Chapter 18. Electrical Quantities

Contents:

18.1 Current
18.2 Voltage
18.3 Electrical resistance
18.4 Electrical energy, work and power

New word list:

4.2.2 Electric current

Core

1 Know that electric current is related to the flow of charge

2 Describe the use of ammeters (analogue and digital) with different ranges

3 Describe electrical conduction in metals in terms of the movement of free electrons

4 Know the difference between direct current (d.c.) and alternating current (a.c.)

Supplement

5 Define electric current as the charge passing a point per unit time; recall and use the equation

$$I = \frac{Q}{t}$$

6 State that conventional current is from positive to negative and that the flow of free electrons is from negative to positive

4.2 Electrical quantities continued

4.2.3 Electromotive force and potential difference

Core

1 Define electromotive force (e.m.f.) as the electrical work done by a source in moving a unit charge around a complete circuit

2 Know that e.m.f. is measured in volts (V)

3 Define potential difference (p.d.) as the work done by a unit charge passing through a component

4 Know that the p.d. between two points is measured in volts (V)

5 Describe the use of voltmeters (analogue and digital) with different ranges

Supplement

6 Recall and use the equation for e.m.f.

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

7 Recall and use the equation for p.d.

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

4.2.4 Resistance

Core

1 Recall and use the equation for resistance

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

2 Describe an experiment to determine resistance using a voltmeter and an ammeter and do the appropriate calculations

3 State, qualitatively, the relationship of the resistance of a metallic wire to its length and to its cross-sectional area

Supplement

4 Sketch and explain the current–voltage graphs for a resistor of constant resistance, a filament lamp and a diode

5 Recall and use the following relationship for a metallic electrical conductor:

(a) resistance is directly proportional to length

(b) resistance is inversely proportional to cross-sectional area

4.2.5 Electrical energy and electrical power

Core

1 Understand that electric circuits transfer energy from a source of electrical energy, such as an electrical cell or mains supply, to the circuit components and then into the surroundings

2 Recall and use the equation for electrical power

$P = IV$

3 Recall and use the equation for electrical energy

$E = IVt$

4 Define the kilowatt-hour (kW h) and calculate the cost of using electrical appliances where the energy unit is the kW h

Supplement

18.1 Current

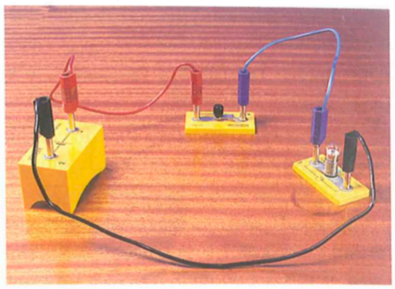
In chapter 17, we discussed static charge. Apart from static charge, do we have “non-static” charge? What is **electric current**?

How to make a current?

1. Complete circuit

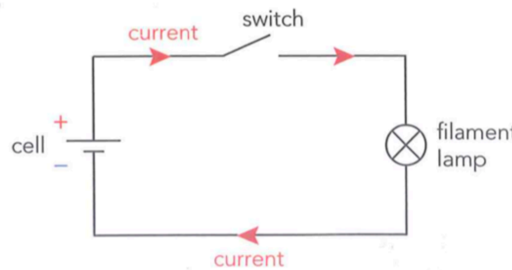
What are used when connecting component to a circuit?

a



Circuit diagram

b



Why do we use Cooper/steel as wire?

Good conductors vs bad conductors (good insulators):

Explanation: (why some materials are good conductors while some are not?)

Metal contains free electrons=> conduction e

Electrons in non-metal

2. “push" provided by battery (two or more cells connected end-to-end)

Exercise 18.1

What is the difference between **static charge** and **electric current**?

Electric current: flow of charge

Def:

Symbol:

Unit:

Current and charge:

Quantity	Symbol for quantity	Unit	Symbol for unit
current	I	amps	A
charge	Q	coulombs	C
time	t	seconds	s

Exercise18.2

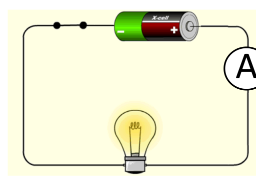
A current of 120 microamps flows around a circuit for one hour. How much electric charge flows around the circuit in this time?

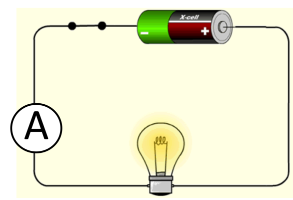
Exercise18.3

Calculate the missing values a-d in the table below.

