COURSE: HSC Physics

MODULE: 9.3 Motors and Generators

SUGGESTED TIME: 28 indicative hours.

CONTEXTUAL OUTLINE

Modern industrialized society is geared to using electricity. Electricity has characteristics that have made it uniquely appropriate for powering a highly technological society. There are many energy sources that can be readily converted into electricity. In Australia, most power plants burn a fuel, such as coal, or use the energy of falling water to generate electricity on a large scale. Electricity is also relatively easy to distribute. Electricity authorities use high-voltage transmission lines and transformers to distribute electricity to homes and industries around each state. Voltages can be as high as 5 x 105 volts from power stations but by the time this reaches homes, the electricity has been transformed to 240 volts. While it is relatively economical to generate electric power at a steady rate, there are both financial and environmental issues that should be considered when assessing the long-term impact of supplying commercial and household power.

The design of a motor for an electrical appliance requires consideration of whether it will run at a set speed, how much power it must supply, whether it will be powered by AC or DC and what reliability is required. The essentials of an electric motor are the supply of electrical energy to a coil in a magnetic field causing it to rotate.

The generation of electrical power requires relative motion between a magnetic field and a conductor. In a generator, mechanical energy is converted into electrical energy while the opposite occurs in an electric motor.

The electricity produced by most generators is in the form of alternating current. In general AC generators, motors and other electrical equipment are simpler, cheaper and more reliable than their DC counterparts. AC electricity can be easily transformed into higher or lower voltages making it more versatile than DC electricity.

This module increases students' understanding of the applications and uses of physics and the implications of physics for society and the environment.

Outcomes

H3 assesses the impact of particular advances in physics on the development of technologies
H4 assesses the impact of applications of physics on society and the environment
H7 explains the effect of energy transfers and transformation
H8 analyses wave interactions and explains the effects of those interactions
H9 explains the effects of electric, magnetic and gravitational fields
H11 justifies the appropriateness of a particular investigation plan
H12 evaluates ways in which accuracy and reliability could be improved in investigations
H13 uses terminology and reporting styles appropriately and successfully to communicate information and understanding
H14 assesses the validity of conclusions from gathered data and information
H15 explains why an investigation is best undertaken individually or by a team
H16 justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for critical evaluation of the consequences of the applications of science

