Lightning Room

Scienceworks Education Kit

Victoria University High Voltage Theatre

Proudly supported by:
Victoria University, Department of Innovation, Industry and Regional Development, Telstra, AGL, Agility, SP AusNet, Olex Cables, Ed Bondarenko and Associates, TXU, Network Ten.

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Introduction

This education kit has been written to support a visit to the *Lightning Room* at Scienceworks by students in Years 2-12. It explores the following science concepts: static electricity, cells and batteries, electrical safety, energy transformations, the function and use of electrical appliances, electromagnetism, electric circuits and alternating and direct current.

The kit contains background information related to electricity and an excursion to the *Lightning Room*, a resource list, and a range of school-based activities. These activities can be completed before or after a visit to the *Lightning Room*, and should be adapted by teachers to meet the needs of their students.

Some activities include worksheets, which are marked by the following logo:

Details of *Lightning Room* shows are provided on the Scienceworks website.
Shows include audience participation and culminate in the discharge of a giant Tesla Coil, which simulates a lightning strike. The presenter will use this demonstration to highlight what happens during a lightning strike and how to be as safe as possible during electrical storms.

Essential preparation

What to do before you visit the Lightning Room

Please check your confirmation letter to ensure that the details for your excursion are correct. If there is a problem with your booking, please call Scienceworks Bookings on 9392 4819.

Bring your confirmation letter with you on the day of your visit.

Research has shown that setting objectives for a museum visit is extremely important for students. Making the purpose of the excursion clear to students and creating interest in the subject is vital to a successful and enjoyable visit to Scienceworks. This education kit includes a range of activities to prepare students for their visit.

Read the **Medical condition caution** below and assess whether this may affect any of your students.

Medical caution

Lightning Room shows use equipment that emit electrical and magnetic fields. Sudden loud noises also occur in the shows. People with any of the following may be at risk:

- heart pacemakers
- heart conditions
- cochlear implants
- hearing aids and hearing problems
- prostheses (including internal metal wires and pins)
- very young children.

We strongly suggest that people who could be at risk do not attend the show. If it is suspected that you or your students may be affected please seek medical advice before visiting the *Lightning Room*.

Curriculum links

Victorian Essential Learning Standards

This table shows the links between the school-based education activities in the *Lightning Room* education kit and the strands and domains of the Victorian Essential Leaning Standards.

VELS Victorian Essential Learning Standards / School-based education activities		Physical, Personal & Social Learning				Discipline-based Learning						Interdisciplinary Learning			
		Health & Physical Education	Interpersonal Development	Personal Learning	Civics & Citizenship	The Arts	English	Languages Other Than English	Humanities	Mathematics	Science	Communication	Design, Creativity & Technology	Information & Communications Technology (ICT)	Thinking
Static electricity	Activity 1		●								●	●		●	
	Activity 2										●				●
	Activity 3		●								●				
	Activity 4		●	●			●			●	●	●		●	●
Cells and batteries	Activity 5									●	●		●		
	Activity 6									●	●		●		●
	Activity 7									●	●		●	●	●
Electric circuits	Activity 8									●	●		●		●
	Activity 9		●				●				●	●		●	
	Activity 10	●	●	●			●				●	●		●	
Electricity and magnetism	Activity 11									●	●			●	●
	Activity 12			●							●				●
Generators	Activity 13										●	●		●	●
	Activity 14	●	●	●			●		●		●	●		●	●
	Activity 15		●				●		●		●	●	●	●	

Gardner's Multiple Intelligences and Bloom's Taxonomy

This table shows the links between the school-based education activities in the *Lightning Room* education kit, Howard Gardner's Multiple Intelligences and Bloom's Taxonomy.

