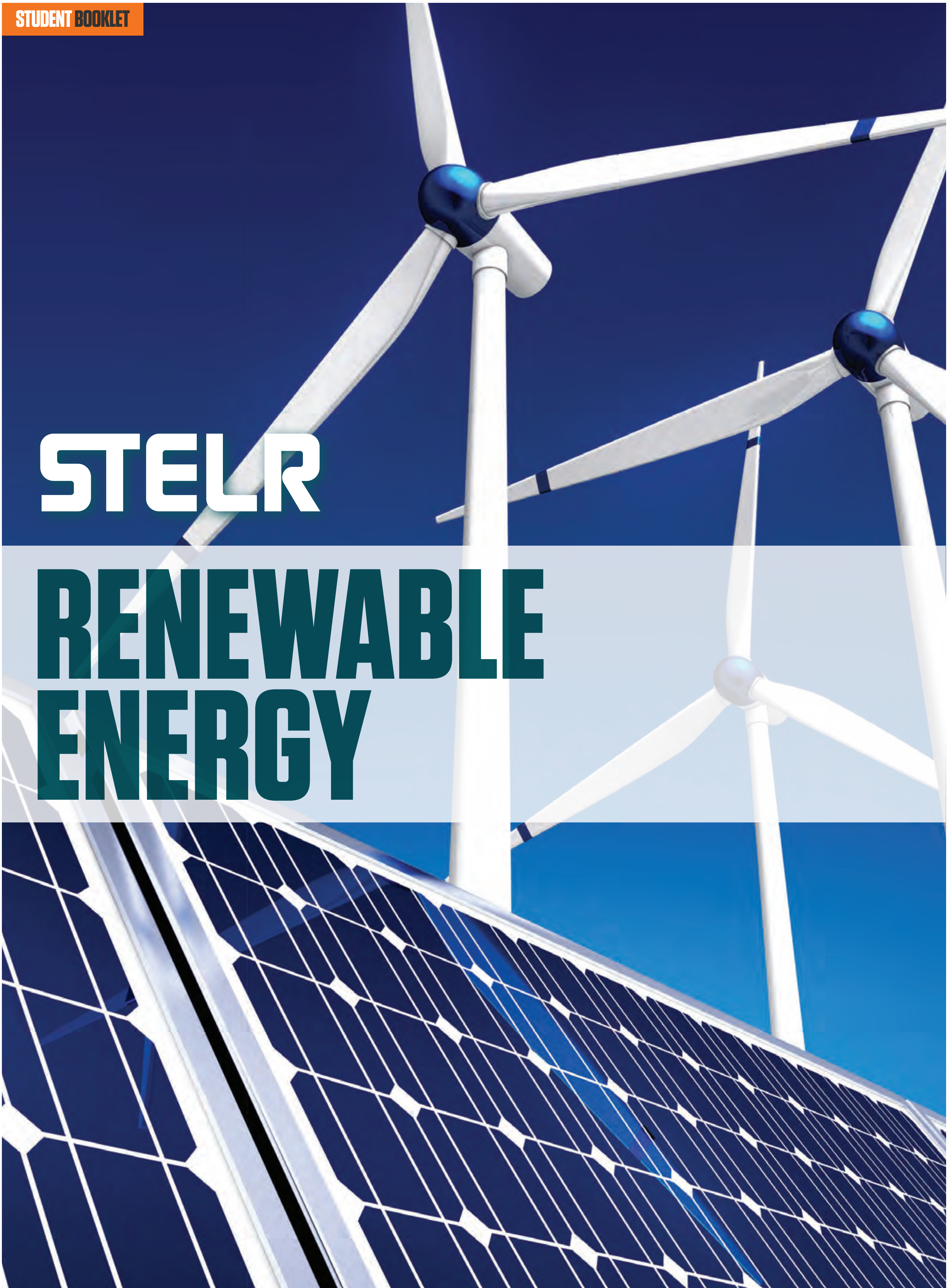
STUDENT BOOKLET



STELR

RENEWABLE ENERGY

NAME

CLASS

STELR

RENEWABLE ENERGY

STUDENT BOOK

RENEWABLE ENERGY was written and produced by the STELR project team.

www.stelr.org.au

Science and Technology Education Leveraging Relevance (STELR) is the key school education initiative of the Australia Academy of Technology and Engineering (ATSE). www.atse.org.au

4th Edition 2019

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1 GLOBAL WARMING

One effect of global warming is an increased number of bushfires.
Credit: CSIRO science image

Earth's climate is changing, and quickly. We need to act to protect people, ecosystems and economies. We know what is causing the changes, and it's mostly to do with how we get energy.

1.1 GETTING STARTED

One of the big issues facing the world at the moment is global warming...or people often call it climate change. So, how much do you know about it?

Share your ideas with your classmates to see what you know and what you are not sure about.

Question 1

In groups of three or four, brainstorm what you know about global warming.

1. Copy the terms below onto small cards or post-it notes.
2. On a large sheet of paper or white-board, write the title *Global warming*.
3. Group the terms that you think belong together and use pens to draw lines and write headings, comments or other words, to show how you think the terms fit together.
4. Mark an area with a question mark in it. Put terms that you do not know, or you are not sure how they relate to global warming, in it.

Some possible terms for the brainstorm are:

- sea level
- energy
- temperature
- flooding
- greenhouse effect
- carbon dioxide
- ice cores
- enhanced greenhouse effect
- heat
- coal
- refugees
- natural gas
- heatwave
- climate change
- ozone
- drought
- methane

1.2 LESSON: GLOBAL WARMING

KEY QUESTIONS

- What is global warming, and what are its causes and effects?
- What can we do about global warming?

Watch this video.

Global Warming: Cold Facts Hot Science
https://youtu.be/CKzxdly7DpY

Take notes for the video below.

There is a lot of information in the video. The questions below will help you to get the main messages.

Each question has the time in the video where you can get the answer.

Question 1

Burning fossil fuels – coal, oil and natural gas – produces carbon dioxide. [3:38]

☐ True

☐ False

Question 2

Carbon dioxide is a greenhouse gas. [3:38]

☐ true

☐ false

Question 3

Greenhouse gases are gases that keep heat that is escaping from Earth into space in the atmosphere longer. [1:42]

☐ true

☐ false

Question 4

Increasing the proportion of greenhouse gases in the atmosphere increases the Earth's average air temperature. [1:47]

☐ true

☐ false

Question 5

The greenhouse effect: [2:03 to 3:03]

(select all the options that are true)

☐ began on Earth around 200 years ago

☐ is caused by how close the Earth is to the Sun

☐ has occurred for so long on Earth that life has evolved for it

☐ is caused by some of the gases in the atmosphere

☐ protects the Earth's surface from dangerous radiation from the Sun

Question 6

Which of the following are effects of global warming that are shown or mentioned in the video?

[0:12 to 0:28 and 7:08 to 8:30]

- ☐ hole in the ozone layer
- ☐ rising sea levels
- ☐ environmental refugees
- ☐ Fires
- ☐ health effects

Question 7

In the video, the narrator, Sean, talks about 'extreme weather events'. Give two examples of the sorts of events you think he's talking about.

____

____

____

As Sean points out, the greenhouse effect makes Earth much warmer than it would otherwise be, and life here has evolved to live in these warmer temperatures. But an increase in the proportion of greenhouse gases in the atmosphere in the last 200 years means we're getting too much of a good thing, and Earth's average temperature is rising.

