Copyrighted Material

AQA

REVISE AQA GCSE (9–1)

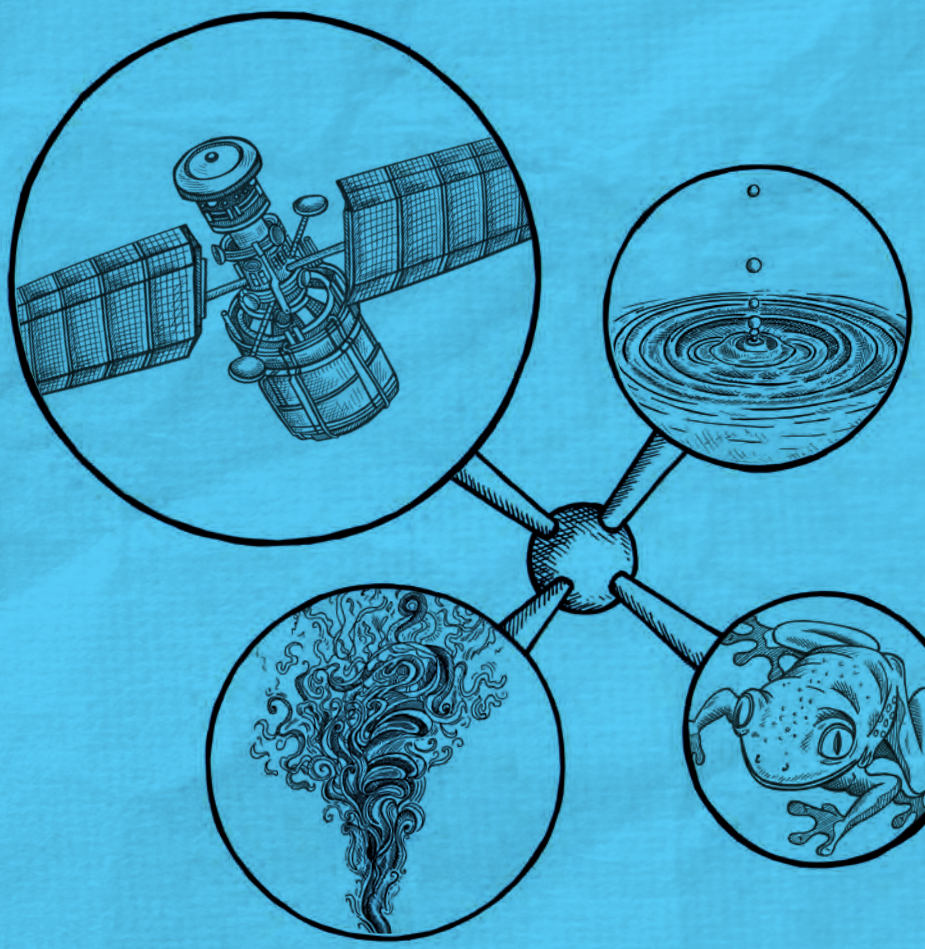
Physics

REVISION GUIDE

Higher

For the 9–1 exams

Includes free online edition



Pearson

Copyrighted Material

AQA

REVISE AQA GCSE (9–1)

Physics

REVISION GUIDE

Higher

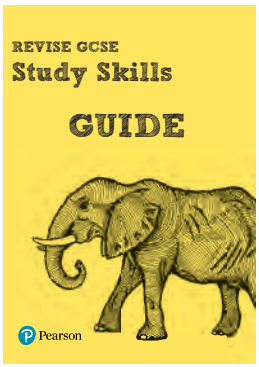
Series Consultant: Harry Smith

Author: Dr Mike O'Neill

Also available to support your revision:

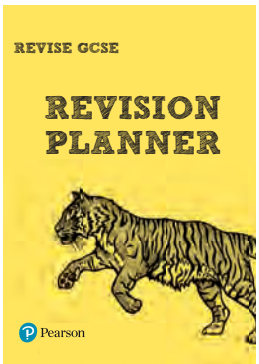
Revise GCSE Study Skills Guide 9781447967071

The **Revise GCSE Study Skills Guide** is full of tried-and-trusted hints and tips for how to learn more effectively. It gives you techniques to help you achieve your best – throughout your GCSE studies and beyond!



Revise GCSE Revision Planner 9781447967828

The **Revise GCSE Revision Planner** helps you to plan and organise your time, step-by-step, throughout your GCSE revision. Use this book and wall chart to mastermind your revision.



For the full range of Pearson revision titles across KS2, KS3, GCSE, Functional Skills, AS/A Level and BTEC visit:
www.pearsonschools.co.uk/revise

Pearson

Copyrighted Material

Contents

1-to-1 Page match with the Physics Higher Revision Workbook ISBN 9781292131504

PAPER 1

1 Energy stores and systems
2 Changes in energy
3 Energy changes in systems
4 Required practical – Specific heat capacity
5 Power
6 Energy transfers and efficiency
7 Required practical – Thermal insulation
8 Energy resources
9 Patterns of energy use
10 Extended response – Energy
11 Circuit symbols
12 Electrical charge and current
13 Current, resistance and potential difference
14 Required practical – Investigating resistance
15 Resistors
16 LDRs and thermistors
17 Required practical – Investigating *I–V* characteristics
18 Series and parallel circuits
19 ac and dc
20 Mains electricity
21 Electrical power
22 Electrical energy
23 The National Grid
24 Static electricity
25 Electric fields
26 Extended response – Electricity
27 Density
28 Required practical – Investigating density
29 Changes of state
30 Internal energy
31 Specific latent heat
32 Particle motion in gases
33 Pressure in gases
34 Extended response – Particle model
35 The structure of the atom
36 Atoms, isotopes and ions
37 Models of the atom
38 Radioactive decay
39 Nuclear radiation
40 Uses of nuclear radiation
41 Nuclear equations
42 Half-life
43 Contamination and irradiation
44 Hazards of radiation
45 Background radiation
46 Medical uses
47 Nuclear fission
48 Nuclear fusion
49 Extended response – Radioactivity

PAPER 2

50 Scalars and vectors
51 Interacting forces
52 Gravity, weight and mass
53 Resultant forces
54 Free-body force diagrams
55 Work and energy
56 Forces and elasticity
57 Force and extension
58 Required practical – Force and extension
59 Moments
60 Levers and gears
61 Pressure and upthrust
62 Pressure in a fluid
63 Distance and displacement
64 Speed and velocity
65 Distance–time graphs
66 Velocity–time graphs
67 Equations of motion
68 Terminal velocity
69 Newton's first law
70 Newton's second law
71 Required practical – Force, mass and acceleration
72 Newton's third law
73 Stopping distance
74 Reaction time
75 Momentum
76 Momentum and force
77 Extended response – Forces
78 Waves
79 Wave equation
80 Measuring wave velocity
81 Required practical – Waves in fluids
82 Waves and boundaries
83 Required practical – Investigating refraction
84 Sound waves and the ear
85 Uses of waves
86 Electromagnetic spectrum
87 Properties of electromagnetic waves
88 Required practical – Infrared radiation
89 Dangers and uses
90 Lenses
91 Real and virtual images
92 Visible light
93 Black body radiation
94 Extended response – Waves
95 Magnets and magnetic fields
96 Current and magnetism
97 Current, magnetism and force
98 The motor effect
99 Induced potential
100 Alternators and dynamos
101 Microphones and loudspeakers
102 Transformers
103 Extended response – Magnetism and electromagnetism
104 The Solar System
105 The life cycle of stars
106 Satellites and orbits
107 Red-shift
108 Extended response – Space physics
109 Answers
120 Physics Equations List

A small bit of small print:
AQA publishes Sample Assessment Material and the Specification on its website. This is the official content and this book should be used in conjunction with it. The questions in Now try this have been written to help you practise every topic in the book. Remember: the real exam questions may not look like this.

Copyrighted Material

Had a look ☐ Nearly there ☐ Nailed it! ☐

Paper 1

Energy stores and systems

A system is an object or a group of objects. There are changes in the way energy is stored when a system changes.

Examples of energy stores

There are eight main energy stores.

Energy store	Example
chemical	fuel, food, battery
kinetic	moving objects
gravitational potential	raised mass
elastic	stretched spring
thermal	hot object
magnetic	two magnets
electrostatic	two charges
nuclear	nuclear fuel

Conservation of energy

Energy can be transferred usefully to other stores and it can be wasted or dissipated to the surroundings. However, energy cannot be created or destroyed – the total energy in a closed system is the same after as it was before the transfer.

A closed system is an isolated system where no energy flows in or out of the system.

