NZ Transport Agency Rail Safety Resource – Primary – Level 1 to Level 4 Science			
What is the big idea or focus?	**What is the key understanding – Why is it important for my students right now?**	**Driving question**	**Focus tasks for assessment** *Understanding and skills*
Citizenship. Science: Physical world: Physical Inquiry and Physical Concepts: Energy: Electrical Energy. In the context of keeping safe around the electrified rail network.	When you are a citizen you belong, you matter and you make a difference. Citizens work together to create safe journeys for everyone around the electrified rail network. Energy exists in many forms. Energy can be transformed when things change or are made to happen.	What is worth knowing and doing as a citizen around places on the electrified rail network? **Stay away from overhead wires carrying electrical energy.** *The electrical energy that moves trains is always dangerous and always on.* *You cannot hear, see or smell electrical energy.* *The electrical energy is 100 times more powerful than the electrical energy used at home.* *The electrical energy can jump gaps of up to 3 metres.* *When electrical energy passes through people, it kills or seriously injures them.* **Always use level crossings to get across the tracks.** *Trains on the tracks are very big, very fast and very quiet.* *Trains take a long time to stop.* *It is dangerous to take shortcuts and trespass.* **Watch out for the second train.** *Obey all warning signs and signals.* *Wait until all warning signs have stopped before crossing – there may be a second train.* *Look and listen in both directions.*	1. **Describe** how electrical energy is transferred in the electrified rail network in ways that keep citizens safe. [multistructural] 2. **Explain why** transferring electrical energy in these ways will keep citizens safe around the electrified rail network. [relational] 3. **Take action to share this information** to help keep citizens safe around the electrified rail network. [extended abstract]
Learning area Essence statement:	**Links to other learning areas:**	**NZC Values**	**NZC Key Competencies**
Science		Excellence	**Thinking** – Critically analyse the factors

In science, students explore how both the natural physical world and science itself work so that they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role.		Innovation, inquiry, and curiosity Diversity Equity Community and participation Ecological sustainability Integrity Respect	contributing to safe electrified rail networks for all citizens. **Managing self** – Act responsibly when around the electrified rail network as a pedestrian, passenger, cyclist or driver to ensure all citizens keep safe. **Participating and contributing** – Display an awareness of the local issues around creating and maintaining safe electrified rail networks. Be actively involved in community issues around safe electrified rail networks. **Relating to others** – Interact with others to create safe electrified rail networks. **Making meaning from language, symbols and text** – Interpret and use language, symbols and text in ways that keep citizens safe around electrified rail networks.

Strand	**Achievement objectives** *Select the achievement objectives that best match the NZTA focus - concept and context - for your students*	**Suggested learning intentions** *(SOLO verbs – e.g. Define, Describe, Sequence, Classify, Compare / Contrast, Explain, Analogy, Analyse, Generalise, Predict, Evaluate, Create)* Use constructive alignment to design SOLO differentiated learning intentions (intended learning outcomes) to match the unit's content. http://pamhook.com/solo-apps/learning-intention-generator/
Nature of Science – Investigating in science	***Levels One and Two*** *- Extend their experiences and personal explanations of the natural world through exploration, play, asking questions, and discussing simple models.* ***Levels Three and Four*** *- Build on prior experiences, working together to share and examine their own and others' knowledge.* *- Ask questions, find evidence, explore simple*	**Bringing in ideas** **Explore** an experience in the natural world related to electrical energy. **Share** an experience in the natural world related to electrical energy. **Describe** an experience in the natural world related to electrical energy. **Explore** simple models of an experience in the natural world related to electrical energy. **Connecting ideas** **Formulate questions** about an experience in the natural world

	models, and carry out appropriate investigations to develop simple explanations.	related to electrical energy. **Explain** an experience in the natural world related to electrical energy. **<u>Extending ideas</u>** **Investigate** an experience in the natural world related to electrical energy. **Create** a simple model for an experience in the natural world related to electrical energy.
Nature of Science – Participating and contributing	***Levels One and Two*** *- Explore and act on issues and questions that link their science learning to their daily living.* ***Levels Three and Four*** *- Use their growing science knowledge when considering issues of concern to them.* *- Explore various aspects of an issue and make decisions about possible actions.*	**<u>Bringing in ideas</u>** **Identify** an issue about a [physical phenomenon] on the electrified rail network. **Describe** an issue related to a [physical phenomenon] on the electrified rail network. **List** possible solutions to an issue related to a [physical phenomenon] on the electrified rail network. **Describe** one or more solutions to an issue related to a [physical phenomenon] on the electrified rail network. **<u>Connecting ideas</u>** **Ask questions** about [physical phenomena] on the electrified rail network. **Explain the causes** for an issue related to a [physical phenomenon] on the electrified rail network. **Explain the effect** of an issue related to a [physical phenomenon] on the electrified rail network. **Compare and contrast** solutions to an issue related to a [physical phenomenon] on the electrified rail network. **<u>Extending ideas</u>** **Create** a model of an issue related to a [physical phenomenon] on the electrified rail network. **Evaluate** the effectiveness of solution/s to an issue related to a [physical phenomenon] on the electrified rail network. **Act on** an issue related to a [physical phenomenon] on the electrified rail network.

Nature of Science – Communicating in science	***Levels One and Two*** *- Build their language and develop their understandings of the many ways the natural world can be represented.* ***Levels Three and Four*** *- Begin to use a range of scientific symbols, conventions, and vocabulary.*	**<u>Bringing in ideas</u>** **Demonstrate** the use of scientific symbols when exploring the use of electrical energy to make something happen. **Demonstrate** the use of scientific conventions when exploring the use of electrical energy to make something happen. **Demonstrate** the use of scientific vocabulary when exploring the use of electrical energy to make something happen.
Physical World – Physical inquiry and physics concepts	***Levels One and Two*** *- Explore everyday examples of physical phenomena, such as movement, forces, electricity and magnetism, light, sound, waves, and heat.* *- Seek and describe simple patterns in physical phenomena.* ***Levels Three and Four*** *- Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as movement, forces, electricity and magnetism, light, sound, waves, and heat. For example, identify and describe the effect of forces (contact and non-contact) on the motion of objects; identify and describe everyday examples of sources of energy, forms of energy, and energy transformations.*	**<u>Bringing in ideas</u>** **Define** [physical phenomena]. **Identify/find** everyday examples of things that use electrical energy and magnetism to make something happen. **List** everyday examples of things that use electrical energy and magnetism to make something happen. **Describe** everyday examples of things that use electrical energy and magnetism to make something happen. **<u>Connecting ideas</u>** **Classify** everyday examples of things that use electrical energy and magnetism to make something happen. **Sequence** the steps involved in operating something that uses electrical energy and magnetism to make something happen. **Compare and contrast** everyday examples of things that use electrical energy and magnetism to make something happen. **Explain the cause for** using electrical energy and magnetism to make something happen. **Explain the effect of** using electrical energy and magnetism to make something happen. **Explain how** electrical energy and magnetism can be used to make something happen. **Analyse** something that uses electrical energy and magnetism to make something happen. **<u>Extending ideas</u>** **Make a generalisation** about things that use electrical energy and magnetism to make something happen

		Create an action in response to an everyday example of things that use electrical energy and magnetism to make something happen. **<u>Bringing in ideas</u>** **Identify/find** everyday examples of the use of electrical energy and magnetism on trains and tracks. **Describe** everyday examples of electrical energy and magnetism on trains and tracks. **<u>Connecting ideas</u>** **Classify** everyday examples of the use of electrical energy and magnetism on trains and tracks. **Sequence** an everyday example of the use of electrical energy and magnetism on trains and tracks. **Compare and contrast** everyday examples of the use of electrical energy and magnetism on trains and tracks. **Explain the causes for** an everyday example of the use of electrical energy and magnetism on trains and tracks. **Explain the effect of** an everyday example of the use of electrical energy and magnetism on trains and tracks. **Analyse** an everyday example of the use of electrical energy and magnetism on trains and tracks. **<u>Extending ideas</u>** **Make a generalisation** about an everyday example of the use of electrical energy and magnetism on trains and tracks. **Create an action** in response to an everyday example of the use of electrical energy and magnetism on trains and tracks.

Learning activities/learning experiences
Build learning activities and experiences for SOLO differentiated learning intentions.
Choose learning intentions that match your students' prior learning, interests and abilities.

Science: Physical World: Physical Inquiry and Physical Concepts: Energy: Electrical Energy.

Think like a scientist about the energy that moves electric trains.

What action would best keep citizens safe around electrical energy that is moving trains on the rail network?

Determining prior knowledge, identifying misconceptions
Determining prior knowledge is a starting place for all learning.

Ask students to:

- Pause – clear your mind and then think deeply about electrical energy.
- Discuss the following question prompts in turn.
  - **Have you** or anyone you know used electrical energy to make something happen?
  - **What happened?**
  - **How did the electrical energy make it happen?**
  - **What happened afterwards**?
  - **What are** the dangerous things you know to watch out for when you use electrical energy to make something happen?
  - **What have you done** around electrical energy that could be dangerous?
  - **Why do you think** you behaved dangerously?
  - **What have you seen** other people do around electrical energy that could be dangerous?
  - **Why do you think** people act in potentially dangerous ways around electrical energy?
  - **How do you feel** when you see people acting in potentially dangerous ways around electrical energy?
  - **What do you do** when you see people acting in potentially dangerous ways around electrical energy?
  - **What do kids need to know** about keeping safe around electrical energy?
  - **What do grownups need to know** about keeping safe around electrical energy?
- Record (write or draw) your answers to each question on separate Post-it notes.
- Label each Post-it note with the date.
- At the end of the discussion on each question, stick your answer onto a large sheet of newsprint labelled with the question prompt.
- Repeat this process with each question prompt.

Keep a record of the prior knowledge of your class.

SECTION 1: What is worth knowing and doing as a citizen around places on the electrified rail network?

Bringing in ideas

These activities provide opportunities for students to bring in ideas about energy and energy transfer in the context of citizens using the electrified rail network.

Learning intention: Describe how electrical energy is transferred in the electrified rail network in ways that keep citizens safe. [multistructural]

Differentiated success criteria: We will know we have achieved this because …

Multistructural	*My description has several relevant ideas about the use of electrical energy in the rail network that are important for keeping safe*
Relational	*… and explains why these ideas are relevant to keeping safe*
Extended abstract	*… and makes a generalisation about the use of electrical energy and keeping safe.*

Key Competency self-assessment rubric[1] Highlight the relevant Key Competencies for section 1.

