Unit 9I Energy and electricity

About the unit

In this unit pupils:

- explore a range of useful energy transfers and transformations
- discuss the use of electricity as a convenient way to transfer energy to do useful things
- associate the concept of voltage with the transfer of energy in a circuit
- investigate the voltage of cells
- study how electricity is generated, with reference to environmental impacts
- use the principle of conservation of energy to identify ways in which energy is dissipated during transfers

In scientific enquiry pupils:

- use models to explain observations relating to electric currents
- use scientific knowledge to frame a question for investigation
- measure voltage in circuits
- identify patterns in the measurements of voltage in series circuits and use these to draw conclusions

Note on the teaching of energy

This unit presents a range of useful changes and helps pupils to use the language of energy transfer and transformation in describing them. The word 'transfer' is used to describe energy's change of place; the word 'transform' is used to describe a change in the way energy shows itself, *eg from electrical energy to light*.

The unit focuses on how transfers and/or transformations of energy by electricity are important in everyday life. It explains these simply and looks at some of the consequences of the electricity supply industry. The unit covers the ideas of dissipation or 'wasted' energy and the conservation of energy. In extending the concept to these contexts, simplifications appropriate to year 9 pupils have been made.

Pupils need labels they can use when they come across energy, *eg electrical energy, light and heat*. This is a first step in developing understanding. Teachers should help pupils recognise that they need to go further in some contexts, *eg that 'spring energy' is the result of the elastic properties of the metal the spring is made of, and so could be called 'potential energy' because of its compressed position*. It would be inappropriate, at this stage, to develop this further and associate the energy with the electric bonding forces between the atoms of the spring. Formal definitions of work, kinetic energy and potential energy are also best left until key stage 4 for most pupils.

This unit is expected to take approximately 8 hours.

Where the unit fits in

This unit builds on work on electricity and energy in units 7I 'Energy resources', 7J 'Electrical circuits' and 8I 'Heating and cooling'. It relates to work on the reactivity of metals in unit 9F 'Patterns of reactivity' and work on fuels in unit 9G 'Environmental chemistry'. It relates to unit 9D 'Using control for electronic monitoring' in the design and technology scheme of work, and to unit 18 'Twentieth-century conflicts' and unit 20 'Twentieth-century medicine' in the history scheme of work.

Expectations

At the end of this unit

in terms of scientific enquiry

most pupils will: identify patterns in measurements of voltage and use these to draw conclusions about circuits; identify and control key factors in investigating simple cells and identify patterns in their results, including observations that do not fit the main trends

some pupils will not have made so much progress and will: measure the voltage of a range of cells; present data as charts or tables

some pupils will have progressed further and will: relate energy transfer devices in the laboratory to everyday appliances; synthesise information from secondary sources about the development of the electricity supply industry and communicate it clearly; consider whether data is sufficient, and account for anomalies

in terms of physical processes

most pupils will: describe some energy transfers and transformations in familiar situations, including dissipated energy, and devices; recognise that the voltage change across a circuit component is a measure of its energy transfer; describe how voltage originates from a chemical cell; give examples of the hazards of high-voltage circuits; compare the energy consumption of common electrical appliances; describe how electricity is generated by energy from fuels, and recognise possible environmental effects of this

some pupils will not have made so much progress and will: describe some useful energy transfer devices; recognise that any functioning circuit needs a power supply to provide a voltage and that high voltages are hazardous; recognise that electricity is a convenient way of 'delivering' energy, but that it must be paid for and that its generation can cause environmental problems; give examples of how energy goes to waste

some pupils will have progressed further and will: apply a model of voltage and energy changes to a circuit; recognise that although the total energy in a system is conserved, energy can be dissipated; use 'power ratings' in comparing the costs of using different electrical appliances; link the function of an electric generator to magnetic effects

Prior learning

It is helpful if pupils:

- know how to connect simple series and parallel circuits
- recall that fossil fuels and wind, waves and the Sun are all energy resources

Health and safety

Risk assessments are required for any hazardous activity. In this unit pupils:

- use mains electrical equipment in their investigations

Pupils must not experiment with mains electricity.