Examples of energy transfers

1. When an object is thrown upwards, the kinetic energy store decreases and the gravitational potential energy store increases.
2. When a moving object hits an obstacle, kinetic energy can be transferred and energy can be dissipated as sound and thermal energy.
3. The kinetic energy store of an object will increase when it is accelerated by a force.
4. When a vehicle brakes, the kinetic energy store decreases and the thermal energy store increases due to friction in the brakes.
5. When a kettle boils, energy is transferred electrically to increase the thermal store in the water.

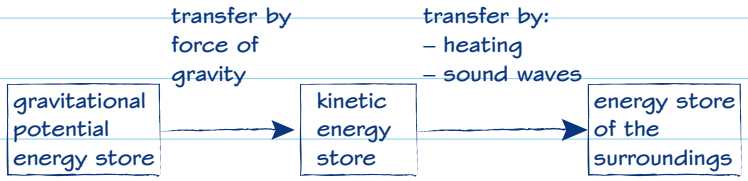
In all the examples, energy will be transferred to less useful forms, or wasted. It is dissipated to the thermal energy store of the surroundings.

Energy transfers

Energy can be transferred in three ways:

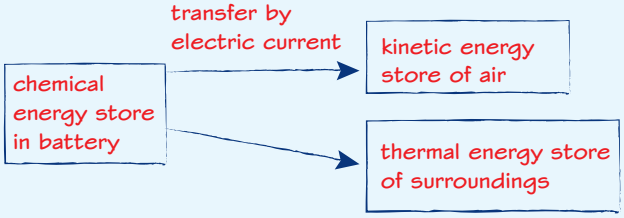
- by **heating**
- through the use of **forces**
- electrically by an **electric current**.

Energy transfers can be shown by flow diagrams. The flow diagram shows the changes in energy stores and the transfers for a falling object:



Worked example

The batteries in a battery-operated fan contain a total of 100 J of energy.
Draw a flow diagram to show the changes in the energy stores and the transfers that are taking place.



Now try this

1 Draw an energy store flow diagram for a car driving up a hill. **(4 marks)**

2 Describe the changes in energy stores and the energy transfers for a swinging pendulum. **(4 marks)**

Copyrighted Material

Changes in energy

Energy changes can be calculated for a moving object, a stretched spring and an object raised above the ground.

Maths skills Kinetic energy

Kinetic energy is stored in moving objects and is calculated using the equation:

$$\text{kinetic energy in J} = \tfrac{1}{2} \times \text{mass in kg} \times (\text{speed in (m/s)})^2$$

$$E_k = \tfrac{1}{2} m v^2$$

LEARN IT! IT'S NOT ON THE EQUATIONS LIST

Kinetic energy is directly proportional to the mass of the moving object: doubling the mass doubles the kinetic energy of the moving object.

It is directly proportional to the square of the speed, so doubling the speed means the E_k increases by a factor of four.

Worked example

(a) A mass of 800 g is moving at 14 m/s. Calculate its kinetic energy. **(3 marks)**

$E_k = \frac{1}{2} m v^2$

$E_k = \frac{1}{2} \times 0.8 \times 14^2 = 78.4\,\text{J}$

(b) A body of mass 4.8 kg has kinetic energy of 200 J. Calculate the speed it is moving at. **(4 marks)**

$200\,\text{J} = \frac{1}{2} \times 4.8 \times v^2$

Rearranging gives $v = \sqrt{400 \div 4.8} = 9.1\,\text{m/s}$

Remember to square the value of speed when calculating the kinetic energy. The term v^2 means $v \times v$.

The amount of gravitational potential energy gained by an object raised above the ground is calculated using the equation:

$$\text{gravitational potential energy in J} = \text{mass in kg} \times \text{gravitational field strength in N/kg} \times \text{height in m}$$

$$E_p = m g h$$

LEARN IT! IT'S NOT ON THE EQUATIONS LIST

Worked example

A body of mass 73 kg is lifted through a vertical height of 26 m. Calculate how much gravitational potential energy it has gained. **(3 marks)**

$E_p = m g h$

$= 73\,\text{kg} \times 10\,\text{N/kg} \times 26\,\text{m} = 18980\,\text{J}$

The amount of elastic potential energy stored in a stretched spring is calculated using the equation:

$$\text{elastic potential energy in J} = \tfrac{1}{2} \times \text{spring constant in N/m} \times (\text{extension in m})^2$$

$$E_e = \tfrac{1}{2} k e^2$$

When calculating the energy stored in joules, ensure that you convert the extension from centimetres to metres by dividing the value in centimetres by 100.

Worked example

A spring is distorted elastically. It increases its length by 25 cm when a total weight of 12 N is added. Calculate the total energy stored in the spring. **(4 marks)**

energy stored = work done

$E_e = \frac{1}{2} k e^2$

$= \frac{1}{2} \times 48\,\text{N/m} \times (0.25\,\text{m})^2 = 1.5\,\text{J}$

Now try this

1 Calculate the kinetic energy store of a ball of mass 12 kg moving at a speed of 8 m/s. **(3 marks)**

2 Calculate how much gravitational potential energy has been gained by a 25 kg mass that has been raised through a height of 36 m. **(3 marks)**

3 Calculate the increase in the elastic potential energy store of a spring of spring constant 50 N/m when it is stretched from its original length of 45 cm to a new length of 80 cm. **(4 marks)**

Copyrighted Material

Energy changes in systems

You can calculate the amount of energy stored in or released from a system as its temperature changes. In order to do this, you need to know the specific heat capacity of the material in the system.

Specific heat capacity

Specific heat capacity is the **thermal energy** that must be **transferred** to change the **temperature** of **1 kg** of a material **by 1 °C**. Different materials have different specific heat capacities. Water has a value of 4200 J/kg °C, which means that 1 kg of water needs 4200 J of thermal energy to be transferred to raise its temperature by 1 °C.

You can calculate the thermal energy required using the equation: $\Delta E = m\,c\,\Delta\theta$

change in thermal energy in J = mass in kg × specific heat capacity in J/kg °C × change in temperature in °C

Typical specific heat capacities

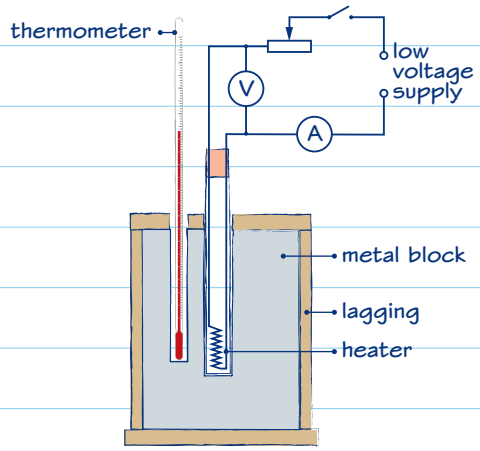
Typical values are given in the table.

Material	Specific heat capacity in J/kg °C
air	1005
water	4200
aluminium	900
concrete	880

Finding specific heat capacity

You can use this apparatus to find the specific heat capacity of a metal block.

An insulating jacket is placed around the metal block to reduce the amount of wasted energy transferred to the thermal store of the surroundings.



Worked example

A mass of 800 g has a specific heat capacity of 900 J/kg °C and is heated from 20 °C to 80 °C. Calculate how much thermal energy was supplied. **(3 marks)**

$\Delta E = m\,c\,\Delta\theta$

$0.8 \times 900 \times (80 - 20) = 43\,200$ J

Worked example

A total of 300 000 J of electrical energy is required to raise the temperature of a metal block of mass 2.8 kg from 18 °C to 52 °C. Calculate the specific heat capacity of the metal block. **(4 marks)**

$\Delta E = m\,c\,\Delta\theta$

$300\,000 \text{ J} = 2.8 \text{ kg} \times c \times (52 \text{ °C} - 18 \text{ °C})$

$c = 300\,000 \text{ J} \div (2.8 \text{ kg} \times 34 \text{ °C})$

$= 3151$ J/kg °C

It requires 3151 J of energy to raise the temperature of 1 kg of this metal block by 1 °C.

Now try this

1 Define the term specific heat capacity. **(3 marks)**

2 Calculate the energy required to raise the temperature of 15 kg of water from 18 °C to 74 °C. **(3 marks)**

3 A mass of 1250 g of metal is connected to a heater rated as 2.8 A and 16 V and heated for 12 minutes. The temperature of the metal block increases by 26 °C. Calculate its specific heat capacity. **(4 marks)**

Copyrighted Material

Specific heat capacity

Practical skills

You can determine the specific heat capacity of water using an electric heater.