School-based education activities		Gardner's Multiple Intelligences: Verbal - Linguistic	Logical - Mathematical	Picture - Spatial	Body - Kinaesthetic	Music - Auditory	Interpersonal	Intrapersonal	Bloom's Taxonomy (First three levels of Cognitive Domain): *Knowledge*	*Comprehension*	*Application*
Static electricity	Activity 1	●					●		●		
	Activity 2		●					●	●	●	
	Activity 3		●		●		●			●	●
	Activity 4	●	●	●		●	●		●	●	
Cells and batteries	Activity 5		●						●	●	●
	Activity 6		●					●	●	●	●
	Activity 7		●	●						●	●
Electric circuits	Activity 8		●	●					●	●	
	Activity 9	●	●				●		●	●	
	Activity 10	●	●	●			●		●	●	●
Electricity and magnetism	Activity 11		●	●					●		
	Activity 12		●					●	●	●	
Generators	Activity 13		●					●	●	●	
	Activity 14		●						●	●	●
	Activity 15	●	●	●			●		●	●	

VCE Physics

The student shows conducted in the *Lightning Room* at Scienceworks and the school-based activities in this kit relate closely to several Outcomes and suggested Learning Activities specified in the current Victorian Certificate of Education Study Design for Physics.

Unit 1

Area of Study 2: Electricity

Investigate and apply a basic DC circuit model to simple battery operated devices, and to car and household (AC) electrical systems, and describe the safe and effective use of electricity by individuals and the community.

- Explore conceptual understandings and prior conceptions of electricity.
- Read an article on 'electric shock' and make notes on what happens when someboday receives an electric shock.
- Make a table of typical power usage of domestic appliances and investigate domestic electrical safety provisions.
- Use a simulation program to model the operation of a DC circuit.

Unit 2

Area of Study 3.5: Sustainable energy sources

- Find information about alternative ways to generate electricity, such as solar, wind, tidal, wave, oceanic thermal currents, geothermal, hot dry rocks.

Unit 4

Area of Study 1: Electric power

Investigate and explain the operation of electric motors, generators and alternators, and the generation, transmission, distribution and use of electric power.

- Use iron filings and/or small compasses to investigate the shape of magnetic fields surrounding permanent magnets, current carrying conductors and solenoids.
- Demonstrate electromagnetic induction by changing the magnetic flux threading a solenoid.
- Demonstrate the motor effect using a pemanent magnet and a current carrying conductor.
- Analyse a low-voltage model of a transmission system.
- Investigate different types of AC generation power plants.
- Build and investigate an electric motor.

High Voltage FAQs

Q. Why is lightning coloured blue, purple or white?
A. When lightning strikes, the gases in the air, oxygen and nitrogen, become excited. They then release energy in the form of light. The colours produced are due to the temperature of the gases – white light is extremely hot, while blues and purples are hotter than reds and oranges.

Q. What's the cage in the *Lightning Room* for?
A. The metal cage surrounding the high voltage equipment is known as a Faraday Cage. It is used to protect us from the electrical sparks produced by the Tesla Coil. It also stops the radio waves produced by the high voltage equipment from escaping and interfering with phones, computers and other electrical devices. Finally it blocks out the strong electric and magnetic fields that are generated within the cage.

Q. If I touch the cage after the Tesla Coil has stopped, will I receive a shock?
A. No. The cage is connected to the ground. This allows the electricity to travel into the Earth's crust where it is safely dispersed.

Q. Why does my hair stand on end when I am in contact with the Van de Graaff generator?
A. When you touch the Van de Graaff generator, the positive charge on the dome attracts electrons (negative charge) from your body. This causes positive charges to accumulate on the surface of your body. Like charges repel each other, so the positive charges that are on the individual strands of your hair repel each other. When this happens your hair stands on end.

Q. Why don't I receive a shock when I'm touching the Van de Graaff generator?
A. When you are in contact with the Van de Graaff generator, you should also be standing on a plastic box. Plastic is an insulator and does not conduct the electricity to the ground. For you to receive a shock, there has to be a movement of charge (a current) across your body to the ground.