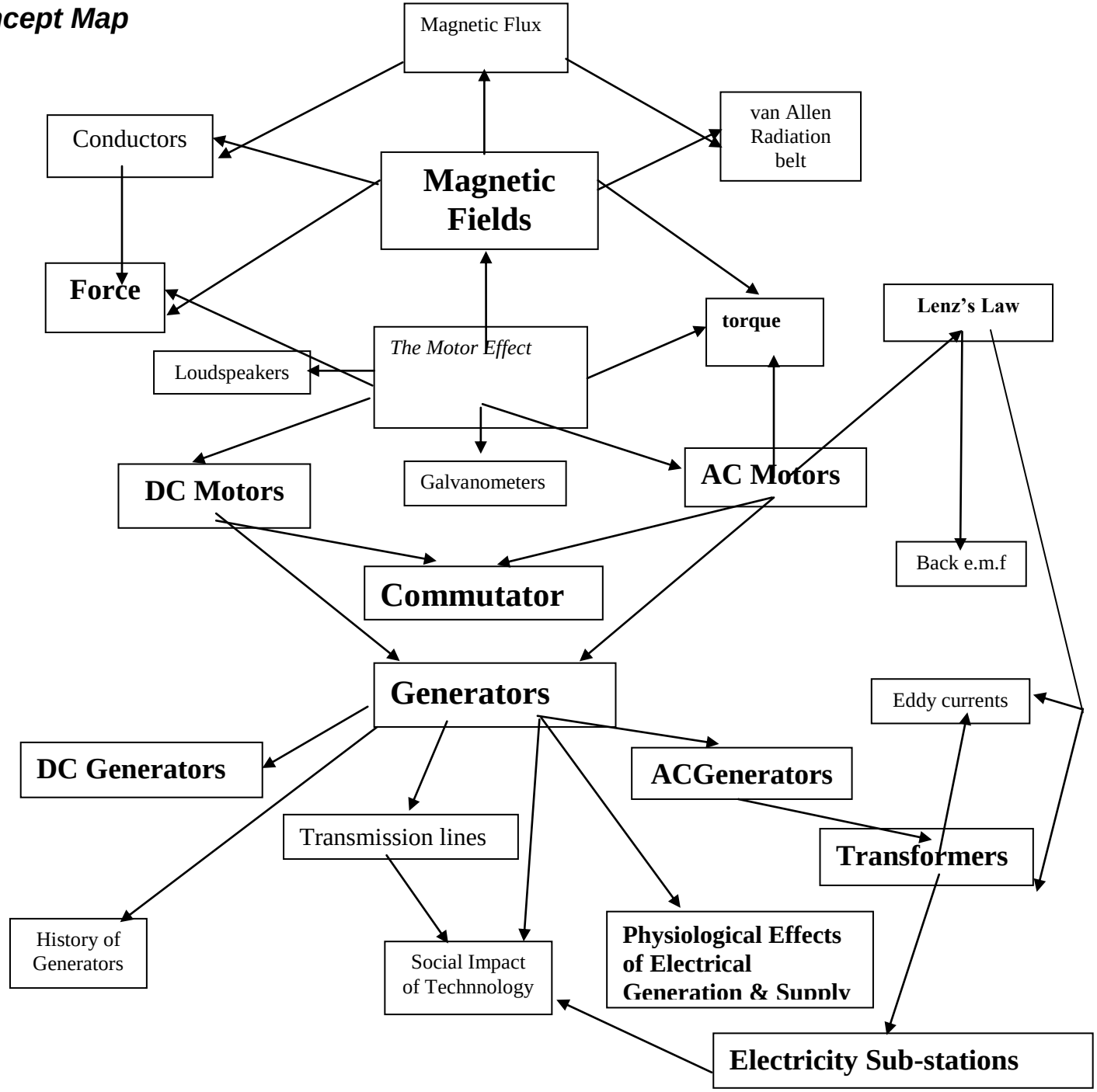
Sense of the Sacred

Students gain an appreciation of the technology behind motors and generators and marvel at God's bounty.

Glossary

AC generator
AC induction motor
AC motor
Alternating current
Back emf
DC generator
DC motor
Direct current
Domestic power supply
Eddy current
Electromagnetic braking
Galvanometer
Lenz's law
Loudspeaker
Magnetic field strength
Magnetic flux
Magnetic flux density
Motor effect
Primary voltage
Secondary voltage
Solenoid
Step-down transformer
Step-up transformer
Sub-station (electrical)
Supply emf
Torque
Transformer
Transmission line

Concept Map


Magnetic Flux
Conductors
van Allen Radiation belt
Magnetic Fields
Force
torque
Lenz's Law
The Motor Effect
Loudspeakers
Galvanometers
DC Motors
AC Motors
Back e.m.f
Commutator
Generators
Eddy currents
DC Generators
ACGenerators
Transmission lines
Transformers
History of Generators
Social Impact of Technnology
Physiological Effects of Electrical Generation & Supply
Electricity Sub-stations

OUTCOMES / ASSESSMENT OPPORTUNITIES

The following tasks are provided as samples that could be used throughout the module.

In general, however it is unlikely that more than 1 task would ever be used.

TASK	DESCRIPTION	P2	P4	P6	P7	P11	P12	P13	P14
1	Pencil and paper tests	3	3	3	3		3	3	3
2	Experimental investigations					3	3	3	3
3									
4									
5									
6									