Required practical

Aim

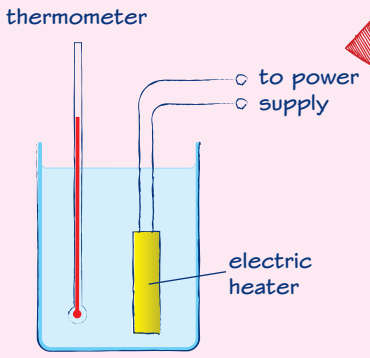
to determine the specific heat capacity of water and to describe the behaviour of ice when melting

Apparatus

water, thermometer, electric heater, power supply, insulation, beaker, electronic balance

Method

1 Set the apparatus up as shown in the diagram.



2 Measure the mass (m) of the water using an electronic balance.

3 Record the potential difference (V) of the power supply and the current (I) through the heater.

4 Take temperature readings every 30 seconds for a time (t) until the water reaches the desired temperature. Record the initial and final temperatures of the water and find the change in temperature ($\Delta\theta$).

Results

Plot a graph of temperature against time. Calculate the specific heat capacity. The value c is found by substituting the results into the equation $c = (V I t) / (m \Delta\theta)$.

Conclusion

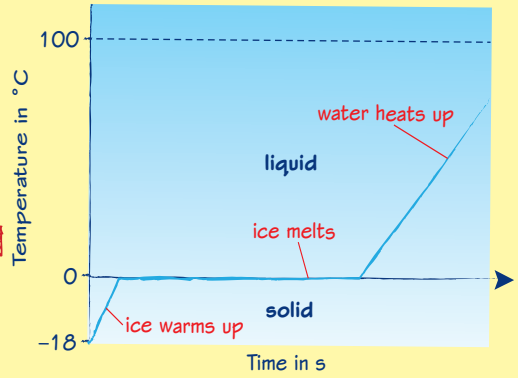
The specific heat capacity of water is the energy required to change 1 kg of water by a temperature of 1 °C. Its value is about 4200 J/kg °C.

There is more information about specific heat capacity on page 3, and more information about the energy transferred by a known current and potential difference on page 22.

Having insulation around the beaker will transfer less energy to the surroundings and give a more accurate value for the specific heat capacity of the water.

When recording the temperature readings, avoid parallax errors by reading the thermometer scale at eye level. Record the temperature values regularly, at equal intervals and ensure that the thermometer is in the middle of the liquid.

You can explore the behaviour of melting ice by drawing a graph like the one shown below. When ice melts, it changes state, but its temperature does not change.



The word 'specific' in this context is for 1 kg of mass. In other words, the values for specific heat capacity and latent heat are for when 1 kg either changes temperature by 1 °C or when it changes state.

Now try this

1 Explain why insulating the beaker leads to a more accurate value for the specific heat capacity of water. **(3 marks)**

2 Explain how the graph above would change for heating the same mass of aluminium that has a specific heat capacity of 880 J/kg °C. **(2 marks)**

3 The results of an experiment to determine the specific heat capacity of 500 g of a liquid are as follows. A 12-V heater was switched on for 20 minutes. The current through the heater was 2 A. The temperature of the liquid increased from 20 °C to 50 °C. Work out the specific heat capacity of the liquid. **(3 marks)**

Copyrighted Material

Power

Power is defined as the rate at which energy is transferred or work is done. The greater the power rating of a device, the more energy it transfers each second.

Power

Power is the rate of doing work (how fast energy is transferred). Power is measured in **watts (W)**. 1 watt is 1 joule of energy being transferred every second.

$$\text{power in W} = \frac{\text{energy transferred in J}}{\text{time in s}}, \quad P = \frac{E}{t}$$

$$\text{power in W} = \frac{\text{work done in J}}{\text{time taken in s}}, \quad P = \frac{W}{t}$$

LEARN IT! IT'S NOT ON THE EQUATIONS LIST



Typical power ratings of devices

Device	Power rating in W
hairdryer	1500
TV	50
microwave oven	850
jet engine	8.2×10^7

A typical nuclear power station generates 1 GW. ($1\text{ GW} = 1 \times 10^9$ W)

A hairdryer with a power of 1800 W transfers 1800 J each second.

Energy transferred and work done

The calculation for the work done or energy transferred depends on the nature of the energy transfer that has taken place.

For a change in gravitational potential energy, use the equation $E_p = m\,g\,h$

For work done by a force, use the equation $W = F\,s$

For electrical energy changes, use the equations $E = Q\,V$ and $Q = I\,t$

Worked example

(a) A microwave oven transfers 48 000 J of energy in 1 minute. Calculate the power rating of the microwave oven. **(3 marks)**

power = energy transferred ÷ time

= 48 000 J ÷ 60 s

= 800 W (or 800 J/s)

(b) A force of 120 N moves an object 40 m in 2 minutes. Calculate the power. **(4 marks)**

work done = force × distance in m

= 120 N × 40 m = 4800 J

power = work done ÷ time

= 4800 J ÷ 120 s = 40 W (or 40 J/s)

Remember to convert from minutes to seconds when calculating power in watts.

Worked example

A climber of mass 78 kg scales a wall of height 30 m in 5 minutes. Work out the power the climber uses to scale the wall. Use g = 10 N/kg. **(3 marks)**

energy transferred = $m\,g\,h$

= 78 kg × 10 N/kg × 30 m

= 23 400 J

power (W) = energy transferred (J) ÷ time taken (s)

= 23 400 J ÷ 300 s = 78 W (or 78 J/s)

Now try this

1 Two identical garage doors use different electric motors to lift the door through the same height. One motor opens the door in 6 seconds. The other opens the door in 8 seconds. Compare the powers of the motors. **(3 marks)**

2 Calculate how much energy an 1800 W hairdryer transfers when used for 8 minutes. **(3 marks)**

3 Calculate the power of a light bulb that transfers 3600 J of energy in 1 minute. **(3 marks)**

Copyrighted Material

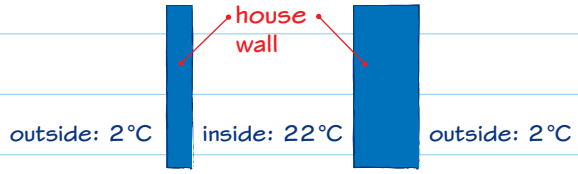
Energy transfers and efficiency

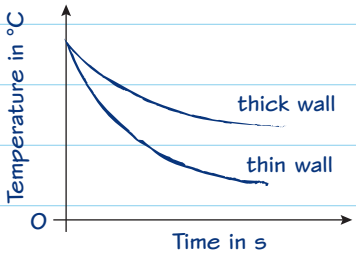
The rate at which a material transfers thermal energy depends on a number of factors. The **efficiency** of a device is a measure of how much **useful** energy it transfers.

Thermal energy transfer

The rate at which thermal energy is transferred through a wall of a house depends on:

1. the difference in temperature between the warmer interior and the colder exterior
2. the thickness of the walls
3. the thermal conductivity of the walls.





Efficiency

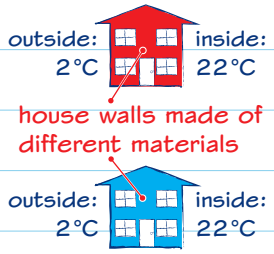
All machines **waste** some of the **energy** they **transfer**. Most machines waste energy as **heat** energy. The **efficiency** of a machine is a way of saying how good it is at transferring energy into **useful** forms.

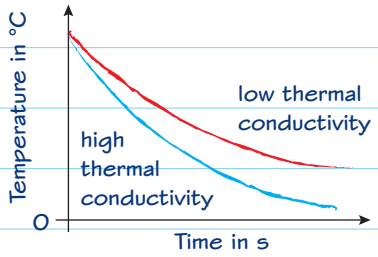
A very efficient machine has an efficiency that is nearly 100%. The higher the efficiency, the better the machine is at transferring energy to useful forms.

You can reduce unwanted energy transfers, for example through lubrication to reduce friction, using wires with low resistance in electrical circuits, and streamlining shapes for moving objects to reduce air resistance. This can also increase the efficiency of an intended energy transfer.

Thermal conductivity

A material with a high thermal conductivity is a better conductor of energy than one with a lower thermal conductivity. The rate at which the blue wall transfers energy is greater than that of the red wall.





Worked example

A motor transfers 100 J of energy by electricity. 60 J are transferred as kinetic energy, 12 J as sound energy and 28 J as thermal energy. Calculate the efficiency of the motor. **(3 marks)**

$$\text{efficiency} = \frac{\text{useful energy transferred by the machine}}{\text{total energy supplied to the machine}} \times 100\%$$

total useful energy = 60 J

$$\text{efficiency} = \frac{60\text{ J}}{100\text{ J}} \times 100\%$$

= 60% (or 0.6 as a decimal)

Efficiency does not have units.