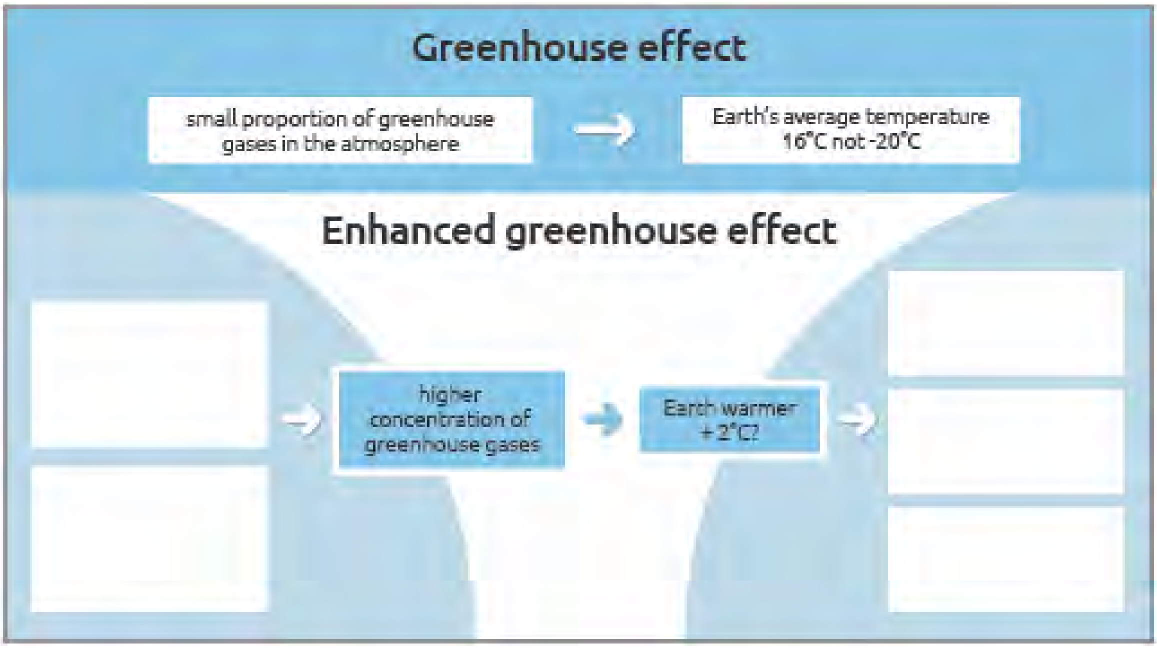
This *increased* greenhouse effect is called the **enhanced greenhouse effect**.

Question 8

The diagram below compares the *normal* greenhouse effect with the *enhanced* greenhouse effect. Complete the diagram by filling in the boxes in the bottom section:

1. two causes of the enhanced effect, on the left-hand side; and
2. three effects of the enhanced effect, on the right.

[3:14 to 4:30]



Question 9

We know that for the last couple of hundred years, as population has increased, we have been burning more and more coal, gas and oil. We might expect that this would lead to higher concentrations of carbon dioxide in the atmosphere, but what evidence is there for this?
[5:17 to 6:22]

Question 10

At 8:50 in the video, Sean talks about how we can turn global warming around. He lists, among other things:

- solar energy
- wind energy
- hydro power
- nuclear energy
- hydrogen for transport
- electric cars

What do these all have in common that will help us stop global warming? Explain.

WRAP-UP

Have you learned what you set out to in this lesson?

Question 11

Which is the best description of global warming?

- ☐ the heating of Earth's atmosphere due to increased proportions of greenhouse gases in the atmosphere
- ☐ the heating of the Earth due to a rise in temperature of the molten rock under the surface
- ☐ the heating of Earth's atmosphere due to holes in the ozone layer
- ☐ the heating of Earth's atmosphere due to increased energy output from the Sun

Question 12

Which options below list some of the effects of global warming?

(select one or more)

- ☐ increased human population and increased use of fossil fuels
- ☐ increased levels of carbon dioxide and methane in the atmosphere
- ☐ increased number of droughts, heatwaves and heavy rainfall
- ☐ migration of people, rising sea level, rising ocean temperature

Question 13

Which of the following are possible ways that we could reduce global warming?

Important: Note the reasons given as well.

- ☐ Use nuclear power stations, because they do not produce greenhouse gases.
- ☐ Use renewable energy technologies like solar and wind, because these energy sources will never run out.
- ☐ Use renewable energy technologies like solar and wind, because these energy sources do not produce greenhouse gases.
- ☐ Don't use plastic bags and containers.
- ☐ Use electric-powered cars, with electricity from renewable sources.

Question 14

What was the biggest thing you learned about global warming doing this lesson?

Question 15

What is the biggest question you still have about global warming?

2 ENERGY

We need energy to hold up a phone, and energy to charge it...what have these things got in common?

It is hard to pin down exactly what energy is.

In this section, you use the STELR equipment to learn more about energy.

2.1 LESSON: WHAT IS ENERGY?

KEY QUESTIONS

- What is energy?
- What are some different types of energy, and what do they have in common?
- What has energy got to do with global warming?

The biggest cause of global warming is the carbon dioxide that we've released into the atmosphere over the last 200 years. And by far the biggest source of that carbon dioxide is from the burning of fossil fuels – oil, coal and gas.

Oil, from in the Earth, is refined and shipped around the world. Almost all of it is burned, chemically changing to carbon dioxide and water vapour, which are released into the atmosphere. Credits: Oil rig, Stephen (danrandom) from UK; car, Steevven1(both Wikimedia Commons)

But what exactly is energy? It is not an easy question...

Question 1

Draw your ideas of what energy is.

Question 2

All of the pictures above have something to do with energy – often more than one type. With a partner, see how many types you can identify.

Note: Do not worry if you're not sure – this is to see what you know now, and you'll get a chance to come back for another attempt later.

	Energy type 1	Energy type 2	Energy type 3
Skier			
Wind turbines			
Sun			
Dog on trampoline			
Petrol pump			
Energy drink			
Radio			
Cow			
High jumper			
Power pylons			
Fire			

Question 3

Now, after discussing with your partner, have a go at saying what energy is.

Energy is about **moving** – either something *actually moving* or with the *potential* to move. Here are some examples.

Actually moving

- Anything that moves has **kinetic energy**.
- If it's a machine that's moving the kinetic energy is often called **mechanical energy**.
- **Light**, and all electromagnetic waves, move...they're a form of kinetic energy.
- **Heat** is the movement of the atoms that something is made up of, so it's a type of kinetic energy.
- **Sound** is the movement of atoms or molecules – also a type of kinetic energy.

Potentially moving

- Something above the ground has the potential to fall – that is, move – so it has **gravitational potential energy**.
- Anything that burns or is eaten as food contains **chemical potential energy**.
- **Electricity** can be used to make light, heat and sound, and to make things move – it is a form of potential energy.
- A spring, compressed or extended, will move when it's let go – it has **elastic potential energy**.

Question 4

When something is moving it has: *(choose the best answer)*

- ☐ potential energy
- ☐ electrical energy
- ☐ chemical energy
- ☐ mechanical energy
- ☐ kinetic energy

Question 5

Which of the following are types of potential energy? *(select one or more)*

- ☐ elastic energy
- ☐ gravitational energy
- ☐ sound energy
- ☐ kinetic energy
- ☐ chemical energy

Question 6

We classify heat as a type of ____________ energy because ____________.
(choose the best answer)

- ☐ kinetic; it can move from one object to another
- ☐ kinetic; the atoms in hot things move faster than in cold things
- ☐ potential; we store it in objects when they get hotter and hotter
- ☐ potential; though it doesn't involve movement itself, it can make things move, like a hot air balloon

Question 7

Nuclear energy is energy contained *inside* atoms. It is different from chemical energy, which is the energy *between* atoms. Nuclear energy is only released if atoms are heated to extremely high temperatures, such as in stars.