MODULE REFERENCES

REFERENCES

T1 Sofoulis N. et al. (eds.) (1994) Physics Investigations in Context (Year 12). STAWA. ISBN 0-949820-29-6.
T2: Bunn D.J. (1990) Physics for a Modern World. Jacaranda Press. ISBN 0-7016-2602-X.
T3: Bragg M. (1998) On Giants' Shoulders. Hodder & Stoughton. ISBN 0340712597.
T4 Goodstein D.L. (1986) Notes to accompany the video series The Mechanical Universe. California Institute of Technology.
T5 Storen A. & Martine, R. (1998) Nelson Physics (VCE Units 3 & 4) (2nd ed.). Melbourne: Nelson. ISBN 0-17-009353-0.
T6 Cutnell J.R. & Johnson, K.W. (1998) Physics (4th ed.). Wiley & Sons. ISBN 0-471-15519-5.
T7 Parham R.T.& Webber B.J. (1986) Fundamentals of Senior Physics. Heinemann Educational Australia, ISBN 0-85859-308-4
T8 Ingram A.D. et al. (1972) Physics: A Laboratory Oriented Approach (Part 1). Adelaide: Rigby. ISBN 0-85179-498-X.
T9 Moyle D.G. et al. (1986) Senior Physics Practical Manual (Year 11). Macmillan. ISBN 0-333-40146-8.
T10 Zealy W.J. et al (1994) Physics: the forces of life. Oxford. ISBN 0-19-553395-X
T11 Moyle D.G. et al. (1988) Senior Physics Practical Manual (Year 12). Macmillan. ISBN 0-333-47663-8.
T12 Moyle D.G. et al. (1988) Year 12 Senior Physics. Macmillan. ISBN 0-333-47662-X.
T13 Walding R. et al. (1997) Senior Physics : knowledge, processes and reasoning. Oxford University Press. ISBN 0-19-553902-8.
T14 Cooper M. & Vella G. (1987) Physics the Core. Brooks Waterloo. ISBN 0-86440-601-0.
T15 Pollock G. (1990) Active Physics. Science Press. ISBN 0-85583-157-X.
T16 Hewitt P.G. (1992) Conceptual Physics. Addison-Wesley. ISBN 0-201-28652-1.
T17 M. Butler (2000) Physics 1 , Macmillan,
T18 Dr F. Huq (1995) Excel HSC Physics. Pascal
T19 N. Warren (2000) Excel Preliminary Physics (New Course). Pascal
T20 J. Jardine, (1989) Physics Through Application, Oxford
T21 J. Murphy, Charles E. (1982) Physics Principles and Problems Merrill
T22 N. Warren (1995) Physics Outlines
T23 Excel HSC Physics Warren pp.47-8 ISBN 1-74040-227-9
T24 Excel Physics, Huq, pp 166-290 ISBN 9 781875 312238
T25 Physics, Davies & McCullough pp.177-193, 220-233 ISBN 0 7157 1988-2
T26 Physics, The Forces of Life, pp 251-283
T27 Physics Outlines, N.G. Warren, pages ISBN 0 08 034438 0
T28 Microsoft Encarta Encyclopaedia
T29 Understanding Physics, Yates, Davies & Harding pp 201-250 ISBN 9 780582 867864

Useful Programs

P1 AC Circuits http://www.educatorscorner.com/experiments/interactive_exp.shtml is a good demonstration of using CROs to analyse AC circuits.
P2 Oscilloscope 2.1 turns a computer into a CRO.

Websites

W1 Institute of Electrical Engineers http://www.faraday.org.uk/faraday/default.htm This has information on Faraday's work
W2 Energy Australia www.energy.com.au/
W3 New Scientist Magazine www.newscientist.com/
W4 University of NSW http://www.phys.unsw.edu.au/%7Ejw/HSCmotors.html This site has a good explanation of the fundamentals of the induction motor.
W5 Columbia University Health Education Program http://www.goaskalice.columbia.edu/0960.html Power Lines-Radiation Very good – it talks about radiation effects from high voltage power lines near one's home and cellular tower radiation.
W6 NASA Goddard Space Flight Centre http://www-spof.gsfc.nasa.gov/Education/Iradbelt.html Excellent explanation on the motion of energetic ions and electrons through space is strongly constrained by the local magnetic field.
W7 University of Colorado at Boulder http://www.eurekalert.org/releases/uco-rbaeaas.html This site explains how radiation belts around Earth adversely affecting satellites
W8 University of Oulu, Finland Space Physics http://www.oulu.fi/~spaceweb/textbook/radbelts.html Very good site produced by Space physics department on the radiation belts and their importance primarily because of the harmful effects of high energy particle radiation for man and electronics
W9 University of Michigan http://www.windows.umich.edu/cgi-bin/tour_def/glossary/radiation_belts.html Excellent information along with graphics on radiation belts
W10 NASA History Officehttp://www.hq.nasa.gov/office/pao/History/sputnik/vanallen.html This site provides information on James A. Van Allen, the American astrophysicist who first predicted the radiation belts.
W11 ABC News Sciencehttp://www.abcnews.go.com/sections/science/DailyNews/belts981207.html This site has news on radiation belts risk
W12 Space Daily http://www.spacedaily.com/spacecast/news/radiation-98e.html This site has latest news on the radiation belt
W13 Electricity, Magnets, & Motors http://www.cpo.com/CPOCatalog/EM/em_a3.htm This site has excellent information on how a motor works
W14 Encyclopedia of free energy http://geoffegel.tripod.com/motor.htm This site has information on the worlds' simplest electric motor
W15 How Electric Motors Work http://www.howstuffworks.com/motor.htm Excellent information on how electric motors work
W16 Loudspeaker Principle http://hyperphysics.phy-astr.gsu.edu/hbase/audio/spk.html This site contains information on the motor principle used in making a loudspeaker
W17 The motor principle http://ourworld.compuserve.com/homepages/g_knott/elect83.htm Excellent information on the principle of an electric motor
W18 The loudspeaker http://ourworld.compuserve.com/homepages/g_knott/elect131.htm Excellent information on the principle of an electric motor used in the construction of a loudspeaker
W19 Build small electric motors using inexpensive materials http://www.sasked.gov.sk.ca/docs/physics/u7c3phy.html Excellent site on how to build small electric motors in the classroom as an activity
W20 Principle of a galvanometer http://www.tpub.com/neets/book3/7a.htm Excellent information on the principle of an electric motor used in the construction of a galvanometer
W21 Home Solutions http://www.sceg.com/home/rekcein.htm Good information on principle and benefit of induction cooktops