No machine is ever 100% efficient. If you calculate an efficiency greater than 100% you have done something wrong!

LEARN IT! IT'S NOT ON THE EQUATIONS LIST

Now try this

1 A device transfers 14 J out of every 20 J supplied to useful energy stores. Calculate the efficiency of the device. **(2 marks)**

2 Explain why it is not possible for any device to be 100% efficient. **(3 marks)**

Use an electric appliance such as a kettle as an example.

Copyrighted Material

Thermal insulation

Practical skills You can investigate how different materials affect the rate of cooling of a material and how the thickness of a material affects the rate of cooling.

Required practical

Investigating thermal insulation

Aim

to measure the rate of cooling of a beaker of hot water when insulated with different materials and with different thicknesses of the same material

Apparatus

beakers, thermometers, kettle and water, pieces of cardboard, scissors, stopwatch, insulating materials and different amounts of one insulating material

Method 1: investigating thickness

1 Wrap three beakers in different thicknesses of the same insulating material.

2 Put the same amount of hot water into each beaker. Use a piece of cardboard for a lid with a hole for the thermometer.

3 Record the temperature of the water every 3 minutes for 20 minutes.

Method 2: investigating different materials

Place some insulating material around the inside of a beaker. Place a smaller beaker inside the insulation. Pour hot water into the smaller beaker.

Then follow method 1 from step 2 onwards. Repeat with a different insulating material.

Results

Record your results in a table similar to this one. Plot a graph of temperature of the water against time.

Method 1				
Number of layers of insulation	**Temperature in °C**			
	at start	**after 3 minutes**	**after 6 minutes**	**after 9 minutes**
0	80	73	67	62
1	80	74	69	65
2	80	75	71	68
Method 2				
Material				
no insulation	80	73	67	62
bubble wrap	80	76	72	70
newspaper	80	75	71	68

Conclusion

The greater the thickness of insulating material, the slower the rate at which the hot water cools.

The lower the thermal conductivity of the insulating material, the lower the rate at which the hot water cools.

Insulating materials could include: newspaper, corrugated cardboard, bubble wrap, sawdust or polystyrene granules.

Be careful not to burn or scald yourself with hot water or steam from the kettle.

The **dependent variable** in this investigation is the temperature of the water and the **independent variable** is the thickness of the insulating material.

The dependent variable is plotted on the *y*-axis and the independent variable on the *x*-axis.

So that the results are accurate, valid and reliable, try to ensure that the same **mass** of insulating material is used for each of the insulating materials.

Now try this

1 Describe **three** potential sources of error that may arise in this investigation. **(3 marks)**

2 Explain why there are data for 'no insulation' in the table of results for method 2. **(2 marks)**

3 Explain why the mass of each insulating material should be kept the same in method 2 for all the materials. **(4 marks)**

Copyrighted Material

Energy resources

Renewable and non-renewable resources are used for transport, heating and electricity generation.

Renewable energy resources can be replenished as they are being used and will not run out.

Non-renewable energy resources cannot be replaced and will eventually run out.

Resource	Description, uses and issues
biomass	Taken from living or recently living organisms including methane gas from animal waste and sewage. Used for fuels such as methanol in transport and as fuel in power stations. Carbon neutral: carbon dioxide released when burnt is the same amount that the organism took in when living.
wind	Wind turbines transfer the kinetic energy of the wind to electrical energy by turning a generator. Do not work if not windy or too much wind.
hydroelectricity	Water stored in a reservoir is used to generate electrical energy when it flows downhill through a generator. Generally reliable but will not be used if the reservoir runs dry in a drought.
geothermal energy	Thermal energy released from radioactive decay within the Earth heats surrounding rocks. Water is pumped down to be heated by the rocks. The resulting hot water or steam is used to heat homes or turn generators to generate electrical energy. Reliable due to constant heat supply.
tidal power	Kinetic energy of tidal streams or from sea water flowing through barrages used by turbines to generate electricity. Tidal power is available at predictable times, but not all of the time. There are few places where these can be situated and they may affect wildlife habitats.
solar power	Solar panels use radiation from the Sun to heat water for use in homes or to generate electricity. Solar cells generate electricity. Can be used to supply energy to people in remote areas. Does not work when not sunny.
water waves	Water waves turn a generator to generate electricity. Unreliable due to small or no wave motion on calm days.
fossil fuels	Coal, oil and gas are burned in power stations to heat water, which becomes steam and turns turbines to generate electricity. Fuels such as petrol, kerosene, diesel and oil are used in transport and heating homes. Reliable, but produce carbon dioxide which leads to global warming.
nuclear	Uranium or plutonium release energy from the fission of their nuclei. The energy released is used in power stations to generate electricity. Reliable. Produces around 10 000 times more energy per kilogram compared with fossil fuels, but also produces large amounts of dangerous radioactive waste.

Worked example

Explain why environmental problems are not always solved by science. **(3 marks)**

Science can identify environmental issues like global warming, but political, social, ethical and economic factors may not allow these to be addressed. There may be resistance from people not wanting wind turbines near their homes or animal habitats to be destroyed, and there may be financial constraints, so politicians don't allow resources to be built due to cost or other social, political or ethical issues.

Now try this

1 Describe how the different renewable and non-renewable resources are used for transport. **(4 marks)**

2 Compare the advantages and disadvantages of renewable and non-renewable energy resources. **(4 marks)**

Copyrighted Material

Patterns of energy use

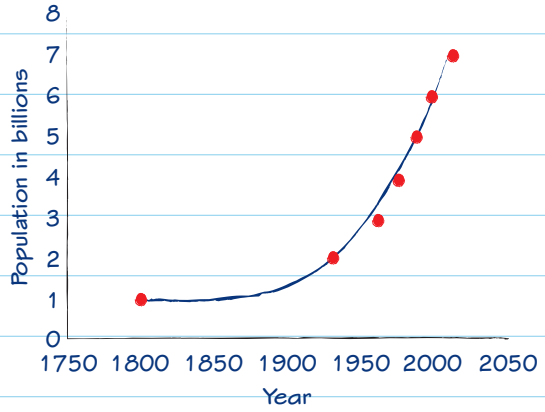
The patterns and trends in how humans have used energy resources have changed over time.

Patterns and trends in energy use

The use of energy resources has changed over the years. This is because of several factors.

1. **the world's population** In the past 200 years, the population of the world has risen from 1 billion to 7 billion people.
2. **the development of technology** Vehicles such as cars, trains and planes and other devices have increased in number and these all require energy.
3. **electrical energy** Power stations require fuels in order to generate electricity.

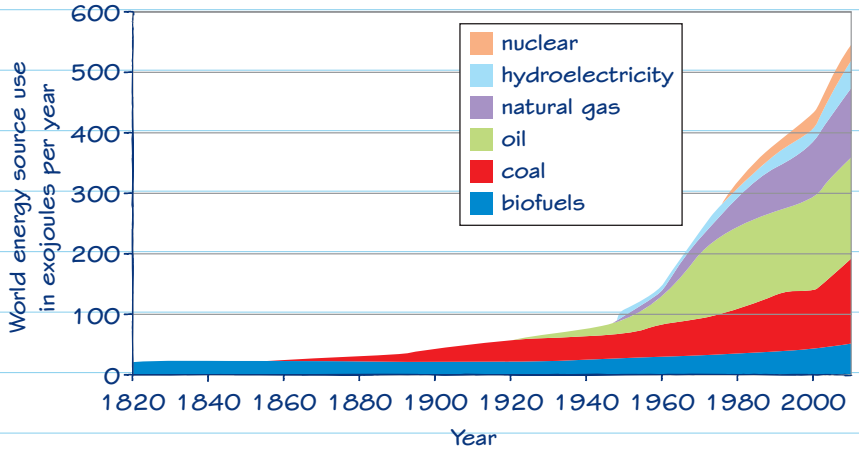
Growth in world population



Trends in the world's energy use

As the graph shows, most of the world's energy use has been fossil fuels. Before about 1900, biomass in the form of wood was the major source of fuel and its use has remained constant over time.

In more recent years, there has been an increase in the use of nuclear fuel and hydroelectric power.



Worked example

Compare the shape of the world's population graph with that of the energy use graph. **(4 marks)**

They are similar in that as the population increases, the total energy used will increase. They differ in that the total energy use has increased faster than the population. As societies develop, they use more technology that requires energy to run it. This means that the average amount of energy used per person also increases.

The future?