Is nuclear energy a type of kinetic or potential energy?

- ☐ kinetic
- ☐ potential
- ☐ neither kinetic nor potential energy

WRAP-UP

How have you gone in this lesson? These questions will check if you have understood the main points.

Question 8

Which is the best description of energy?

- ☐ what moving things have, and what can make them move
- ☐ how active you feel
- ☐ what anything made of atoms has
- ☐ how fast something is going, or how hot it is

Question 9

All the different types of energy:

- ☐ are in or come from living things
- ☐ are basically different – we call them all energy but in physics they're different things
- ☐ always involve objects that are moving, or have moving parts
- ☐ involve either things moving, or the potential to make things move

2.2 PRAC: ENERGY TOYS

KEY QUESTION

- What happens to the energy in these toys?

Energy stories

If you watch something for a while, you can generally tell an *energy story* about it. That is, you can say what it does, or what happens to it, paying particular attention to its energy.

You know how to identify quite a few types of energy now, so you should have no trouble telling energy stories for the devices in these demonstrations.

COTTON-REEL RACER

Set up the cotton-reel racer and get it going. You may have to play around a bit before you get it to run smoothly.

Question 1

Discuss with a classmate and then write the energy story of the racer.

See if you can include the following in your story:

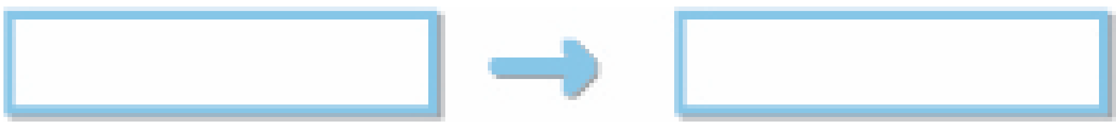
- Is any potential energy involved?
- Is any kinetic energy involved?
- Does energy change location?

Note: It will help your story a lot if you include diagrams.

Question 2

When the racer is moving along it seems to be using up one form of energy and turning it into another form.

Write what the energy types are in the boxes.



JUMPING CUPS

Fold a jumping cup inside out and place it on a tabletop. Let go and stand clear...

Question 3

Discuss with a classmate and then write the energy story of a jumping cup.

See if you can include the following:

- Is any potential energy involved?
- Is any kinetic energy involved?

Note: As before, consider using diagrams to illustrate your story.

Question 4

Consider a jumping cup from the time that you let it go until when it falls back to the table-top again (just before it hits the table).

Identify the main types of energy that the cup has in this time and write them in order, using arrows to show the changes.

WRAP-UP

Question 5

Compare the two demonstrations and your energy stories for them.

- In terms of the energy involved, both the demonstrations had something in common. What?

  Hint: This should be evident from the energy changes that you identified in Question 2 and Question 4.

Describe two differences in this common feature in the two demonstrations.

2.3 LESSON: TRANSFORMATIONS AND TRANSFERS

KEY QUESTIONS

- What is energy transformation and how can we represent it?
- What is energy transfer?

ENERGY TRANSFORMATION

Fossil fuels such as coal, oil and natural gas contain chemical energy. When we use them, it's not chemical energy that we want. We want:

- kinetic energy, for example using petrol to power cars;
- heat energy, for example in a gas home-heating system;
- electrical energy, for example in coal-fired power stations.

We start with energy in one form, and then change or **transform** it into another.

We can represent energy transformations with word formulas, using arrows. For example, for a car using petrol the transformation is:

chemical energy → kinetic energy

Burning gas for heat it's:

chemical energy → heat energy

and in a coal-fired power station it's:

chemical energy → electrical energy

Question 1

Like all coal-fired power stations, Eraring in New South Wales is designed to carry out a particular type of energy transformation. In this photo, you can see coal, electrical poles and wires, and structures where the transformation takes place.

Put stickers on the photo where the chemical energy is, where the electrical energy is, and where the energy transformation takes place. Write 'chemical energy' and 'electrical energy' on the appropriate stickers, and draw an arrow in the right direction for the transformation. (Write on the photo if you do not have stickers.)

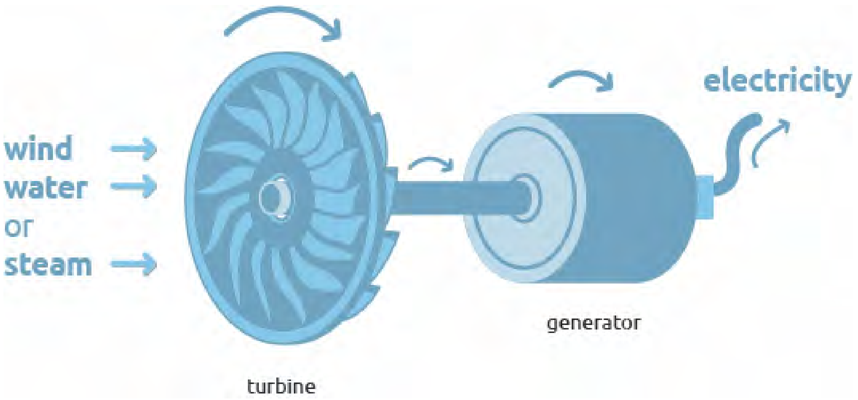
Question 2

The poster to the left was issued in the United States during the First World War.

- Explain the message it is conveying.
- Do you think that 'consumes' is a good word to use here? What would be a more scientific way of saying 'light consumes coal'?

Turbines and generators

Coal-fired power stations do not transform coal's chemical energy directly into electricity – there is a chain of transformations in between.



In a coal-fired power station, the coal fires heat up water to make high-pressure steam to turn a *turbine* – a mechanism that spins. The turbine, in turn, spins a *generator* – a mechanism that turns mechanical energy into electricity (by spinning a magnet inside wiring, but you don't have to remember this). Hydro-electric power stations use falling water to turn the turbine and wind turbines use moving air.

Question 3

Turbines are moved by wind, water or steam. Which of the following best describes the energy transformations when a turbine is connected to a generator to create electricity?

- ☐ kinetic → mechanical → electricity
- ☐ mechanical → gravitational → electricity
- ☐ kinetic → chemical → electricity
- ☐ elastic → kinetic → electricity
- ☐ light → elastic → electricity

Two hydro-electric plants in Tasmania. Left. Wilmot power station, 32 MW. Water flows down the pipe to the turbine in the building at the bottom. Right: The Gordon Dam, 450 MW. Three underground turbines are fed from an 80 m vertical channel from the bottom of the lake.

Hydro-electric power

In hydro-electric power stations, turbines are moved by water. The water comes from dams above the turbines, where it has gravitational potential energy relative to the turbines.