Thinking	Managing self	Participating and contributing	Relating to others	Using language, symbols and text
Critically analyse the factors contributing to safe electrified rail networks for all citizens. *Example – describe, explain and justify ways to stay safe at places on the electrified rail network.*	Act responsibly when around the electrified rail network as a pedestrian, passenger, cyclist or driver to ensure all citizens keep safe. *Example – adopt a "sort it and report it" approach to unsafe behaviour around the electrified rail network.*	Display an awareness of the local issues around creating and maintaining safe electrified rail networks. Be actively involved in community issues around safe electrified rail networks. *Example – listen, respond and act together to make the electrified rail network a system free of death and serious injury.*	Interact with others to create safe electrified rail networks. *Example – demonstrate a commitment to safer outcomes for self, friends, family and whānau at places on the electrified rail network.*	Interpret and use language, symbols and text in ways that keep citizens safe around electrified rail networks. *Example – share safe rules and behaviours for places on the electrified rail network.*

[1] For draft versions of these Key Competency self-assessment rubrics, see the appendix to this Rail Safety Resource.

1.0. Think like a scientist about the energy that moves electric trains
What action would best keep citizens safe around the electrical energy that moves trains on the electrified rail network?

What is worth knowing and doing as a citizen and a scientist around places on the electrified rail network?

- **Stay away from overhead wires carrying electrical energy.**
  - *The electrical energy that moves trains is always dangerous and always on.*
  - *You cannot hear, see or smell electrical energy.*
  - *The electrical energy is 100 times more powerful than the electrical energy used at home.*
  - *The electrical energy can jump gaps of up to 3 metres.*
  - *When electrical energy passes through people, it kills or seriously injures them.*
- **Always use level crossings to get across the tracks.**
  - *Trains on the tracks are very big, very fast and very quiet.*
  - *Trains take a long time to stop.*
  - *It is dangerous to take shortcuts and trespass.*
- **Watch out for the second train.**
  - *Obey all warning signs and signals.*
  - *Wait until all warning signs have stopped before crossing – there may be a second train.*
  - *Look and listen in both directions.*

Think like a scientist about physical phenomena – like the movement of trains on the electrified rail network.

Background: A **physical phenomenon** is an event – something that happens that you can observe (or detect using an instrument). Examples of physical phenomena include movement, forces, electricity and magnetism, light, sound, waves and heat. The spark from static electricity in a storm cloud is a physical phenomenon; so is your hair standing on end after you have taken off a woollen beanie. The electric train moving along the tracks is a physical phenomenon; so is the arcing of electrical charge from the live contact wire to the pantograph when ice builds up on the wires above the train.

Scientists explore physical phenomena by:

- **observation** (What can I see?)
- **inference** (Why do I think it is like that? Explaining the observations)
- **wondering/predicting** (What does it make me wonder? Making a forecast based on what you already know).

Watch a video clip showing an electric train moving across the rail network.
Auckland Transport: First test run for Auckland's new train: http://youtu.be/wdEAZbGlAFs

Discussion prompts
[think-pair-share, or small group or whole class discussion only]

What do you see? Why do you think it is like that? What does it make you wonder?

If you are a citizen using the electrified rail network, what is worth knowing about electrical energy and energy transfer?

1.1. What is the electrified rail network and what does it do?

Background: The New Zealand rail network

In New Zealand the electrified rail network uses electrical energy to make trains move.

The newly built trains (or electric multiple units, EMUs) on the Auckland electrified rail network use electrical energy to move. The trains use this electrical energy to carry up to 375 passengers along with their bicycles, pushchairs, wheelchairs, guide dogs and luggage at speeds of 110km/h. To transport 375 passengers in another way, you would need approximately 8 buses or up to 375 cars and they would have to travel much more slowly.

The electrified rail network has many advantages over the old diesel-powered network. It offers a faster, more environmentally friendly way for people to get around the city. The new train service is faster because the new trains powered by electrical energy can accelerate (and decelerate) twice as fast as the older diesel-powered trains. The new electric trains are also more energy efficient and quieter, and make no air pollution.

Citizens interact with the electrified rail network all the time: when waiting at the station platform for a train to arrive or depart; when travelling as passengers on trains using the rail network; and when crossing the rail network at level crossings or overbridges as pedestrians or cyclists or in cars.

The electrified rail network has hazards as well as advantages. Electrical hazards include shock hazards, arcing hazards, blast hazards and possible electromagnetic field hazards from the high voltage used to transfer energy to the train. The electricity is never switched off so these hazards are always present on and around the rail network. You don't need to touch an electrified source to be electrocuted – high-voltage electricity can jump from one conductor to another. Any activity that brings you or objects you are holding close to the live wires is highly dangerous. Even if the shock doesn't kill you, you will suffer horrible burns and injuries that will affect you for the rest of your life.

Other hazards are associated with the way trains move on the rail network. Heavy trains move along the track at high speeds (110km/h). They cannot swerve or stop quickly to avoid you. Adding to the danger, the electric trains move very quietly; you cannot hear them coming.

Because they are travelling at a high speed, trains need a long distance to stop. By the time a driver sees someone on the tracks, the train cannot stop soon enough to avoid hitting them.

The high speed makes it hard for people to predict how far away the train is so they can make the wrong decision about when it is safe to cross. A train travelling at 110km/h takes only 5 seconds to travel 150m. Never try to "beat the train".

Trains can travel in any direction, on any line, at any time. You can never be sure where the next train is coming from or which track it is using. Even when you are certain the first train has passed, you can be hit by the second train travelling at high speeds on the other track.

The high speeds also create turbulence. If you are standing too close to the tracks or the edge of the platform, you can be dragged under the train.

A train track on the electrified rail network is like a corridor overstuffed with dangers you cannot see, hear or control. For all these reasons crossing the tracks as a pedestrian or cyclist or in a car will always be highly dangerous. The only safe way to get from one side of the tracks to the other is to use a railway overbridge, footbridge or level crossing.

There are many other safety systems and structures built into the rail corridor to keep people safe while they use trains. You can see these systems and structures at stations, on platforms and on trains and tracks.

The electrical energy moves up to 375 passengers (along with their bicycles, pushchairs, wheelchairs, guide dogs and luggage) at speeds of 110km/h.

As a class, study images and video of trains using the electrified network. Arrange a visit to the electrified rail network; while there, observe, ask questions and take photographs of what you see. Invite people who have used the electrified rail network or who work for the electrified rail network to visit your class.

Ask students to use the ideas and information they have gained to write (or draw) a class description of the electrified rail network and what it does. Include a section that describes the hazards that citizens must manage if they are to stay safe around the rail network.

Resources
You can select photographs and video of electrical energy being used to move trains from the resources below. Include images of electric trains, pantograph, overhead wires (catenary and contact), level crossings, overbridges and warning signs. When sharing the resources with students, encourage them to think like a scientist about using electrical energy to move trains.

All About Our New Electric Trains: http://www.aktnz.co.nz/2011/10/06/all-about-our-new-electric-trains/
Auckland Electrification Safety: http://www.kiwirail.co.nz/projects/major-projects/auckland-rail-electrification/auckland-electrification-safety.html
Live Wire: http://youtu.be/2TQ6QCs4rqo
Staying Safe Around the Electrified Rail Network: http://www.kiwirail.co.nz/projects/major-projects/auckland-rail-electrification/auckland-electrification-safety/staying-safe.html
If You Live Next to the Rail Tracks: http://www.kiwirail.co.nz/projects/major-projects/auckland-rail-electrification/auckland-electrification-safety/living-next-door.html
Level Crossings: http://www.kiwirail.co.nz/projects/major-projects/auckland-rail-electrification/auckland-electrification-safety/level-crossings.html
Frequently Asked Questions: Electrification of Auckland's Network:
http://www.kiwirail.co.nz/projects/major-projects/auckland-rail-electrification/auckland-s-electrification---frequently-asked-questions.html
Auckland Transport: First Test Run for Auckland's New Train: http://youtu.be/wdEAZbGIAFs
Auckland Transport: Auckland's First Electric Train Unveiled: http://youtu.be/mm0CoqkTV_U
Auckland's NEW Electric Trains from CAF, Spain. Testing + (New Horn): http://youtu.be/zozNrWCg-PM
New EMUs for Auckland's Transport Future Undergo Testing: http://youtu.be/ed8zrCtCNRo
Our New Trains – Take a Video Trip: http://www.aktnz.co.nz/2011/10/06/our-new-trains-take-a-trip/
Johnsonville Line, Driver's Eye View filmed with a GoPro Hero 2 Camera: http://youtu.be/_tq5ljQquLo
KiwiRail Image and Film Library: http://www.kiwirail.co.nz/media/image-library

Work with students to further develop the class description using the following learning experiences.

1.1.1. Identify, label and describe the purpose of the two wires running above the tracks

Background: Wire 1: The **contact wire** is the source of electrical energy (live wire). This wire has to carry the current, remain in line above the tracks, and withstand extreme weather conditions. It gets its electrical energy from the rail substation (a railway substation is part of a system to generate and/or transmit electricity across the railway) which gets its energy from the Transpower substation. Wire 2: The **catenary wire** is used to support the weight of the contact wire that carries the electrical energy, keeping the contact wire taut so it can remain in a horizontal position above the tracks.

Note:

- The masts carrying the electrified overhead wires will be 6–7m tall and the wires will be directly over the rail tracks.
- The electric wires over the track carry 25,000 volts, which is 100 times more powerful than the electrical energy used in homes.
- The wires are live all the time. They are never switched off.
- You don't have to touch the wires to get electrocuted.
- The wires are extremely dangerous and potentially deadly to anyone who contacts them or comes too close to them, as electricity can arc (jump) across gaps of up to 3 metres and can also travel through water or other liquids.
- It is important to keep right away from these wires and to make sure anything you may be carrying or playing with is also well clear. Playing with kites or balloons near the wires is dangerous.
- Screening will be in place to prevent any accidental contact at bridges or alongside walkways.

Adapted from KiwiRail's Frequently Asked Questions: http://www.kiwirail.co.nz/auckland-s-electrification---frequently-asked-questions

Resources

Completed wires out near Swanson: http://transportblog.co.nz/2013/05/13/electrification-project-running-late/

Railway Technical: Overhead line – Catenary: http://www.railway-technical.com/etracp.shtml#Overhead-Line-Catenary

1.1.2. Identify and label the structure used to connect the contact wire with the train

Background: The **pantograph** is a spring-loaded structure on the roof of the train that connects the train to the live contact wire. It does this by pushing a contact shoe against the live contact wire. This structure allows the transfer of electrical energy from the live wire to the train. For reliable train operation there should be minimal, if any, loss of contact between the pantograph and the live contact wire.

The electrical energy from the pantograph is used by the traction motors to move the train and also to provide heat, light, air conditioning and other services to passengers.

Demonstrate how a pantograph works using a simple copper wire loop circuit and a bulb or buzzer.

