

## UNIT 7 Magnetism and Electric Current

### Recommended Prior Knowledge

Pupils are likely to have some elementary ideas concerning magnetism and the Earth's magnetic field but many will be convinced that all metals are magnetic and will need to be shown otherwise. The first section of this unit is free-standing and could be taught at several stages in the course. It links in well, however, with the second part of the unit which could not properly be taught without a significant amount of current electricity preceding it; this is dealt with in unit 4.

### Context

The unit deals with magnetism and electromagnetism and it follows on from and extends ideas met in unit 4. The use of electricity in motors and loudspeakers and the generation of electricity by generators are hugely significant features of the modern world. Physics has changed the human condition enormously and electricity has been a significant factor in this achievement.

### Outline

At the beginning of the unit, the phenomenon of permanent magnetism and magnetic materials is dealt with and this is vital for the understanding of the topics and devices in the second half. Pupils will learn about three related magnetic effects. These are the production of a magnetic field by a current, the motor effect and the dynamo effect. Their understanding of these is enhanced by studying particular field patterns, the d.c. motor and the a.c. generator. All these ideas are brought together to explain the operation of a transformer and the use of transformers in power supply systems concludes the unit.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
17(a)	State the properties of magnets.	Pupils should experiment with magnets.  They probably know that like poles repel and that unlike poles attract. Emphasise "north pole" is an abbreviation for "north-seeking pole".	Law of magnetism: <a href="http://www.lancs.ac.uk/depts/physics/teaching/py103/ch27.pps">http://www.lancs.ac.uk/depts/physics/teaching/py103/ch27.pps</a>	Use, flat magnets whose flat faces are the poles. Pupils might investigate these more carefully.
17(c)	State the difference between magnetic, non-magnetic and magnetised materials.	Pupils often think that all metals are magnetic.  Try attracting copper, aluminium, brass, nickel (chemical spatulas are often made of nickel), carbon, nylon or wood to a magnet.	Magnetic materials: <a href="http://www.zephyrus.co.uk/magneticmaterials.html">http://www.zephyrus.co.uk/magneticmaterials.html</a>	Although iron is often said to be magnetically soft, real iron often retains some residual magnetisation. Find out how stainless steel behaves?
17(f)	State the differences between the properties of temporary magnets (e.g. iron) and permanent magnets (e.g. steel).	Given a magnet how would you tell whether a piece of steel was magnetised or unmagnetised?  Why are permanent magnets and compass needles made of steel?  Why are the cores of electromagnets made of iron?	Permanent/temporary magnets: <a href="http://www.sciencetech.technomuses.ca/english/schoolzone/info_Magnets.cfm">http://www.sciencetech.technomuses.ca/english/schoolzone/info_Magnets.cfm</a>	

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17(b)	Describe induced magnetism.	Pick up chains of iron nails or paper-clips end to end. Remove the original magnet.	Induced magnetism: <a href="http://www.phy6.org/earthmag/inducemg.htm">http://www.phy6.org/earthmag/inducemg.htm</a>	
17(e)	Describe the plotting of magnetic field lines with a compass.	Plot the field patterns of different arrangements of one or two magnets using iron filings (keep the magnet in a plastic bag to keep it clean).  Find the neutral point where appropriate. Also use plotting compasses. Pupils can become adept at plotting these patterns.	Plotting magnetic fields: <a href="http://www.practicalphysics.org/go/Experiment_313.html?topic_id=7&amp;collection_id=41">http://www.practicalphysics.org/go/Experiment_313.html?topic_id=7&amp;collection_id=41</a>	Avoid mentioning electric fields here as this causes confusion.
17(d)	Describe electrical methods of magnetisation and demagnetisation.	Wrap wire around a brass, iron and steel nail. Pass a current through the wire.  Note the different behaviour as you try to pick up paper-clips. What is the core of an electromagnet made from?  The phenomenon of electromagnetic induction needs to be taken on trust here, as it is not encountered until later in the unit.	Electromagnets: <a href="http://www.bbc.co.uk/schools/gcsebitesize/physics/electricity/electromagneticforcesrev5.shtml">http://www.bbc.co.uk/schools/gcsebitesize/physics/electricity/electromagneticforcesrev5.shtml</a>	Pupils make their own electromagnet and see how many paper-clips, N, can be picked as the current changes. Plot $N \rightarrow I$ .
17(g)	Describe uses of permanent magnets and electromagnets.	Uses include: motors, loudspeakers, generators, dynamos, speedometers, medical scanners, maglev trains,		
17(i)	Describe the use of magnetic materials in audio/video tapes.	Uses include tape-recorders and video recorders.	Magnetic tape: <a href="http://hyperphysics.phy-astr.gsu.edu/hbase/audio/tape2.html">http://hyperphysics.phy-astr.gsu.edu/hbase/audio/tape2.html</a>	
17(h)	Explain the choice of material for, and use of, magnetic screening.	Attach a magnet to the top of a match-box. Remove the drawer and place paper-clips at the bottom surface. See how many paper-clips can be held.  Put into the gap blocks of various materials: polythene, copper, wood, aluminium, brass, steel, iron. How is the number of paper clips affected?	Magnetic Screening: <a href="http://www.exploratorium.edu/snacks/magshield/">http://www.exploratorium.edu/snacks/magshield/</a> Uses of magnetic screening: <a href="http://www.magneticshield.com/">http://www.magneticshield.com/</a>	Do not confuse with the Faraday cage which screens the protected region from electric fields. Magnetic screening can be used to prevent the magnetic component of a radio frequency electro-