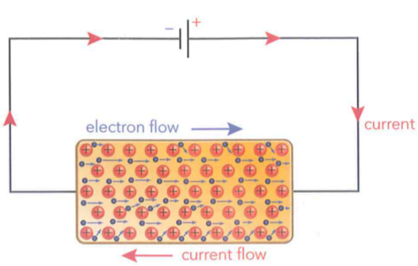
Charge	Current	Time
charge	current	time
220 C	2 A	**a**
57.6 C	**b**	3 hours
c	0.5 A	9 minutes
5.4 C	70 mA	**d**

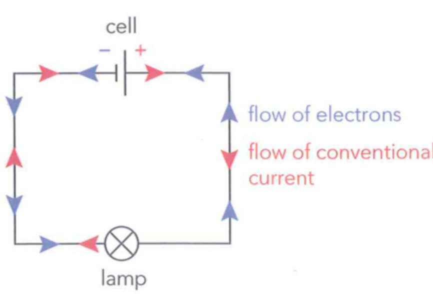
Measuring electric current: Ammeter vs galvanometer





Conventional current:Current and electrons:





18.2 Voltage

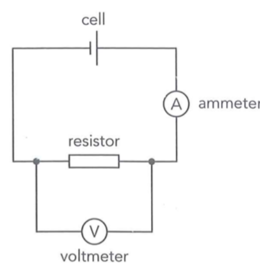
What make electric current flow?

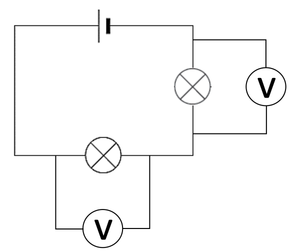
Voltage/potential difference(p.d.) PD makes a current flow through a conductor
Def:
Symbol:
Unit:

Work done and voltage:

Electromotive force(e.m.f.): pd across battery. EMF of a cell is the work done per unit of charge by the cell in driving charge round a complete circuit (including the cell itself) EMF is the maximum PD between two electrodes

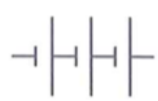
Measuring voltage:





Combining e.m.f.s

a



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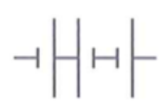


c

Exercise 18.4

Calculate the e.m.f. of a battery that gives 60J of energy to a charge 5C.

Exercise 18.5

The p.d. across a lamp is 12V. The lamp is connected for 10s. Calculate how many joules of energy are transferred when:
A a charge of 1C passes through it.
B a charge of 5C passes through it.
C a current of 2A flows.

18.3 Electrical resistance

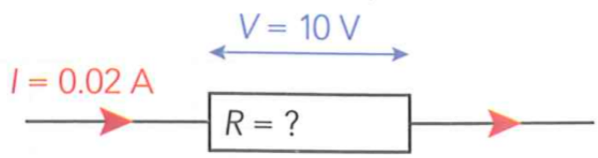
What if we connect the positive and negative terminal of a cell together with a short wire?

Resistance

Def:
Symbol:
Unit:

Exercise 18.6

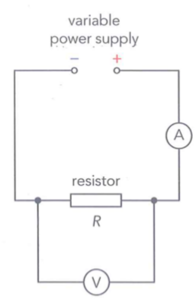
A resistor allows a current of 0.02A to flow through it when there is a p.d. of 10.0 V between its ends. What is its resistance?



18.3.1 Resistance and thickness & length

Assumption:

Method: measuring resistance



EXPERIMENTAL SKILLS 18.1

How length and thickness affects the resistance of a wire

Understanding how to measure resistance is really important because it introduces the measurements of voltage and current, which are essential for understanding circuits. In more sophisticated (complicated) circuits, resistance can change so that a device can respond to the environment (for example, a light can come on when it gets dark).

You will need:

- power supply
- 5 insulated (coloured) wires
- 2 crocodile clips
- metre ruler
- 2 lengths of resistance wire of different diameter
- masking tape
- heatproof mat to go underneath the resistance wire
- ammeter
- voltmeter.

CONTINUED

If a power supply is not available then use a suitable cell or series of cells but include a switch and only close the switch when you take measurements (to avoid draining the cell or battery). If two different gauges of wire are not available, lightly twist two lengths of the same gauge wire together to double the effective cross-section.

Safety: If the insulation on the wires melts or gives off poisonous fumes, reduce the voltage you use. Hot wires have the potential to burn skin. Avoid connecting the positive terminal of the power supply directly to the negative terminal (ensure that the current has to pass through the resistance wire). It may be necessary to place a resistor (fixed or variable) in series with the resistance wire in order to reduce the current through it. The voltages involved are too low to cause an electric shock.

