Unit 7J Electrical circuits

About the unit

In this unit pupils:
- consolidate and extend their ideas about circuits
- use concepts of electric current and energy transfer to explain the working of circuits
- explain patterns in the measurements of current and voltage
- use the concept of resistance qualitatively
- build circuits in which current flow is usefully controlled
- consider the hazards of electricity for humans

In scientific enquiry pupils:
- explore early ideas about electric current
- model current in a variety of ways
- plan safe procedures and recognise hazards
- use ammeters to measure current

Note on the teaching of energy

This unit applies the concept of energy to electrical circuits. In particular, pupils learn that while current is not used up in the circuit, energy is. This work focuses on distinguishing between two abstract concepts: electricity as 'flowing stuff' and electrical energy as something that is identified by input and output effects. Its effects are associated with the brightness of bulbs and its origins in the voltage rating of batteries. There are necessary simplifications in the treatment, as appropriate to this early unit.

This unit is expected to take approximately 8 hours.

Where the unit fits in

This unit uses ideas developed in the key stage 2 programme of study. It builds on ideas introduced in unit 6G 'Changing circuits' and unit 4F 'Circuits and conductors' in the key stage 2 scheme of work.

This unit should precede unit 8J 'Magnets and electromagnets' and unit 9I 'Energy and electricity'.

Expectations

At the end of this unit

in terms of scientific enquiry

most pupils will: select and use appropriate equipment to investigate circuits which include cells, bulbs and switches; measure current; identify patterns in their results and draw conclusions about series and parallel circuits; describe hazards associated with electricity and how to deal with them

some pupils will not have made so much progress and will: explore circuits using appropriate equipment; identify patterns in their results and use these to describe the behaviour of simple circuits; identify and report on hazards associated with electricity

some pupils will have progressed further and will: plan and carry out a systematic investigation of series and parallel circuits to obtain sufficient evidence to draw conclusions; give examples of the development of scientific ideas about electricity, *eg Galvani and Volta on electric current*, and explain how electricity can be hazardous to humans

in terms of physical processes

most pupils will: construct a range of working electrical circuits and represent these in circuit diagrams; state that electric current is the same at all points in a series circuit and divides along the branches of a parallel circuit; use a flow model to describe resistance and to distinguish between electric current and energy transfer in a circuit; compare and contrast the advantages of series and parallel circuits in use, *eg fuses, ring main*

some pupils will not have made so much progress and will: construct simple electrical circuits and represent these diagrammatically; give examples of useful circuits; state safety rules for use of electricity

some pupils will have progressed further and will: relate voltage of cells and batteries qualitatively to energy transfer in circuits; use a flow model to explain the difference between electric current and energy transfer; apply the idea that nerves are electrical conductors to explain electrical hazards

Prior learning

It is helpful if pupils:
- recall that a complete circuit is required for electrical devices to work
- can connect a circuit
- can draw and interpret standard electrical symbols for connection, cell/battery, bulb and switch

Health and safety

Risk assessments are required for any hazardous activity. In this unit pupils:
- test fuses and use high currents (at low voltage)
- must not experiment with mains equipment

Model risk assessments used by most employers for normal science activities can be found in the publications listed in the *Teacher's guide*. Teachers need to follow these as indicated in the guidance notes for the activities, and consider what modifications are needed for individual classroom situations.

Language for learning

Through the activities in this unit pupils will be able to understand, use and spell correctly words and phrases relating to:
- circuit components, *eg battery, cell, bulb or lamp, connecting wire, switch, power supply, fuse*
- electrical concepts, *eg current, resistance, energy transfer*

Through the activities pupils could:
- collaborate with others to share information and ideas, and solve problems
- identify the main points in each paragraph, distinguishing key points from supporting material
- follow the sequence of actions, processes or ideas being described
- use skimming, scanning, highlighting and note making as appropriate to different texts

Resources

Resources include:
- battery-powered appliances, *eg torch, motorised toy*
- variable resistors or potentiometers, *eg dimmer controls*
- low-voltage model ring main and/or series lighting array
- steel wool and fuse wire
- water flow model of electrical circuit or alternative model
- secondary sources about the work of Volta and Galvani and about the use of pacemakers and defibrillators

Out-of-school learning

Pupils could:
- talk to adults about the control and safe use of domestic mains appliances, including fuses (caution them not to experiment with mains equipment)

