Unit 8J Magnets and electromagnets

About the unit

In this unit pupils:

- identify magnetic materials, make a magnet and test the strength of a magnet
- use the concepts of a magnetic field, a permanent magnet and an electromagnet
- investigate factors affecting the strength of an electromagnet
- explain the working of a number of devices that use magnets and electromagnets

In scientific enquiry pupils:

- use scientific knowledge and understanding to make predictions about the behaviour of magnets and magnetic material
- use preliminary work to find out whether an approach is practicable
- investigate the strength of an electromagnet, controlling relevant variables and evaluating the limitations of the data collected

This unit is expected to take approximately 7 hours.

Where the unit fits in

This unit builds on work done in unit 3E 'Magnets and springs' in the key stage 2 scheme of work and on unit 7J 'Electrical circuits'.

It lays the foundation for unit 9I 'Energy and electricity', which includes the generation and uses of electricity.

Expectations

At the end of this unit

in terms of scientific enquiry

most pupils will: make predictions about the behaviour of magnets and magnetic materials and draw conclusions from patterns in evidence; identify factors affecting the strength of electromagnets, make sufficient observations in an investigation of electromagnets to draw conclusions

some pupils will not have made so much progress and will: suggest how to carry out a test to distinguish between magnets and magnetic materials; make changes to vary the strength of an electromagnet

some pupils will have progressed further and will: use a model of the magnetic field to explain phenomena

in terms of physical processes

most pupils will: distinguish between magnetic and non-magnetic materials; describe magnetic shielding; make a permanent magnet and an electromagnet; describe how the Earth's magnetic field can be used for navigation; describe the shape and direction of a magnetic field; give examples of the use of magnets and electromagnets

some pupils will not have made so much progress and will: identify steel, iron and iron oxide as magnetic materials; make a magnet and electromagnet; describe the use of an electromagnet in sorting metals

some pupils will have progressed further and will: explain how magnetic materials can be magnetised using a simple particle/domain model; identify similarities in the magnetic fields of a bar magnet, the Earth and a straight coil; describe the shape of the field around a straight current-carrying conductor

Prior learning

It is helpful if pupils:

- know that magnets attract magnetic materials
- know that magnets can attract and repel other magnets
- know that magnets have a range of uses in everyday life, *eg fridge door catches*
- have constructed simple circuits and used power supplies

Health and safety

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

- use high currents at low voltage

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 magnets and electromagnets, *eg north-seeking pole, south-seeking pole, magnetic field, magnetic field line, core, solenoid, coil*
- words and phrases relating to scientific enquiry, *eg qualitative and quantitative observation, range, precision, variable, trials, repeats*

Resources

Resources include:

- sheets of magnetic material, *eg steel, nickel*
- materials for making permanent magnets and electromagnets
- secondary sources on the discovery of the Earth's magnetic field

Out-of-school learning

Pupils could:

- think about how aluminium and metal cans are sorted for recycling and/or visit a scrapyard to see magnets
- observe the use of magnetic tags fitted to clothes to prevent shoplifting in clothes shops