It is not possible to continue using the Earth's non-renewable energy reserves to the extent that they are being used now. They are a finite reserve, so will run out and not be replaced.

Greater use of fossil fuels will lead to more carbon dioxide in the atmosphere. There will be greater global warming, leading to severe weather, flooding and threats to food supplies.

Now try this

1 Describe the main issues with using the Earth's energy supplies. **(2 marks)**

2 Wood is a biofuel. Suggest why wood has been used constantly for many years, whereas other fuels have only been used much more recently. **(3 marks)**

Copyrighted Material

Extended response – Energy

There will be at least one 6-mark question on your exam paper. For these questions, you will need to think scientifically and structure your answer logically, showing how the points you make are related to each other. You can revise the topics for this question, which is about **the principle of the conservation of energy**, on page 1.

Worked example

Figure 1 shows the arrangement of apparatus for a simple pendulum. Figure 2 shows how the kinetic energy of the pendulum changes with time.

Describe the energy transfers taking place during the motion of the simple pendulum.

Your answer should refer to the energy stores and energy transfers that are involved.

(6 marks)

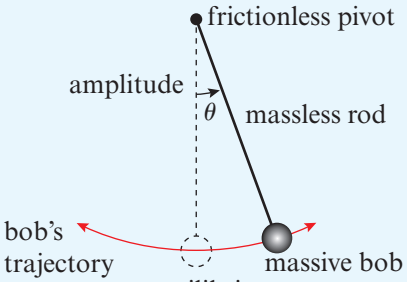


Figure 1

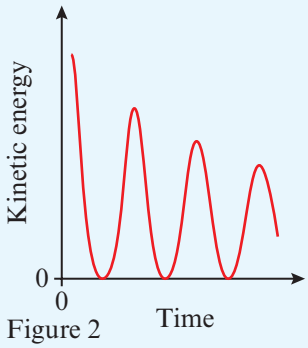


Figure 2

Initially, the pendulum has to be raised through a small angle, so it will gain gravitational potential energy. Once released, this gravitational potential energy store will be transferred mainly to a kinetic energy store, with some energy being dissipated as sound and heat by thermal transfer from friction due to air resistance.

The principle of conservation of energy states that the total energy of the system at any time must be the same, since energy cannot be created nor destroyed. Initially, this was all in the gravitational potential energy store, but this is then transferred to the kinetic energy store once the pendulum starts to swing. At the bottom of the swing, the gravitational potential store will be greatly reduced and the energy will be mostly in the kinetic store. Some energy is also transferred to the surroundings as heat and sound by thermal transfer from friction due to air resistance, which must also be taken into consideration as part of the total energy of the system.

Eventually, the pendulum will stop swinging, so the gravitational energy has been transferred to kinetic energy and it has eventually all ended up in the surroundings by friction due to air resistance, leading to the surroundings becoming slightly warmer. The useful energy store has been dissipated to the surroundings.

Command word: Describe

When you are asked to **describe** something, you need to write down facts, events or processes accurately.

It is a good idea to state what the principle of conservation of energy is, so that the examiner knows that you understand it. You can then apply this idea to the changes in the energy stores and transfers in the system. It is also worth noting that the way we talk about energy at GCSE now has changed – you need to refer to energy stores as well as energy transfers. In this example, the main stores are gravitational and kinetic, and the motion of the pendulum is via mechanical transfer, with energy transfer to the surroundings by thermal transfer.

In energy transfers, the energy stores are usually dissipated to the surroundings, which become warmer. In a perfect situation, with no frictional forces or energy wasted, the pendulum would swing forever, but in reality this does not happen.

Refer to *energy stores* and *energy transfers* in your answer. There are eight energy stores and three energy transfers that you need to know. See page 1 to remind yourself of these.

Now try this

The people on a small island want to use either wind power, on hills and out at sea, or its reserves of coal to generate electrical energy. Compare the advantages and disadvantages of each resource. **(6 marks)**

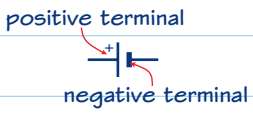
Copyrighted Material

Circuit symbols

Electric circuit diagrams are drawn using agreed symbols and conventions that can be understood by everybody across the world.

Circuit symbols

You need to know the symbols for these components.

Component	Symbol	Purpose
cell		provides a potential difference
battery		provides a potential difference
switches		allows the current flow to be switched on or off
voltmeter		measures potential difference across a component
ammeter		measures the current flowing through a component
fixed resistor		provides a fixed resistance to the flow of current
variable resistor		provides a variable (changeable) resistance
lamp		converts electrical energy to light energy as a useful form
fuse		wire melts if the current in a circuit gets too high
diode		allows current to flow in one direction only
thermistor		resistance decreases when the temperature increases
LDR		resistance decreases when the light intensity increases
LED		a diode that gives out light when current flows through it

Worked example

Name four components that are commonly used to change or control the amount of resistance in a circuit. **(2 marks)**

thermistor, LDR, fixed resistor, variable resistor

2 marks for all correct, 1 mark for 3 correct and zero marks for fewer than 3 correct.

Worked example

Describe how an LED is different from a filament lamp. **(1 mark)**

An LED will only allow electrical current to pass through it in one direction.

Now try this

1 State which components in the table above are output devices. **(2 marks)**

2 State how ammeters and voltmeters should be arranged with components in circuits. **(2 marks)**

3 Design a circuit to turn on a lamp when it goes dark. **(3 marks)**

Copyrighted Material

Electrical charge and current

An **electric current** is the **rate of flow of charge**. In a metal, electric current is the flow of electrons.

Charge and current

The size of a current is a measure of how much charge flows past a point each second. It is the rate of flow of charge. The unit of charge is the **coulomb** (C). One ampere, or amp (A), is one coulomb of charge per second. You can calculate charge using the equation:

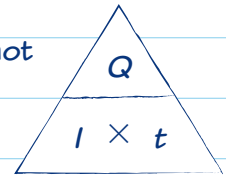
charge in C = current in A × time in s

$Q = I t$

LEARN IT! IT'S NOT ON THE EQUATIONS LIST

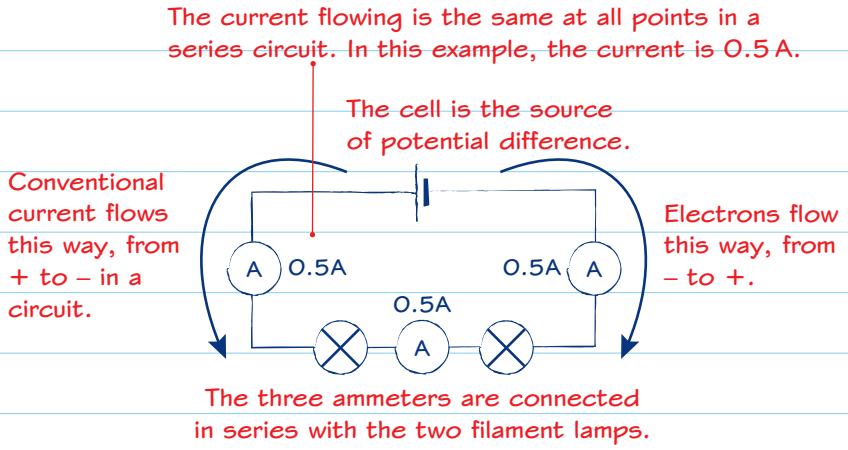
Watch out! Don't get the units and quantities confused. The units have sensible abbreviations (C for coulombs, A for amps). The symbols for the quantities are not as easy to remember (*Q* stands for charge, *I* for current).

You also need to know how to rearrange the equation using the triangle shown so that you can calculate *Q*, *I* and *t* using values provided in questions.



Measuring current

Electric current will flow in a closed circuit when there is a source of potential difference. To measure the size of the current flowing through a component, an ammeter is connected in series with the component.



Worked example

(a) Describe how ammeters should be connected with components in circuits. **(1 mark)**

Ammeters should always be arranged in series with the component to be measured.

(b) Describe what happens to the size of the current in a series circuit. **(1 mark)**

The current is the same value at any point in a series circuit.

Worked example

(a) A current of 1.5 A flows for 2 minutes. Calculate how much charge flows in this time. **(3 marks)**

$Q = I \times t$

$= 1.5\,A \times 120\,s = 180\,C$

(b) A charge of 1200 C flows through a filament lamp for 4 minutes. Calculate the average current in the filament lamp. **(3 marks)**

$I = Q \div t$

$= 1200\,C \div 240\,s$

$= 5\,A$

You can give the units of current as A or amps.

