Chapter 17 Current Electricity

Learning Outcomes

(a) state that current is a rate of flow of charge and that it is measured in amperes

(b) distinguish between conventional current and electron flow

(c) recall and apply the relationship *charge* = *current* × *time* to new situations or to solve related problems

(d) define electromotive force (e.m.f.) as the work done by a source in driving unit charge around a complete circuit

(e) calculate the total e.m.f. where several sources are arranged in series

(f) state that the e.m.f. of a source and the potential difference (p.d.) across a circuit component are measured in volts

(g) define the p.d. across a component in a circuit as the work done to drive unit charge through the component

(h) state the definition that *resistance* = *p.d.* / *current*

(i) apply the relationship $R = V / I$ to new situations or to solve related problems

(j) describe an experiment to determine the resistance of a metallic conductor using a voltmeter and an ammeter, and make the necessary calculations

(k) recall and apply the formulae for the effective resistance of a number of resistors in series and in parallel to new situations or to solve related problems

(l) recall and apply the relationship of the proportionality between resistance and the length and cross-sectional area of a wire to new situations or to solve related problems

(m) state Ohm's Law

(n) describe the effect of temperature increase on the resistance of a metallic conductor

(o) sketch and interpret the I/V characteristic graphs for a metallic conductor at constant temperature, for a filament lamp and for a semiconductor diode

(a) What is an electric current?

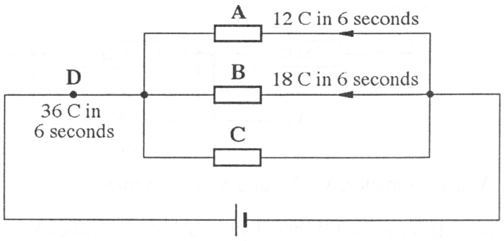
- An electric current is formed in a closed circuit when there are ______________ _______________.
- For example, when electrons (charge) flow through a conducting path in a circuit.
- An **electric current** I is a measure of the __________ of flow of _____________ ____________ Q through a given cross section of a conductor

Formula:

I is the current, Q is the charge, and t is the time taken. The SI unit is the __________ (A)

- We make use of an **ammeter** to measure current.
- The ammeter should be connected in **series** to the circuit.
- The resistance of an ammeter is **zero**.

Example 1
The diagram shows an electric circuit. The amounts of charge, which flowed in 6 s through resistor A, B and point D, are indicated.



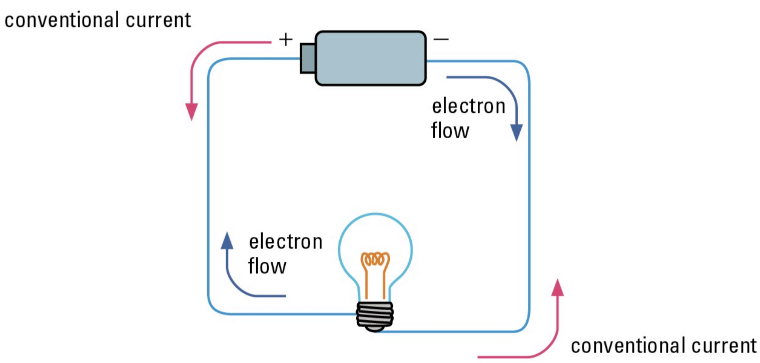
a) What was the amount of charge, which flowed through resistor C in 6 s?

b) What was the current, which flowed through C?

(b) Conventional current and electron flow

- *The movement of electrons from a _____________ charged end (negative terminal) of a cell towards the _____________ charged end (positive terminal) is known as electron flow.*

- *Conventional current flow is the flow of positive charge from a _____________ charged end to a ___________ charged end.*



Electric charge (optional)

- *Either electrons or positive charges. Because they are so numerous, a simpler number is used to represent them.*
- *Charge is measured in coulomb (C)*
- *1 C of charge → 6.25×10^{18} electrons*

(d) Electromotive Force (e.m.f)

- The electromotive force (e.m.f) of an electrical energy source is defined as the __________ __________ by the source (battery) in driving a unit _________ round a ____________ _____________.

$$\varepsilon = \frac{W}{Q}$$

ε is the e.m.f of the power supply, W is the amount of electrical energy converted from non-electrical forms (work done) and Q is the amount of charge

- The SI unit of e.m.f is __________________ (J/C) or __________ (V)

Example 2
A 9.0 V battery of negligible internal resistance is connected to a light bulb. Calculate the energy transferred in the light bulb when 20 C of charge flows through it.