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		<p>The strength of the magnet (the number of flux lines emerging) is relatively constant.</p> <p>These lines cannot be destroyed or absorbed but they may be channelled away from the protected area; materials which do this are called permeable.</p> <p>All such materials are themselves <b>magnetic</b>.</p>		magnetic wave from reaching a given location.
17(j)	Describe the pattern of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and direction of the current.	<p>Use standard equipment to plot the patterns caused by current-carrying straight wires, flat coils, solenoids.</p> <p>If possible allow pupils to plot the fields with compasses or iron filings.</p>	<p>Fields due to currents:  <a href="http://schools.matter.org.uk/Content/MagneticFields/Default.htm">http://schools.matter.org.uk/Content/MagneticFields/Default.htm</a></p>	Plot the field pattern caused by a Helmholtz pair of coils. Notice how uniform it is in the middle.
17(k)1	Describe applications of the magnetic effect of a current in relays and circuit-breakers.	<p>Get pupils to use a relay to switch one circuit on and off using another circuit. Examples include the car ignition system.</p> <p>These ideas can prepare pupils for circuitry using transistors. Trip switches and relays can be demonstrated in class.</p>	<p>Relays:  <a href="http://www.technologystudent.com/elec1/relay1.htm">http://www.technologystudent.com/elec1/relay1.htm</a>            Circuit breakers:  <a href="http://hyperphysics.phy-astr.gsu.edu/hbase/electric/bre-gnd.html">http://hyperphysics.phy-astr.gsu.edu/hbase/electric/bre-gnd.html</a></p>	
22(a)	Describe experiments to show the force on a current-carrying conductor, and on a beam of charged particles, in a magnetic field, including the effect of reversing (1) the current, (2) the direction of the field.	<p>Possible experiments include:</p> <ul style="list-style-type: none"> <li>• Lay an unwound paper-clip on top of two parallel rails (also unwound paper-clips) which lie between the poles of a strong magnet (field downwards). Pass a current into one rail and out of the other. This is the catapult effect.</li> <li>• Pass a current through a strip of aluminium foil in a magnetic field. The foil moves.</li> <li>• Reverse the current and the field both separately and together.</li> <li>• The motor effect is a 3D effect and the relative directions are not easy to describe or memorise. Fleming's left-hand rule is a useful way of remembering</li> </ul>	<p>The motor effect:  <a href="http://www.walter-fendt.de/ph11e/lorentzforce.htm">http://www.walter-fendt.de/ph11e/lorentzforce.htm</a>            Fleming's left hand rule:  <a href="http://www.schoolscience.co.uk/content/4/physics/copper/copch3pg2.html">http://www.schoolscience.co.uk/content/4/physics/copper/copch3pg2.html</a>            or:  <a href="http://www.le.ac.uk/se/centres/sci/selfstudy/mam12.htm">http://www.le.ac.uk/se/centres/sci/selfstudy/mam12.htm</a></p>	<p>Draw the circular field pattern surrounding a straight wire and add the uniform, straight field pattern of a permanent magnet.</p> <p>On one side of the wire they reinforce whilst on the other side they cancel. Hence there are more field lines on the first side and fewer on the other. The lines behave like stretched</p>