Learning objectives Pupils should learn:	**Possible teaching activities**	**Learning outcomes** Pupils:	**Points to note**
What can a magnet do?			
• that magnets attract magnetic materials – iron, steel, nickel and cobalt, but not other metals – and magnetic iron oxide	• Elicit pupils' ideas about magnets from their key stage 2 work about magnets, what they can do and where they are used. This can lead to the compilation of a class list of the types and uses of magnets, which will be added to as the unit progresses.	• name materials that magnets attract • make a record of uses of magnets	• Some pupils think all metals, and only metals, are magnetic. Introduce non-magnetic metals and ceramic magnets, which contain iron oxide.
• that like poles of a magnet repel and unlike poles attract • that repulsion is the test of a magnet • to use scientific knowledge to solve a problem • to listen and evaluate the contributions of others	• Offer groups of pupils two magnets and a bar of steel of similar appearance. Challenge them to work out which one is not a magnet. • Ask each group to describe and explain what they did and encourage other pupils to ask questions of them.	• state that magnets both attract and repel each other • explain why attraction is not proof of magnetism • describe, *eg orally,* their technique for deciding which bar was a magnet	• Pupils will be familiar with magnets attracting and repelling from key stage 2, but may not be familiar with the notion of magnetic poles.
Can magnetism be stopped? Can magnets be made?			
• that magnetic forces act through non-magnetic materials but not through magnetic materials	• Ask pupils to recall whether magnetism will act through any materials, using evidence they have from everyday life, *eg fridge magnets, games such as magnetic football.* • Ask pupils to devise a test to see which materials allow magnetism to act through them, *eg when a thread is attached to paper clip and taped to a bench, the paper clip will 'hover' below a magnet and fall when a sheet of magnetic material is inserted between it and the magnet.* Ask pupils to suggest what the materials have in common to prevent the magnet working.	• describe how they found out that magnetic materials block the action of magnetic fields	
• that magnetic materials can be made into magnets by stroking them with the pole of a magnet • about the reasons for repeating observations • to use observations to draw conclusions • how discussion helps clarify ideas	• Establish that those materials which shield magnetism can be made into magnets, *eg pupils make 'soft' iron nails into magnets using the stroking technique and test the magnet's effectiveness.* This could include a competitive aspect with a prize for the strongest magnet. Pupils could discuss and agree how the magnets' strength is to be tested, *eg number of paper clips picked up, numbers of trials to be carried out.*	• describe how to magnetise a magnetic material • design and use a method for measuring magnetic strength	• Pupils may have tested the strength of permanent magnets in key stage 2, so concentrate on the criteria which enable good comparisons to be made, *eg sensitivity (Are paper clips too big?)* • Extension: the domain theory of magnetism is not included at this point, but a simple version could be given to some pupils.
What is a magnetic field?			
• that a freely moving magnet comes to rest pointing in a north–south direction • that all magnets have a magnetic north-seeking pole and south-seeking pole	• Elicit pupils' ideas about the Earth's magnetic field. Draw on their experience of a compass for direction finding. Elicit the idea that the Earth acts like a magnet. Explain that the polarities of the Earth's magnetic poles are reversed relative to the geographic poles, as a consequence of the 'opposite poles attract' rule.	• recognise that the Earth has a magnetic field, which attracts a freely pivoted magnet to line up with it	• Many pupils think that the magnetic field and gravity are somehow linked. • Extension: pupils could find out about William Gilbert, Queen Elizabeth I's physician, who discovered that the Earth is magnetic.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
• what to take into account when deciding which equipment to use	• Ask different groups to devise and test various suspension techniques, *eg on a thread, by floating*, for allowing a freely suspended magnet to line up north–south. Discuss how well it works and when it could be used.	• identify that for magnets to point north to south, the suspension mechanism must be almost completely unaffected by other forces, *eg friction, moving air* • use appropriate equipment	• It is not necessary to demonstrate angle of inclination of the Earth's magnetic field.
• that the area of force around a magnet is called a magnetic field • that the magnetic field around magnets can be shown using iron filings • that magnetic field line patterns show the relative strength of magnetic fields	• Demonstrate the toy which allows you to add hair to a face by moving iron filings using a magnet. Invite suggestions as to how it works. • Use a magnet on the overhead projector (OHP), covered with a piece of perspex, to demonstrate the magnetic field lines around a single magnet, and also between magnets with like and unlike poles facing. Explain or show, *eg using a 'Magnaprobe'*, that the field exists in three dimensions.	• recall the shape of the magnetic field line pattern around a bar magnet, *eg strongest forces at the poles* • describe how the model of field lines shows that the field strength (magnetic force) falls as the distance from the magnet increases	• Field lines may be explored as a class practical, but this rarely gives satisfactory results unless the quantity of iron filings is limited and pupils know what to look for. • Enclose magnets in plastic bags or cling film to stop iron filings from sticking to them.
• that the direction of the magnetic field can be plotted using compasses • that the magnetic field lines can show the direction of the magnetic field • to convert ideas presented orally into diagrammatic form • to make and test predictions based on their scientific knowledge	• Elicit pupils' ideas about what would happen if you put a magnetic compass near a magnet and at various positions around the magnet. Invite them to generate a diagram which predicts where the compass needle will point at each position around the magnet. • Ask pupils to test their ideas by plotting the field direction with correctly magnetised compasses and to decide how far their predictions are supported.	• extend the model of magnetic field lines to represent the direction of the field • present their predictions and observations diagrammatically	• Pupils often think that a compass will point directly towards a magnet from all positions.