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 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 scientific enquiry, *eg independent and dependent variable, control*
- words and phrases describing energy transfers and transformations, *eg movement as kinetic energy, position as potential energy, chemical energy, electrical energy, sound, heat and light*
- words and phrases relating to energy supply and waste, *eg conservation, dissipation, electric generator, dynamo, power station*

Through the activities pupils could:

- use secondary sources to assess conflicting evidence and arrive at a considered viewpoint
- write coherent text to communicate information effectively

Resources

Resources include:

- a selection of electrical toys and devices to show energy transfers and transformations
- samples of fruit and vegetables or dilute acid solutions
- a selection of samples of metals to make electrodes, *eg copper, zinc, iron, aluminium, magnesium*
- secondary source material on generating electricity and associated environmental issues, electric cars and other 'energy-saving' appliances
- small motors or materials to build generators
- a bicycle dynamo
- a joulemeter (and datalogger)
- ammeters and voltmeters or digital multimeters
- a household electricity meter or picture of one
- domestic appliances, including low-energy bulbs, or pictures of and energy information about these

Out-of-school learning

Pupils could:

- survey the power rating of various devices in the home or observe their electricity meter when different appliances are running
- check their own electricity bill
- keep a diary of energy experiences, *eg Today I used my personal stereo with new batteries*

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
How is energy involved in doing useful things?			
• that useful changes usually involve energy transfers and transformations • that the terms 'kinetic', 'potential', 'radiation' and 'chemical' are useful when describing energy	• Remind pupils of their experience of energy transfers and transformations in years 7 and 8 with demonstrations of 'useful changes', *eg working a model steam engine, a spring-driven clock, eating food.* Help pupils associate the presence of energy with the different situations in the demonstrations, *eg steam-engine fuel, flame, hot water, movement*, and to use the terms 'kinetic', 'potential', 'chemical energy', 'heat', 'light' and 'sound' as ways of describing energy in such situations. • Ask pupils to explore a circus of toys and devices that work by transferring and/or transforming energy. Ask pupils to identify the source of energy and the use to which it is put. Include a range of electrical toys and devices, *eg* – *battery-operated and clockwork/spring-operated vehicles* – *yo-yo (if possible one that lights up at maximum speed)* – *battery-operated and manually operated fans* – *electromagnet for lifting* – *electric bell or buzzer* – *solar-powered calculator or motor* – *low-voltage heater that is set to get warm, not hot, to the touch* – *toys that feature light-emitting diodes (LEDs)* – *simple control circuit, eg one that sounds a buzzer when a light sensor is covered*	• recognise that energy is routinely converted from one form to another in order to be useful • categorise devices on the basis of type of energy input or output • explain why electricity is used widely as a source of energy • describe energy transfers in everyday changes	• The energy 'transfers' met in conduction in unit 8I 'Heating and cooling' can be contrasted with energy 'transformations' in these devices. Energy should, however, be associated with the situations rather than being described as different 'types of stuff'. See the note on teaching energy in the *Teacher's guide.* • Potential energy is used to refer to energy associated with an object's position, *eg a stretched spring or a raised mass.*
• that electrical circuits are used to perform a variety of useful tasks • that electrical energy is transferred around circuits and can be transformed in components, *eg to produce light, sound, movement and heat* • to identify devices and situations that act as energy stores	• Elicit from pupils' observations the conclusion that electrical energy is a convenient way to do many useful things. Recall pupils' year 7 work on fuels as energy stores and elicit other ways that energy can be stored, *eg compressed spring – potential; flywheel – kinetic; battery – chemical*. Contrast this with electricity, which cannot be stored.	• describe the energy transfers and/or transformations in several toys or devices • recognise that electricity is a useful means of transforming energy • give examples of ways in which energy can be stored	
How does electricity transfer energy?			
• how current behaves in electrical circuits	• Review pupils' understanding of simple circuits – the requirements for current to flow, and the effect of the number of cells or components in series and parallel circuits (unit 7J 'Electrical circuits') – by using quiz cards that describe real circuits with faults and by measuring currents in circuits.	• describe current as not being used up in a circuit and as dividing along the different branches in a parallel circuit • identify that an ammeter measures flow of current	