Now try this

1 Name the units of current and charge. **(2 marks)**

2 Calculate the charge that flows in one hour when there is a current of 0.25 A in a circuit. **(3 marks)**

3 A charge of 3×10^4 C is transferred by a current of 250 mA. Calculate the length of time the current flows. **(4 marks)**

Copyrighted Material

Current, resistance and potential difference

Ohm's law states how the **current** through a component relates to its **resistance** and the **potential difference** across it.

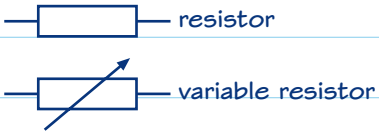
Resistance

The **resistance** of a component is a way of measuring how hard it is for electricity to flow through it. The units for resistance are **ohms (Ω)**.

The resistance of a whole circuit depends on the resistances of the different components in the circuit. The higher the total resistance, the smaller the current.

resistance UP, current DOWN

The resistance of a circuit can be changed by putting different **resistors** into the circuit, or by using a **variable resistor**. The resistance of a variable resistor can be changed using a slider or knob.



Ohm's law

Ohm's law states that the size of the current, I, flowing through a component of resistance, R, is directly proportional to the potential difference, V, across the component at constant temperature.

The equation for Ohm's law is:

potential difference in V = current in A × resistance in Ω

$$V = I R$$

LEARN IT! IT'S NOT ON THE EQUATIONS LIST

Components that obey Ohm's law are said to be ohmic conductors whereas those that do not obey Ohm's law are non-ohmic. Examples of both of these can be found on page 15.

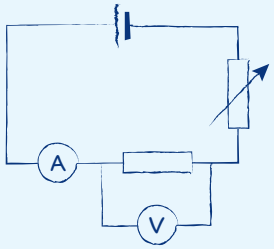
Worked example

(a) Resistor A has a current of 3 A flowing through it when the potential difference across it is 15 V. What is the size of its resistance? **(3 marks)**

From $V = I R$ you obtain $R = V / I$

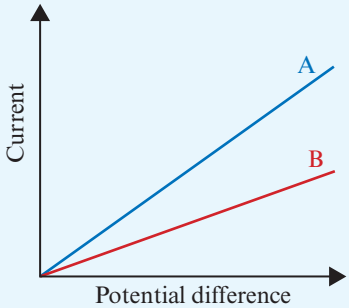
Substituting gives $R = 15\,V / 3\,A = 5\,\Omega$

(b) Sketch a circuit that could be used to plot current against potential difference for this resistor. **(4 marks)**



The variable resistor can be used to collect numerous values for I and V so that an I–V graph can be plotted.

(c) Resistor A is then replaced with resistor B. A graph of current against potential difference is plotted. Explain what the graph tells you about the two resistors. **(2 marks)**



The steeper line shows that resistor A has a lower resistance than resistor B.

Both resistors are ohmic because the graphs are straight lines.

Now try this

1 A current of 3.2 A flows through a lamp of resistance 18 Ω. Calculate the size of the potential difference across the lamp. **(3 marks)**

2 The potential difference across a resistor is 28 V when the current flowing through it is 0.4 A. Calculate the resistance of the resistor. **(3 marks)**

Copyrighted Material

Investigating resistance

Practical skills You can use appropriate circuits to investigate how combinations of resistors in series and parallel affect the overall electrical resistance in the circuit and how the length of a wire affects its resistance.

Required practical

There is more information relating to current, potential difference, resistance and series and parallel circuits on pages 13 and 15–18.

Aim

to investigate electrical resistance in series and parallel circuits and how the resistance of a wire varies with its length

When resistors are arranged in series, potential difference is split across the resistors.

When resistors are arranged in parallel, the potential difference (pd) across each resistor will be the same as the power supply or battery pd.

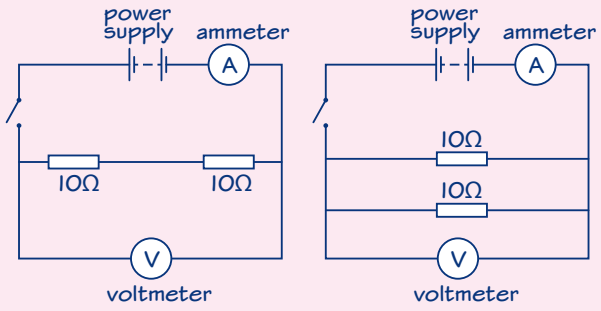
Apparatus

battery or suitable power supply, ammeter, voltmeter, switch, crocodile clips, two resistors, resistance wire, metre ruler, variable resistor, connecting leads

Method 1: series and parallel

Set up the circuits in both series and parallel arrangements. Record the potential difference and current.

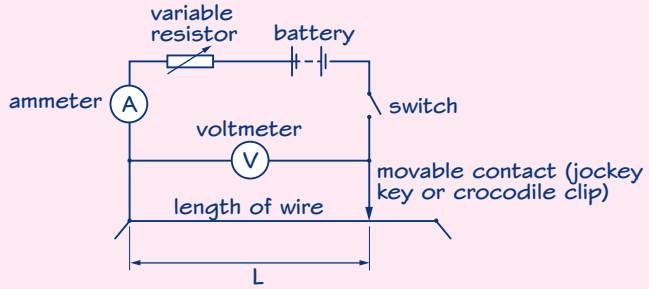
For both circuits, calculate the total effective resistance using the equation $R = V \div I$



The electrical resistance of each length of wire is found by dividing the potential difference value by the current value. Take repeat results (at least two sets) and then plot a graph of resistance on the *y*-axis against length on the *x*-axis.

Method 2: resistance of a wire

Set up the circuit shown in the diagram. Record the potential difference across the wire and the current in the wire for different lengths of wire.



Now try this

1 Explain why it is good practice to obtain at least two sets of data when performing this investigation. **(4 marks)**

2 Explain why the total effective resistance is greater when resistors are arranged in series compared with being arranged in parallel. **(4 marks)**

3 Explain why a graph of resistance against length may not produce a straight line that goes through the origin. **(4 marks)**

Results

Record your results for each method in a table similar to the one shown.

Length of wire in cm OR Arrangement of resistors	Potential difference in V	Current in A

Conclusion

The effective resistance when two resistors are connected in series is four times greater than when they are connected in parallel.

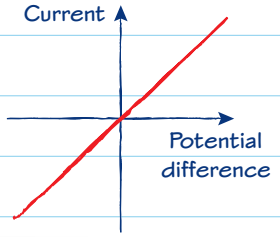
The resistance of the wire is directly proportional to its length. A graph of resistance against length should be a straight line through the origin.

Copyrighted Material

Resistors

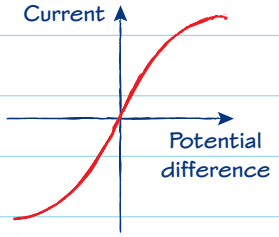
An ***I–V* graph** shows how the **current** flowing through a component varies as the **potential difference** across it varies. You need to know the characteristics of these *I–V* graphs.

1 Fixed resistor



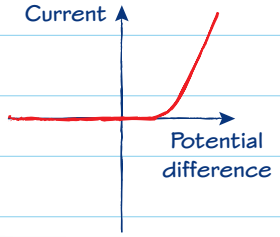
The temperature remains constant so the resistance remains constant. The slope or gradient is constant and the line remains straight throughout. Fixed resistors are ohmic conductors and show a linear relationship between current and potential difference.

2 Filament lamp



As the potential difference increases, the filament gets hotter, and atomic vibration increases. This leads to greater resistance. The slope or gradient decreases as the potential difference increases since resistance is increasing. The relationship is non-linear.

3 Diode

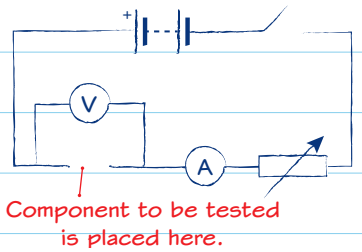


The current only flows in one direction. There is a **threshold** in the forward direction, which is why the graph is flat initially. A diode behaves like a fixed resistor – the resistance does not change. A diode has a very high resistance in the reverse direction.

Drawing an *I–V* graph

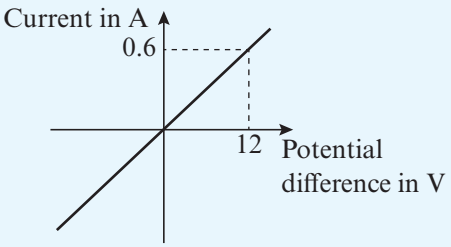
You can use a circuit like this to collect data about current and potential difference.

- When the switch is closed you can read current from the ammeter and potential difference from the voltmeter.
- Varying the value of the variable resistor allows you to record the current for different potential differences.
- You can reverse the cell to obtain negative values for potential difference.