W22 Induction Cooktops http://www.fpl.com/html/hes_html/rekcein.htm Good information on principle and benefit of induction cooktops
W23 Cookpower http://www.cookpower.com/features.htm Good site for students to log on for information on principle and benefit of induction cooktops
W24 Residential energy systems http://www.epelectric.com/apogee/res_html/rekcein.htm Good information on induction cooktops
W25 CSW Corporation http://www.csw.com/apogee/res_html/rekcein.htm Good information on principle of induction cooktops
W26 Encyclopaedia Britannica http://www.britannica.com/bcom/eb/article/2/0,5716,108542+2+106043,00.html Excellent article on induction motors
W27 Sydney University http://www.physics.usyd.edu.au/teach_res/mteach/mt93/w93teachers.htm Teaching program on Motors and Generators put together by masters students
W28 University of NSW http://www.phys.unsw.edu.au/%7Ejw/HSCmotors.html notes from a lecturer on motors AC & DC
W29 University of NSW http://newt.phys.unsw.edu.au/hsc/ site for HSC and Prelim phys notes
W30 http://www.phys.unsw.edu.au/hsc/index.html University of New South Wales resource page for this topic.
W31 http://www.school-for-champions.com/science/magnetism.htm is a good tutorial on magnetism.
W32 http://www.school-for-champions.com/science/ac.htm is an excellent tutorial on AC electricity.
W33 http://www.howstuffworks.com/maglev-train.htm How Stuff Works page on maglev trains.
W34 http://www.phys.ufl.edu/~phy3054/extras/contents/Welcome.html University of Florida Physics II course has good slides on generators.
W35 http://230nsc1.phy-astr.gsu.edu/hbase/emcon.html#emcon Hyperphysics Concepts page for Electricity and Magnetism. Very good graphics.
W36 http://www.mos.org/sln/toe/ The Theatre of Electricity provides some good background information on electricity.

Videos

V1	992 Magnetic Fields	R45358
V2	418 Electricity and Magnetism	R58083
V3	985 Magnetism and Electricity	R45354
V4	1373 Magnetism (ACME School of Stuff)	R49890