For instructions on how to build a wire loop game circuit, refer to:
Central Networks: Making a Buzzing Circuit Game: http://www.eon-uk.com/downloads/worksheet12.pdf
Buzz Wire: http://youtu.be/4g7TBXnLucA
Wire Loop Game: http://youtu.be/mz7lzikzIOs
Constructing the Steady Hand Buzzer Game: http://youtu.be/0a2gX7VMIT4

Materials: Bulb or buzzer, battery, metal loop, insulated connecting wires, 1m bare copper wire, shoebox (support wire), crocodile clips, sticky tape.

Ask students to move a small metal loop along the wavy copper wire without touching it. Without a complete circuit, the energy from the battery cannot get to the charge in the light bulb or buzzer.

How should the metal ring be moved to make sure the bulb is always lit?

Make an analogy between the components in the buzzing game circuit and the pantograph on an electric train.

Resources
Pantograph and Overhead Wire: http://youtu.be/gE-HCIdxWuc
Pantograph Arcing at 27,000V: http://youtu.be/tYjIRgMHwpI

1.1.3. Explain how the connection between the pantograph and the live wire can be maintained when the train is travelling at 110km/h

Background: The spring-loaded structure of the pantograph keeps an upward pressure on the contact shoe so that it can rub against the undersurface of the contact (live) wire as the train travels along the tracks. This helps maximise the contact of the pantograph with the live wire so that the train can operate reliably.

Resources
Catenary and Pantograph: How Does It Work? http://youtu.be/kFPJ8eF9M2A
Sparking Matangi Electric Train at Silverstream, Upper Hutt, New Zealand: http://youtu.be/sPxG4W4mDhE
High Speed Beaujolais and Pantograph Action: http://youtu.be/A0G14ee3tR8

1.1.4. Identify and label the return path for the flow of charge (electrical current)

Background: The steel **rails** of the tracks provide a return path for the flow of charge (electrical current). The train completes the circuit: source of the electrical energy > live contact wire > train > rails > back to source.

1.1.5. Identify, label and explain the purpose of a level crossing

Background: Level crossings help keep people safe when they cross the tracks on foot, on a bike or in a car. Crossings use half-arm barriers, flashing lights, bells and passive signs and road markings to let people know when and where it is safe to cross the rail corridor. Train drivers use their horns when approaching a level crossing.
(Source: http://www.kiwirail.co.nz/in-the-community/safety-and-compliance/level-crossing-safety.html)

Electrification of the rail network has changed some of the measures for keeping safe around trains and tracks. The overhead wiring carries high-voltage electrical energy. This electrical energy can jump through the air (or through water) to other objects that get too close. Electricity becomes unsafe when the current (flow of charge) in the contact wire takes an unintended route. For example, the current can jump through the air to fishing rods sticking up too high from the back of a boat trailer, causing smoke, fire and electrocution. It means new height restrictions are in place at level crossings. If any part of the vehicle or load exceeds the height restriction of 4.25m, you have to seek special permission to use the crossing.
(Source: http://www.kiwirail.co.nz/projects/major-projects/auckland-rail-electrification/auckland-electrification-safety/level-crossings.html)

Visit a level crossing in your local area.

Invite a KiwiRail representative to visit you at the crossing or at school and talk about keeping safe around trains and tracks in the electrified rail network.

Take photographs of the different ways used to warn people when a train is close. Take photographs of the messages that tell people they have to be careful of the overhead wires even when no trains are around.

Use these photographs to write a report or create a simple model to show how level crossings help keep people safe when they cross the rail corridor. Refer to the different physical barriers and signs and symbols used to communicate safety information about electrical energy on the rail network.

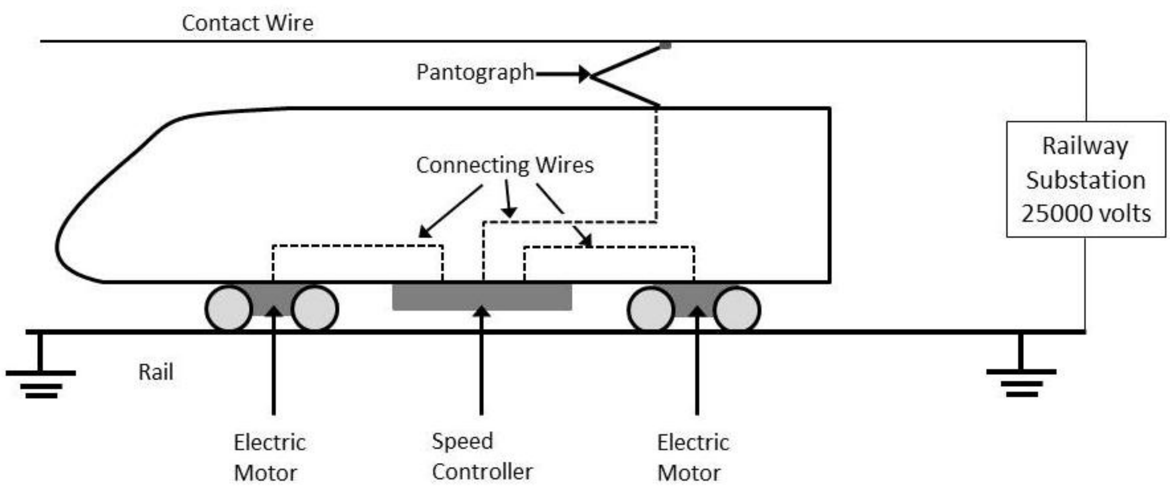
Resource
Glen Eden Level Crossing photograph: http://www.kiwirail.co.nz/projects/major-projects/auckland-rail-electrification.html

1.1.6. Create a simple model to show energy transfer on the electrified rail network

Background: Electric trains do not carry their own electrical energy supply. They get their electrical energy from an external source, the rail substation. The rail substation takes the electrical energy from a Transpower substation and transforms it into a form that can give energy to the motors on the wheels that move the train. It supplies this electrical energy to the train through an overhead wire hanging 6–7 metres directly over the rail tracks. The train uses a spring-loaded arm (pantograph) to touch the overhead contact wire from the rail substation, allowing electrical current to carry the energy from the wires to the speed control system and from there to the traction motors that turn the wheels. The electrical current leaves the train through the wheels and returns to the rail substation through the rails, completing the circuit.

Refer to Figure 1 – Electric Railway Car Propulsion System:
http://www.engineeringexpert.net/Engineering-Expert-Witness-Blog/?p=2111

Ask students to work in groups to demonstrate the transfer of electrical energy from the substation to an electric train on the rail network. The demonstration can use role play, a simple 3-D model made from recycled materials, a series of sketches or a computer graphic (suitable programs listed below).



The presentation should include advice on how people can stay safe around the electrical energy on the electrified rail network. Groups present their model to other students in a short (3-minute) oral presentation, in person or by video.

Co-construct success criteria for the presentation against the following categories: Introduction; Development of ideas about electrical energy transfer and staying safe on the electrified rail network; Ability to engage and involve audience; Suitability for purpose and audience; Use of voice; Use of scientific and technological vocabulary; Use of 3-D model or computer animation; Conclusion; Answering questions from audience.
Use the success criteria to self- and peer-assess each presentation.

Suitable graphics programs include:
Google SketchUp: http://www.sketchup.com/
Kid Pix Deluxe 4 for Schools: http://softwareforlearning.tki.org.nz/Products/Kid-Pix
HyperStudio 5: http://www.mackiev.com/hyperstudio/index.html
Tux Paint: http://www.tuxpaint.org/
Draw.To: http://draw.to/new
ABCya Paint: http://www.abcya.com/abcya_paint.htm
timtim: http://www.timtim.com/coloring/drawing/
Crayola Digi Colour: http://www2.crayola.com/coloring_application/index.cfm
Kerpoof: http://www.kerpoof.com/#/activity/draw

1.2. Identify what you know you don't know about electrical energy and moving trains on the rail network
What do you know you still don't know about energy transfer?
What do you know you still don't know about the electrified rail network?

Ask students to imagine the rail network could answer questions. What questions they would like to ask the train, the tracks, the substation, the catenary and contact wires or the pantograph? What questions would they like to ask "energy"?

Write these "what we know we don't know" questions on Post-it notes and display them on the classroom walls. Encourage students to add to them as they progress through the unit. Add a few of your own questions and invite any visitors to the class to add some as well.

Examples
What is energy?
What is electrical energy?
How is electrical energy made?
How does electrical energy move around?
How does electrical energy make things happen?
Where does the electrical energy come from to move the trains around the track?
How does the electrical energy move through the contact wires?
How does the electrical energy get to the train?
How does electrical energy move the trains along the tracks?
What makes the charge move around in a circuit?
How do the lights come on straight away even when they are a long way away from the switch?
Do some things move electrical energy better than others?
When something gets full of energy, does the energy leak out into the air?
Why are the covers on plug sockets made of plastic?

Why do fuses blow?
How much energy is in lightning?
Why does lightning strike some places and not others?
Why don't all the fish die when a lightning strike hits the sea?
Could we use the energy in lightning to bring energy to our homes and factories?
Is lightning like the electrical energy that moves trains in the rail network?
How do people who work on the power lines keep safe from electrocution?
How do electric eels protect themselves from being electrocuted?
Can we use energy from an electric eel to make a train move?
How can birds sit on power lines without being electrocuted?
How much energy is there in a torch battery?
Why is it dangerous to fly kites near power lines?
Is it safe to help someone who has had an electric shock?
Where does the energy go when a torch battery goes" flat" all by itself?
Why is electrical energy dangerous?
If electrical energy can be dangerous for living things, how can we keep people safe from electrical energy when they are around trains and the rail network?
How can we keep people safe around the electrical energy that moves trains on the rail network?

As students work through the unit, mark off the answered questions or move them to another location .

The following learning experiences will help answer some of the questions raised.

Note: The research literature shows that students bring a number of deeply held misconceptions to learning experiences that explore the transfer of electrical energy. These misconceptions result from "common sense" explanations, everyday language, imprecise use of technical language, and previous experience and teaching. A student's understanding of electrical energy transfer is often significantly at odds with a scientist's explanation and results in persistent errors and faulty reasoning. On the surface, students can appear to be knowledgeable, able to connect up simple circuits, and make buzzers buzz and light bulbs light up, but their explanation of what is happening in terms of electrical energy transfer reveals a lower level of knowledge and skills. Challenging their misconceptions and flawed understandings is difficult but necessary if they are to avoid problem solving errors when thinking about electrical energy.

1.3. What is energy?

1.3.1. Define energy (What is energy?)

Background: Energy makes something happen. Energy is not matter (stuff) – it does not take up space like matter (solid, liquid, gas). Energy is not directly visible. It is not something you can touch. You cannot pick it up or pour it into a container like you can with matter. Energy comes in different forms – the kinetic energy of a moving object, radiant energy carried by light, potential energy – and can be changed from one form to another.
Refer also to: BBC Bitsize revision:
http://www.bbc.co.uk/bitesize/ks3/science/energy_electricity_forces/energy_transfer_storage/revision/1/

Ask students to think about what they know about energy. "What is energy?"
Show students energy-related images taken from their local community or experience. Use these to prompt new thinking about energy.