Worked example

A student is testing the resistance of a component. She draws an *I–V* graph.



The component being tested is a

- ☐ diode
- ☐ filament lamp
- ☒ fixed resistor
- ☐ cell

(1 mark)

An *I–V* graph always has the current (*I*) plotted on the vertical *y*-axis and the potential difference (*V*) plotted on the horizontal *x*-axis. To find the resistance of a component from an *I–V* graph, you will need to divide the *x*-axis value by the corresponding *y*-axis value. That is, the gradient is not the resistance, the

$$\text{gradient} = \frac{1}{\text{resistance}}$$

Now try this

Amy is testing the resistance of a filament lamp. She varies the potential difference across the lamp and records the current that flows.

(a) Sketch a graph of potential difference (*V*) against current (*I*) for Amy's experiment. **(2 marks)**

(b) Explain the shape of your graph. **(3 marks)**

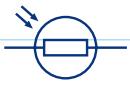
Copyrighted Material

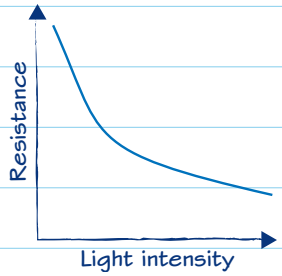
LDRs and thermistors

The resistance of **light-dependent resistors (LDRs)** and **thermistors** changes according to light conditions (LDR) or temperature (thermistor).

Light-dependent resistors

The resistance of a **light-dependent resistor (LDR)** is large in the dark. The resistance gets less if light shines on it. The brighter the light, the lower the resistance. LDRs can be used to switch lights on when it gets dark.



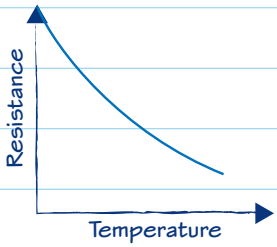


brightness UP, resistance DOWN

Thermistors

The resistance of a **thermistor** depends on its temperature. The higher the temperature, the lower the resistance. Thermistors can be used as a thermostat.

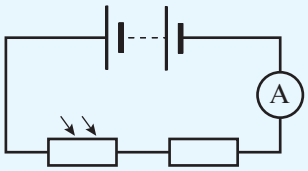




temperature UP, resistance DOWN

Worked example

A 6 V battery is connected in series with an LDR, a 300 Ω fixed resistor and an ammeter, as shown.



(a) Describe how the circuit shown can be used to explore the variation in resistance as the light levels change. **(2 marks)**

The amount of light being shone on the LDR can be changed by varying the intensity of the light it is exposed to from a torch or a lamp. The size of the current flowing in the circuit can then be recorded for each of these light levels.

(b) Describe the results you would expect. **(2 marks)**

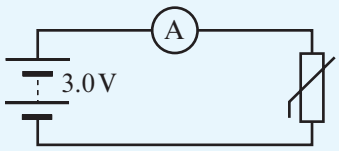
The output current will be highest when the light level is greatest. As the brightness increases, the LDR's resistance decreases.

(c) How could a voltmeter be used in the circuit to show how the resistance changes with light levels? **(3 marks)**

Connect a voltmeter across the LDR. As the light level increases, the potential difference across the LDR will decrease since the resistance has decreased and a greater share of the 6 V will be across the fixed resistor.

Worked example

A 3 V battery is connected in series with a thermistor and an LDR, as shown.



(a) Explain how the circuit can be used to explore how the resistance of the thermistor changes. **(2 marks)**

The thermistor could be immersed in a beaker of cold water, or a water bath, which is then heated from 10°C to 80°C. The current flowing in the circuit is recorded at each temperature over this range.

(b) Describe what your results would show. **(2 marks)**

As the temperature increases, the current increases. This is because the thermistor's resistance decreases as it gets warmer.

If a buzzer were placed in this circuit then it could be used as a simple fire alarm, with the buzzer sounding when the current reached a certain value. This could be controlled or calibrated by using a variable resistor.

Now try this

1 State what affects the resistance of (a) a thermistor and (b) an LDR. **(2 marks)**

2 Explain how an LDR and a thermistor could be used together in a circuit. **(4 marks)**

Copyrighted Material

Investigating *I–V* characteristics

Practical skills You can construct appropriate circuits to investigate the *I–V* characteristics of a variety of circuit elements, including a filament lamp, a diode and a resistor at constant temperature.

Required practical

Aim

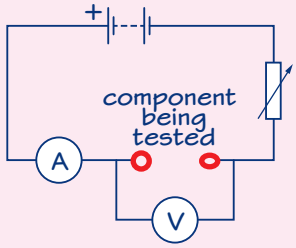
to investigate *I–V* graphs for a resistor, filament lamp and diode

Apparatus

ammeter, voltmeter, component holders, filament lamp, resistor, diode and protective resistor, variable resistor, leads

Method

Set up the circuits as shown and record the current through each component for different values of the potential difference (pd). The pd across each component is varied using the variable resistor. Reverse the cell or battery to obtain negative values for current and pd.



Results

Record your results in a table for each component. The results shown here are for the filament lamp.

Potential difference (*V*)	Current (*I*)
−2.0	−0.20
−1.5	−0.18
−1.0	−0.15
−0.5	−0.10
0	0
0.5	0.10
1.0	0.16
1.5	0.18
2.0	0.20

Draw a graph of current against potential difference.

Conclusion

The *I–V* graphs for the components should look as shown on page 15.

There is more information relating to current, potential difference and resistance in filament lamps, diodes and resistors on pages 13–16.

Be careful when using electrical circuits as electric current can produce heat and cause burns.

In order to improve the accuracy of your results, place a switch in your circuit so that the current does not get too large. Too large a current leads to a greater value of the resistance being recorded, due to thermal energy causing extra vibrations of the ions in the metal lattice.

Data collected in an investigation are accurate if close to the true value. The data are precise if the repeat readings of a certain variable are close to one another. The best data are both accurate and precise.

An *I–V* graph has current plotted on the *y*-axis and potential difference on the *x*-axis. The shape of the graph depends on the size or direction of the current through each component.

Now try this

1 Explain why the *I–V* graph for a filament lamp has the shape that it does. **(5 marks)**

2 Explain why the *I–V* graph for the diode has the shape that it does. **(3 marks)**

3 Explain how the resistance of a resistor can be determined from an *I–V* graph. **(3 marks)**

Copyrighted Material

Had a look ☐ Nearly there ☐ Nailed it! ☐

Series and parallel circuits

Components can be arranged in series or parallel. The rules for current, potential difference and resistance are different for these two types of circuit.

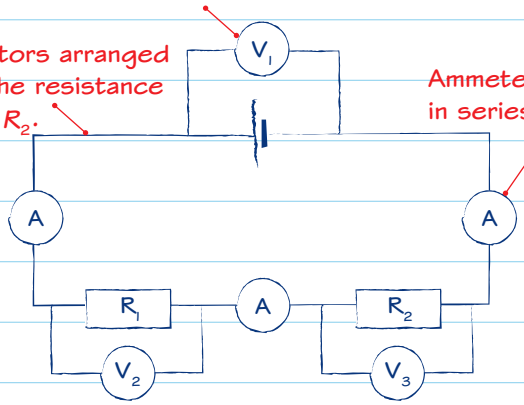
Series circuits

A **series circuit** contains just one loop, around which an electric current can flow.

Adding more resistors in series means that the cell's potential difference is shared between more resistors. The current through the resistors decreases ($V = I R$), so the total resistance has increased.

The total resistance of two resistors arranged in series is equal to the sum of the resistance of each component, $R_{total} = R_1 + R_2$.

Ammeters have a very low resistance so the current can flow through them and be measured accurately.



Ammeters are always connected in series with components.

The size of the current in a series circuit is the same at every point in the circuit. All three ammeters in this circuit will show the same value for the current.

The potential difference across components that are arranged in series must add up to give the cell voltage, so $V_1 = V_2 + V_3$.

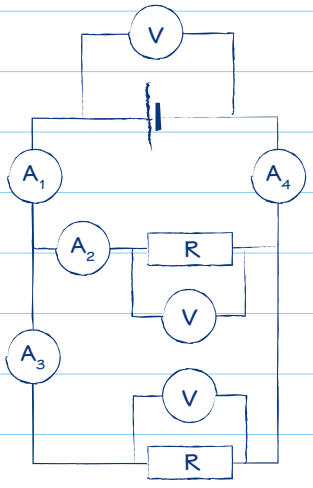
Voltmeters have a very high resistance so that no current will flow through them.