Q. How is the can crushed in the *Can Crusher* when there are no moving parts?
A. Electric currents make magnetic fields. (Think of electromagnets!) We place the can inside a coil of wire in the Can Crusher Machine. The large capacitor makes a changing current flow through the coil. This generates a changing magnetic field around the coil and through the can. This, in turn produces an electric current on the surface of the aluminium can. This current then produces its own magnetic field. The two magnetic fields repel each other and the can is crushed in the process.

Q. How is lightning formed?
A. Thunderstorms are caused by rapidly rising and falling streams of air inside very tall clouds. The friction forces between these streams of air cause electrical charges to gather in different parts of the cloud. The bottom of the cloud becomes negatively charged. The upper part of the cloud becomes positively charged. When the attraction between the positive and negative charges grows strong enough, the charges travel though the air as lightning.

Q. How does lightning strike the Earth?
A. The negative charge at the bottom of a cloud makes the ground below the cloud become positively charged. When the negative charge becomes great enough a small stream of negative charge escapes and rushes towards the ground. As this stream nears the ground, a stream of positive charges rises up to meet it. When this happens it creates a conducting pathway between the cloud and the ground, allowing the visible lightning to occur. http://museumvictoria.com.au/scidiscovery/lightning/whatmakes.asp

Q. What causes thunder?
A. The air around a lightning bolt is superheated to about 30,000°C – five times hotter than the Sun's surface!. This sudden heating causes the air to rapidly expand and then contract again as it cools. This forms a shock wave that travels out through the air. We hear it as thunder.

Lightning Quick Facts

- Around 45,000 lightning storms occur every day throughout the world. These produce approximately 6,000 lightning strikes per minute! Since your last breath, lightning has struck the Earth over 100 times.

- 9 out of 10 lightning bolts strike the land rather than the sea.

- Lightning can, and often does, strike more than once in the same place. The Empire State Building in New York City is struck by lightning about 100 times every year.

- The diameter of a typical lightning bolt is around the same as a 20 cent coin! Lightning looks much wider because its light is so bright.

Notice the small leader strokes still visible to the left of the main stroke.
Photographer: Michale Fewings
Source: strikeone.com.au

Safety in an electrical storm

Estimating distance

You see lightning before you hear the thunder because light travels almost a million times faster than sound. It takes sound about three seconds to travel one kilometre. When you see lightning, count the seconds before the thunder arrives. Divide this number by 3 and you'll know approximately how many kilometres you are from the lightning strike. If you are less than ten kilometres from the lightning strike, you are in danger of being struck by lightning.

If caught outdoors

- Never shelter under trees.
- If far from shelter, crouch down in a low area but don't lie down flat.
- Remove metal objects from your head and body.
- If your hair stands on end or you hear 'buzzing' from nearby rocks, fences, etc, move immediately.
- Don't fly kites or handle fishing rods, umbrellas or any objects with metal parts.
- Don't ride horses, bicycles or travel in open vehicles.
- If driving, slow down or park away from trees, power lines, etc.
- Stay inside metal-bodied vehicles or caravans but turn off the radio and don't touch any metal sections.
- If swimming, surfing etc, leave the water immediately.
- If boating, go ashore to shelter as soon as possible.

If indoors

- Before the storm arrives, disconnect aerial and power leads to electrical appliances.
- Close all curtains and keep clear of windows, electrical appliances, pipes and other metal fixtures.
- Avoid the use of fixed telephones or water taps.
- Avoid touching brick or concrete, or standing bare-footed on concrete or tiles.

Visit the website of the US National Weather Service for lots of information about lightning and lightning safety:
http://www.lightningsafety.noaa.gov/index.htm

Photo Courtesy of Douglas Berry
http://www.lightningsafety.noaa.gov/photos.htm

Features of the Lightning Room

Faraday Cage

The *Lightning Room* houses a huge Faraday Cage, containing the largest Tesla Coil on public display anywhere in the world. The Tesla Coil produces the spectacular high voltage 'lightning' display, while the Faraday Cage restricts the transmission of associated electromagnetic radiation, particularly at radio-frequencies.