(g) Potential difference (p.d.)

- The potential difference (p.d) between __________ **points** in an electric circuit is defined as the amount of electrical _____________ converted to ____ when one coulomb of positive charge passes between the two points.

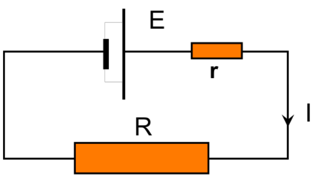
$$V = \frac{W}{Q}$$

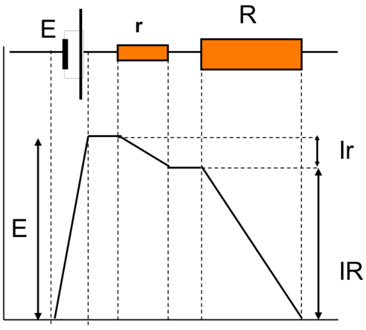
where V is the potential difference, W is the electrical energy converted to other forms and Q is the amount of charge.
The SI unit for **potential difference** is the volt (V).

Voltmeter

A voltmeter is used to measure emf or potential difference. It is connected **in** **parallel** with the component whose emf or p.d. it is measuring. A voltmeter has **infinite resistance** (very very high) so that no current can flow through it.

Potential difference and electromotive force





(resourcefulphysics.org)

E = electromotive force

Ir and IR = potential difference

E = Ir + IR

Example 3
The potential difference across a light bulb is found to be 3.0 V. The current flowing through it is 0.40 A.
(a) How much charge flows through the light bulb in 2.0 min?
(b) How much electrical energy is dissipated by this charge?

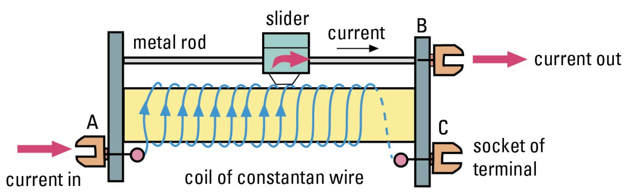
(h) Resistance

- It measures how **difficult** it is for an electric current to pass through a material.
- It is a property of the material that restricts the movement of free electrons in the material.
- **The resistance R of a component is defined as the ratio of the voltage or potential difference V across it to the current I flowing through it. (MEMORISE)**
- The SI unit for resistance is **ohm** (Ω)

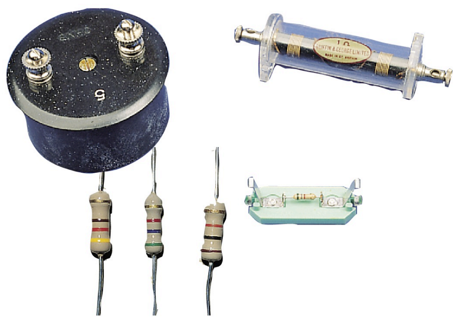
$$R = \frac{V}{I}$$

Resistor

- A resistor is a conductor in a circuit that has a known value of resistance.
- They are mainly used to **vary** the size of **the current** flowing in a circuit.
- There are two types of resistors — fixed resistors and variable resistors (or rheostats).