Refer students to energy interactives online for more ideas about energy transfer.

Examples
Eon Energy Educational Resources:
Energy Home: 5 to 7 year olds http://www.eon-uk.com/EnergyExperience/85.htm
Energy Town: 7 to 11 year olds: http://www.eon-uk.com/EnergyExperience/93.htm
Energy Nation: 11 to 14 year olds: http://www.eon-uk.com/EnergyExperience/479.htm

The following sites are useful when looking for alternative, copyright-friendly images or information on energy transfer and energy sources online:
Search Creative Commons: http://search.creativecommons.org
Shahi Visual Dictionary: http://blachan.com/shahi/
Pics4Learning: http://www.pics4learning.com/index.php

Record students' responses (as individuals, groups or the whole class) onto SOLO Hexagon templates using drawings, images or text.

Use the HookED Hexagon generator to make the templates: http://pamhook.com/solo-apps/hexagon-generator/

Cut out the individual hexagons and work in groups of three to make connections between the individual ideas by tessellating the hexagons. When making links, give reasons to explain why two ideas have been linked (use text annotation or oral explanation). Use glue sticks to fix hexagons to a backing sheet if required.

Step back from the connected hexagons and make a generalisation – "Overall we think energy is .... because (insert reason) because (insert evidence or examples)."

Give students multiple opportunities to revisit this activity, adding extra ideas and improving their generalisations about energy, as you progress through the learning experiences that follow.

Extension: The HookED SOLO Hexagon energy templates in appendix 2 contain energy-related terms that can prompt students to extend their thinking for this SOLO Hexagons activity.

1.3.2. Classify forms of energy (Are there different types of energy?)

Background: Energy makes things happen. It changes things. Energy comes in different forms including light, heat, chemical, electrical and movement energy. The many forms of energy can be sorted into two categories: potential and active (kinetic). Potential energy is stored energy. Potential energy can come from the position of the object – gravitational energy when an object is raised up. Energy is also stored in chemicals like coal and gas as well as in food, compressed springs, and the nucleus of an atom. Active energy (kinetic energy) is motion. It includes the motion of objects, waves, electron s, atoms, molecules and substances. So light energy, heat energy, sound energy and electrical energy are all types of energy in motion.
Also refer to: BBC KS3 Bitesize revision: Energy Transfer and Storage:
http://www.bbc.co.uk/bitesize/ks3/science/energy_electricity_forces/energy_transfer_storage/revision/2/

Use demonstrations, video, images and text to show examples of different forms of energy and what they can make happen. For example, show examples of light energy, heat energy, electrical energy, magnetic energy, atomic energy, chemical energy, elastic energy and kinetic energy. Include examples of energies associated with the electrified rail network. For each example, ask students, "Is this energy?"

Add these ideas to SOLO Hexagon templates, using different coloured pens (or paper) to distinguish them from the initial responses. Cut out these hexagons and add them to the prior knowledge tessellation.

Extension: Re-sort the different forms of energy into two categories:

- **active**, meaning they are easily seen or detected
- **potential**, meaning they are stored and only have an effect when they are changed into another (active) form.

1.3.4. Design a Joseph Herscher type installation to connect a train moving at 110km/h with an electrical energy supply

The plans for your machine must show at least five different types of energy and five different types of energy transformation.

Refer to:
Joseph Herscher (NZ artist based in New York): http://www.josephherscher.com/
Joseph Herscher – The Page Turner: http://youtu.be/GOMIBdM6N7Q
Rube Goldberg machines: http://www.rubegoldberg.com/
W Heath Robinson: http://en.wikipedia.org/wiki/W._Heath_Robinson
Mouse Trap game: http://en.wikipedia.org/wiki/Mouse_Trap_%28game%29
The Incredible Machine: http://en.wikipedia.org/wiki/The_Incredible_Machine_%28game%29

SECTION 2: Explain what is worth knowing and doing as a citizen around places on the electrified rail network

Relating ideas

These activities provide opportunities for students to connect ideas about energy and energy transfer in the context of the electrified rail network.

Learning intention: Explain why transferring electrical energy in these ways will keep citizens safe around the electrified rail network. [relational]

Differentiated success criteria: We will know we have achieved this because …

Multistructural	*My explanation has several relevant reasons why knowing about this use of electrical energy will help keep people in the community safe around the rail network*
Relational	*…. and explains why these reasons are relevant*
Extended abstract	*… and makes a generalisation about the reasons.*

Key Competency self-assessment rubric[2] Highlight the relevant Key Competencies for section 2.

Thinking	**Managing self**	**Participating and contributing**	**Relating to others**	**Using language, symbols and text**
Critically analyse the factors contributing to safe electrified rail networks for all citizens. *Example – describe, explain and justify ways to stay safe at places on the electrified rail network.*	Act responsibly when around the electrified rail network as a pedestrian, passenger, cyclist or driver to ensure all citizens keep safe. *Example – adopt a "sort it and report it" approach to unsafe behaviour around the electrified rail network.*	Display an awareness of the local issues around creating and maintaining safe electrified rail networks. Be actively involved in community issues around safe electrified rail networks. *Example – listen, respond and act together to make the electrified rail network a system free of death and serious injury.*	Interact with others to create safe electrified rail networks. *Example – demonstrate a commitment to safer outcomes for self, friends, family and whānau at places on the electrified rail network.*	Interpret and use language, symbols and text in ways that keep citizens safe around electrified rail networks. *Example – share safe rules and behaviours for places on the electrified rail network.*

[2] For draft versions of these Key Competency self-assessment rubrics, see the appendix to this Rail Safety Resource.

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2.1. What are some everyday examples of charge imbalance?

Background: Charge imbalance is all around us. There are many everyday life examples of charge imbalance accumulating on the surface of objects. For example, electric charges can make the hairs stand up on your head when you go down a slide. You get the same effect when you take off a woollen beanie and the wool rubs against your hair. The friction charges your hair. Each hair has the same charge and, because like charges repel each other, the hairs on your head move away from each other by standing up straight, giving you a "bad hair" look. The surfaces of TV screens and computer monitors are dustier than other vertical surfaces in the home or classroom because charge accumulating on the screens attracts dust. You can sometimes demonstrate this effect by brushing your arm close to the screen and watching the fine hair on your arms stand up. Some students will have experienced getting zapped by small electric charges when they touch the door handle while getting out of a car or when they have rubbed their feet across carpet and then touched a metal object. The friction from tumble drying synthetic materials can charge the clothes, making them cling to each other or to your body when you put them on. Pulling apart synthetic materials after they have been dried in a tumble dryer creates a series of small sparks as the charge imbalance is discharged. People touching the body of an isolated coach on an electric train can get a charge imbalance shock from the charge built up from the overhead wires if it is not sufficiently earthed.

Note: Charge imbalance is commonly called static electricity but this name wrongly suggests that the charges are stationary and cannot move.

Demonstrate charge imbalance using a Van de Graaff generator to generate a charge imbalance on its dome.

If you cannot get hold of a generator to use in the classroom, watch an online demonstration on YouTube. For example:
Should a Person Touch 200,000 Volts? A Van de Graaff Generator Experiment:
http://www.youtube.com/watch?v=ubZuSZYVBng&list=PL41778092B7768366
Static Electricity: Van de Graaff Generator http://youtu.be/rNEY3Yv9kC8

Use charge imbalance to transfer energy to a small fluorescent bulb. Build charge imbalance on a plastic comb by rubbing it through your hair. In a darkened room, touch the comb to the end of a fluorescent light bulb.

Discussion prompts
[think-pair-share, or small group or whole class discussion only]

What do you see? Why do you think it is like that? What does it make you wonder?

Extension: Investigate other ways of building charge imbalance to light the fluorescent bulb. For example, rub PVC piping with a piece of fur or wool.

2.2. Explore electric charges (What is charge? Where does it come from? What does it do?)

Background: An object becomes **electrically charged** when it gains electrons (negative charge) or loses electrons (positive charge). Some materials gain charge more easily than others. You can accumulate charge on an object by rubbing it against another surface. The friction between the two surfaces helps builds up a charge on an object by increasing the contact surface available for adding or removing negatively charged particles called electrons.

Charge accumulation due to friction is called charge imbalance (or static electricity). The imbalanced charge moves away by **electrical discharge or by** electrical **current** (flow of electric charge).

When two differently charged objects are brought close to each other, a momentary electric discharge may occur as charge moves from one object to another. If you look carefully, you can see sparks (visible as a small flash of light) jump through the air between the two objects.

In an electric current, the electric charge (electrons) moves freely in metal wires such as overhead power lines used to deliver electrical energy to homes, railway substations and contact wires above the rail corridor.

2.2.1. Demonstrate charge imbalance
Ask students to hold an inflated balloon close to a wall. What do they predict will happen when the balloon is released? Release the balloon and observe what happens.

Then ask students to try rubbing a balloon on their head before placing it close to the wall. Explain that rubbing the balloon on their hair will cause an imbalance of charge to accumulate on the surface of the balloon. Hold this charged balloon close to the wall and release it.

The accumulation of unbalanced charge on the balloon can make things happen when a balloon is released close to the wall. Friction causes electric charges to build up on the surface of the balloon and this unbalanced charge causes the balloon to be attracted to ("stick" to) the wall.

Discuss what is different between the two events. What do these differences make the students wonder about electrical charge?

Extension: Use student wonderings to investigate other ways of demonstrating unbalanced charge.
For some ideas using plastic bottles and Styrofoam balls, refer to:
Steve Spangler Science: http://www.stevespanglerscience.com/lab/experiments/floating-static-bands

2.2.2. Investigate unbalanced charge (How is it created? What does it do?)
Get students to charge an object using friction – by rubbing two surfaces together.

Let students experiment (think like a scientist) with a range of materials. Materials that gain charge more easily include: balloons, plastic comb, glass rod, PVC piping, rubbed-on human hair, nylon, wool, fur or silk.

For example, students can build up static charge on a balloon, plastic ruler, pen or comb by rubbing it with a woollen jumper or a piece of silk.

Use an electroscope to detect any charge build-up.

Can all objects be charged?
Can you make charge by rubbing the same substances together?
Is the whole object charged or just a part of it? (Which end of the comb attracts pieces of torn tissue paper?)
Can you make the charge stronger or weaker?
Are both substances charged?
How long does the charge last? (How long are pieces of tissue paper held onto the comb?)
How do the charged objects interact with each other?

Observe what happens when the charged object is held close to:

- small scraps of tissue paper
- the smoke from a burning mosquito coil
- an empty aluminium can placed on its side on a flat surface
- an electroscope (charge detector)
- other charged objects (another balloon)
- the small stream of water leaving a tap.