Getting started

- State what devices you will use to measure voltage and current and describe how they should be wired into the circuit.
- What variable should be kept the same (control variable)?
- Why is it important to avoid taking measurements when the wire has zero length?
- Predict how the resistance of the wire will vary with the length of the wire.
- Predict how the resistance of the wire will vary with the diameter of the wire.
- Identify the independent and dependent variables.
- State two reasons why it is important to plot a graph of your results.
- You will be plotting a graph of your results. What should be plotted along on each axis?

Method 1

1 Set up the circuit as shown in Figure 18.13a. Set the power supply to 12 V.

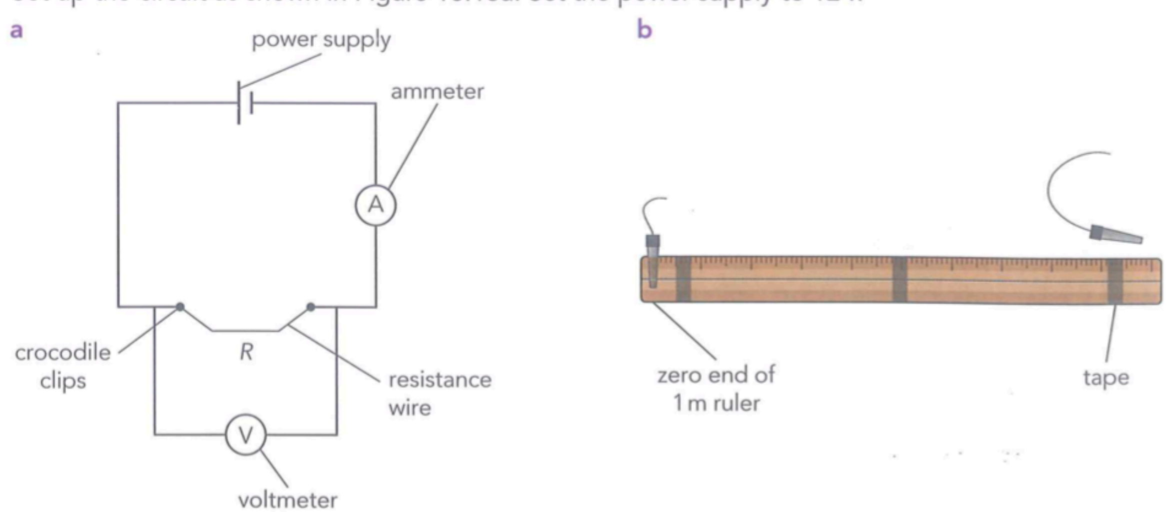


Figure 18.13a: Circuit diagram for the experiment. **b:** How to attach the wire to the ruler.

CONTINUED

2 Draw a table like Table 18.5, but remember to add more rows as you need them.

Length of resistance wire / cm	Current / A	Voltage / V	Resistance / Ω
Thin			
10			
20			
30			
Thick			
10			
20			
30			

Table 18.5

3 If your teacher has not already done so, attach the resistance wire along a metre ruler with insulating (or masking) tape at both ends and at the centre (see Figure 18.13b).

4 Put crocodile clips at the ends of the insulated (coloured) wires that will attach to the resistance wire.

5 Attach the first crocodile clip to the resistance wire where it crosses the 0.0 cm mark on the ruler and leave this in place throughout the experiment.

6 Attach the second crocodile clip where the resistance wire crosses the ruler at 10.0 cm and record the current and voltage values in the table.

7 Move the second crocodile clip at 10.0 cm intervals, each time recording the current and voltage values in the table.

8 Calculate the resistance values using $R = \frac{V}{I}$ and record the results in the table.

9 Plot a graph of resistance against length of the resistance wire (with the resistance along the horizontal axis) and label it 'thin'.

10 Repeat the experiment with thicker resistance wire (or loosely twist two wires of the same diameter together but, if you do, ensure the teeth of the crocodile clips are in contact with both wires). Plot the graph on the same axes for easy comparison and label it 'thick'.

Method 2

If you do not have access to resistance wires of five different diameters, twist wires of the same diameter together. Keep the length of wire the same (say, 50 cm).

1 Use a micrometer to determine the diameter of the wire or look up the wire diameter corresponding to the SWG (standard wire gauge) value on the reel that the wire comes from.

2 Use this information to work out the cross-sectional area of the wire or wires.

3 Using wires of the same length but increasing cross-section, record the voltage and current values, and calculate the resistance.