A Faraday Cage is a complete cage made of metal or metallic meshwork. It is named after Michael Faraday (1791-1867), a British physicist.

Faraday discovered that if a hollow conductor is given a charge on its inside, then the charge will spread evenly over the outside surface of the conductor in such a way as to produce no electric field inside. It is also true that a hollow metal conductor will protect the interior from external electric fields.

Aircraft are frequently struck by lightning, but this does not harm the plane or passengers. The metal body of the aircraft acts as a Faraday Cage and protects the interior. For the same reason a car is a relatively safe place to be in a thunderstorm.

If a region in space is completely surrounded by a Faraday Cage, electromagnetic waves are effectively prevented from entering or leaving the enclosed region. The cage can be a mesh because electromagnetic waves do not penetrate very far through holes. It is therefore possible to make a 'see-through' Faraday Cage without affecting its performance, provided that the holes are small enough.

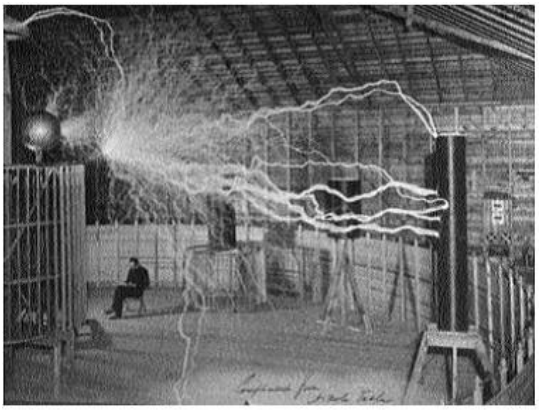
Part of the Faraday Cage in the *Lightning Room*

Faraday Cages are used in all high-voltage laboratories to prevent radio-frequency interference (RFI) from leaving the cage and affecting electronic equipment such as computers and aircraft navigation devices. They are also used in hospital rooms where nuclear magnetic resonance (NMR) investigations are carried out.

All NMR experiments including MR imaging and MR spectroscopy have to be performed in a Faraday Cage to prevent radiofrequency waves from ambient sources from interfering with the reception of the radio waves emitted from the sample (patient) during the experiment.

Tesla Coil

The 'lightning' that is a feature of the shows presented in the *Lightning Room* is generated by a large Tesla Coil situated in the centre of the Faraday Cage. Tesla Coils are transformers that discharge very high voltage electricity through the air in spectacular arcs. They were invented by Nikola Tesla in about 1891.



Nikola Tesla timeline

Nikola Tesla has been called the father of radio, television, power transmission, the induction motor, and the robot, and the discoverer of the cosmic ray.

1856 Born July 9 in Smiljan, Croatia (then part of Austria-Hungary).

1884 Moved to the United States and began working for Thomas Edison.

1887 Filed for seven U.S. patents in the field of polyphase AC motors and power transmission. These comprised a complete system of generators, transformers, transmission lines, motors and lighting.

1888 Designed the first practical system of generating and transmitting alternating current for electric power.

1888 Invented the first practical AC induction motor.

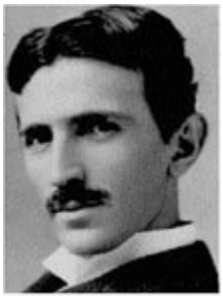
1890 Illuminated a vacuum tube wirelessly, using energy transmitted through the air.

1891 Patented the Tesla Coil.

1893 Displayed phosphorescent lighting powered without wires by high-frequency fields.

1895 Began experimentally monitoring the radio emissions of his high-frequency generators.

1896 November 16, Tesla's AC generators supply electricity using Niagara Falls as the source of energy.



1897 Filed basic radio patent.

1898 Demonstrated his remote-control boat at Madison Square Garden in New York City to an astonished group of potential investors.