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		<p>it but it is not a law of physics.</p> <p>Apply these principles to a beam of electrons. Where possible show a fine-beam tube or a Maltese Cross tube.</p>		rubber bands and so eject the wire in the direction predicted.
<b>22(b)</b>	State the relative directions of force, field and current.			
<b>17(k)2</b>	Describe applications of the magnetic effect of a current in loudspeakers.	<p>Let the pupils see dismantled loudspeakers. Hand out sheets showing incomplete or unlabelled diagrams and let the pupils complete them.</p> <p>Make a large, cardboard model (~50 cm diameter) to show the shape and position of the components.</p> <p>Pupils can make coils of fine wire (enamel covered), attach them to a cone of paper, place near a bar magnet and when a.c. from a signal generator passes through sound is heard.</p>	Loudspeakers: <a href="http://hyperphysics.phy-astr.gsu.edu/hbase/audio/spk.html">http://hyperphysics.phy-astr.gsu.edu/hbase/audio/spk.html</a>	Link in with sound waves (unit 2) and alternating current (later in this unit). An a.c. produces an alternating force and the diaphragm vibrates.
<b>22(c)</b>	Describe the field patterns between currents in parallel conductors and relate these to the forces which exist between the conductors (excluding the Earth's field).	Pass a current through two parallel strips of aluminium foil – no magnet needed. Like currents attract. Reverse the current in one strip. Unlike currents repel. Consider the field of one strip and its effect on the current in the other.	Parallel wires: <a href="http://www.kineticbooks.com/physics/17181/17196/sp.html">http://www.kineticbooks.com/physics/17181/17196/sp.html</a> or <a href="http://www.physchem.co.za/Current%20Electricity/Current.htm#Force2">http://www.physchem.co.za/Current%20Electricity/Current.htm#Force2</a>	<p>Draw the field patterns for parallel wires carrying currents in the same directions and then in the opposite directions.</p> <p>Notice, in each case, where the two fields cancel out.</p>
<b>22(d)</b>	Explain how a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by increasing (1) the number of turns on the coil, (2) the current.	<p>Illustrate the effect with a large (~50 cm x ~50 cm), non-functioning cardboard model.</p> <p>The magnetic poles are painted cardboard boxes. Use real, thick wire but paint arrows to show the current and use drinking straws with arrowheads to show the forces on the two sides of the coil.</p>	Torque on coil: <a href="http://www.plus2physics.com/current_and_mgfield/study_material.asp?chapter=3">http://www.plus2physics.com/current_and_mgfield/study_material.asp?chapter=3</a>	<p>Wind a simple coil and place it between the poles of a magnet.</p> <p>Its plane lies in the field. It rotates through a quarter turn and stops when perpendicular to the field.</p>

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22(e)	Discuss how this turning effect is used in the action of an electric motor.	Use the cardboard model to show that if the current is reversed when the coil is perpendicular to the field then it will continue to rotate in the same direction.	The electric motor: <a href="http://howstuffworks.com/motor.htm">http://howstuffworks.com/motor.htm</a>	Make a simple motor from wire, flat magnets, a former on which to wind the coil and show that it can be made to rotate.
22(f)	Describe the action of a split-ring commutator in a two-pole, single coil motor and the effect of winding the coil on to a soft-iron cylinder.	Make a "commutator" from aluminium foil and a cardboard tube and fit it to the model.  Use two other lengths of wire to rub against the commutator.  Explain that a soft-iron core magnifies and concentrates the magnetic field.		
23(a)	Describe an experiment which shows that a changing magnetic field can induce an e.m.f. in a circuit.	Insert a bar magnet into a solenoid connected to a sensitive meter (needle meter or mirror galvanometer). Withdraw it.  Repeat with the other pole and repeat using the other end of the solenoid.  Insert two or three identical magnets taped together. Vary the rate of insertion.	Electromagnetic induction: <a href="http://micro.magnet.fsu.edu/electromag/java/faraday2/">http://micro.magnet.fsu.edu/electromag/java/faraday2/</a> or: <a href="http://www.bbc.co.uk/schools/gcsebitesize/physics/electricity/electromagneticinductionrev1.shtml">http://www.bbc.co.uk/schools/gcsebitesize/physics/electricity/electromagneticinductionrev1.shtml</a>	Other experiments include: (1) Move a wire up and down between two poles of a magnet. (2) Rotate a copper disc between the two poles and measure the e.m.f. between axle and circumference. In both cases use a sensitive galvanometer.
23(b)	State the factors affecting the magnitude of the induced e.m.f.	A coil with more turns may well have a greater resistance. This produces a similar meter reading.  Show the dependence on the number of turns, N, using the same piece of wire wound into more or fewer turns.		
23(c)	State that the direction of the current produced by an induced e.m.f. opposes the change producing it (Lenz's Law) and describe how this law may be demonstrated.	Consider the two possible current directions when inserting a magnet into a coil.  Both make the coil into a magnet: one attracts the magnet → larger current → stronger field → faster magnet → even larger current.	Lenz's Law: <a href="http://micro.magnet.fsu.edu/electromag/java/lenzlaw/">http://micro.magnet.fsu.edu/electromag/java/lenzlaw/</a> or: <a href="http://www.catandogs.net/english/Lenz_s_Law/lenz_s_law.htm">http://www.catandogs.net/english/Lenz_s_Law/lenz_s_law.htm</a>	Demonstrate the direction of the current induced by moving a wire up through the gap between two poles of a strong magnet. The directions are given by