Journals / Articles

J1

Outcomes	Students Learn:	Reg.	Teaching / Learning Strategies	Resources
	1. Motors use the effect of forces on current-carrying conductors in magnetic fields			
H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields H11 justifies the appropriateness of a particular investigation plan (11.2a, b, c) H12 evaluates ways in which accuracy and reliability could be improved in investigations (12.3a, d) H14 assesses the validity of conclusions from gathered data and information (14.1a, b, c)	• discuss the effect, on the magnitude of the force on a current-carrying conductor, of variations in: – the strength of the magnetic field in which it is located – the magnitude of the current in the conductor – the length of the conductor in the external – magnetic field – the angle between the direction of the external magnetic field and the direction of the length of the conductor • *solve problems using* $\frac{F}{l} = k\frac{I_1 I_2}{d}$ by ○ *identify trends, patterns and relationships as well as contradictions in data and information (14.1a)* ○ *identify and explain how data supports or refutes an hypothesis, a prediction or a proposed solution to a problem (14.1c)* ○ *use models, including mathematical ones, to explain phenomena and/or make predictions (14.1f)* • *perform a first-hand investigation to demonstrate the motor effect by* ○ *carrying out the planned procedure, recognising where and when modifications are needed and analysing the effect of these adjustments (12.1a)* ○ *identifying and using safe work practices during investigations (12.1d)*		**Suggested Time: 3 hours** ♦ Guiding a charged and uncharged ebonite rod through a major magnet. ♦ Record observations, from teacher devised demonstration, of the deflection of an electron stream in a Cathode Ray Tube, by a permanent magnet. ♦ Undertake a first hand investigation, devised by the teacher, to observe the Motor Effect using bar magnets and a current carrying conductor. ♦ Determine by class discussion, and by experiment in the above investigation, the factors which influence the force on the current carrying conductor. Students apply the right-hand rule after teacher modelling. (*GT, num*) ♦ Students also investigate the auroras and the ionosphere and compare earth's magnetic field to other planets. ♦ Teacher demonstrations of these effects using bar magnets and high currents through wire. ♦ Using large magnets to deflect thin wires carrying currents. ♦ **Key – Policy implementation** *SOS – Sense of the Sacred* *GT* – Gifted and Talented *ab* – aboriginality *tech* – technology *ESL* – English as a Second Language *lit* - Literacy *ns* – non-sexist *SE* – Special Education *num* - Numeracy	T1-T29 P1-P2 W1-W26 V1-V4

Outcomes	Students Learn:	Reg.	Teaching / Learning Strategies	Resources
	• *solve problems and analyse information about the force on current-carrying conductors in magnetic fields using* $F = BI\ell$ *by* o *identify trends, patterns and relationships as well as contradictions in data and information (14.1a)* o *identify and explain how data supports or refutes an hypothesis, a prediction or a proposed solution to a problem (14.1c)* o *use models, including mathematical ones, to explain phenomena and/or make predictions (14.1f)*		♦ Record the factors influencing the force, noting the direction relative to the field and current. ♦ Solve problems using F=BIl. (*SOS, GT, ab, tech, ESL, lit, SE, num*)	
H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields H14 assesses the validity of conclusions from gathered data and information (14.1a, c, d; 14.2a, c)	• describe qualitatively and quantitatively the force on long parallel current-carrying conductors: $\frac{F}{l} = k\frac{I_1 I_2}{d}$ • define torque as the turning moment of a force using: $\tau = \vec{F}d$ • *solve problems and analyse information about simple motors using* $\tau = nBIA\cos\theta$ *by* o *identify trends, patterns and relationships as well as contradictions in data and information (14.1a)* o *identify and explain how data supports or refutes an hypothesis, a prediction or a proposed solution to a problem (14.1c)* o *use models, including mathematical ones, to explain phenomena and/or make predictions (14.1f)*		**Suggested Time: 2 hours** ♦ Current balance experiment set up as demo. ♦ Can also use vector cross product to explain directions. ♦ Hold and manipulate spinning bicycle wheels to demonstrate torque. ♦ Do problems on Ampere's Law and torque ♦ Review the operation of the loudspeaker by research or teacher provided material. Relate the operation to the motor effect. (*ESL, lit*) ♦ Undertake a first hand investigation, devised by the teacher, to observe Oersted's experiment. Students record the method, their observations, and the significance of the experiment, after teacher lead discussion. ♦ Undertake a first hand investigation, devised by the teacher, to observe Ampere's Law experiment. Teacher lead discussion of, and investigation into, the variables that could vary the magnitude and direction of the force on the wires. Students record their observations of the investigation. ♦ Record information, after teacher lead discussion, to explain the force between the wires as an example of the motor effect. ♦ Solve problems using $\frac{F}{l} = k\frac{I_1 I_2}{d}$ and $\tau = \vec{F}d$ (*num*)	T1-T29 P1-P2 W1-W26 V1-V4
H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields	• describe the forces experienced by a current-carrying loop in a magnetic field and describe the net result of the forces • identify that the motor effect is due to the force acting on a current-carrying conductor in a magnetic field		**Suggested Time: 2 hours** ♦ Turn an armature in a generator using a spring balance to gauge the forces involved. ♦ Move conductors (eg metal rods, loops of wire) in magnetic fields (eg major magnets)	T1-T29 P1-P2 W1-W26 V1-V4