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
• how to measure voltage in a circuit	• Ask pupils to construct simple series circuits incorporating several components and batteries or power supplies of different voltages. Help them to connect the voltmeter across each component in turn, without breaking the circuit. Individual readings can be seen to add to the total voltage. Encourage pupils to associate large voltage changes with large energy transfers by the components, *eg bright bulbs*.	• use a voltmeter correctly • draw from trends in numerical data conclusions about the way voltage varies around a circuit	• Emphasise that ammeters measure flow 'through', so are inserted in a circuit; voltmeters measure a 'difference', so are connected across a circuit, without breaking it.
• a simple model of energy transfer from batteries to components in circuits • a simple model of potential difference making a current flow in a circuit • to work with others to simulate energy transfer around a circuit	• Introduce a model to associate energy transfer with voltage, *eg the 'almost Monopoly' or 'pocket money' analogy, where pupils are given money that has to be spent around the circuit before they can return.* Pupils are the current, the cell is the source of the money ('GO'), which is the energy. The cells or voltage permit them to move. If they go through more cells, they pick up more money; and as they go round the circuit, they have to pay out equal amounts per device (assuming identical devices). As an analogy of resistance, money could be paid out in proportion to 'number of hotels', or use a similar rule from Monopoly. Note the shortcoming in the analogy – in Monopoly circuits all the money does not have to be spent. • An alternative model is the 'up-and-down' ski-lift. Chairs are the 'current/charge' which the 'voltage' of the motor causes to move (flow). Skiers are the 'energy', climbing on at the motor-house and getting off at suitable places ('devices') around the ski-lift circuit.	• use a simple model to describe the link between voltage and energy in a circuit • learn how to identify faults in equipment • choose a suitable method for presenting results	• With some pupils, the term 'potential difference' could be substituted for 'voltage' and linked with other uses of the word 'potential'. • Other models use ideas of water pressure and gravitational potential energy. Encourage pupils to devise their own models to explain features of their observations, *eg an energy carrier/ supplier, continuity of circuit.* • A particle model of electricity is not required (electrons can be left until key stage 4), but the idea of static charge could be used here.
• that a cell has chemical energy, which is transformed to electrical energy in a circuit • to consider which factors are important and how to vary them • to choose appropriate techniques and equipment • to explain results that do not fit a pattern that arises • to compare their investigative method and results with those of others and evaluate the work in the light of comparisons	• Show the inside of a dry cell. Establish that there is a chemical change when a battery/cell produces a current. Associate the energy of the chemical change with input to a circuit. • Ask pupils to plan an investigation into how to make a cell from a fruit or vegetable to produce the highest voltage, *eg the performance of a particular fruit with a range of electrode sizes, separations or metal combinations, the relative effectiveness of different fruit.* If appropriate, link to work on the relative reactivity of different metals.	• describe energy transformation from a cell/battery to a circuit • identify and describe patterns in data • draw conclusions from their data • describe how to improve their work, *eg by identifying strengths in the work of others*	• Reactivity of metals is covered in unit 9F 'Patterns of reactivity'. ⚠ **Safety** – a dry cell contains hazardous chemicals. The use of solutions such as vinegar or lemon juice provides a cheaper alternative to a range of fruits. The size of the voltage depends mainly on the difference in reactivity of the metals used as electrodes, *eg the best will probably be copper and magnesium, giving about 1.5V* – pupils' plans should be checked for health and safety before practical work begins
• to apply scientific knowledge to explain the use and occurrence of high voltages	• Use the Electricity Council video *Electric graffiti*, or other secondary sources, to identify the hazards of high voltages and associate these with the transfer of large amounts of energy, *eg lightning, overhead and power lines on railway tracks*.	• give a reasoned report associating the use/hazard of high voltage with energy transfer	

