal B is positive. Current flows through diode 4, downwards through R, and through diode 1 to terminal A. Diodes 2 and 3 do not conduct because they are pointing the wrong way

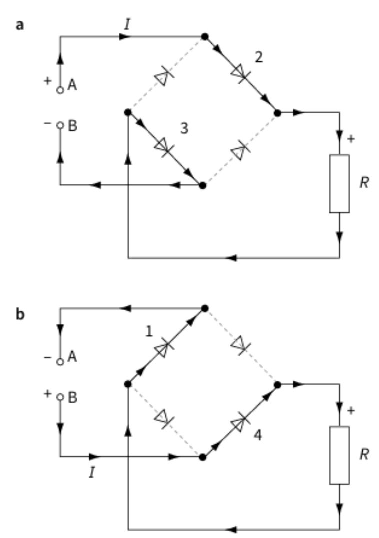

Figure 29.17 Current flow during full-wave rectification.

Smoothing

In order to produce steady d.c. from the 'bumpy' d.c. that results from rectification, a smoothing capacitor must be incorporated in the circuit, in parallel with the load resistor R. This is shown in Figure 29.18.

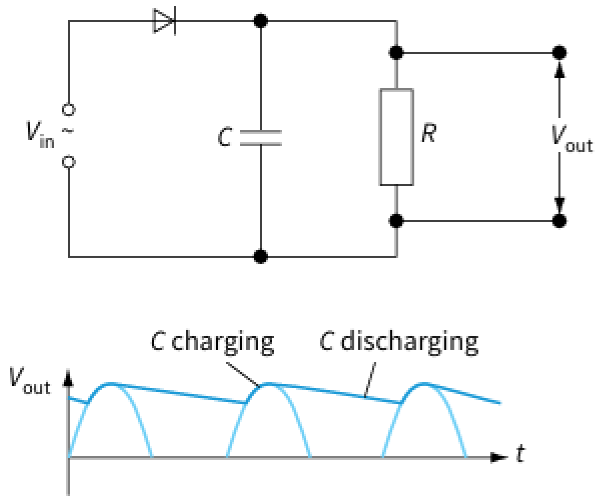

Figure 29.18 A smoothing capacitor is connected across (in parallel with) the load resistor.