Outcomes	Students Learn:	Reg.	Teaching / Learning Strategies	Resources
H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields H12 evaluates ways in which accuracy and reliability could be improved in investigations H14 assesses the validity of conclusions from gathered data and information (14.1a, b, c)	• describe the main features of a DC electric motor and the role of each feature.		**Suggested Time: 1 hour** ♦ Pull apart a DC motor to identify, and explain the function of, the parts of a D.C. motor including the split ring and brushes ♦ Build a commutator ♦ Build a split-ring commutator ♦ Create a poster that describes the application of the motor effect in the galvanometer. Students use their own references and acknowledge them (*GT, ESL, lit*)	T1-T29 P1-P2 W1-W26 V1-V4
H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields H12 evaluates ways in which accuracy and reliability could be improved in investigations H14 assesses the validity of conclusions from gathered data and information (14.1a, b, c)	• identify that the required magnetic fields in DC motors can be produced either by current-carrying coils or permanent magnets • *identify data sources, gather and process information to qualitatively describe the application of the motor effect in:* – *the galvanometer* – *the loudspeaker by* ○ *accessing information from a range of resources, including popular scientific journals, digital technologies and the Internet (12.3a)* ○ *extracting information from numerical data in graphs and tables as well as written and spoken material in all its forms (12.3c)* ○ *summarising and collating information from a range of resources (12.3d)* ○ *identify and apply appropriate mathematical formulae and concepts (12.4b)* ○ *assess the reliability of first-hand and secondary information and data by considering information from various sources (12.4e)* ○ *selecting and using appropriate methods to acknowledge sources of information (13.1c)*		**Suggested Time: 2 hours** ♦ Experiments with generating currents from armatures using bar magnets and current-carrying wires. ♦ Students build a simple motor. ♦ Use the library or internet to research this issue. (*ESL, lit*)	T1-T29 P1-P2 W1-W26 V1-V4

Outcomes	Students Learn:	Reg.	Teaching / Learning Strategies	Resources
	2. The relative motion between a conductor and magnetic field is used to generate an electrical voltage			
H1 evaluates how major advances in scientific understanding and technology have changed the direction or nature of scientific thinking H2 analyses the ways in which models, theories and laws in physics have been tested and validated H3 assesses the impact of particular advances in physics on the development of technologies H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields H12 evaluates ways in which accuracy and reliability could be improved in investigations (12.1a, d) H14 assesses the validity of conclusions from gathered data and information	• outline Michael Faraday's discovery of the generation of an electric current by a moving magnet • define magnetic field strength B as magnetic flux density • describe the concept of magnetic flux in terms of magnetic flux density and surface area • describe generated potential difference as the rate of change of magnetic flux through a circuit • *perform an investigation to model the generation of an electric current by moving a magnet in a coil or a coil near a magnet* • *plan, chose equipment or resources for, and perform a first-hand investigation to predict and verify the effect on a generated electric current when:* - *the distance between the coil and magnet is varied* - *the strength of the magnet is varied* - *the relative motion between the coil and the magnet is varied*		**Suggested Time: 3 hours** ♦ Use the library or internet to research this issue. ♦ Students move a magnet in a solenoid and measure the current produced in the solenoid using a galvanometer. ♦ Use a water/gravitation analogy ♦ Students use magnetic compasses to map the magnetic field around a current carrying wire, changing the variables indicated as needed. ♦ Perform a first hand investigation, designed by the teacher, to observe E.M. induction, using a solenoid, a meter and a magnet. Students record their observations. ♦ Research and write a contemporary newspaper or journal article on Michael Faraday's discovery of electromagnetic induction. (*SS, ESL, lit*) ♦ Through class discussion and experimentation, identify and record the factors that affect the current/EMF generated by the induction experiment above. (*ESL, lit*) ♦ Distinguish between flux and flux density through class discussion and teacher demonstration of an analogy/diagrams/video. Students identify flux density with magnetic field strength. (*ESL, lit*)	T1-T29 P1-P2 W1-W26 V1-V4
H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields H12 evaluates ways in which accuracy and reliability could be improved in investigations (12.3a, b, c, d) H14 assesses the validity of conclusions from gathered data and information (14.3a, b, c, d)	• account for Lenz's Law in terms of conservation of energy and relate it to the production of back emf in motors • explain that, in electric motors, back emf opposes the supply emf • explain the production of eddy currents in terms of Lenz's Law. • *gather, analyse and present information to explain how induction is used in cooktops in electric ranges* • *gather secondary information to identify how eddy currents have been utilised in switching devices and electromagnetic braking*		**Suggested Time: 2 hours** ♦ Correlate Lenz's law as a restatement of the Law of Conservation of Energy as discuss its parallels in other sciences eg. Le Chatelier's principle, homeostasis ♦ Perform an internal resistance experiment on a motor to calculate back emf at a given current. ♦ Investigate back emf effects such as magnetic dampening, electromagnetic braking, etc. ♦ Use the library or internet to research this issue. (*ESL, lit*) ♦ Relate the above effect to back EMF and Lenz's Law by class discussion or research. Students report on the reason for increased risk of motor "burnout" in a stalled D.C. motor. ♦ Produce a report, using teacher identified references, on how an electric induction cooker works. (*ESL, lit*) ♦ Make notes, after class discussion, on application of eddy currents to switching devices and electromagnetic braking.	T1-T29 P1-P2 W1-W26 V1-V4

