

Circuit symbols

1		cell	8		switch (open)
2		battery	9		switch (closed)
3		lamp	10		resistor
4		fuse	11		variable resistor
5		diode	12		thermistor
6		LED	13		voltmeter
7		LDR	14		ammeter

Current-Voltage graphs

1		Resistor at a constant temperature $I \propto V$ Obeys Ohm's law. Is an ohmic conductor.
2		Filament lamp: As the I increases the filament heats up meaning R increases. This is because the energy transfer increases the lattice vibrations, leading to more frequent collisions between the e^- and lattice ions.
3		Diode: Forward bias - R is initially very high, resulting in a small I . At about 0.7 V the R rapidly decreases meaning I increases rapidly. Reverse bias - R is very high, giving almost zero current until the breakdown current after which $R \sim 0$ leading to large I .

Circuit basics

1	Series circuits have one loop. Parallel circuits have two or more loops.
2	Conventional current flows from positive to negative BUT the electrons actually move from negative to positive.
3	Resistance is caused by collisions between the charge carriers in the material with each other and the fixed positive ions in the material through which the current is flowing.

I-V graph practical

1	This is the set-up needed to collect the results for a filament lamp.	
2	The variable resistor is adjusted to give a range of I and V values.	
3	Repeat for at least 6 different I and V values.	
4	To obtain negative readings, reverse the connections to the power supply.	
5	You can determine the resistance from an I-V graph by doing $R = 1/\text{gradient}$. Or if voltage is on y-axis and current on x-axis $R = \text{gradient}$.	

Thermistors and LDRs

1	Thermistors and LDRs are made from semiconductors which are materials with a limited number of charge carriers.
2	As semiconductors are supplied with energy electrons can gain enough energy to become free to move through the material.
3	Thermistors (NTC) are devices whose resistance drops at temperature increases.
4	LDRs are devices whose resistance drops as light intensity increases.

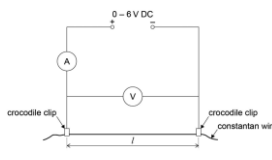
Key equations

1	Current	$I = \frac{Q}{t}$
2	Potential difference	$V = \frac{W}{Q}$
3	Potential difference	$V = IR$
4	Power	$P = IV = I^2R = \frac{V^2}{R}$
5	Energy	$E = Pt = IVt = I^2Rt = \frac{V^2t}{R}$
6	Efficiency	$= \frac{\text{useful energy output}}{\text{total energy input}} \times 100$ $= \frac{\text{useful power output}}{\text{useful power input}} \times 100$

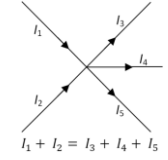
Key Vocabulary

1	Current	The rate of flow of charge.
2	Potential difference (voltage)	The work done in moving a unit charge between two points.
3	Resistance	The ratio of the potential difference applied across a component to the current passing through it.
4	Ohm's law	Provided that the temperature and other physical conditions remain the same, the current through a conductor is directly proportional to the potential difference across it.
5	Power	The rate of energy transfer.
6	Efficiency	Measures how much of the energy supplied to a device is used usefully.

Resistivity

- 1 It depends on the material structure as well as environmental factors e.g. light and temperature. It is measured in Ωm .
- 2 Good conductors have small resistivities.
- 3 **Required practical: Determining the resistivity of a wire**

- 4 Measure the diameter of the wire using a micrometer. Calculate the cross-sectional area. Set length = 0.100 m using a ruler. Set $V = 0.5\text{V}$ and measure current. Calculate R using $R = V/I$. Repeat for different lengths. Plot a graph of R against length. The gradient is R/l , meaning resistivity is given by gradient $\times A$.

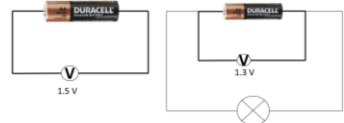
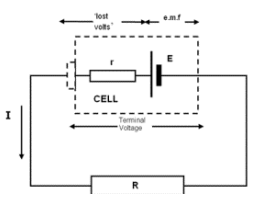
Kirchoff's laws

- 1 **Kirchoff's first law (conservation of charge):**
At any junction in a circuit, the total current leaving the junction is equal to the total current entering the junction.

- 2 This means that in a series circuit the current must be the same everywhere as current does not get used up.
- 3 **Kirchoff's second law (conservation of energy):**
The sum of the potential differences around a circuit is equal to the sum of the emfs of the power source.
- 4 This means that in a series circuit the pd across components add up to the emf of the power source.
- 5 In parallel circuits the pd across parallel components is equal

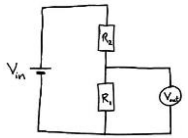
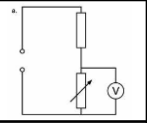
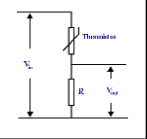
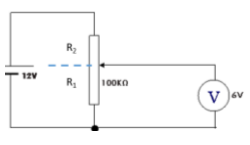
Key equations

- 1 Resistivity $\rho = \frac{RA}{l}$
- 2 Cross-sectional area $A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4}$
- 3 Resistors in series $R_T = R_1 + R_2 + R_3 + \dots$
- 4 Resistors in parallel $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
- 5 Electromotive force $\epsilon = I(R + r)$
- 6 Potential divider $\frac{V_{out}}{V_{in}} = \frac{R_1}{R_1 + R_2}$

Internal resistance and emf

- 1 When no current flows the voltmeter reads 1.5 V. When a current flows the voltmeter reads 1.3 V.

- 2 The missing volts are lost across the **internal resistance (r)** of the power supply.

- 4 When current flows through a power source electrons collide with ions in the cell, transferring some energy by heating the internal resistance of the cell.
- 5 Emf is the energy transferred by a power source to each coulomb of charge. It is usually less than the voltage measured across the power supply (V_{term}).
- 6 To measure the emf of a power source measure the terminal potential difference when there is no current flowing.

Potential dividers

- 1 This is a simple potential divider. The power supply provides a fixed potential difference, V_{in} . BUT we don't want all this potential difference for our appliance. We use two resistors to get the output potential difference we need, V_{out} .

- 2 By altering R_1 and/or R_2 we can alter the output voltage. By replacing one of the fixed resistors with a variable resistor you can vary V_{out} .

- 3 Here a resistor has been replaced with a thermistor. The output voltage depends on temperature. You could use a LDR instead meaning V_{out} depends on light intensity.

- 4 A potentiometer has a variable resistor replacing R_1 and R_2 of the potential divider. You move a slider or turn a button to adjust the relative sizes of R_1 and R_2 . This is useful when you want to change the voltage regularly e.g. volume control of stereo.


Key Vocabulary

- 1 Resistivity A measure of how much a particular material resists current flow. It is equal to a material's resistance $\times$ cross-sectional area divided by its length.
- 2 Kirchoff's first law At any junction in a circuit, the total current leaving the junction is equal to the total current entering the junction.
- 3 Kirchoff's second law The sum of the potential differences around a circuit is equal to the sum of the emfs of the power source.
- 4 Electromotive force (emf) The energy transferred by a power source to each coulomb of charge.
- 5 Internal resistance The resistance between the terminals of a power supply which reduces the terminal pd when a current flows.
- 6 Superconductor A conductor that has zero resistance at or below a **critical** temperature.
- 7 Potential divider A pair of resistors that divide input pd in the ratio of the resistors.