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		<p>Ever larger amounts of energy come from nowhere. This is impossible.</p> <p>The other repels the magnet → smaller current → weaker field → slower magnet → even smaller current. A small amount of energy is generated by a small initial push. This is what happens.</p>	<a href="#">ml</a>	Fleming's right-hand rule or by using the left-hand rule and remembering Lenz's Law.
23(d)	Describe a simple form of a.c. generator (rotating coil or rotating magnet) and the use of slip rings where needed.	<p>Use a large cardboard model to show the arrangement of the parts (similar to the motor model in 22(e) and (f)).</p> <p>Place small arrows on the coil to show the direction of the current induced. Make a set of slip rings from aluminium foil and some cardboard tubes.</p>	The a.c. generator: <a href="http://www.walter-fendt.de/ph11e/generator_e.htm">http://www.walter-fendt.de/ph11e/generator_e.htm</a>	Show an old, cut-up a.c. generator or make a model a.c. generator. Rotate it at a constant rate. A C.R.O. displays the output.
23(e)	Sketch a graph of voltage output against time for a simple a.c. generator.	Connect an a.c. generator to a C.R.O. (unit 10) and look at the trace. Measure the periodic time and the amplitude.	An a.c. supply: <a href="http://www.eng.uct.ac.za/~victor/electric/ACDC.htm">http://www.eng.uct.ac.za/~victor/electric/ACDC.htm</a>	
23(f)	Describe the structure and principle of operation of a simple iron-cored transformer.	<p>Make a simple electromagnet (an iron nail wound with wire connected to a supply).</p> <p>Insert it into a coil connected to a galvanometer. Withdraw it. Place the electromagnet into the coil and switch off the supply. This is like withdrawing it. Switch on.</p> <p>Use an a.c. supply and replace the galvanometer with a C.R.O. (unit 10).</p>	The transformer: <a href="http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/transformer.html">http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/transformer.html</a> or: <a href="http://people.clarkson.edu/~svoboda/eta/plots/transformer.html">http://people.clarkson.edu/~svoboda/eta/plots/transformer.html</a>	Construct a transformer from an iron bar and wind two coils on it (this is not very efficient). Use a transformer kit with a laminated iron core.
23(g)	State the advantages of high voltage transmission.	Use a model power lines demonstration with torch lamps at the beginning and end. Transmit at 3V. Then step up to 12V, transmit and step down to 3V. <b>Do not use high voltages on bare wire which the teacher or pupils can come into contact with.</b>	Power lines: <a href="http://www.practicalphysics.org/go/Experiment_352.html">http://www.practicalphysics.org/go/Experiment_352.html</a> or: <a href="http://www.bsharp.org/physics/stuff/xmission.html">http://www.bsharp.org/physics/stuff/xmission.html</a>	
23(h)	Discuss the environmental and cost implications of	Overhead: cheaper to build, cheaper to maintain, cheaper to inspect, no insulation needed, they stay cool, ugly, a	Environmental effects: <a href="http://www.nationalgrid.com/uk">http://www.nationalgrid.com/uk</a>	

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	underground power transmission compared to overhead lines.	hazard for helicopters, hang-gliders, children with kites. Underground: the reverse of the above but a hazard for diggers may ignite gas supplies in earthquakes, problems in flooding.	<a href="#">/library/brochures/overhead_ug</a> <a href="#">nderground/</a>	