Discuss what happens in each instance.

Discussion prompts
[think-pair-share, or small group or whole class discussion only]

What do you see? Why do you think it is like that? What does it make you wonder?

Use the student explanation and wonderings as the basis for further student inquiry and experimentation.

Note: Experiments on unbalanced charge work best on dry days.

Extension: You can make your own unbalanced charge detector (electroscope) using a binder clip and two strips of clear plastic (overhead transparency film). Watch the YouTube video, How to Make Your Own Electroscope! http://www.youtube.com/watch?v=Zo6I6rvtu2g&list=PL41778092B7768366&index=10

2.3. Keep safe around electric charge

2.3.1. Explain the dangerous effects of unbalanced charge (Why can a build-up of unbalanced charge be dangerous?)

Background: Unbalanced charge can be dangerous. When the difference between two charged surfaces is large enough, the charge can arc (jump) through the air to the other object or person. The spark of charge is especially dangerous around inflammable materials (e.g. petrol vapour) and clouds of fine dust where the spark can cause fire and explosions. The spark is dangerous for people who get too close to any highly charged power source. You don't need to touch a charged object to be electrocuted – the charge can jump through the air and zap you.

Share stories about the Hindenburg explosion, petrol pump flare-ups, dust explosions, lightning and everyday life examples of strategies used to stop people getting too close to any highly charged source of electrical energy.

Examples

- Hindenburg Explosion "Caused by Static Electricity": http://www.telegraph.co.uk/news/worldnews/northamerica/usa/9908985/Hindenburg-explosion-caused-by-static-electricity.html
- Stop Static (campaign to prevent refuelling fires at gas pumps): http://www.pei.org/PublicationsResources/SafetyResources/StopStaticCampaign/tabid/121/Default.aspx
- Dust Explosion: http://science.howstuffworks.com/dust-explosion-info.htm
- Lightning: The friction between drops of water can cause unbalanced static charge to build up to dangerous levels in a storm cloud. When the charge grows large enough, it can jump from one

part of a cloud to another, to another cloud or to the ground. When it jumps, this huge spark of charge flows through the air, heating it so much that it glows and in this way produces lightning.

You can watch charge jumping through the air in the following images and video.
Steve Spangler: The Science of Lightning:
http://www.stevespanglerscience.com/lab/experiments/lightning-science
The Birth of a Lightning Bolt (slow motion lightning strike): http://youtu.be/6MUYsIjTKvk
The Science of Making Lightning: http://youtu.be/WyygaemPt9s
National Geographic: Lightning Strikes: http://youtu.be/H_MG__53wsM
Seeing Electricity: http://www.sciencelearn.org.nz/Contexts/Super-Sense/Sci-Media/Images/Seeing-electricity

If you are struck by lightning or touch something with a large electric charge (or get so close that a large charge jumps through the air to you), the charge will flow through your body to the ground, causing an electric shock. The electric shock can kill. It causes bad burns, breaks bones and can stop your heart.

Challenge students to find at least 10 examples of places where unbalanced charge in everyday life would be dangerous to people. Make a wall display of the warning signs, images and text examples. Rank them in order from the most dangerous to the least dangerous.

Note: Wires and other objects using electric current (moving charge) to carry high levels of electrical energy (**voltage**) are also dangerous. These wires are called "live" as in "live wire" and are used to carry mains electricity to homes. Electrical appliances using mains electricity have an earth wire which connects the appliance (through the fuse box) to a metal stake or water pipe that connects to the earth. The earth wire usually carries no current. However, if something goes wrong in the appliance, the current does not pass through you; instead, it flows harmlessly from the live wire through the earth wire to the ground.

The overhead wires carrying electrical energy to the new electric trains in Auckland supply charges with 25,000 volts of energy from the wires to the train. This is 100 times more powerful than the mains electricity in your home. Special safety measures are put in place to keep people from getting too close to the live wires around trains and tracks in the rail corridor. If a spark of charge arcs through the air (or across water) to the person, the current from the rail network wires will pass through the person, electrocuting them.

Extension: Find out how to help someone who has been electrocuted without getting shocked yourself. Refer to:
KiwiRail: Electrical Safety (emergency rescue procedures):
http://www.kiwirail.co.nz/infrastructure/infrastructure-and-engineering/accessing-the-corridor/electrical-safety.html
Wikipedia: First Aid/Electrocution: http://en.wikibooks.org/wiki/First_Aid/Electrocution
Make a fridge magnet or a card to keep in a wallet to inform others what they should do to keep safe when someone has been electrocuted.

2.3.2. Describe how we can manage some of the risks from static and/or current electricity (How can we manage the risks from electric charge?)

Background: The risks from unbalanced charge and current electricity can be managed in various ways. These include:

- providing an alternative path for the charge – for example, connecting to the earth by an earth wire, which lets the charge pass harmlessly to the ground
- preventing the charge flowing through the person to the earth – for example, using an insulator such as insulated matting, insulated casing or screens, or shoes with insulated soles
- using signage and enforcement measures aimed at keeping people from trespassing too close to the live wires.

Examples of **insulators** (materials that prevent the flow of charge) include plastics, Styrofoam, paper, rubber, glass and dry air.
Examples of **conductors** (materials where charge flows easily) include water, carbon and metals like iron, aluminium, copper and silver.

Ask students to work in groups to find an everyday life example of the use of earth wires (conductors) and/or insulated surfaces to manage the risks from static or current electricity. For example, how should we manage the static charge that can build up when inflammable liquids flow through a hose or pipe when refuelling a plane or an automobile?

Describe the example using text or annotated diagrams.

Write a list of instructions on how to avoid a potentially dangerous static discharge.

Extension: Plan and create a "Stop the charge flowing through you" multi-media advertisement to "sell" a static energy protection device to the public. Use persuasive language and appropriate technical and scientific language.

2.4. Explore everyday examples of flowing electric charge (electrical current)

Background: When charge moves through a material, we describe the moving charge as **an electric current** or **electricity**. It is easier for charge to move in some materials (**conductors**), which have a looser hold on their free electrons, than in others (**insulators**). These moving charges carry energy that can be used by light bulbs and other components to make something happen. The energy to move charges can come from batteries (electrochemical cells) or mains electricity. Voltage is a measure of the **energy** available to move (push) the charges.

SAFETY NOTE
Exploring electricity is safe as long as it is done under supervision using low-voltage batteries to supply the energy to the charges. Never experiment with electricity from the mains. Fatal electric shocks and serious burns can result.

2.4.1. Describe physical phenomena involving moving electric charge
Introduce the idea of physical phenomena involving moving electric charge through a series of physical events for students to observe and/or measure and role play.

Get students to role play moving charge. In an open area in the classroom or field, mark out a corridor representing a section of a connecting wire (metal conductor) in a circuit. Some students act as fixed nuclei of the metal atoms and are dotted across the wire. Other students act as charged particles (electrons). They are not attached strongly to the nuclei in a metal. When the circuit is connected (the switch is on), these students get a push force from the electrical energy from the battery and start to flow freely everywhere along the wire at the same time.

These moving charge scenarios can be set up in the classroom and outside. Also show video clips of electricity-based events that are hard to demonstrate. These events should demonstrate changes in movement, light, forces, sound, heat and magnetism caused by an action involving the energy of charged particles.

Show students energy-related images taken from their local community or experience. Use these to prompt new thinking about energy from moving charges. For example, show images of a CD player, MP3 player, television, electric motors, computers, digital camera, defibrillator, electric guitar, laser pointer, metal detector, smoke detector, solar cells, tooth brushes, electric trains and/or electric cars. Include examples of **battery-powered** appliances (torch, remote control, battery operated toys, radio, remote control vehicle) and **mains-powered** appliances (bar heater, electric train, toaster, television, electromagnet, doorbell). Provide specific technical vocabulary.

The following sites are useful when looking for alternative copyright friendly images online.
Search Creative Commons: http://search.creativecommons.org
Shahi Visual Dictionary: http://blachan.com/shahi/
Pics4Learning: http://www.pics4learning.com/index.php

At each station, get students to observe carefully, think about what they see and then wonder about what they see. Add their see, think, wonder responses to a HookED Describe ++ (See Think Wonder) map in which they respond to prompts – What do you see/measure? (Observation of the event) Why do you think it is like that? (Inference) What does it make you wonder? (A question for further research).

Ask students to use the class responses to the HookED Describe ++ map to think like a scientist when writing a paragraph, drawing an annotated picture or talking about their favourite physical phenomenon involving electric charge. Each paragraph should describe what happens, explain why they think it happens and reflect on what it makes them wonder.

Extension: Ask students to fill a container with images or sketches of five objects that represent, in their opinion, the five most important uses of moving electric charge in the world. Annotate each object with an explanation of why you have chosen it.

2.4.2. Demonstrate a physical phenomenon using electrical energy (BIG circuits and physical phenomena)

Use a simple battery-powered circuit as an example of a physical phenomenon – BIG circuit demonstration.

Ask students to look carefully at the filament of wire passing through a light bulb. What do they see? Why do they think it is like that? What does it make them wonder?

Role play the passage of electrons through the filament of a bulb. Create a narrowing in the "wire" corridor to represent the narrower filament in a bulb. Explain that the amount of space the electrons have is reduced. Ask the students to move at a constant rate through the "filament wire" in the bulb. What did they experience when they tried to flow through the connecting wire? Some students will make the link between collisions, friction forces, and heat and light.

Note: This model can reinforce the misconception that electrons slow down when they travel though the filament wire. It is harder for the electrons to get through the narrower filament wire BUT they do not travel more slowly as a result. Adding resistance to the circuit in the form of light bulbs does NOT make it harder for electrons to get through the bulb; rather, it makes it harder for the electrons to get around the whole circuit. If the overall rate of flow in the complete circuit remains the same then the charges must speed up through the resistance wire.

1. Make a BIG circuit with a 2.5V bulb and a 4.5V battery. Ask students to predict what will happen when you complete the circuit. Ask students to note the brightness of the bulb.

   Note: Disconnect the circuit after students have observed the brightness of the bulb. A 4.5V battery will burn out a 2.5V bulb if the circuit is left on.

2. Make a BIG circuit with two (or more) identical 2.5V bulbs and a 4.5V battery. Ask students to predict what will happen when you complete the circuit. If they think both bulbs will light, ask them to predict how bright the bulbs will be. When both bulbs light, note that although they are not as bright as the bulb in the single-bulb circuit, the brightness of each bulb in the two-bulb circuit is the same.

   Note: The flow of charge is the same all around the circuit – the same number of electrons is flowing at any (and every) point in the circuit. The charge is present in all the wires in the circuit all the time. The battery supplies energy to move the charge. The electrical energy supplied to the charge in the wire from the battery is shared equally between the two bulbs.