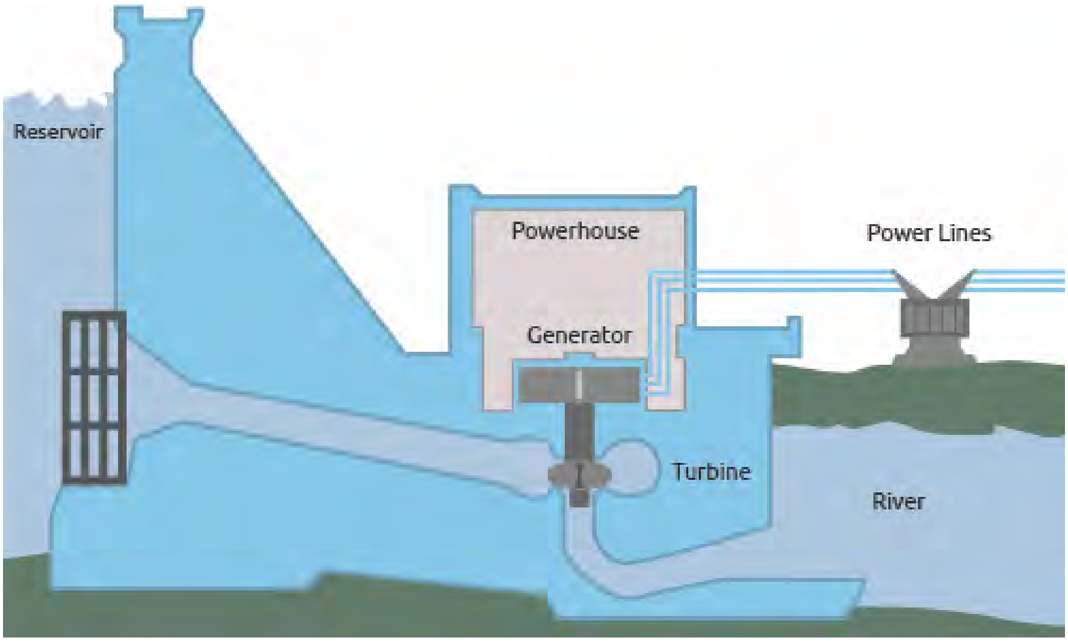
Water is piped to the turbines from the bottoms of the dams. Sometimes the turbines are at the base of the dam and sometimes they are further downhill (or even underground, as at the Gordon dam) to maximise the height of the water above them.

Question 4

Below is a diagram of a hydro-electric power station.

User stickers or a contrasting coloured pen to label where the following types of energy are:

1. electrical
2. mechanical
3. gravitational
4. kinetic



Question 5

Create a word formula for the three energy transformations that occur in a hydro-electric power station. Write the four energy types in the boxes below.

ENERGY TRANSFER

Energy **transfer** is when energy stays in the same form, but moves from one place to another. Here are two examples:

- **Turbine spinning a generator**
  In a power station, the turbine is connected to the generator by a shaft – a long metal rod. The mechanical energy of the turbine is transferred along the shaft and becomes mechanical energy in the generator.
- **Power lines**
  Electrical energy generated in power stations is transferred *via* power lines to houses and businesses where it is used.

Question 6

Describe two other examples of energy transfer.

Energy type	Transfer example

WRAP-UP

Are you on top of what energy transfers and transformations are?

Question 7

Which is the best description of what energy transformation is?

☐ when something gets more energy

☐ when energy in a particular form moves from one place to another

☐ when energy changes into matter

☐ when energy changes from one form into another

Question 8

Which is the best description of what energy transfer is?

☐ when something gets more energy

☐ when energy in a particular form moves from one place to another

☐ when energy changes into matter

☐ when energy changes from one form into another

2.4 PRAC: TRANSFORMATIONS AND TRANSFERS

KEY QUESTION

- How many energy transformations and transfers can you identify?

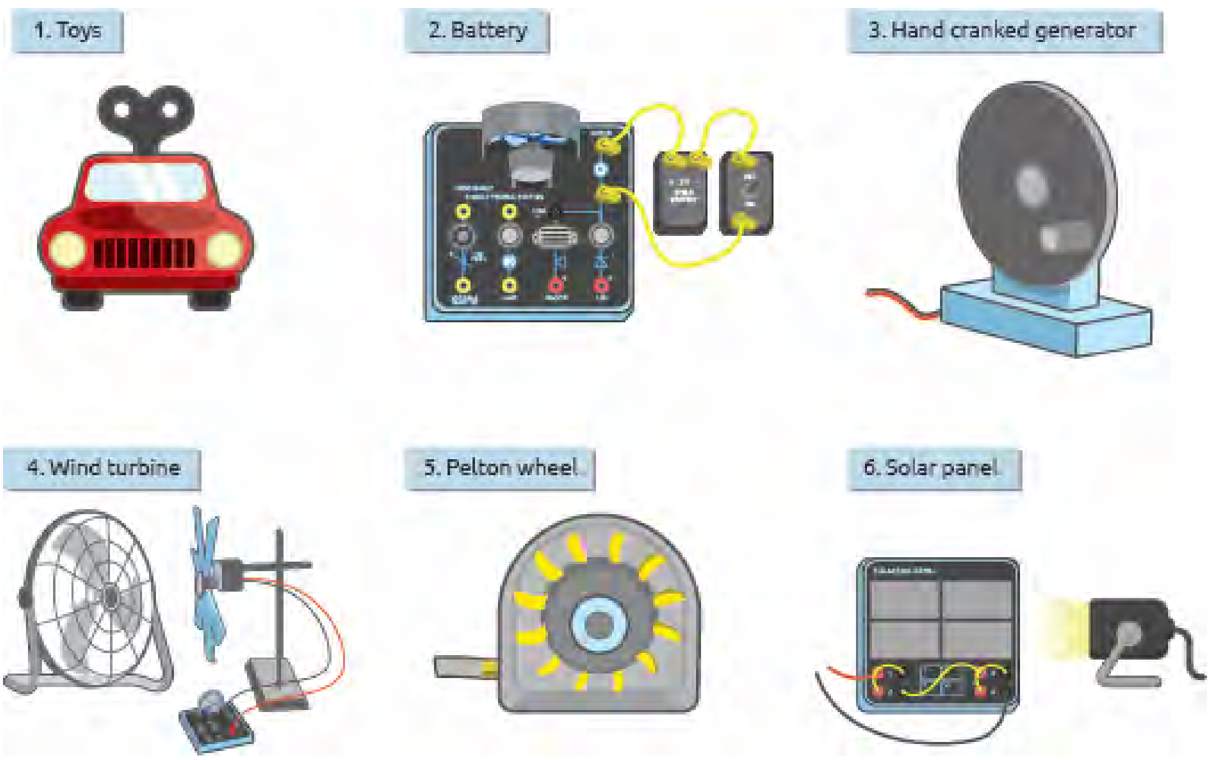
In this prac you get to observe more energy transformations, most of them with electricity as one of the energy forms. Look out for energy transfers as well.

There are six stations. In groups, move around to explore the energy transfers and transformations that can be carried out on the equipment at each one.

Each station should be ready for you when you get to it, which means:

leave each station as you found it!

The numbers and names of the stations are:



Your teacher will give you directions for each station and tables to record your observations.

2.4.1 STATION 1: TOYS

WHAT TO DO

Examine the toys and make them work.

Think about the starting energy in each toy and how it might be *transferred* from one place to the next, or how it is *transformed* into another form of energy.

Question 1

Toy 1: Give a brief description of the toy and a quick explanation of how you think it works.

Question 2

Toy 2: Give a brief description of the toy and a quick explanation of how you think it works.