1899 Built his largest Tesla Coil (15.6 metres in diameter and generating pulses as high as 12 million volts).

1943 Died January 7.

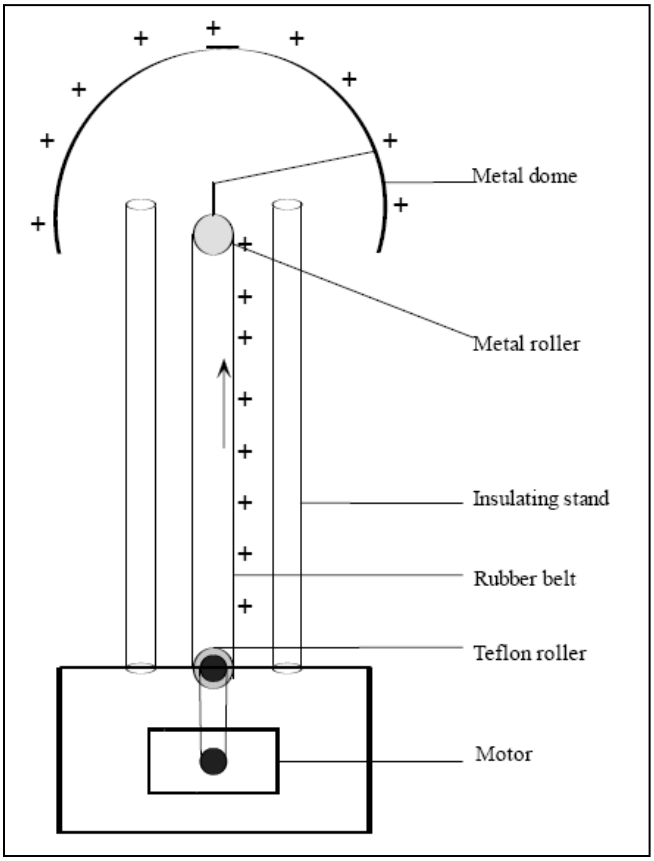
Van de Graaff Generator

Van de Graaff Generators are machines which employ a moving belt to produce very high electrostatic voltages on a hollow metal globe. They were invented by Robert J Van de Graaff at Princeton University in 1929.

The Van de Graaff Generator used in the *Lightning Room* consists of a motor, a Teflon roller, a metal roller, a metal dome, a rubber belt and an insulating column to keep the dome separated from the base.

The motor rotates the Teflon roller. As the rubber belt separates from the roller it becomes positively charged. This happens because when different materials are rubbed together they transfer charge from one to the other. This leaves one of the materials carrying a positive charge and the other carrying a negative charge. The amount of charge transferred and which material becomes positive and which becomes negative can be determined by examining the triboelectric series. (See below.)

The rubber belt carries the positive charge to the metal roller. The positive charges attract negative charges (electrons) off the metal roller and the inside of the dome. This causes the dome to become positively charged. The positive charge is distributed across the metal dome. When a person isolated from the earth touches the dome they become positively charged also.



The Triboelectric Series

+ Positive

Air
Human skin
Asbestos
Rabbit fur
Glass
Human hair
Nylon
Wool
Silk
Aluminium, zinc
Paper
Cotton
Steel
Wood
Hard rubber
Copper, nickel, carbon
Brass, silver
Gold, platinum
Polyester
Polyurethane
Polyethylene
PVC (vinyl)
Teflon