Outcomes	Students Learn:	Reg.	Teaching / Learning Strategies	Resources
	3. Generators are used to provide large scale power production.			
H4 assesses the impact of applications of physics on society and the environment H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields H11 justifies the appropriateness of a particular investigation plan (11.1a, d; 11.3a, b, c) H12 evaluates ways in which accuracy and reliability could be improved in investigations (12.2a, c) H14 assesses the validity of conclusions from gathered data and information (14.1a, c, d; 14.2b, c)	• describe the main components of a generator • compare the structure and function of a generator to an electric motor • describe differences between AC and DC generators • discuss the energy losses that occur as energy is fed through transmission lines from the generator to the consumer • *plan, chose equipment or resources for, and perform a first-hand investigation to demonstrate the production of an alternating current* • *gather secondary information to discuss advantages and disadvantages of AC and DC generators and relate these to their use* • *analyse secondary information on the competition between Westinghouse and Edison to supply electricity to cities.*		**Suggested Time: 3 hours** ♦ Draw diagrams of generators ♦ Describe each feature in a generator and electric motor. ♦ Use the library or internet to research this issue. ♦ Shine a torch on a solar cell and measure the current with a milliammeter. ♦ Create a report on their observations of a teacher devised demonstration showing the output from a *voltaic cell* using a data logger and voltage sensor and a light bulb. Students describe the current under different lighting conditions. A graph of the output could be included (*tech, num*) ♦ Create a report on their observations of a teacher devised demonstration showing the output from a *hand generator* using a data logger and voltage sensor and a light bulb. Students describe the current as the handle is turned at differing rates. A graph of the output could be included. ♦ Discuss, as a class, the similarities in the structure of an A.C generator and a D.C. motor. Students, in small groups, plan an investigation to demonstrate the current output from an externally driven DC motor. Students produce individual reports on their investigation. (*ESL, lit*) ♦ Using teacher-supplied resources, students research the competition between Westinghouse and Edison.	T1-T29 P1-P2 W1-W26 V1-V4
H4 assesses the impact of applications of physics on society and the environment H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields H12 evaluates ways in which accuracy and reliability could be improved in investigations (12.2a, b, d,) H14 assesses the validity of conclusions from gathered data and information (14.1a, b, c, d)	• assess the effects of the development of AC and DC generators on society and the environment • *gather and analyse information to identify how transmission lines are:* – *insulated from supporting structures* – *protected from lightning strikes*		**Suggested Time: 2 hours** ♦ Compare the output and structure of the AC and DC generator by using a hand generator model with C.R.O., or data logger and voltage sensor. Students learn about the advantages and disadvantages of the A.C. and D.C. generator through observations, teacher led class discussion and note taking. ♦ Demonstrate the heating effect of current in nichrome wire and/or pencil lead and relate this, through class discussion, to energy losses in transmission lines. ♦ Write a journal article on the impact of the introduction of a diesel generator to a remote community. Consider both social and environmental changes. (*ESL, lit*) ♦ Study photographs of transmission lines, to suggest through class discussion, how the lines are insulated from supporting structures and protected from lightning strikes. (*ESL, lit*)	T1-T29 P1-P2 W1-W26 V1-V4