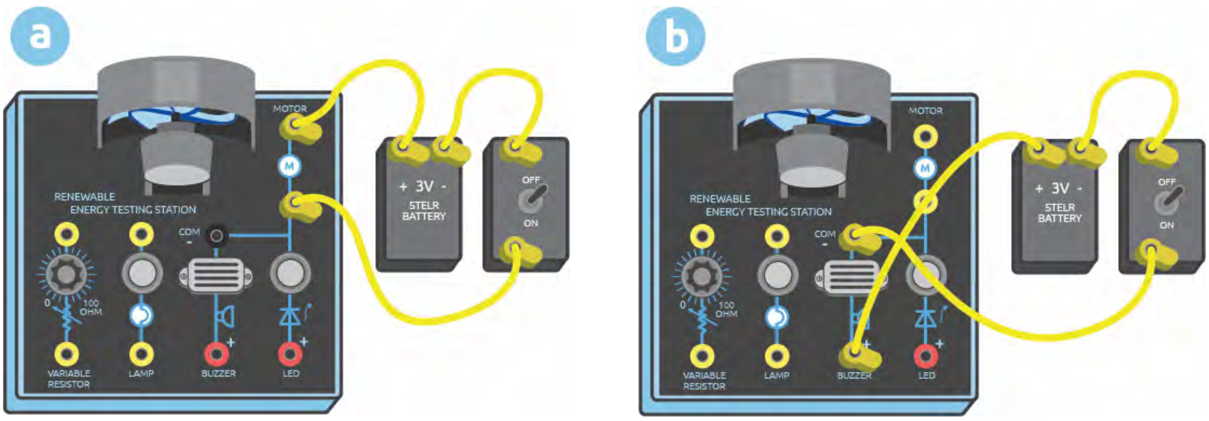
Question 3

Identify energy transformations and transfers in the toys.

Toy no.	Energy transformations	Energy transfers
1		
2		

2.4.2 STATION 2: BATTERY

This station has the STELR battery connected to the fan and then the buzzer on the testing station.



WHAT TO DO

- With the equipment set up as in A above, turn on the switch and observe what happens.
- Turn off the switch and reconnect as in B:

  a. **red +** on the battery → **red + BUZZER** on the testing station;

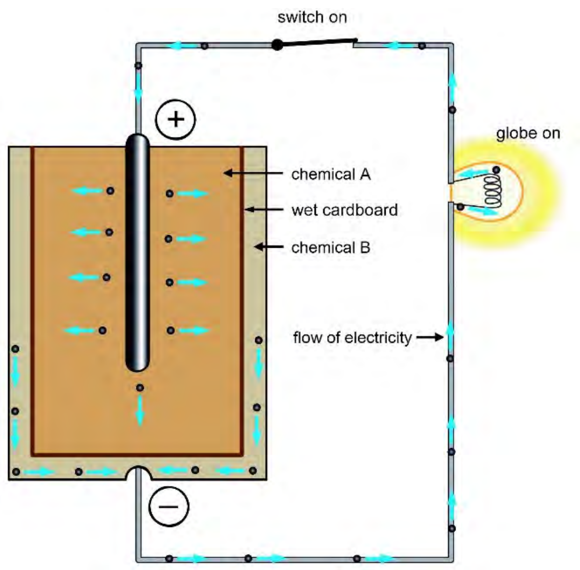
  b. switch connector → **black COM –** on the testing station.
  Turn on the switch and observe.

Question 4

Identify energy transformations and transfers in the two setups.

	Energy transformations	Energy transfers
Fan		
Buzzer		

If you’re not sure about the type of energy in a battery, the diagram to the right should give you a clue.



ADDITIONAL QUESTIONS

For both setups, swap the connections to the testing station.

Question 5

Did you observe any changes when you reversed the cables to the fan? If so, describe them.

Hint: Look closely...there is a difference.

Question 6

Did you observe any changes when you reversed the cables to the buzzer? If so, describe them.

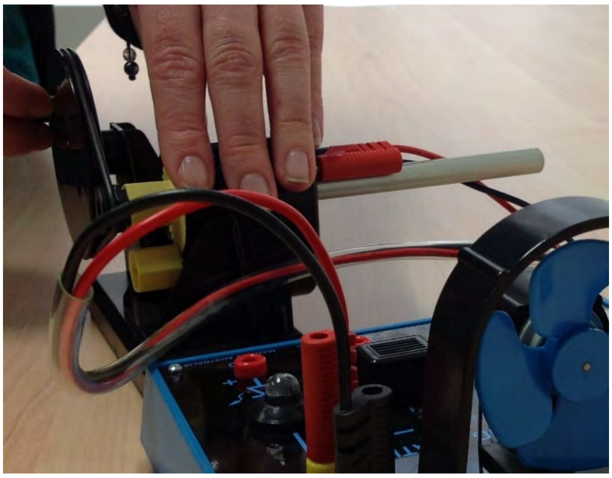
When you’re finished, leave the equipment as in diagram A, with the switch off.

2.4.3 STATION 3: HAND-CRANKED GENERATOR

This station has the STELR hand-cranked generator connected to the fan and then the lamp on the testing station.

WHAT TO DO

- With the hand-cranked generator connected to the MOTOR connections, turn the handle of the generator. Observe.
- Move the cables on the testing station to the two yellow LAMP connections.
- Turn the generator handle and observe.



Question 7

Identify energy transformations and transfers in the two setups.

	Energy transformations	Energy transfers
Fan		
Lamp		

ADDITIONAL OBSERVATIONS

With the generator connected to the fan:

- turn the handle each way. Does it make any difference?
- change the speed you turn the handle. Does it make any difference?

With the generator connected to the lamp:

- turn the handle each way. Does it make any difference?
- change the speed as you turn the handle. Does it make any difference?

Question 8

What did you observe with the fan:

- when you changed the direction that you cranked?
- when you changed the speed that you cranked?

Question 9

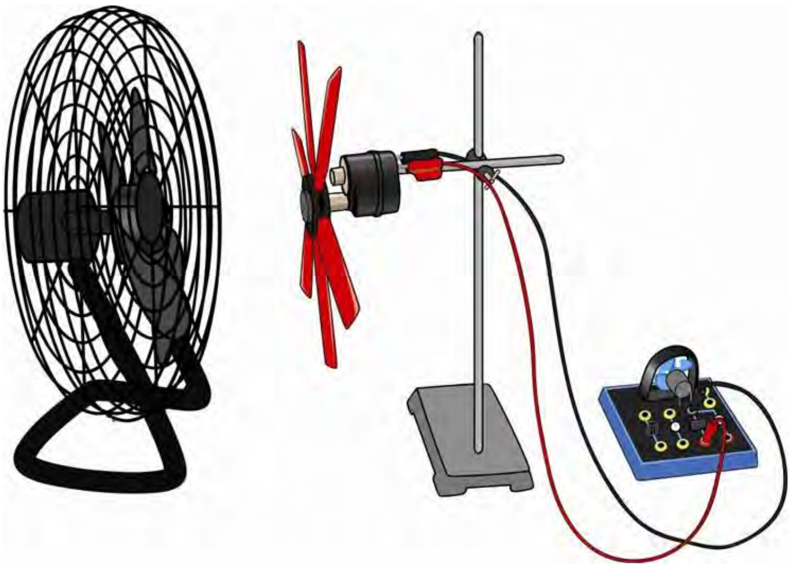
What did you observe with the lamp:

- when you changed the direction that you cranked?
- when you changed the speed that you cranked?

When you are finished, leave the generator connected to the fan.

2.4.4 STATION 4: WIND TURBINE

This station has the wind turbine connected first to the buzzer, and then to the lamp on the testing station.



Initial setup with the wind turbine connected to the buzzer.

WHAT TO DO

- Turn the fan on medium and listen.
- Move the cables to the two yellow LAMP connections on the testing station.
- Observe.
- Turn off the fan.

Question 10

Identify energy transformations and transfers in the two setups.

	Energy transformations	Energy transfers
Buzzer		
Lamp		

ADDITIONAL OBSERVATIONS

With the turbine connected to the buzzer and, after that, to the lamp, change the fan setting between low, medium and high.