1	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
How do electrical circuits work?				
	• to make and test predictions about circuits • how to represent simple circuits using symbols • that a cell/battery provides an electric current which travels round the circuit • that a switch breaks the circuit and stops the electric current	• Use class discussion to review pupils' knowledge and understanding of electrical circuits, *eg draw a simple pictorial representation of a single cell and a single bulb (without holder) on the board.* Ask individual pupils in turn to draw connections to make the bulb light. Discuss/vote on whether each one will work. Also ask if differently drawn circuits are the same. Repeat with more than one cell and bulb, in series. Alternatively, ask pupils to work in groups doing the same exercise using prepared cards. • Ask pupils to test their predictions about whether the bulbs will light using short lengths of wire. Some pupils may need to be reminded about removing insulation from the wires. Others will need to identify the connection points on both the cell and the bulb. Pupils should record their observations, using conventional symbols. Pupils continue to explore the circuits by including simple switches. • Ask pupils or groups of pupils to explain their observations to others.	• make and explain predictions about circuits, *eg two connections are needed to light a bulb, there has to be a complete circuit, the battery provides 'something' to the circuit* • support their predictions by demonstration circuits, or circuit diagrams • explain that the bulb(s) light because electricity travels round the circuit	• Encourage pupils to work systematically, laying out circuits in simple shapes and tracing continuity with their fingers. • Pupils should be encouraged to use conventional symbols. • Some pupils may think only one wire is active – unipolar model. Others may think that current flows out of both terminals of a battery and it meets with a 'clash' in the bulb, causing light – clashing-current model. Many think that current travels round a circuit from the battery, getting used up as it goes, so that there is less current at the 'end' of the circuit – current-consumed model. Fewer will hold the idea that current is unchanged – current-conserved model.
	• to use ideas about complete circuits to describe how a switch works • to devise a system for fault finding using knowledge of circuit ideas • to test and evaluate their system • to collaborate with others to share information and ideas, and to solve problems	• Demonstrate to the whole class how a torch works. • Provide each group of pupils with a device or circuit that is not working and ask them to find the fault. Help them to devise a checking system to find faults, *eg using ideas of circuit continuity or substitution of a component that they know works.* Ask pupils to demonstrate their system to another group, and set a fault for that group to find.	• present an account in speech, diagrams or writing to explain the working of an appliance • show their understanding of circuit ideas by successfully finding fault(s)	• This activity can be differentiated by the number and type of faults. • Extension: pupils could be asked to explain how a similar appliance works. • This work could be linked with unit 7D 'Using control to control a display' in the design and technology scheme of work.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
What happens in a circuit?			
• that the nature and number of components in a circuit affects current flow • to measure current with an ammeter • that current in a series circuit is not used up by components • to use the term resistance to mean opposition to flow of electricity	• Provide pupils, for work in small groups, with a battery and several identical bulbs. Ask them to explore connecting them in series, and to note patterns in their observations of the brightness of bulbs. • Show pupils how to measure current in their circuits. Demonstrate how to connect an ammeter and how to use it carefully. Ask them to measure the current at one point in a circuit and predict the current at other places. Extend the work to include circuits with different numbers of cells. • Draw on pupils' experience of other electrical circuits, *eg dimmer switches*, and of other uses of the term 'resistance' to develop the qualitative idea of electrical resistance. • Establish that the readings are constant for a given circuit, perhaps using a demonstration as a follow-up, as anomalous results can confuse pupils. Demonstrate with a variable resistor in circuit, *eg dimmer switch.*	• describe how increasing the number of bulbs reduces their brightness in a series circuit • use an ammeter with care • measure and record current in simple series circuits • know that current does not change in a simple series circuit, that it is not 'used up' as it travels in the circuit • use the term 'resistance' in describing circuit effects	• Check that the bulbs are matched to the voltage of the battery so that there is a change in brightness and bulbs do not 'blow'. • Digital ammeters are easier to read than those with analogue scales, though pupils may then find it harder to see approximately equivalent currents. Show pupils how to ensure an ammeter is not damaged in use. • The quantitative relationship between current and resistance will be covered at key stage 4. It may be helpful to make qualitative connections with physical resistance to movement, such as friction.
• that cells and batteries are a source of electrical energy • that a battery is a number of cells connected together with regard for polarity • that a cell's voltage has a chemical source	• Ask pupils the purpose of cells and batteries in a circuit. Provide cells and batteries marked with different voltages, *eg 1.5, 4.5, 9V,* and link their use with the concept of energy as 'the ability to make things happen', *eg greater voltage rating, more bulbs light*, so that voltage is understood simply as what makes the current flow. • Raise the issue of polarity of cells and ask pupils to name a simple rule for connecting cells to make a battery, *eg in a series positive connects to negative*. Show the inside of a dry cell, identifying the connections to the positive and negative electrodes. Link the chemical origin of the cell's voltage to pupils' experience of 'leaking' and 'dead' batteries.	• identify a cell or battery as a source of energy • describe why cells have positive and negative terminals, and connect them correctly in circuits	• At this stage it is sufficient for pupils to think of a battery as something that drives the current and provides the energy it carries. • Pupils will use a voltmeter in unit 9I 'Energy and electricity'. They will also investigate simple chemical cells.