– Negative

Glossary

Alternating current	A flow of electric current in which the direction of movement periodically changes. The number of complete cycles in a second is called the frequency. In Australia, AC current has a frequency of 50 cycles per second or 50 Hertz.
Ammeter	An instrument which measures electric current.
Ampere	The unit of measurement for electric current. It corresponds to the flow of approximately 6 x 10^{18} electrons per second. Ampere is usually shortened to amps or A.
Arc	A brief flash of light caused by an electric current moving through a gas between two points with a high voltage difference. An arc lasts much longer than a spark.
Atom	The basic particle, or 'building block' of all matter. Atoms consist of a positively charged centre, called the nucleus, surrounded by negatively charged electrons.
Battery	A battery is a combination of cells connected together in series. Most car batteries are made up of six separate cells.
Capacitor	A pair (or pairs) of conductors separated by insulators. A capacitor stores electric charge.
Cell	A single device that changes chemical energy into electrical energy. It usually consists of two electrodes and a conducting liquid called an electrolyte. Many commonly used batteries (for example a D-sized torch battery) more correctly should be called a cell.
Charge	A basic property of all matter (see Atom). Charge can be positive or negative. Negative charges, or electrons, can be transferred from one material to another. An excess of electrons results in an object having a negative charge and a deficiency of electrons results in an object having a positive charge. The unit of measurement of charge is the coulomb (C).
Conductor	An object or substance through which electricity can flow easily.
Coulomb	The unit of measurement of electric charge. One coulomb is the amount of charge carried by approximately 6 x 10^{18} electrons.
Current	A flow of electrons from one place to another. The symbol for current is I. Current is measured in amperes (A).

Direct current	A flow of electric current in one direction only. Batteries supply direct current (DC).
Dry cell	A cell where the conducting liquid (electrolyte) is in the form of a paste or jelly so that it doesn't spill. The common torch battery is an example of a dry cell.
Electricity	A general term for the phenomena associated with electrons at rest or in motion.
Electrode	A conductor which allows electricity to flow in or out of a material or object. Electrodes are usually made from a metal or graphite.
Electromagnet	A coil of wire which only becomes magnetic when electricity passes through it. The coil may be wound around a material such as iron to increase the magnetic effect.
Electron	A sub-atomic particle found in every type of atom. Electrons have a negative charge and are found outside the nucleus of an atom.
Electrolysis	A method of separating chemically bonded elements and compounds by passing an electric current through them.
Galvanisation	An electrolytic process where iron objects are coated with a thin layer of zinc. This reduces the rate at which the iron rusts.
Galvanometer	An instrument which can be converted for use as a voltmeter or an ammeter.
Generator	A machine which converts one form of energy into another. An electricity generator converts kinetic energy into electrical energy.
Induction (electromagnetic)	The creation of an electric current in a circuit as a result of it being close to a changing magnetic field. For example, in an electric generator, a current arises in a wire that is wound around a cylinder (a solenoid) when a magnet is moved inside the cylinder.
Insulator	An object or material that has a high resistance to the flow of electricity.
Leyden Jar	An old fashioned device for storing static electricity.
Magnet	A piece of metal that exists naturally with a magnetic field surrounding it. This field exerts a force on other magnets and iron pieces.
Motor (electric)	A machine which converts electrical energy into kinetic energy.

Ohm	The unit of measurement of the resistance to the flow of electric current in a circuit. Ohms is often represented by the symbol Ω.
Parallel circuit	A way of arranging wires and 'appliances' in a circuit The circuit is in parallel when the current flowing has more than one pathway to flow through.
Resistance	The tendency for materials to resist the flow of electric current and convert electrical energy into heat. The unit of measurement for resistance is the ohm. The symbol for resistance is R.
Series circuit	A way of arranging wires and 'appliances' in a circuit. A circuit is in series when all the parts are arranged end to end in a continuous path.
Solar cell	A device for converting the Sun's energy into electrical energy. A solar panel is made up of many solar cells.
Solenoid	A coil of wire which is usually wound around a tube. It is used to produce a magnetic field (see electromagnet).
Spark	A brief flash of light caused by an electric current moving through a gas between two points with a high voltage difference. A spark lasts for a very short time.
Static electricity	Electric charge acquired by an object as a result of being rubbed, being brought close to, or touching another charged object.
Transformer	A device used to alter voltage or (alternating) current. They work without moving parts by the process of electromagnetic induction.
Volt	A unit of measurement of voltage. Voltage is a measure of the amount of electrical energy available. The symbol for volt is V.
Voltmeter	An instrument which measures voltage.
Watt	The unit of measurement of power. In electrical systems it is the number of amps multiplied by the number of volts. The symbol for watt is W.
Wet cell	A cell where the electrolyte is in the form of a liquid. This means that they must be kept upright to avoid spillage. Most car batteries are wet cells.