4 Plot a graph of resistance against the cross-sectional area.

5 Describe the relationship between resistance and cross-section.

6 How would you show that there is an inverse relationship?

CONTINUED

Questions

1 Copy each statement choosing the correct answer from the brackets.

a The resistance of a resistance wire {increases/decreases} when its length increases.

b The resistance of a resistance wire {doubles/halves} when its length doubles.

c This means that the resistance is {inversely/directly} proportional to its length. A straight-line graph passing through the origin will show this.

d The resistance of a resistance wire {increases/decreases} when its diameter increases.

e The resistance of a resistance wire {doubles/halves} when its cross-sectional area doubles.

f This means that the resistance is {inversely/directly} proportional to its cross-sectional area.

2 Extrapolate your resistance against length graph (Method 1) towards the origin. What is the resistance when the length of the resistance wire is zero?

3 Use your answer to the previous question to suggest why a direct connection between the terminals of the power supply is not a good idea.

Conclusion:

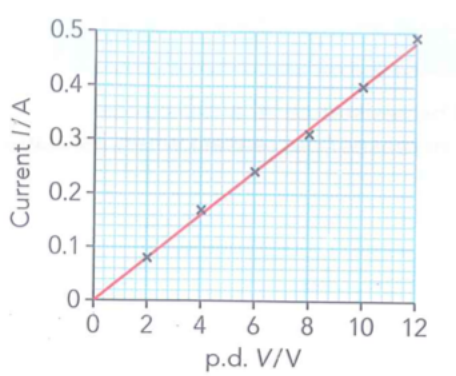
Exercise 18.7

A 2.0 meter length of wire has a resistance of 4.0 ohm.
A what is the resistance of a piece of the same wire of length 20.0 meters?
B what is the resistance of a 4.0 meter wire with half the cross-sectional area, made of the same material?

18.3.2 current-voltage characteristics: ohmic vs non-ohmic resistor

Example:

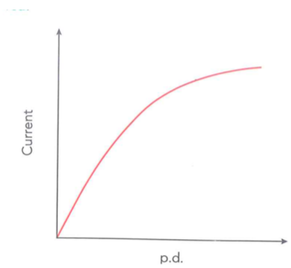
p.d. V/V	Current I/A	Resistance R/Ω
2.0	0.08	25.0
4.0	0.17	23.5
6.0	0.24	25.0
8.0	0.31	25.8
10.0	0.40	25.0
12.0	0.49	24.5



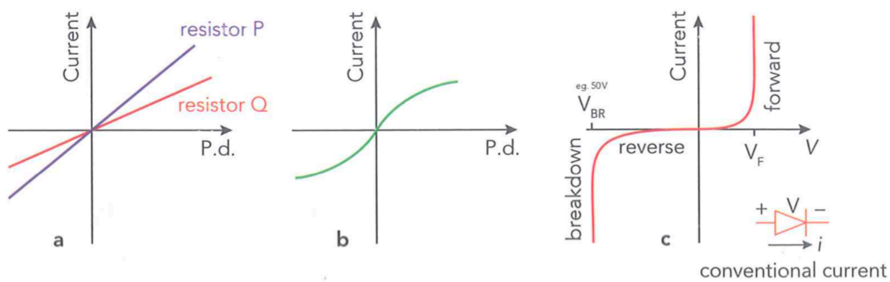
$$R = \frac{V}{I}$$

Ohmic resistor:

Non-ohmic device:



Typical current-voltage characteristics



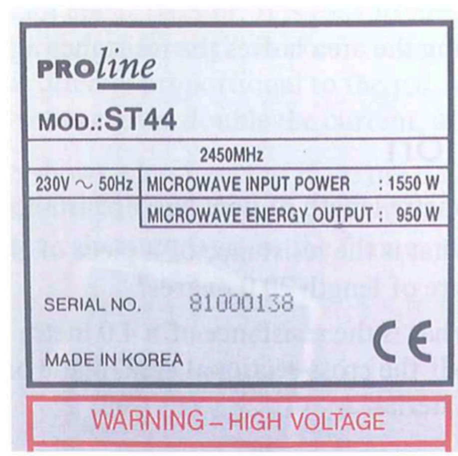
18.4 Electrical energy, work and power

Why do we need electric current?

Electrical power & energy

Exercise 18.8

A electric fan runs from the 230V mains supply. The current flowing through it is 0.40A. At what rate is electrical energy transferred by the fan? How much energy is transferred in one minute?



Unit of electrical energy: kWh

Exercise 18.9

Marcus switches on a water heater for two hours. The power of the heater is 3.5 kW. How much energy is transferred in kWh?