Checking progress

• to relate ideas about magnets and magnetism	• Bring together pupils' ideas about magnets and magnetism by asking them to construct a concept map, using the terms encountered, *eg magnet, magnetic field, field lines, north seeking, south seeking, attract, repel, Earth,* and respond to a series of written or oral questions.	• show, by their responses, that they understand the key ideas and relationships between them	• A concept map shows connections between key ideas and is a useful diagnostic tool for assessing pupils' understanding.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
How can electricity make a magnet?			
• how to make and change the strength of an electromagnet • to use their previous experience to decide whether a possible approach is practicable • to consider how their methods of investigation could be improved	• Show pupils examples of solenoid coils acting as electromagnets, *eg bell, buzzer, relay, etc.* Ask them to make a coil, *eg from insulated wire around a wooden dowel,* and connect it to a low-voltage power supply and observe effects. • Ask pupils to plan how to investigate the factors that affect the strength of an electromagnet. They could use iron cores or soft iron nails. Remind them of their investigation into the strength of the magnets they made. Discuss the best way of obtaining and presenting results so that conclusions can be drawn. Ask them to consider the limitations in their findings, *eg range and precision of results,* and to suggest improvements by comparing their methods with those of others.	• identify the factors that affect the strength of an electromagnet • make an electromagnet • make appropriate measurements and present data in a suitable form to draw conclusions • identify strengths and weaknesses in their own methods	• Ensure the paper clips do not become magnetised during the experiment. ⚠ **Safety** – electromagnet power supplies need quite high currents. Care should be taken to ensure that this investigation does not fuse the power supply or melt the plastic insulation
• how electromagnets are used in domestic and industrial devices, *eg electric bells, lifting magnets, relays* • to use sources of information independently • to present information concisely for an audience	• Provide pupils with access to a range of resources on electromagnets, *eg models, devices and CD-ROMs,* and ask them to report on how one application works, *eg orally or using diagrams.*	• recall that electromagnets are used in a wide range of applications and show their understanding of electromagnetism through their report of how a device works	• Pupils could use a CD-ROM for their presentation.
How can we explain how electromagnets work?			
• that wires carrying an electric current produce a magnetic field • that the current in a coil produces a magnetic field pattern similar to that of a bar magnet • that the strength of an electromagnet is increased by the presence of an iron core	• Use an OHP and/or compass to demonstrate that an electromagnet has a magnetic field pattern similar to permanent bar magnets. Ask pupils to predict whether there is still a magnetic field when the iron core (the only magnetic material present) is withdrawn. Demonstrate and ask pupils to use their knowledge of magnetic materials to explain why the electromagnet's strength is far weaker without the core than with the core present. Relate this to pupils' findings in their investigation.	• draw the field pattern of an electromagnet made from a straight coil • explain the effect of an iron core, using ideas of magnetising materials	• This work links to unit 9I 'Energy and electricity'. • Extension: pupils could predict what the effect of straightening out the wire would be, then demonstrate the circular field pattern along the length of the wire using a perspex platform, above an OHP, on which to show the field.
Reviewing work			
• to summarise and make connections between key ideas	• Ask pupils to construct a series of 'key facts' cards based on information about the types of magnets and their uses that they have compiled during this unit.	• produce a set of succinct 'key facts' cards	