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
What are we paying for when we use electricity?			
• that electric current is conducted from 'the mains' to components in electrical circuits • that energy is transmitted via electricity to an appliance, where it is converted to another form of energy • that some appliances transfer more energy than others (in a given time) • to identify the power rating of common household electrical devices • to present advice based on scientific understanding as a coherent text	• Discuss the household mains supply at 230V and how appliances, *eg television, computer,* run from this, using pupils' experiences. Show an electricity bill and ask pupils *What are the units used?* Remind them that current is not used, but energy is. Show (pictures of) a household electricity meter. • Demonstrate the energy used by a range of electrical devices, *eg for heating, lighting,* (over a fixed period of time for comparison purposes) using a joulemeter/ datalogger. Show how these comparisons relate to the power ratings on devices. • Ask pupils if they think people are aware of these differences, *eg Do parents talk about the waste of money of 'leaving the TV on all evening'?* Ask how they could find evidence to check such comments, and then devise a parents' guide entitled 'How to get your children to save energy by switching the right things off'. This could be supported by putting examples of household appliances on cards and asking pupils to arrange them in order of energy consumption. Compare the amount of energy used by a range of devices in the home or school, as shown by the power rating noted on the devices, *eg light bulbs, fridges, microwaves, heaters, cookers, computers, televisions.*	• give examples of some devices that use energy at a greater rate than others, *eg heating appliances transfer more energy than others* • give an example of their own use of an electrical appliance that has to be paid for • contribute to planning and carrying out a survey of energy use of household devices • communicate data effectively through writing a coherent text	• This is best not done as a class experiment as the joulemeter may be confused with the ammeter. Here it is simply required to gather data for comparison purposes. • The concept of power as rate of energy transformed could be introduced to some pupils. Here it is used to support the simple comparisons, *eg heaters use a lot of energy, other devices less.* • Spreadsheets could help pupils make quantitative comparisons. • Extension: some pupils could be told that the unit charged for is a kilowatt hour, and be asked to find out about the costs of using devices for typical times per day, *eg TV for 6 hours, fridge for 24 hours.* This could be compiled and presented as a bar chart. **Safety** – mains appliances must have been tested using a portable appliance tester. Any brought from home must be carefully checked
Checking progress			
• to review their understanding of energy and electricity	• Ask pupils to summarise ways in which electricity can transfer and transform energy to provide people with useful facilities – as a list or a concept map.	• relate use of electricity to energy supply in everyday situations/ devices	• Use an internet search engine to look for information.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
Where do we get electricity from?			
• that electricity can be made to flow by causing movement in an electrical generator • that fossil fuels, nuclear fuels and renewable energy sources can be used to drive electrical generators • to follow instructions carefully to construct and/or test a generator • that electrical energy cannot be stored	• Elicit ideas about where mains electricity comes from. Trace the story back to a power station. • Demonstrate a bicycle dynamo or simple generator. Show how increasing (energy) input will increase (energy) output. • Use a small motor as an electrical generator, or make one from a kit, and test its output using a sensitive meter. Possibly drive it using a windmill to simulate wind turbines. Plan a visit, show a video or use information resources such as a CD-ROM to introduce pupils to the generation of electricity in power stations. Contrast the scale of the operation with laboratory generators, and consider the fuels used.	• identify a range of energy resources used to generate electricity • describe a simple electrical generator	• Details of how a generator works are not required at this stage. Some pupils, however, might like to compare the device with the electric motor. It has the same structure, but with input and outputs reversed. • The role of Michael Faraday in laying the foundations for electricity generation could link with the history area of study 'Britain 1750–1900'. • Pupils are often surprised to realise that electricity is generated 'on demand' and that commercial breaks on TV can increase demand, so that workers at power stations have to increase the supply to provide for the nation's electric kettles.