Outcomes	Students Learn:	Reg.	Teaching / Learning Strategies	Resources
	4. Transformers allow generated voltage to be either increased or decreased before it is used			
H4 assesses the impact of applications of physics on society and the environment H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields H11 justifies the appropriateness of a particular investigation plan (11.3a, b, c, d) H12 evaluates ways in which accuracy and reliability could be improved in investigations (12.1a, b; 12.3b, c, d) H14 assesses the validity of conclusions from gathered data and information (14.1a, b, c, d, e)	• describe the purpose of transformers in electrical circuits • compare step-up and step-down transformers • identify the relationship between the ratio of the number of turns in the primary and secondary coils and the ratio of primary to secondary voltage • explain why voltage transformations are related to conservation of energy • explain the role of transformers in electricity sub-stations • discuss why some electrical appliances in the home that are connected to the mains domestic power supply use a transformer • discuss the impact of the development of transformers on society • *perform an investigation to model the structure of a transformer to demonstrate how secondary voltage is produced* • *solve problems and analyse information about* $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ *transformers using:* • *gather, analyse and use available evidence to discuss how difficulties of heating caused by eddy currents in transformers may be overcome* • *gather and analyse secondary information to discuss the need for transformers in the transfer of electrical energy from a power station to its point of use*		**Suggested Time: 2 hours** ♦ Use a multicore transformer with several secondary tapping voltages ♦ Create a transformer using two solenoids and a soft iron bar. ♦ Modify experiment 14 to find this ratio. ♦ Do transformer problems. ♦ Using a water analogy helps here. ♦ Students make simple transformers, both step-up and step-down,. and measure primary and secondary voltages. Students create a report on their investigation. ♦ Observe a teacher demonstration of the function of a commercial transformer. Note the features of a partly dismantled commercial transformer. ♦ Identify the parts of a transformer on a diagram or model or sheet. Locate the parts on a partly dismantled commercial transformer ♦ Use power equation (P=VI) and the above demonstration to relate primary current to secondary current in terms of conservation of energy. (*num*) ♦ Review and reinforce concepts by solving worksheet problems on voltage, current and power of transformers. Students apply P=VI and $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ (*num*) ♦ Trace the voltage changes that occur from a power station to a domestic appliance. Identify the type of transformer at each step ♦ Identify home or school mains electrical appliances that use a transformer and discuss the reasons for the necessity of the transformer. (*GT, ESL, lit*) ♦ Observe the laminations in a commercial transformer and discuss their significance in the reduction of eddy currents.	T1-T29 P1-P2 W1-W26 V1-V4

Outcomes	Students Learn:	Reg.	Teaching / Learning Strategies	Resources
	5. Motors are used in industries and the home usually to convert electrical energy into more useful forms of energy			
H4 assesses the impact of applications of physics on society and the environment H7 explains the effect of energy transfers and transformation H9 explains the effects of electric, magnetic and gravitational fields H12 evaluates ways in which accuracy and reliability could be improved in investigations (12.1a, d) H14 assesses the validity of conclusions from gathered data and information (14.1a, b, c, d, e; 14.2a, b, c, d)	• describe the main features of an AC electric motor • *perform an investigation to demonstrate the principle of an AC induction motor* • *gather, process and analyse information to identify some of the energy transfers and transformations involving the conversion of electrical energy into more useful forms in the home and industry*		**Suggested Time: 2 hours** ♦ Pull apart an AC motor. Label the parts of an A.C. motor diagram on a worksheet, after studying a teacher provided OHP diagram and a dissected motor. ♦ Pull apart some power tools. ♦ Pull apart some more AC induction motors. ♦ Use the library or internet to research this issue. ♦ Demonstrate, after student and teacher discussion, the turning effect on a suspended closed circuit solenoid as a magnet is moved past the coils. ♦ Explain that household A.C. motors are not powerful enough/have low efficiency and are not suitable for industrial purposes. Discuss the advantages of 3 phase power. ♦ Study some domestic appliances at home or at school to determine the energy transformations which occur. Identify energy losses as well. Produce a report in the most appropriate form (probably a flow chart). (*SOS, ESL, lit*)	T1-T29 P1-P2 W1-W26 V1-V4

Program Evaluation Sheet

Program: 9.3 Motors & Generators Stage/Course: Physics

Please comment where appropriate on the strengths and weaknesses of this Program. Factors that should be considered include:

1. Time allocation: _____
2. PFAs: _____
3. Domains: Knowledge and Understanding:

   _____

   _____

   Domains: Skills:

   _____

   _____
4. Context:

   _____

   _____
5. Cross-curricular activities are appropriate (Stage 4/5 only)

   _____

   _____
6. Lesson sequence is appropriate:

   _____

   _____
7. Teaching strategies:

   _____

   _____
8. Improvements:

   _____

   _____
9. Assessment:

   _____

   _____

Please use the other side of this sheet for any further comment