Question 11

Did you notice any changes with the buzzer when you changed the fan setting? If so, describe them.

Question 12

Did you notice any changes with the lamp when you changed the fan setting? If so, describe them.

When you are finished, leave the turbine connected to the buzzer (so it will sound). Turn off the fan.

2.4.5 STATION 5: PELTON WHEEL

This station has the STELR Pelton wheel connected first to the lamp and then the LED on the testing station.

Pelton wheels are a type of water turbine. Traditional water wheels feed water to the top of the wheel and the water's weight turns the wheel. Pelton wheels use the force of the running water striking the 'buckets' around the wheel.

A Pelton wheel from the Walchensee Power Plant, Germany. Credit: Wikimedia Commons

WHAT TO DO

- Make sure that the hose is firmly connected to the tap and Pelton wheel, and that the water coming out of the wheel will flow into the sink.
- Turn on the tap to get the Pelton wheel spinning and observe.
- Move the cables to the red **+ LED** and black **COM –** connections on the testing station. If the LED doesn't light up, swap the connections.
- Observe.
- Turn off the tap.

Question 13

Identify energy transformations and transfers in the two setups.

Setup	Energy transformations	Energy transfers
Lamp		
LED		

ADDITIONAL OBSERVATIONS

- Turn the tap handle to change the water flow from the tap for both the lamp and LED.
  CAREFUL! Don't twist the tap onto full rapidly!
- Reverse the connections for the lamp and LED.

Question 14

What did you observe with the lamp when you changed the water flow and swapped connections?

Question 15

What did you observe with the LED when you changed the water flow and swapped connections?

Now set the tap so that the lamp or LED is glowing. Listening carefully, pull out a cable connector from the testing station.

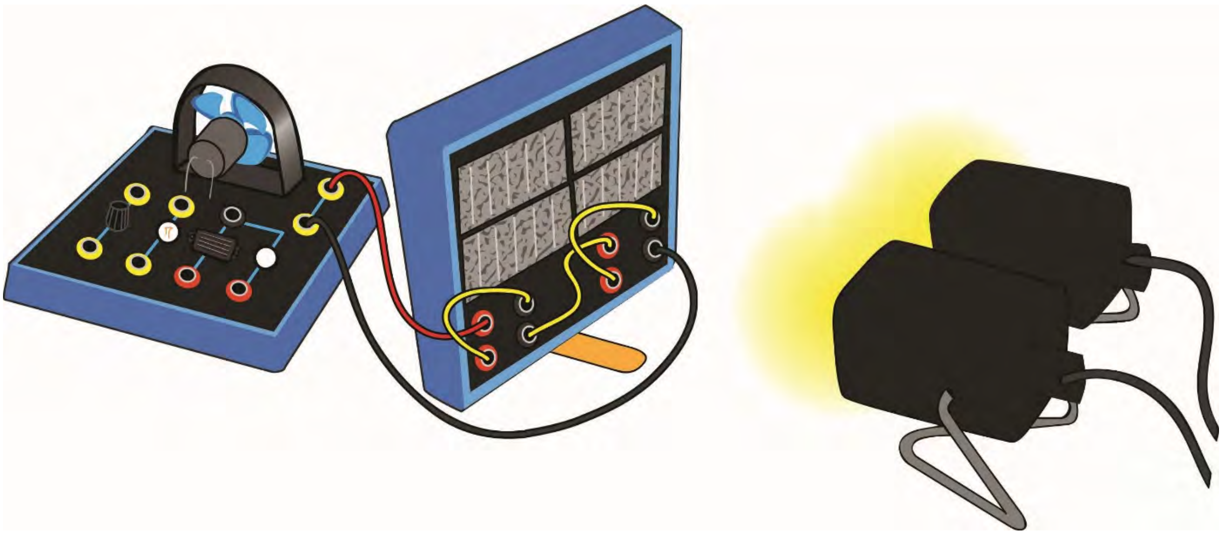
Question 16

Did you hear anything when the cable connector was pulled out of the testing station? Describe what you heard.

When you are finished, leave the Pelton wheel connected to the lamp, with the tap turned off.

2.4.6 STATION 6: SOLAR PANEL

This station has the STELR solar panel connected first to the fan and then to the LED on the testing station.



The STELR solar panel connected to the fan.

WHAT TO DO

- If using halogen lamps as a light source, turn them on at the wall and adjust if necessary to point them at the solar panel.
  If using sunlight, move the panel into direct light.
- Observe.
- Move the cables to the red **+ LED** and black **COM –** connections on the testing station. If the LED doesn't light up, swap the connections.
- Observe.
- Turn off the halogen lights or move the panel out of direct sunlight.

Question 17

Identify energy transformations and transfers in the two setups.

Setup	Energy transformations	Energy transfers
Fan		
LED		

ADDITIONAL OBSERVATIONS

- For both the fan and LED, change the amount of light falling on the solar panel by moving the halogen lamps or moving the panel between direct light and shade. **CAREFUL!** The halogen lamps get hot!
- Reverse the connections for the lamp and LED.

Question 18

What did you observe with the fan:

- when you changed the amount of light falling on the solar panel?
- when you swapped connections?

Question 19

What did you observe with the LED:

- when you changed the amount of light falling on the solar panel?
- when you swapped connections?

When you are finished, leave the solar panel connected to the fan.
Turn off the halogen lights.

2.4.7 PRAC SUMMARY

It is time to consider what all the different station setups tell us about energy.

Answer the questions below to help build up an overview.

Question 1

Identify two stations where the starting energy was kinetic energy.

What was similar and what was different about the two examples?

Question 2

How many different forms of energy were produced from electrical energy? What were they?

Question 3

Was there an example of energy transformation **kinetic** → **electrical** → **kinetic**? What was it?

Can you think of another, real-world example, where a chain of transformations like this occurs? If you start and finish with kinetic energy, what is the advantage of such a chain?

Question 4

Give an example from the prac showing that one type of energy can be produced from different types of energy.

Question 5

Name some common devices in which the following energy *transformations* take place:

	Transformation	Example of device
1	Electrical energy to sound and light energy	
2	Electrical energy to heat energy	
3	Chemical energy to mechanical energy	
4	Kinetic energy to mechanical energy	
5	Electrical energy to mechanical energy	

Question 6

There is no example in the prac of *sound* being transformed into another type of energy.

Do you think that this is because sound is a type of energy that cannot be transformed? Explain.

ADDITIONAL QUESTIONS

Question 7

In the prac you were asked to:

- vary the speed that you turned the hand-cranked generator;
- move the fan different distances from the wind turbine;
- change the amount of water flow in the Pelton wheel; and
- change the amount of light striking the solar panels.

What happened in each case?

Donna, a student, thinks that these examples tell us something about the *amounts* of energy involved in transformations. What could it be? Do you think she is on to something?

Question 8

Remember what happened when you:

- swapped connections for the lamp, buzzer, fan and LED;
- changed the direction you turned the hand-cranked generator for the lamp and fan.

What happened in each case?

Derek, another student, says that the results show that electricity always flows in a particular *direction*. Do you think he is right? Explain.

2.5 LESSON: BRANCHING TRANSFORMATIONS

KEY QUESTIONS

- Are energy transformations usually one-to-one?
- How can we represent branching energy transformations?
- What role does heat play in energy transformations?

You should be feeling comfortable with the idea of energy transformations by now, but they are not quite as simple as we have presented them so far. To see this, consider two examples: jumping cups again, and riding a bike.