• to use secondary sources about an environmental aspect of the generation of electricity and contribute to a presentation • to examine conflicting evidence and arrive at a considered viewpoint	• Ask pupils to use secondary sources to compare the impact on the environment of various forms of electrical generation. This may be done in groups, with each group reporting back its findings. This may include both renewable and non-renewable resources as well as the more complex issue of nuclear waste.	• present a considered viewpoint based on information from secondary sources, *eg identify the problems of pollution associated with electricity generation by fossil fuels and the environmental impact of renewable and nuclear energy sources*	• This builds on unit 7I 'Energy resources' and links to unit 9G 'Environmental chemistry'.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
How can we reduce the waste of energy?			
• that in energy transfers, energy may go to waste	• Recall earlier work on energy devices and on burning fuels. Review the paradox that although electricity is clean and safe to use, its generation can have a big environmental impact. Introduce the idea of dissipation of waste energy as an inevitable consequence of many energy transfers; refer to cooling towers at power stations. • Broaden the issue to looking at use of energy in different ways, *eg ask pupils to consider how environmentally friendly electric cars really are. (Although electric motors are three times as efficient as internal combustion engines, the electricity has to be generated first.) Compare battery-powered cars (recharged at the mains) with fuel-cell powered models. Compare the energy required to make a car with the energy needed to run it (ratio is approximately 10:1). Is the real issue about replacing old, inefficient cars with new, more energy-conserving ones?* • Use questions to discuss with pupils the difference between tungsten-filament light bulbs and 'energy-saver' bulbs, *eg a 20W energy-saver lamp is said to be equivalent to a 100W filament lamp. Can this be supported? What happens to the other 80W from the filament lamp?* (Feel the heat – carefully.) • Provide information about these lamps, *eg advertising material,* and ask pupils to work out whether the purchase of energy-saver bulbs is cost effective.	• distinguish between useful energy and wasted or dissipated energy • make comparisons between appliances and devices concerning their efficient use of energy	• Power stations dissipate about 70% of their energy input as waste – an inevitable consequence of their processes, not simply inefficient working practices. **Safety** – if using school-produced holders for lamps, these must have been checked with a portable appliance tester
• that when energy is transferred the total amount of energy remains constant • to use flow diagrams to show qualitatively how energy is transferred/transformed in devices	• Introduce the principle of the conservation of energy, using a range of examples to make the distinction between energy that is useful and energy that is dissipated and not useful. Ask pupils to draw flow diagrams, *eg Sankey-type,* to show energy transfers in everyday situations, *eg home heating, transport, use of insulation.*	• use flow diagrams as a simple means of energy accounting	• Energy flow diagrams need not be quantitative at this stage; simply show where all the energy is transferred.
Reviewing work			
• to summarise and make connections between the key ideas in this unit, and those preceding it	• Draw flow diagrams identifying energy transfers and transformations in a wider range of situations, *eg the devices studied earlier in the unit, home insulation*. • Encourage pupils to use games to review connections, *eg* – *chain games from the numeracy strategy* – *'energy consequences' (first line – describe an event, second line – describe an energy transformation. When the text is revealed pupils have to explain whether the consequences are possible or not)* – *'energy dominoes' (prepare a set of cards with a question about an aspect of energy on one half and an unrelated answer on the other. One pupil asks a question and the pupil who has the answer reads it aloud, then asks his/her question)* • The opportunity could be taken to revise related topics from previous years, *eg conduction and convection, covered in unit 8I 'Heating and cooling'*.	• identify key points • contribute to a summary sheet of key ideas	• The domino game is similar to chain or loop games used in the numeracy strategy. • Relates to work done in unit 8I 'Heating and cooling' on house insulation to reduce heat loss.