Parallel circuits

A **parallel circuit** contains more than one loop and the current will split up or recombine at the junctions.

The total resistance of two resistors arranged in parallel is less than the resistance of the smallest individual resistor.

Adding more resistors in parallel means that the cell's potential difference will be the same across each resistor. The total current increases, so the total resistance must have decreased.

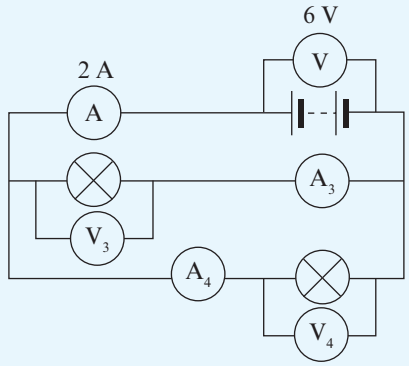


The potential difference across the components in each branch of a parallel circuit must add to give the cell voltage. The voltmeter readings across the two resistors will both have the same value as the potential difference across the cell.

The sum of the currents in each of the branches must equal the current leaving the cell. For this example, $A_1 = A_4 = A_2 + A_3$.

Worked example

What are the missing values in this parallel circuit if the bulbs are identical? **(2 marks)**



Both the ammeter readings A_3 and A_4 = 1 A. The voltmeter readings V_3 and V_4 will both be 6 V.

Now try this

1 Describe the differences for current and potential difference in series and parallel circuits. **(4 marks)**

2 Explain why car lights are connected in parallel and not in series. **(3 marks)**

3 Explain why a cell goes flat more quickly when lamps are arranged in parallel. **(4 marks)**

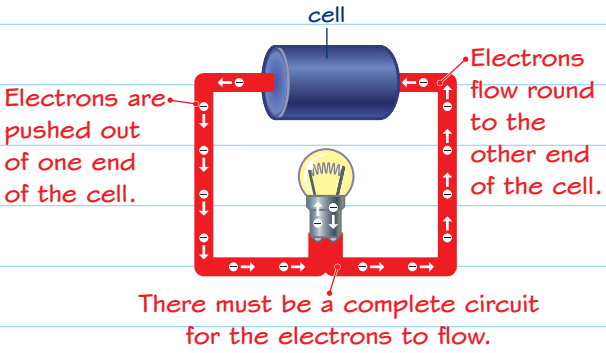
Copyrighted Material

ac and dc

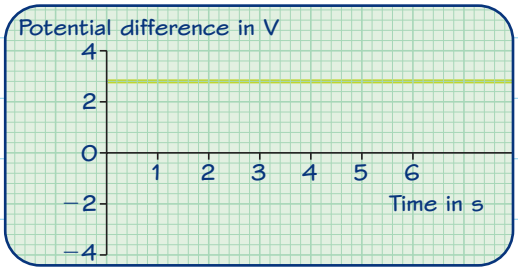
Circuits can be operated using **alternating current (ac)** or **direct current (dc)**.

Direct current

An **electric current** in a wire is a flow of electrons. The current supplied by **cells** and **batteries** is **direct current (dc)**. In a direct current the electrons all flow in the same direction.



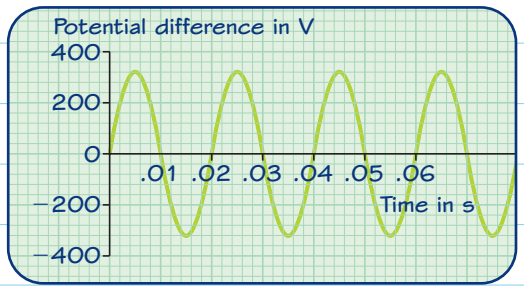
The oscilloscope trace for dc from a battery is a horizontal line. The potential difference can be read off the vertical scale.



The potential difference above has a constant value of 2.8 V.

Alternating current

Mains electricity supplied to homes and businesses is an **alternating current (ac)**. Alternating current is an electric current that changes direction regularly, and its potential difference is constantly changing.



For an ac supply, the movement of charge is constantly changing direction. The mains supply has an average working value of 230 V and a frequency of 50 Hz. This means that the electric current and voltage change direction 100 times every second.

dc and ac supply in the home

Both dc and ac can be used in the home; dc is supplied in the form of cells and batteries, ac is the mains supply. Both can be used by devices to transfer energy to motors and heating devices.

Different electrical appliances have different power ratings. The power rating tells you how much energy is transferred by the appliance each second.

Appliance	Power rating
kettle	2200 W
hairdryer	1500 W
microwave	850 W
electric oven	3000 W
electric shaver	15 W

Worked example

Compare the power rating of a hairdryer and an electric shaver, and the changes in stored energy when they are in use. **(4 marks)**

The hairdryer has a power rating of 1500 W, which means that it transfers 1500 J per second to stores of kinetic energy and thermal energy. The electric shaver has a power rating of one-hundredth of the hair dryer. It transfers only 15 J per second, mainly to a kinetic energy store.

Now try this

1 Give **three** examples of devices that use
(a) dc **(3 marks)**
(b) ac. **(3 marks)**

2 Explain how ac and dc are
(a) similar **(1 mark)**
(b) different. **(2 marks)**

3 Explain how and why alternating current is generated in power stations instead of direct current. **(3 marks)**

Copyrighted Material

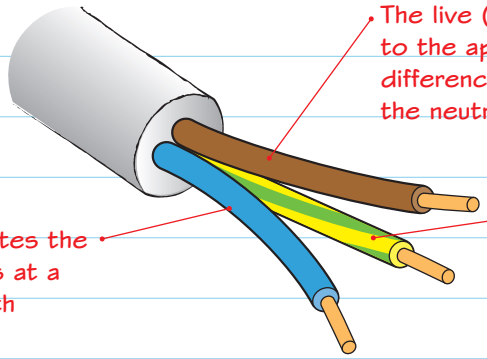
Had a look ☐ Nearly there ☐ Nailed it! ☐

Mains electricity

Electrical energy enters UK homes as mains electricity at 230 V ac. Most electrical appliances are connected to the mains using a three-core cable.

Live, neutral and earth wires

The live, neutral and earth wires are made from copper, but covered in colour-coded insulating plastic so that the consumer is not exposed to a dangerous voltage.



The live (brown) wire carries the supply to the appliance. It is at a potential difference of 230 V with respect to the neutral and earth wires.

The neutral (blue) wire completes the circuit with the appliance. It is at a potential difference of 0 V with respect to the earth wire.

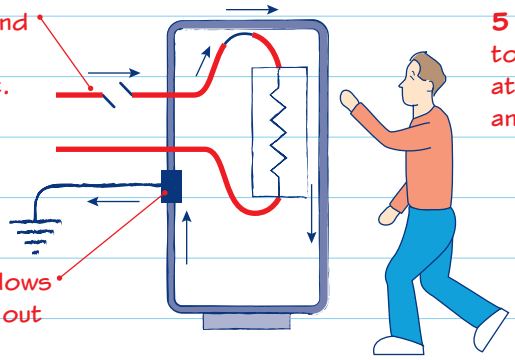
The earth (yellow and green) wire does not form part of the circuit but acts as a safety feature along with the fuse.

Earthing

A live wire may be dangerous even when a switch in the mains circuit is open. If a person touches a metal device that is live, current would flow through him to earth and could be fatal. Appliances are earthed so that a user cannot be electrocuted.

1 The live wire inside the appliance may come loose and touch a metal part of the device's casing.

2 The large current heats and melts the wire in the fuse, making a break in the circuit.



5 By having an earth wire connected to the metal casing, the user is not at risk if the live wire comes loose and touches anything metallic.

3 The earth wire is connected to the metal casing and a large current flows in through the live wire and out through the earth wire.

4 The circuit is no longer complete, so there is no chance of electric shock or fire.

Worked example

Describe how two safety devices keep the user safe when using mains electricity. **(4 marks)**

A fuse will melt if the current through it gets too high, so the appliance cannot overheat and will be isolated at 0 V.

If the live wire touches the metal case, a large current will pass through the fuse to the earth wire. The fuse melts, reducing the potential difference to 0 V and making it impossible to be electrocuted.

Potential differences

The potential difference between the wires in the mains supply has different values.

Wires	Potential difference in V
live and earth	230
live and neutral	230
earth and neutral	0

Now try this

1 State the colours of the
(a) live wire **(1 mark)**
(b) neutral wire **(1 mark)**
(c) earth wire. **(1 mark)**

2 Explain how an earth wire and fuse protect the user when the live wire comes loose. **(4 marks)**

3 Explain why the earth wire is not normally part of the circuit in a mains appliance. **(3 marks)**