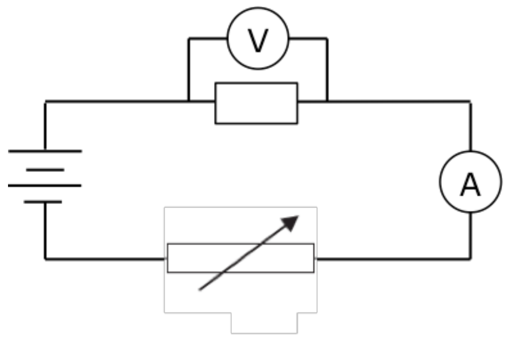


Variable resistor



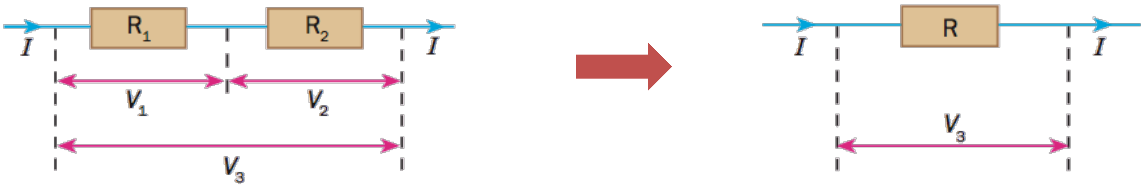
Fixed resistors

(j) Determining Resistance R

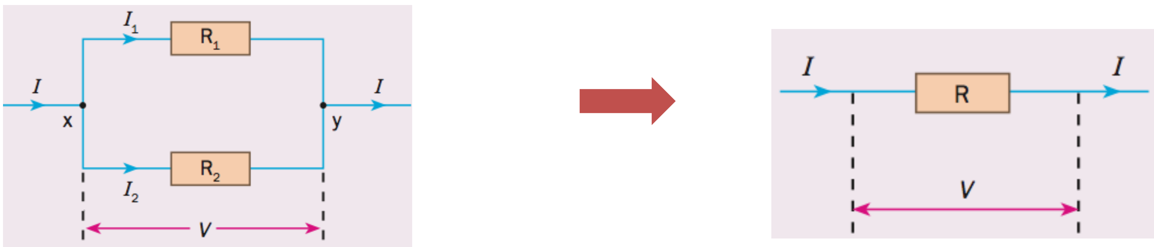


1. Adjust the variable resistor such that its resistance is maximum. (why?)
2. Close the switch
3. Record the voltmeter and ammeter reading
4. Adjust the variable resistor to obtain other voltmeter and ammeter readings for a total of six sets of readings (the voltage range should be more than half of the emf of the battery)
5. Plot a graph of voltage against current
6. The gradient of the straight line is the resistance of the component

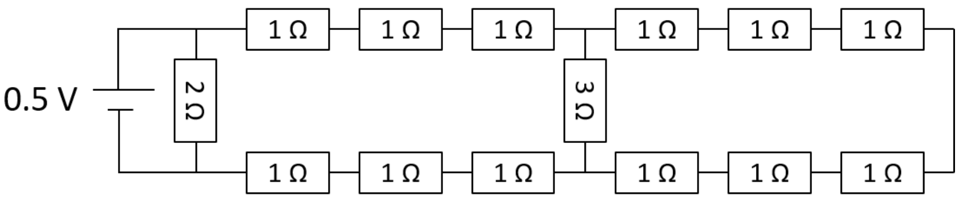
(k) Resistance in a series circuit



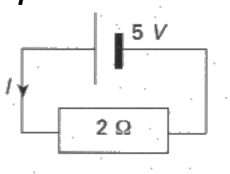
Resistance in a parallel circuit



Formula:



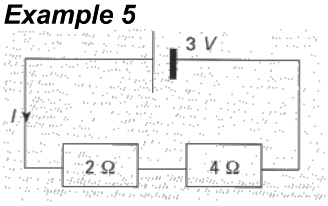
Example 4



a) *Calculate the current I.*

b) *What is the potential difference across the 2Ω resistor?*

Example 5

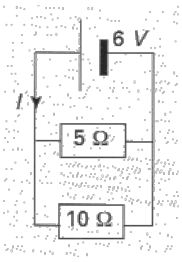


a) *Calculate the effective resistance.*

b) *Calculate the current I.*

c) *Calculate the potential difference across the 2Ω and 4Ω resistor.*

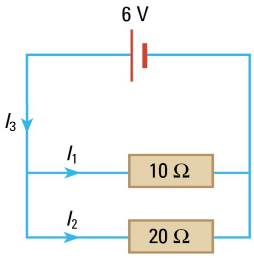
Example 6



a) Calculate the effective resistance.

b) Calculate the current I.

Example 7

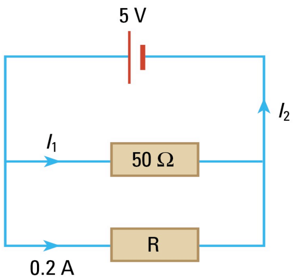


a) Find the currents I_1, I_2, I_3

b) What is the voltage or potential difference across the 10 Ω and 20 Ω resistors?

c) Calculate the effective resistance of the 10Ω and 20Ω resistors.

Example 8



Find I_1, I_2 and R

Example 9

The circuit shows a light bulb connected to 3 resistors and a 12 V source. Initially, all the switches are opened.

