PE1.1: ELECTRICITY: BASICS

Current I and Charge q

Current (I) is the rate of flow of electric charge (q) past a point.

$$\text{Current} = \frac{\text{Charge}}{\text{Time}} \qquad \text{or} \qquad I = \frac{q}{t}$$

Units: Current is measured in Amps (A). Charge is measured in Coulombs (C).
Time is measured in seconds (s)

Example 1

Determine the charge that has flowed through a torch battery producing a current of 300mA if it has been left on for 20 minutes.

If $I = q/t$, $q = I \times t$ where $I = 300 \times 10^{-3}$A, and $t = 20 \times 60 = 1200$s.
Thus, $q = 0.300 \times 1200 = 360$C

A circuit must be closed (complete) for current to flow. Contrary to popular belief the current does not get weaker as it goes around the circuit. The direction of the current is taken to be from the positive terminal of the battery, around the circuit, to the negative terminal of the battery. This is called conventional current flow. In the diagram below conventional current flow is counter clockwise.

In actual fact the electrons are the charges that move, and they flow from the negative terminal of the battery, around the circuit, to the positive terminal of the battery, ie, in the opposite direction to conventional current flow. In the diagram below electron flow is clockwise.
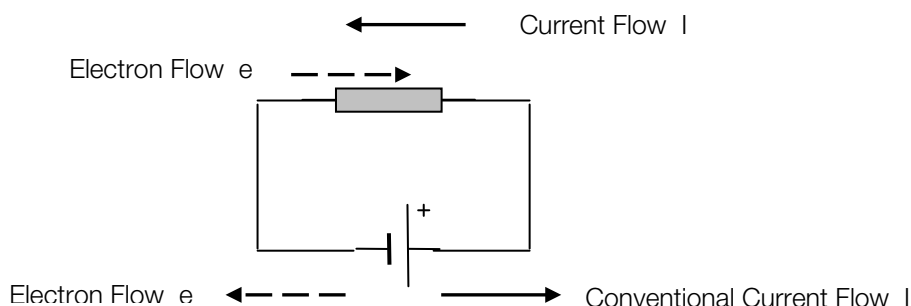
In terms of electron charges:

$$1 \,\text{coulomb of charge} \quad 1C = 6.25 \times 10^{18} \,\text{electrons} \qquad \text{or} \qquad 1 \,\text{electron} \quad 1e = 1.6 \times 10^{-19}\,C.$$

EMF (Electromotive Force)

If charges are moving they have energy. A battery or generator is the usual source of this energy. When electrons flow through a battery or other power supply they gain electrical potential energy. As the electrons flow around a circuit, they lose this energy when passing through components that have resistance, e.g. globes.

The energy transferred to one coulomb of charge within the battery is called the electromotive force EMF of the battery.

The unit of EMF is the volt (V). It can be considered to be a concentration of charge. The energy, measured in Joules (J), required in pushing the charges together is stored as electrical potential energy. A battery with an EMF of 6V, for instance, transfers 6 Joules of energy to each coulomb of charge.

The energy transferred E to a circuit component per unit charge q is called the **potential difference** PD between the two terminals of the component. The unit of potential difference is also the volt.

$$\text{EMF} = \frac{\text{Energy}}{\text{Charge}} \quad \text{or} \quad V = \frac{E}{q}$$

Units: EMF is measured in Volts (V). Charge is measured in Coulombs (C).
Energy is measured in Joules (J).

Note: The terms EMF and PD are often simply referred to as voltage.

Since $E = V \times q$, and $q = I \times t$

$$E = V \times I \times t$$

Example 2
The potential difference across a torch globe is found to be 2.7V. The current flowing through it is 0.2A.
(a)   How much charge flows through the torch in 1 minute?
(b)   How much energy is lost by this charge?

(a) $q = I \times t = 0.2 \times 60s = 12C$
(b) Each coulomb lost 2.7J of energy (why?).
     Since $V=E/q$, $E = q \times V = 12 \times 2.7 = 32.4J$

Power P

Power (P) is the rate of energy transfer, ie. energy transfer divided by the time taken.

$$\text{Power} = \frac{\text{Energy}}{\text{Time}} \quad \text{or} \quad P = \frac{E}{t} = \frac{V \times I \times t}{t} = V \times I$$

Units: Power is measured in Joules per second (J/s) or Watts (W).

Exercise

1. Calculate the amount of charge that would flow through a:
   (a) 5mA pocket calculator in 10 minutes.
   (b) 200A car starter motor in 5 seconds.
   (c) 400mA light bulb in 1 hour.

2. 1.7×10^{26} electrons pass a point in a wire each second. What electric current does this represent?

3. A charge of 5C flows from a battery through an electric water heater and delivers 100J of heat to the water. What was the EMF (voltage) of the battery?

4. How much energy will each coulomb of charge flowing from a 9V MP3 player possess?

5. How much charge must have flowed through a 12V car battery if 2kJ of energy was delivered to the starter motor?

6. What is the power used by a:
   (a) 3V torch bulb drawing 0.2A?
   (b)   Starter motor which takes 200A from a 12V battery?
   (c) Mains-powered (240V) toaster rated at 3A?

7. How much current is used by a:
   (a) 60W, 240V light bulb? Give your answer in milliamps (mA).
   (b) 1200W mains-powered (240V) heater?
   (c) 90W car (12V) windscreen wiper motor?

8. What is the voltage of a:
   (a) 100W spotlight which draws 4A?
   (b) 200mW radio operating with a current of 23mA?
   (c) 7500W industrial motor using 18A?

9. A large power station generator might be rated as 500MW with a 24kV output. What current would it be generating? Give your answer in kiloamps (kA).

Answers

Exercise
1. (a) 3C (b) 1000C (c) 1440C 2. 2.7×10^{7}A 3. 20V 4. 9J 5. 167C

6. (a) 0.6W (b) 2400W (c) 720W 7. (a) 250mA (b) 5A (c) 7.5A 8.(a) 25V (b) 8.7V

(c) 417V 9. 21kA