3. Make a BIG circuit with up to five identical 2.5V bulbs and a 4.5V battery. Unused (new) bulbs work best. Ask students to predict what will happen when you complete the circuit.

   Note: The extra bulbs make it harder for the electrical energy to push the electrons around the circuit. Fewer electrons flow so the bulbs are dimmer. However, the same number of electrons is flowing at every point in the circuit so the bulbs will all be the same brightness.

The next BIG circuit exercise is useful for challenging students' misconceptions about electrical energy transfer. The original exercise is described in Wainwright, *Towards Learning and Understanding Electricity: Challenging Persistent Misconceptions*, p28.

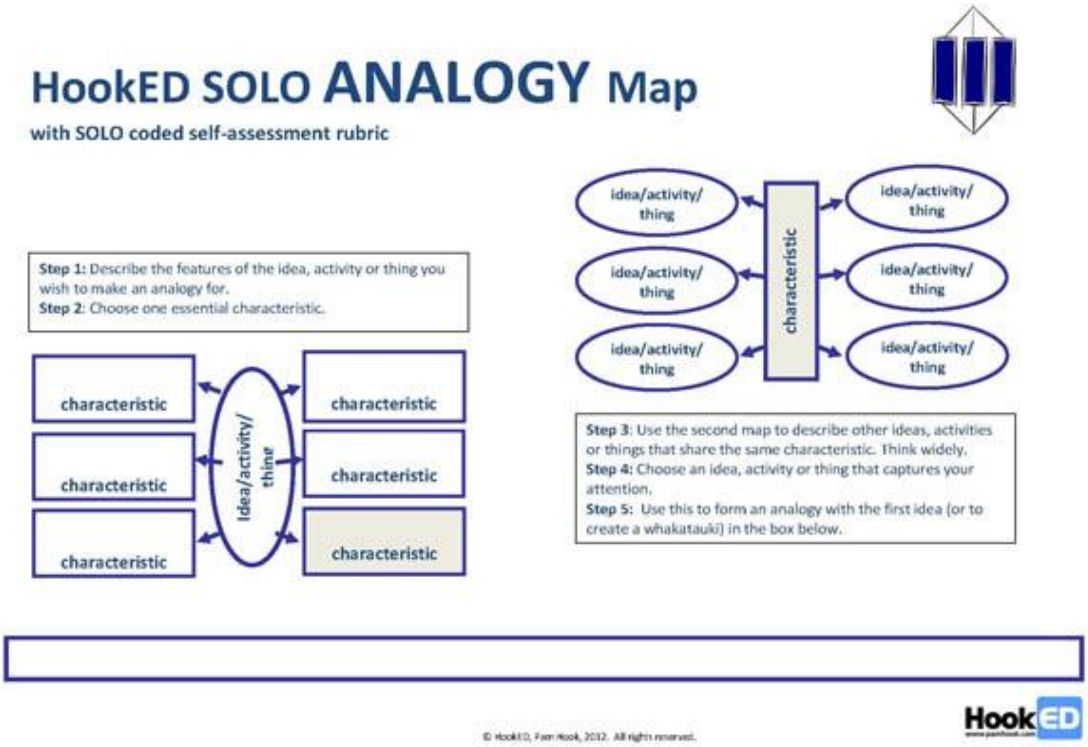
1. Make a BIG circuit and place a brighter (newer) bulb near one of the battery terminals and a dimmer (older) bulb near the other.
   Ask students:
   - What do you notice about the brightness of the bulbs? (What do you see?)
   - Why do you think it is like that? (What do you infer from the difference in brightness?)
   - What do you infer about the way the electrical charge is moving? (Most students will predict that the charge is moving from the pole nearest the bright bulb and getting use up as it travels around the circuit.)
   - What do you predict will happen if the position of the bulbs is reversed?
2. Reverse the position of the bulbs so students can observe that brightness has NOTHING to do with the position on the circuit.
3. Explain that brightness is a characteristic of the individual bulbs and even identical bulbs may differ because brightness will change as bulbs age.
4. Ask students to observe which bulb goes on first and which goes off first. (There is no discernable difference – all bulbs go on instantaneously.)
5. Ask students to wonder (hypothesise) how all bulbs could go on instantaneously.

Use an electrical energy model to help students understand how charge moves instantaneously in a circuit.
Refer to section 2.5.1.

Write a paragraph or annotate a series of diagrams to show that a physical phenomenon like a bulb lighting is caused by the transfer of electrical energy from a battery by moving electric charge in a circuit.

Extension: Make an analogy for the flow of charge in a simple circuit.

> **Step 1:** Describe the features of the idea, activity or thing you wish to make an analogy for.
> **Step 2:** Choose one essential characteristic.
> **Step 3:** Describe other ideas, activities or things that share the same characteristic. Think widely.
> **Step 4:** Choose an idea, activity or thing that captures your attention.
> **Step 5:** Use this to form an analogy with the first idea. You can use the HookED SOLO Analogy map to help you.
> **Step 6:** Share your analogy with others in your class. See if you can persuade others to adopt it in their everyday conversations about the movement of charge and energy transfer in simple circuits.



2.4.3. Explore everyday appliances that use energy from electric charges to make something happen (Where does the electrical energy come from?)

1. **List** everyday appliances and technologies that use energy, from moving electric charges, to make something to happen. (What uses energy from moving electric charges to make things happen?) Use pictures cut from magazines and photographs taken on your walk around the school. Brainstorm different things (appliances) that use energy from electric charges to make things happen. Make an electricity map of the classroom showing the appliances and equipment that use electrical energy from the mains or from batteries. Go on a walk around the school, putting Post-it notes on any appliances that use electrical energy. List the appliances in the left-hand column of a three-column table.

2. **Classify (sort)** the examples into appliances that use the energy given to the charges by **mains electricity** and appliances that use energy given to the charges by **batteries** (**electrochemical cells**). (What type of energy supply is used?) Note that "mains" electrical energy is much more powerful than the electrical energy from batteries, making mains electricity much more dangerous.

   In the middle column, identify whether the appliance uses electricity from the mains socket or from batteries. Read and respond to the sorting activity in Engineering Interact: Electricity in Our Lives: http://www.engineeringinteract.org/resources/siliconspies/flash/concepts/electricity.htm

3. **Explain** what each appliance does with the energy – the results of the energy transfer. What does each appliance do with the energy given to the charges (**electrical energy**)? In the right-hand column of the table, describe what each appliance uses electricity for – for example, does the appliance use the electrical energy to make heat energy, light energy, movement (kinetic energy) or sound energy?

2.4.4. Identify the energy (push or voltage) provided by different sources (How much energy is transferred?)

Challenge students to find out how much energy is supplied to moving charges by:

- an electric eel
- batteries sold at a local convenience store
- a car battery
- mains electricity supply
- electricity supply lines running along main roads
- overhead wires in the rail network between Palmerston North and Hamilton
- lightning.

Which is the largest supplier of electrical energy (supplying the most electrical energy)? Which supplies the least electrical energy?

Extension: What if electric trains were powered by electric eels? Draw a plan showing how you would set up a circuit to move electric trains with the voltage from electric eels. List some of the advantages and disadvantages of using energy from eels.

Note: Voltage is like an electrical pressure or push force: it can cause electric charges to flow. Voltage is measured between two points. In some ways it is a measure of the charge imbalance. However, voltage can exist without current. Current can exist without voltage.

Resources

Electric Eel: Moody Institute of Science (1954 Educational Film) Part 1 of 2: http://youtu.be/NNZmlcBpRLw
Electric Eel : Moody Institute of Science (1954 Educational Film) Part 2 of 2: http://youtu.be/HdMp7qyyhB8
Electric Eel Christmas Tree: http://youtu.be/8oS9YuGIWMU

Background:

Volts: The casing on the outside of a battery tells you how much energy the battery supplies to the charges – it can vary depending on the battery used, e.g. 1.5 volts, 9 volts, 12 volts. The battery supplies the energy to the appliance (light bulb, buzzer, motor etc.) by two insulated wires. One wire has 1.5 volts of electrical force pushing the charge to the appliance. The other wire returns the charge (with 0 volts of energy) to the battery where it can be given more energy.

Mains electricity: Mains electricity supplies moving charges with much higher levels of energy (240 volts) than a battery. Mains electricity is supplied to the home by two insulated wires. One wire is the "live wire" and carries charge with 240 volts of electrical force pushing the charge; the other is called the neutral wire and carries charge with zero volts from the house and back to the power station.

Power lines: The power lines along the sides of roads are insulated. They supply charges with even higher levels of energy than mains electricity: it varies between 400 volts and 33,000 volts.

Overhead wires: The overhead wires carrying electrical energy to the new electric trains in Auckland are not insulated. They are bare wires running at a height of 6 to 7 metres immediately above the train tracks. They supply charges with 25,000 volts of energy from the wires to the train. This is 100 times more powerful than the mains electricity in your home. The charge will get to the train through a structure called a pantograph. The pantograph maintains contact with the wires at all times so the electricity can be used by the train's engine.

2.5. Think like a scientist about moving charges

2.5.1. Use models as analogies for electric current

Introduce students to a mental model to help them understand current flow.

Scientists use a number of models to help understand what is going on when charge flows through a simple circuit.

Examples

- **Mental Model 1:** You can think of "charge" as being like a fleet of supermarket vans linked together in a circle as they deliver kiwifruit (energy) to different supermarkets (components) before returning to the packing store to get more kiwifruit.
- **Mental Model 2:** You can think of the moving charge in wires as water flowing through pipes.
- **Mental Model 3:** You can think of the circuit as a big loop of rope. When the person acting as a battery pulls on the rope, all parts of the rope move at once – just as charges carrying energy do in a circuit. For example, refer to TES Connect: Teachers' TV: Primary Science – Electricity (role play modelling energy flow in simple circuits): http://www.tes.co.uk/teaching-resource/Teachers-TV-Primary-Science-Electricity-6044058/
- **Mental Model 4:** You can think of a circuit as a hula hoop. Students hold the hoop loosely with their right hand. Their left hand represents a light bulb. One student is the energy supply and is responsible for moving the hoop. When the other students feel the hula hoop moving, they raise their left hand. Much like the big loop of rope model, this model suggests that charge is everywhere in a circuit and, when it gets energy to move, it moves everywhere at once.

However, all models misrepresent the flow of charge and energy transfer in a circuit in some way – so only share them with caution. For example, the "water model" leads students to see a battery as a source of current much like a tap or reservoir is a source of water. Water cannot be compressed in the way that charge is compressed when it travels through a light bulb.

For further discussion of using analogies to teach electricity, refer to Furry Elephant: Electric Circuit Analogies: http://www.furryelephant.com/content/electricity/teaching-learning/electric-circuit-analogies/

2.5.2. Use scientific terms

Encourage students to use correct scientific and technical language when talking about energy transfer, charge and the electrified rail network.