Resources

Internet addresses

Facts about lightning:

Museum Victoria
http://museumvictoria.com.au/scidiscovery/lightning/index.asp

How Stuff Works
http://science.howstuffworks.com/search.php?terms=lightning&x=53&y=20

Bureau of Meteorology
http://www.bom.gov.au/info/thunder/#protectionn

Space.com
http://www.space.com/scienceastronomy/lightning_backgrounder.html

Public Broadcasting Service (PBS) (USA)
http://www.pbs.org/wnet/savageplanet/03deadlyskies/01lforms/indexmid.html

Information on Nikola Tesla:

Nick's Personal Website
http://nickf.com/tesla.php

PBS: Tesla for Teachers
Includes lesson plans on mechanical – electrical energy conversion
http://www.pbs.org/tesla/tt/index.html

Stoneridge Engineering
Tesla timeline
http://205.243.100.155/frames/tesla.html

Exploratorium, San Francisco
Simple activities on electricity
http://www.exploratorium.edu/snacks/iconelectricity.html

Science Made Simple
Detailed information about static electricity and fun experiments to try
http://www.sciencemadesimple.com/static.html

Ergon Energy (Qld)
Activities on electricity suitable for students in Years 1-10
http://www.ergon.com.au/ergonia/aboutelec.shtml

University of New South Wales
Animations on electric motors and generators for senior students
http://www.physclips.unsw.edu.au/jw/electricmotors.html#schematics

Energy Safe Victoria
Information on safety when using electricity
http://www.esv.vic.gov.au/

Excursion ideas

CERES (Centre for Education and Research in Environmental Strategies)
The Energy Park provides access to a variety of hands-on activities and demonstrations on energy use, alternative technologies, energy efficient building design and smart energy solutions. Programs cater for primary, secondary, VCE and tertiary groups.

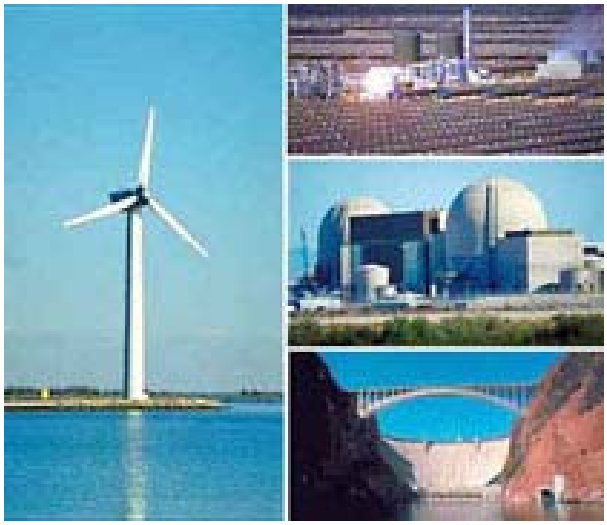
Cnr Roberts and Stewart Streets
BRUNSWICK EAST, 3057
Ph: (03) 9387 2609
http://www.ceres.org.au//

PowerWorks Museum Exhibition Centre
Provides power station and mine tours for primary and secondary students.

Ridge Road
MORWELL, 3840
Ph: (03) 5135 3415
http://www.powerworks.com.au//

Alternative Technology Association
Information and events promoting energy conservation.

Level 1, 39 Little Collins St.
MELBOURNE, 3000
Ph: (03) 9639 1500
http://www.ata.org.au//



Clockwise from top-right: Solar-electric power station; nuclear power plant; hydroelectric dam; wind turbine
http://www.howstuffworks.com/hydrogen-economy4.htm