Example 1: Jumping cups

Make a jumping cup jump on the top of your desk or bench. We know you get this transformation: **elastic** → **kinetic**, but is this the *only* transformation that occurs?

Hint: Listen.

Question 1

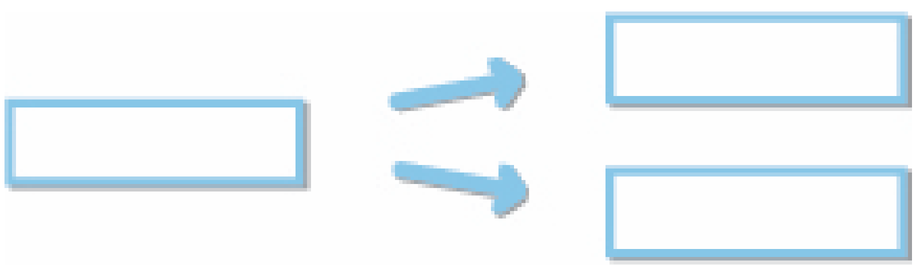
What other energy transformation occurs when the jumping cup snaps back into shape?

The jumping cup carries out two transformations at once, both starting with elastic energy. These can be represented as two word formulas, as above, but an **energy transformation flow chart** saves time and gives a better overall picture.

You'll see what an energy transformation flow chart is in the next question.

Question 2

Complete the energy transformation flow chart for a jumping cup below.



Example 2: Riding a bike

When you ride a bike, you use chemical energy from your food, and of course the purpose is to make yourself (and the bike) move. But that's not the only energy transformation.

Question 3

Do you stay the same temperature when you ride a bike (at least, if you ride for a while, and the air temperature isn't particularly hot or cold)?

☐ Yes, you stay the same temperature.

☐ No, you cool down.

☐ No, you heat up.

Question 4

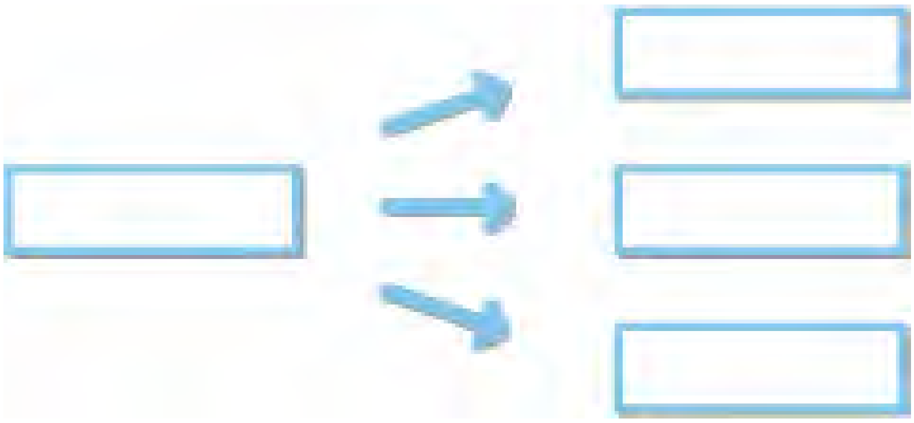
Does a bike make any noise (even if it is very little) when you ride it?

☐ Yes, there's always some sound.

☐ No, it doesn't make the slightest sound.

Question 5

With the hints from the questions above, complete a flow chart for the energy transformations that occur when you ride a bike.



USEFUL AND WASTE

Whenever we 'use' energy, we are actually transforming it from one form into another form that is useful to us.

For example, when we 'use' electricity to run our phones, we are transforming it into light, to see the screen, sound, to listen to music, and radio waves, so that we can make calls. But phones also get warm. So, some of the electricity is transformed into heat and in a phone, the heat is waste energy.

On the other hand, sometimes we want heat – it just depends on the way we're making use of the energy transformation.

Question 6

For the machines and devices below, identify which energy types they produce that are useful and which are wasted.

Finish the exercise with two machines or devices of your own.

Device	Useful energy	Waste energy
		
		
		

WRAP-UP

What are the main take-away messages you have from this lesson? The best way to show your teacher is with an energy flow chart.

Question 7

Wind turbines produce electricity, but they make some noise and the mechanisms get hot as well.

Create an energy flow chart to show the energy transformations in a wind turbine.

Question 8

Explain what your chart above means.

Question 9

Are all the energy types that are produced wanted? Explain.

2.6 LESSON: ENERGY CONSERVATION

KEY QUESTIONS

- What happens to the amount of energy during energy transformations?
- How can we represent the amounts of energy in energy transformations?

Most energy transformations produce energy in more than one form. For example, when a jumping cup jumps it transforms elastic energy into kinetic energy, sound and heat.

DEMONSTRATION: JUMPING CUPS, ONE MORE TIME

Use the cups again in a simple demonstration to look at *how much* energy is produced in the different forms: kinetic, sound and heat. We can't measure these accurately – and we won't try to measure heat at all – but it's possible to get enough information to make comparisons:

- the height a cup goes indicates how much kinetic energy it got; and
- how loud it is indicates the amount of sound energy it released.

Try jumping cups on the following surfaces:

- desk or bench-top;
- carpet;
- palm of hand;
- tip of finger;
- any other surfaces you have available.

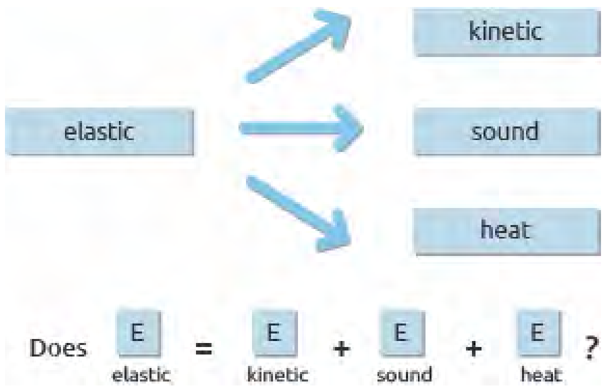
You should have observed quite a range in the heights the cups jumped and some significant differences in the sounds as well!

But, a question:

- Was the total amount of output energy – that is, kinetic, sound and heat – always the same as the amount of elastic energy before the transformation?

If we use $E_{[energy\ form]}$ to represent the amounts of energy (in joules) this is the same as asking if:

$E_{elastic} = E_{kinetic} + E_{sound} + E_{heat}$ is true.



Discussion and poll

Discuss the question in groups. You are not going to be able to give an answer for sure, but see if you can think of reasons why you would answer one way or another. Then answer the poll below in a show of hands.

The options are:

- energy after equals energy before;
- energy after is less than energy before;
- energy after is more than energy before; and
- it depends...there is not a single rule.

CONSERVATION OF ENERGY

Over many years of observation, scientists have concluded that energy cannot be created or destroyed. This is called the **law of conservation of energy**. It means that:

- for the jumping cups that we started this lesson with, $E_{elastic} = E_{kinetic} + E_{sound} + E_{heat}$ is true; and
- in every energy transformation or transfer there is the same amount of energy after as before. The energy is in different forms and/or places, but the total number of joules never changes.

Question 1

In almost every energy transformation, a very small amount of energy is destroyed.

☐ true

☐ false

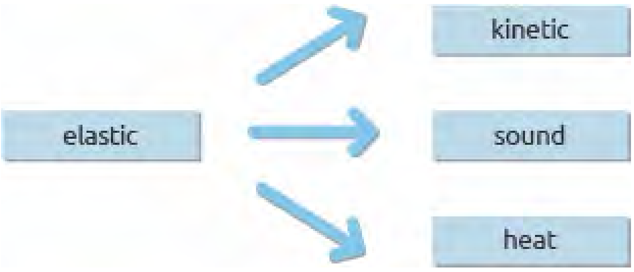
Question 2

According to the law of conservation of energy, the total amount of energy in the universe never changes.