Build a class glossary of key terms associated with electrical energy transfer on the electrified rail network. Refer to electrical energy glossaries; for example, Science Learning: http://www.sciencelearn.org.nz/Contexts/Super-Sense/Key-Terms#term7023

Challenge students to create a range of plush toys, with each one representing a different aspect of electrical energy – one for each word in your class glossary. Each character must come with an information tag summarising what it is and how it can be used to transfer energy.

Resources
Particle Zoo: http://www.particlezoo.net/index.html
Giant Microbes: http://www.giantmicrobes.com/
Canned Dragon Meat: http://www.thinkgeek.com/product/1144/
Canned Unicorn Meat: http://www.thinkgeek.com/product/e5a7/

Other strategies

- Build a collaborative online class glossary – using a wiki.
- Get students to make electricity vocabulary word games to practise meaning; for example, Flash cards, Guess the question, Hangman. Bingo, Floating questions game. Refer to TES Connect: Teachers' TV: Primary Science – Electricity (use Floating questions game with components in electrical circuits): http://www.tes.co.uk/teaching-resource/Teachers-TV-Primary-Science-Electricity-6044058/
- Earn the right to use the science vocabulary. Students can only use a key term if they show they can define it and demonstrate its attributes within a simple circuit.

2.5.3. Energy transfer challenge
Note: Check for misconceptions when students are experimenting with simple circuits. Refer to appendix 1.

Challenge: Connect an energy provider (battery/cell) with an energy transformer (light bulb) in a way that changes electrical energy in the battery to light and heat energy in the bulb.

SAFETY NOTE
Exploring electricity is safe as long as it is done under supervision using low-voltage batteries to supply the energy to the charges. Never experiment with electricity from the mains. Fatal electric shocks and serious burns can result.

Materials

- 1.5V cell (commonly referred to as a battery) – to supply energy to the charge in the wire
- Connecting wires with crocodile clips (at least 2 long and 2 short) – allow the charge to flow around the circuit; metal in the wires contains loose charge that can carry the electrical energy
- 2.5V torch bulbs with holders – energy transformer – a fine filament wire in the bulb gets very hot when electrical energy flows through it; it gets so hot it transforms the energy carried by the charge to light energy and heat energy, much like the electric hob on a cooker or the wire on the bars of a radiator
- Tape

Procedure

Ask students to work in groups of two to try to light the bulb with the electrical energy stored in the battery. Challenge them to use trial and error (and all they have found out about electrical energy) to light the bulb by connecting the wires and components in the circuit in different ways.

Use diagrams, photographs or video to keep a record of all attempts (successful and unsuccessful).

Many students will start by thinking that only one wire from the battery will light the bulb. Others believe that electric charge is stored in the battery and, when it gets used up, the battery goes flat. Refer to common student misconceptions in appendix 1.

Ask students to describe what they see when they connect the components, why they think it is like that and what it makes them wonder. Take photographs of their circuits or draw simple diagrams. You can use the HookED Describe ++ map to draft your answers.

Ask students what is required for a working circuit where the bulb lights up. Record their responses – an energy supply (battery), an unbroken path for the energy to travel through, components with two ends so the energy can flow through the components.

Explore different ways to make the light bulb go out. Introduce the idea that switches break the circuit. Electrical energy cannot easily pass through the air. Electrical energy can pass easily through metal. Invite students to create their own switches to connect the circuit, using the metal in paper fasteners and/or paper clips.

Note: For older students, you may wish to introduce the use of electrical symbols when students are drawing the different arrangements of battery, wires and components used to light the bulb. Introduce symbols for a conductor, electric cell, battery, light bulb/globe, terminal, switch open, switch closed, bell, ammeter, resistor etc.

Refer to appendix 2 for online resources and ideas for exploring simple circuits.

Extension: Explore conductors and insulators. These activities require students to have some prior knowledge of the material world – properties of matter.

1. Test various substances to see how well they let electrical energy through – that is, how well they conduct electric charge. Some materials will let electrical energy through easily (conductors); other materials will not (insulators).

   Set up a simple circuit using three wires with crocodile clip connectors, a bulb and a 4.5V battery. Use the third wire to make a break in one of the wires. Connect different substances in turn. Attempt to complete the circuit using different substances (e.g. a paper clip, plastic, coin, matchstick, rubber band, wood, paper, plastic-coated wire, pencil graphite, piece of copper, piece of glass, graphite block, strip of aluminium foil, water) open at each end. Record whether the light bulb glows. Which materials are good conductors of electricity? Explain your answer. Which materials are poor conductors (insulators)? Does the electric charge flow through the air? Address students' misconceptions that electrical energy will only flow through metals. If it has enough power, electrical energy flows through salty water and through people who are largely made of salty water. The electrical energy from a battery does not have enough power to push the energy through people but the electrical energy from the mains is much more powerful and consequently more dangerous.

2. Try making a paper circuit using graphite markings on a sheet of paper. Refer to the instructions on YouTube: Paper Circuit: http://youtu.be/BwKQ9Idq9FM

SECTION 3: Extend your thoughts and your actions as to what is worth knowing and doing as a citizen around places on the electrified rail network

Looking in a new way
These activities provide opportunities for students to extend their connected ideas about energy and energy transfer in the context of the electrified rail network.

Learning intention: Take action to share this information to help keep citizens safe around the electrified rail network. [extended abstract]

Differentiated success criteria: We will know we have achieved this because …

Multistructural	*I have created a circuit game to teach people how to keep safe around the electrified rail network*
Relational	*…. and I explain how and why the game works to teach others how to stay safe*
Extended abstract	*… and I seek and act on feedback to improve the learning outcomes from the game.*

Key Competency self-assessment rubric[3] Highlight the relevant Key Competencies for section 3.

Thinking	**Managing self**	**Participating and contributing**	**Relating to others**	**Using language, symbols and text**
Critically analyse the factors contributing to safe electrified rail networks for all citizens. *Example – describe, explain and justify ways to stay safe at places on the electrified rail network.*	Act responsibly when around the electrified rail network as a pedestrian, passenger, cyclist or driver to ensure all citizens keep safe. *Example – adopt a "sort it and report it" approach to unsafe behaviour around the electrified rail network.*	Display an awareness of the local issues around creating and maintaining safe electrified rail networks. Be actively involved in community issues around safe electrified rail networks. *Example – listen, respond and act together to make the electrified rail network a system free of death and serious injury.*	Interact with others to create safe electrified rail networks. *Example – demonstrate a commitment to safer outcomes for self, friends, family and whanau at places on the electrified rail network.*	Interpret and use language, symbols and text in ways that keep citizens safe around electrified rail networks. *Example – share safe rules and behaviours for places on the electrified rail network.*

[3] For draft versions of these Key Competency self-assessment rubrics, see the appendix to this Rail Safety Resource.
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3.0. Challenge: Design and create your own circuit game to teach others how to keep safe around the electrified rail network

Explore simple games and how they work; for example, Snakes and ladders, Matching items, Paper, scissors, rock, Snap, Branching stories, Wheel of fortune, Jeopardy, Who wants to be a millionaire, Hangman, Word jumble.

Show examples of games based on connecting simple circuits – Operation, Electrical quiz boards, Wire loop or Buzzing circuit games.

Ask students to work in groups to make a game to teach people something about staying safe around the electrical energy in the rail network.

1. Identify the game message:

   Use the transfer of electrical energy as a context for communicating these key messages:

   - **Stay away from overhead wires carrying electrical energy.**
     - *The electrical energy that moves trains is always dangerous and always on.*
     - *You cannot hear, see or smell electrical energy.*
     - *The electrical energy is 100 times more powerful than the electrical energy used at home.*
     - *The electrical energy can jump gaps of up to 3 metres.*
     - *When electrical energy passes through people, it kills or seriously injures them.*

   - **Always use level crossings to get across the tracks.**
     - *Trains on the tracks are very big, very fast and very quiet.*
     - *Trains take a long time to stop.*
     - *It is dangerous to take shortcuts and trespass.*

   - **Watch out for the second train.**
     - *Obey all warning signs and signals.*
     - *Wait until all warning signs have stopped before crossing – there may be a second train.*
     - *Look and listen in both directions.*

2. Design a game to help others understand the message.

3. Brainstorm ways to include simple electrical phenomena in the game play through the use of simple DC circuit/s in the game design.

4. Create your circuit board game using the ideas generated previously.

Suggested materials

- 4.5V cells (batteries)
- Connecting wires
- 2.5V bulbs
- LEDs
- Switch
- Aluminium foil
- Copper wire

- Alligator clips
- Paper clips
- Stiff card
- Tape

For additional ideas, refer to:
Lesson plan for designing your own circuit game in TES Connect Teachers TV: Primary Science – Electricity: http://www.tes.co.uk/teaching-resource/Teachers-TV-Primary-Science-Electricity-6044058/
Claire's Electric Quiz Board: http://youtu.be/EdMnObe6D4M
Electric Exam: A Home-made Electrical Quiz Board: http://www.darkstar.cc/discovery/electricexam.htm
How to Make an Electronic Matching Game: http://www.youtube.com/watch?v=z8wadyalsy0
Instructables: A Simple Circuit Game: http://www.instructables.com/id/A-Simple-Circuit--Game/
Instructables: Build a Simple Circuit from a Pizza Box: http://www.instructables.com/id/Build-a-Simple-Circuit-from-a-Pizza-Box-No-Solder/
Instructables: How to Make a Custom Operation Game: http://www.instructables.com/id/How-to-Make-a-Custom-Operation-Game/
Instructables: Robot Surgery Game: http://www.instructables.com/id/Robot-Surgery-Game/
Instructables: Wire Loop Game: http://www.instructables.com/id/Wire-Loop-Game/
Instructables: Operation? No O-Paul-Ration: http://www.instructables.com/id/Operation-No-O-Paul-Ration/
Giant Buzz Wire Game: http://youtu.be/_gfSxVIXH2M

Appendix 1: Challenging misconceptions

Look out for common misconceptions about the flow of charges and energy transfer in the student explanations.

Some of these misconceptions and the correct scientific explanations are detailed in Table 1 below. The following websites offer explanations of some other misconceptions.
Common Misconceptions regarding Electric Currents:
http://www.physicsclassroom.com/class/circuits/u9l2e.cfm
Furry Elephant: Common Misconceptions about Electricity:
http://www.furryelephant.com/content/electricity/teaching-learning/misconceptions/
Electricity – Diagnostic Assessment:
http://www1.curriculum.edu.au/sciencepd/teacher/assessment/resr_electricity.htm
Wainwright, C. "Towards Learning and Understanding Electricity: Challenging Persistent Misconceptions" (PowerPoint): http://fg.ed.pacificu.edu/wainwright/presentations.html
Wainwright, C. "Toward Learning and Understanding Electricity: Challenging Persistent Misconceptions" (article pdf) http://fg.ed.pacificu.edu/wainwright/publications.html

Challenge these assumptions through further experimentation, analogies, simple models and discussion.