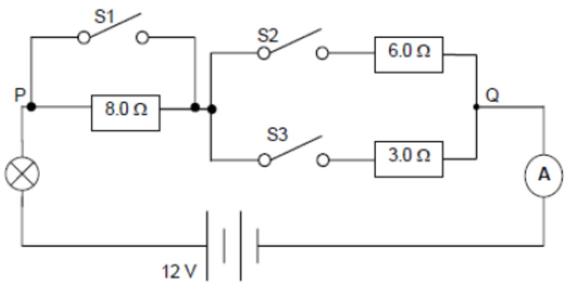


Fig 7

(a) S1 is opened and S2 and S3 are closed.

(i) Calculate the total resistance between points P and Q.

(ii) The ammeter registers a reading of 0.3 A. Calculate the resistance of the light bulb.

(iii) The lamp is switched on for 2 minutes. Calculate the amount of energy consumed by the lamp.

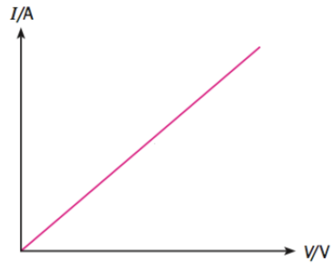
(l) Resistivity ρ

- The longer a wire, the higher its resistance
- The bigger the cross sectional area of a wire, the lower its resistance
- The **resistance** of a wire is therefore **directly proportional to its length** and **inversely proportional to cross sectional area**

$$R \propto L$$
$$R \propto \frac{1}{A}$$
$$R = \rho \frac{L}{A}$$

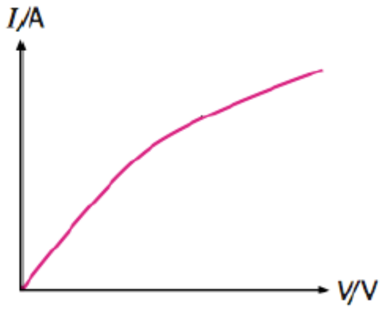
(m) Ohm's Law

- For a metallic conductor that obeys Ohm's Law, the current flowing through it is directly proportional to the potential difference across it provided physical conditions remain constant



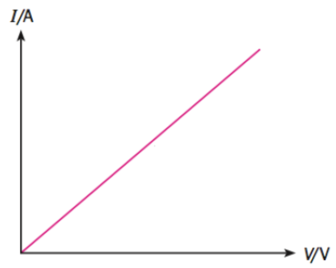
(n) Effect of temperature on the resistance of a metallic conductor

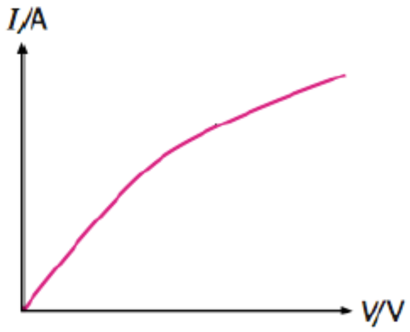
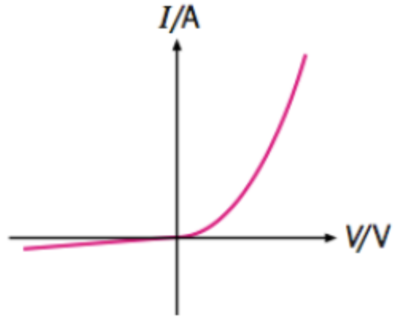
- When **temperature** of a metallic conductor increases, the atoms in it vibrate more energetically. The mobile electrons moving through the conductor collide more frequently with the atoms and slow down. This reduces the **rate of flow of charge (current)** through the conductor and the **resistance** (R = V/I**) increases**



(o) I-V graphs

Ohmic conductor: Metallic conductor at constant temperature



Non ohmic conductors	
Filament lamp	**Semiconductor diode**
	
The lamp has a low resistance (small V/I) at first (i.e. small applied voltage). However as the voltage increases, the current increases less rapidly. As the lamp heats up, its resistance increases, as evidenced by the decreasing slope of the graph. (Note: Ohm's law generally applies to metals at constant temperature.)	*The resistance change is not now due to a temperature change; in fact the diode is an almost perfect 'one way' device. For positive voltages above about 0.5 V, the resistance (V/I) is very low, and the diode is an excellent conductor. For voltages of the opposite polarity, the resistance is very high: the diode hardly conducts at all.*