3	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
How can we explain what happens in electrical circuits?				
	• to distinguish between energy and electric current in a circuit • to use a model to explain ideas about electric circuits	• Draw together the observations pupils have made about their circuits, *eg current is not used up around the circuit, the cell which provides energy to the circuit runs down, energy is transferred from the cell to components in the circuit.* Ask pupils to try to explain the difference between current and energy. Introduce the idea of a model, to show something has to be imagined such as the inside of circuit components, *eg the water circuit can be used with a pump as cell, and water flow as electric current.* Show how this demonstrates the concept of resistance of components in the circuit. Other models are possible, *eg a bicycle chain, trucks carrying loads, tight string.*	• distinguish between current and energy, *eg current just circulates back to the battery, energy is used to light a bulb* • explain current in terms of a model	• The important distinction between the material (current) and non-material (energy) is difficult for pupils at this stage. Models have an important role in developing concepts. Pupils need to understand that a model helps them imagine what is happening and doesn't represent physical reality.
	• to construct parallel circuits • to predict the current in branches of a parallel circuit • to identify patterns in measurements • to apply the water model or a similar model to parallel circuits • to consider the limitations of a model	• Ask pupils to set up parallel arrangements of bulbs and use a model to explain why bulbs connected in parallel remain at the same brightness. • Show circuit diagrams of simple parallel circuits with identical components in each branch. Ask them to predict current readings and to check this by measurement. Follow up with a demonstration to confirm that the sum of the current flowing in each branch is the same as that flowing in the main circuit. This offers more evidence of current conservation. • Demonstrate a water circuit, or other model, to show the effect of resistance in parallel. Ask pupils to think of ways in which electricity is not like water, *eg when the wire breaks it doesn't run out.* Invite pupils to think of other models, and to discuss their strengths and weaknesses.	• explain how connecting bulbs in parallel allows each to shine equally brightly • predict and explain measurements of current in different parts of parallel circuits • explain these observations using a model • identify strengths and weaknesses of a model for electricity	• Many pupils will be surprised that both bulbs are of equal brightness when two in series are much dimmer. Distance from a battery is often seen as important and pupils might suggest that a bulb is dimmer because it is 'further from the battery'. Circuit boards are useful for laying out parallel circuits clearly, but they often have additional resistance at connections in the circuit – so beware. Variations in apparently identical bulbs can lead to anomalous results. It may help to swap the bulbs round. • The nature and behaviour of electrons and charge is not required until key stage 4. A flow model is adequate to explain all the work covered in key stage 3.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
What kinds of circuits are useful and what are the hazards?			
• to compare and contrast series and parallel circuits • to plan a circuit as a model of a domestic ring main	• Demonstrate extensive series and parallel circuits, *eg some commercial Christmas tree light sets and a model ring main*, to prompt discussion of the advantages of parallel connections. Ask pupils to make a plan of a circuit and draw up a component list, *eg use a single low-voltage power supply to build a ring main to supply five rooms with electric lighting; switches should be used to control the circuits.*	• use ideas about series and parallel circuits to help decide on a plan • describe the advantages and disadvantages of different circuit connections	⚠ **Safety** – the low-voltage unit may trip if the current is too high. This can provide a link to the next activity
• that electrical energy from the battery is transformed by a fuse to light and heat; this can cause it to melt • to plan safe procedures, recognising hazards	• Show the pupils a circuit with three cells, ammeter and variable resistor in series with a short length of steel wool. Reduce the resistance and observe that as the current increases, the steel wool gets hot and then fuses (melts). • Provide lengths of suitably current-rated fuse wire and ask pupils to plan and then test them to (planned) destruction using low-voltage power supplies and a bulb in a new circuit. Discuss the reasons for the use of fuses, including the resettable ones in modern fuse boxes and the cut-outs in laboratory power supplies.	• explain how a fuse protects a circuit • work safely • compare predictions with observations, *eg current to 'blow' a fuse*	• Resettable cut-outs are not fuses; they are coils which use magnetic effects to detect current flows, and are better described as circuit breakers. ⚠ **Safety** – choose fuse wire that will blow at a current lower than the bulbs in the circuit
• about hazards of mains supply	• Remind pupils of work they will have done in key stage 2 on the hazards of mains electricity. Point out that the supply voltage (230V) is capable of delivering much more energy than the batteries and low-voltage supplies used in the laboratory.	• associate high voltage with electrical hazards	• Extension: using secondary sources of information, pupils could write a safety leaflet about mains supply, using the term 'voltage'.
• that the nerves are electrical conductors • how scientists' ideas can be used • to identify the main points in a text, distinguishing key points from supporting material • to follow the sequence of actions, processes or ideas being described • to use skimming, scanning, highlighting and note taking as appropriate to different texts	• Describe simply how the nerves carry messages around the body (acting as electrical circuits) and invite pupils to imagine what would be the effect of the body being subjected to input from external currents. Provide pupils with secondary sources of information. Remind them of how to use texts to identify key points and sequence ideas. Ask pupils to research a topic of choice, and present an account, *eg* – *Galvani's discovery of the effect of electricity on frogs' legs, Volta's explanation of this and his construction of the first battery to demonstrate the effect* – *the use of defibrillators or pacemakers for keeping the heartbeat regular* – *the effects of electric fences on people and animals*	• provide descriptions and/or explanations of the effects of electric current on the human body • describe in a clear sequence the work of scientists in developing ideas and applications of electric current	• The historical material could be used to show the interplay between empirical questions, evidence and scientific explanation.
Reviewing work			
• to apply knowledge and understanding to a range of circuits	• Provide a range of circuit diagrams, showing series and parallel connections, switches and fuses. Give some current values and ask pupils to work out others.	• determine current values in given circuits	• A software simulation could be used for generating questions and reviewing with pupils how circuits work.