Table 1: Common student misconceptions about electricity

What can you see? What happened?	**Common student misconceptions** **Why do you think it is like that?** **How and why did it happen?**	**Scientific explanation** **Why do you think it is like that?** **How and why did it happen?**
Circuit	*The circuit as a sequence – where the order matters – for example, the amount of current flowing in components of a circuit is dependent on which one comes "first" or which one is closest to the battery.*	The circuit as a system – any changes affect the entire circuit. An electric circuit is a complete, unbroken pathway for very tiny particles of charge called electrons.
Current	*Current travels around the circuit and is influenced by each component it meets in turn.* *A change made at a particular point in the circuit does not affect the current until it reaches that point.* *The current comes from the battery.*	An electric current consists of a flow of a very large number of moving electrons (negative charge). The current (negative charge) is found in all parts of the circuit – the wires, the battery and the bulb.
Electron	*Electrons are made by the battery.*	Electrons are part of all atoms that make up all matter – they are found in all components and wires in the circuit. For example, there are electrons in the battery, the bulb and the connecting wires.

		In a circuit the charge is conserved and recycled.
Conductors and insulators	*Conductors and insulators are seen as opposites.*	Electrical conductivity varies in different materials and in different conditions. Conductors have free electrons (charges) that can move. Some conductors have more free electrons than others. The electrons in insulators have very little freedom to move around. Some insulators hold onto their electrons more strongly than others.
Battery (several electrochemical cells joined together)	*"Batteries (cells) store electric charge (electrons)."* *"The battery provides the charge (electrons) that flow through the connecting wires in the circuit."* *"The battery supplies the same amount of current (flow of charge) to every circuit regardless of the number and/or arrangement of the circuit components.*	A battery provides the push (energy) to move the electrons (charge). A battery does NOT store electric charge (electrons). The battery (electrochemical cells) stores the energy needed to move charge from a low-energy terminal to a high-energy terminal. A battery does NOT supply the charge (electrons) to the circuit. The battery supplies the energy that moves the charge in the wires through the circuit. A chemical reaction in the battery sets up an electric field that exerts a "push" force on the charge (electrons) already in the metal wires in the circuit. The energy (push) the battery can provide is measured in volts.
Battery voltage		Battery voltage is a measure of the "push" the battery can exert on the electrons (charge) in the wire.
Battery does not work – "Flat battery" *In everyday language, we talk about "recharging batteries",*	Batteries (cells) are constant current providers. When a battery goes "flat", it has run out of charge or electrons.	Batteries are energy providers. Batteries do not run out of charge. Batteries run out of energy to make the charges in

creating misconceptions for students – we should talk about "re-energising batteries".	When a battery or an electrochemical cell no longer works, it must be "recharged" (get more charge) before it can be used again.	the circuit move. When a battery or cell goes "flat", the chemicals reacting to produce the energy for the "push" have been used up and the chemical reaction is finished. When an electronic cell no longer works, it must be "re-energised" (by reversing the chemical reaction) before it can be used again.
Connecting wires – connecting the battery to the bulb and a return wire connecting the bulb to the battery	The wire provides a pathway for the charge to flow along. The wire is empty. When we complete the circuit, a flow of charge (electrons) moves through an initially empty wire. When the flow of charge goes through a light bulb, the charge is used up. The charge flows from the battery to the light bulb, but not from the light bulb to the battery.	Wires are full of charge – free electrons. Electrons (charge) are in the wire and the battery and bulb at all times. Charge is everywhere in the wire at all times. When we complete the circuit, we supply energy to the electrons (charges) and they all move instantaneously – they all move together.
Light bulb – thin metal wire (resistance wire) housed in a glass bulb	The narrow metal wire in the light bulb "resists" or "slows down" the charge flowing through the circuit.	The rate of flow of the charge does not slow down when flowing through resistance wire. The rate of flow of the current remains the same everywhere in the circuit. To ensure the rate of flow of the charge (current) remains the same, the charges speed up at resistances like the narrow metal wire in a light bulb. This increase in speed means the moving charges (electrons) collide more frequently with the fixed atoms in the metal lattice, causing them to vibrate.

		The vibration is emitted as heat and light energy.
When the battery is connected to the light bulb by the wires in a simple circuit, the light goes on – the light bulb emits heat and light energy.	Charge from the battery flows to the light bulb, where it is used up as heat and light. This means there is no charge in the return wire that connects with the battery. The light goes on when the charge in the wire goes through the light bulb (component). Less charge leaves the light bulb than enters the light bulb. Alternatively – the charge leaves both terminals of the battery and meets up in the light bulb. The collision releases heat and light.	Charge is not used up in the light bulb. Energy is delivered to the light bulb. The amount of charge that leaves a light bulb is the same as the amount of charge that entered the light bulb. The energy carried by the charge flowing out of the light bulb is less than the energy carried by the charge entering the light bulb. This is because some energy has been dispersed as heat and light. Charge travels in one direction around the circuit.
The light bulb emits light immediately after the switch is flipped on.	The light goes on when the charge from the battery gets to (or goes through) the light bulb. Charge flows through circuits at very high speeds. Current travels sequentially around the circuit and is influenced by each component in turn. A change made at one point in a circuit does not influence the flow of charge (current) until it reaches that point. For example, students will argue that opening a switch located after a bulb in a circuit will allow the bulb to light up because the current has already passed the bulb.	The light goes on when the battery supplies energy to the charges in the circuit. The energy is delivered to the light bulb by the charges – the energy leaves the circuit as heat and light – the charges keep moving. *Charge does not come from the battery – charge is already everywhere in the wire. Charge is the same everywhere in the wire.* *Charge does not move all the way around the circuit in a short time. It can take hours for a charge to make a complete trip around the circuit.* *Charge moves at the same speed throughout the circuit. For every charge that leaves a battery at one terminal, another one enters the battery at the other*

		terminal. *Charge is just a way of moving the energy from place to place. The rate at which charge flows is the same anywhere in the circuit.*
Adding more light bulbs to a series circuit dims the light from each bulb.	The flow of charge (current) from the battery stays constant. Charge becomes used up by light bulbs so that there is less of it as it goes around.	Changing the circuit by adding extra components changes the current drawn from the battery. The addition of extra components in the circuit increases the current drawn from the battery. The battery does not provide constant current (flow of electrons – charge). The battery provides a push force or energy to each charge. In a series circuit the energy is shared between components. The total energy drop across all the light bulbs must equal the total energy drop across the battery. If you put more light bulbs into a series circuit, the energy from the battery is shared and the lights are dimmer than they were before. The lights are equally dim.
Adding extra light bulbs to a parallel circuit divides the “constant current” provided by the battery.	The current takes the easiest route.	Current cannot choose a route. The energy drop across each component in a parallel circuit is the same as the energy drop across the battery.
A series circuit		A series circuit has only one pathway for the charge to flow along – all the components are in a line.
Current in a series circuit		The rate of flow of charge (current) is the same all around the series circuit.

Appendix 2: Online resources and ideas for exploring simple circuits

University of Colorado: Circuit Construction Kit: http://phet.colorado.edu/en/simulation/circuit-construction-kit-dc

Squishy Circuits (create circuits and explore electronics using play dough):
http://courseweb.stthomas.edu/apthomas/SquishyCircuits/index.htm
TED Talks: Hands on Science with Squishy Circuits:
http://www.ted.com/talks/lang/en/annmarie_thomas_squishy_circuits.html

Engineering Interact: The Real Deal – Electricity:
http://www.engineeringinteract.org/resources/discovermore/electricity.htm
Engineering Interact: Silicon Spies (electricity game): http://www.engineeringinteract.org/interact.htm
Engineering Interact: Simple Circuits:
http://www.engineeringinteract.org/resources/siliconspies/flash/concepts/simplecircuits.htm
Engineering Interact: Building Circuits:
http://www.engineeringinteract.org/resources/siliconspies/flash/concepts/buildingcircuits.htm
Engineering Interact: Circuit Experiments
http://www.engineeringinteract.org/resources/siliconspies/flash/concepts/experimenting.htm
The Blobz Guide to Electric Circuits (interactive animations):
http://www.andythelwell.com/blobz/guide.html

BBC Schools Science Clips: Simple Circuits – ages 6 to 7:
Worksheet: http://www.bbc.co.uk/schools/scienceclips/teachersresources/ages6_7/tr_ages6_7.shtml#

BBC Schools Science Clips: Circuits and Conductors – ages 8 to 9:
Worksheet: http://www.bbc.co.uk/schools/scienceclips/teachersresources/ages8_9/tr_ages8_9.shtml#
BBC Schools Science Clips: Changing Circuits – ages 10 to 11:
Worksheet:
http://www.bbc.co.uk/schools/scienceclips/teachersresources/ages10_11/tr_changing_circuits_wk.shtml
BBC Schools: Static – Static Electricity:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_edexcel/static_elec/staticrev1.shtml
BBC Schools: Static – Electric Shocks:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_edexcel/static_elec/staticrev2.shtml
BBC Schools: Static – Safety Measures:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_edexcel/static_elec/staticrev3.shtml
BBC Schools: Static – Uses of Electrostatics:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_edexcel/static_elec/staticrev4.shtml

BBC Schools: Electric Current – Electric Circuits:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_edexcel/static_elec/electriccurrentrev1.shtml
BBC Schools: Circuits – Series and Parallel Circuits:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_edexcel/controlling_current/circuitsrev1.shtml
BBC Schools: Circuits – Current and Voltage:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_edexcel/controlling_current/circuitsrev2.shtml
BBC Schools: Circuits – Cells and Circuits:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_edexcel/controlling_current/circuitsrev3.shtml
BBC Schools: Circuits – Potential Difference and Charge:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_edexcel/controlling_current/circuitsrev4.shtml

BBC Schools: Annie's Circuit Builder: http://www.bbc.co.uk/schools/podsmission/electricity/annie03.shtml

BBC Schools: Pod's Lemon Battery: http://www.bbc.co.uk/schools/podsmission/electricity/pod.shtml
BBC Schools: Ollo's Electricity – Top Facts:
http://www.bbc.co.uk/schools/podsmission/electricity/ollo.shtml

TKI: Science Online: Nature of Science: Which of these Materials Make the Lights Go on:
http://scienceonline.tki.org.nz/Nature-of-science/Nature-of-Science-Teaching-Activities/Which-of-these-materials-make-the-light-go-on

The FuseBox: Circuit Builder: http://thefusebox.northernpowergrid.com/page/circuitbuilder.cfm