☐ true

☐ false

CHALLENGE: REPRESENTING THE CONSERVATION OF ENERGY



Flow charts are good at showing when energy transforms into more than one type. But they don't indicate *how much* energy is in each form – for example, in the flow chart to the left, for a jumping cup, it's impossible to tell if most of the energy transformed into kinetic, sound or heat energy.

Your challenge is to create a way of representing energy transformations that also represents the *amounts* of energy, or at least, the *proportions* of each energy type.

Therefore, for example, your new means of representation should be able to show if (for the transformation above):

- most of the elastic energy became kinetic energy; and
- that overall, energy was conserved.

Question 3

Create a new way to represent energy transformations that indicates relative amounts of energy in each form, and which can be used to represent the conservation of energy.

Note: You will probably need to try out ideas with pencil and paper, and then draw a final copy below.

WRAP-UP

Question 4

In your own words, say what the law of the conservation of energy is.

2.7 LESSON: ENERGY EFFICIENCY

KEY QUESTIONS

- What is energy efficiency and how do you calculate it?
- What are Sankey diagrams?

When we transform energy in a machine or with a device, only a portion of the original energy is transformed into the form we want. The rest is wasted – at least, from our perspective.

For example, incandescent light bulbs, like the lamp on your STELR testing station, only transform about 2% of the electrical energy they receive into light. The rest becomes heat. For the purpose that a light bulb is intended to carry out, that is 98% of the energy wasted! In comparison, the LED on the testing station converts a bit under half of the electrical energy it receives into light.

The percentage of energy that a machine or device converts into the form we want is called its **efficiency**.

Therefore, in our examples, an incandescent light bulb is just 2% efficient, and an LED is about 50% efficient.

Calculating energy efficiency

Calculate energy efficiency with the following formula:

$$\text{energy efficiency (\%)} = \frac{\text{useful energy out (J)}}{\text{total energy in (J)}} \times 100$$

Example 1

A compact fluorescent light bulb uses 40 J of electrical energy to produce 4 J of light and 36 J of heat. What is the bulb’s efficiency?

In this example the useful energy out is the light, so...

$$\begin{aligned} \text{energy efficiency (\%)} &= \frac{\text{useful energy out (J)}}{\text{total energy in (J)}} \times 100 \\ &= \frac{4}{40} \times 100 \\ &= 10\% \end{aligned}$$

The bulb is 10% efficient.

Example 2

A toaster uses 80 J of electrical energy to produce 72 J of heat and 8 J of light. How efficient is the toaster?

This time the useful energy out is the heat.

$$\text{energy efficiency (\%)} = \frac{\text{useful energy out (J)}}{\text{total energy in (J)}} \times 100$$

$$= \frac{72}{80} \times 100$$

$$= 90\%$$

The toaster is 90% efficient.

Question 1

A typical coal-fired power station transforms each 1000 J of chemical energy in the coal into 100 J of sound, 550 J of heat and 350 J of electrical energy. What is such a station's efficiency?

(show your working)

Question 2

A hair dryer converts each 500 J of electrical energy into 50 J sound, 125 J of kinetic energy (blowing the air) and 325 J of heat. How efficient is the dryer?

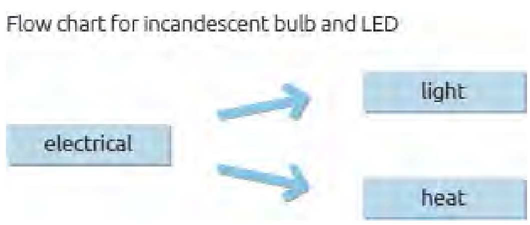
Note: Careful...this question is a bit more difficult than the examples.

SANKEY DIAGRAMS

Returning to incandescent bulbs and LEDs, we currently have two ways of representing their energy transformations. We can use a word formula:

electrical energy → light + heat

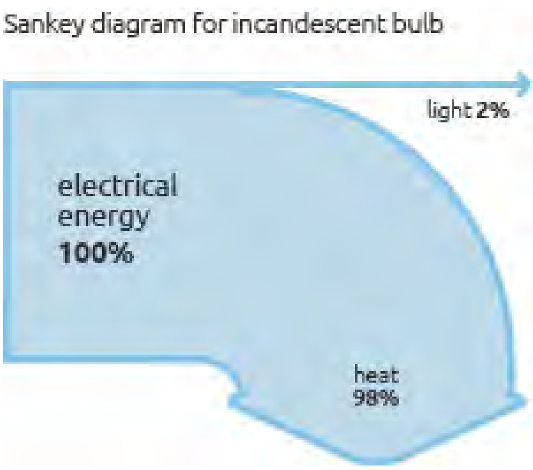
or a flow chart, as shown below.

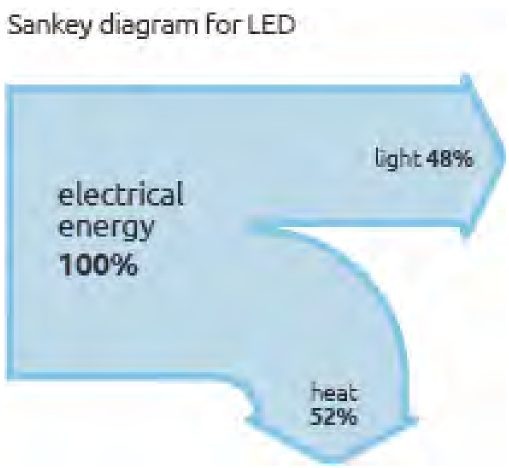


Incandescent globe LED

But with these types of representation, incandescent bulbs and LEDs look exactly the same – neither of them show the proportions of the output energy forms.

Sankey diagrams are ones that show these proportions:





Sankey diagrams use the width of the arrows to represent the proportions of energy. The base of the arrow, on the left, always represents *all* of the starting energy – 100% – then this breaks into arrows to represent each energy type produced in the transformation. Downwards-curving arrows indicate unwanted energy and straight arrows show the energy we want from the transformation.

Question 3

The toaster mentioned above was 90% efficient, wasting the remainder of its input energy as light.

Complete the Sankey diagram for the toaster below by writing the correct energy type – electrical energy, heat or light – in the box for each arrow. Then add the percentage values.

To draw Sankey diagrams accurately you need to calculate the percentage of each of the output energy forms.

This uses essentially the same equation as you used to work out efficiency. For example, to calculate the percentage of energy transformed to heat in a transformation:

$$\text{heat energy (\%)} = \frac{\text{heat produced (J)}}{\text{total energy in (J)}} \times 100$$

or to calculate the percentage of energy transformed to kinetic energy:

$$\text{kinetic energy (\%)} = \frac{\text{kinetic energy produced (J)}}{\text{total energy in (J)}} \times 100$$

Question 4

The hair dryer in the question above transforms each 500 J of electrical energy it receives into:

- 50 J of sound
- 125 J of kinetic energy
- 325 J of heat

So, the percentage of sound energy it produces is:

$$\begin{aligned}\text{sound energy (\%)} &= \frac{\text{sound energy produced (J)}}{\text{total energy in (J)}} \times 100 \\ &= \frac{50}{500} \times 100 \\ &= 10\%\end{aligned}$$

Calculate the percentages of kinetic and heat energy that it produces.

Question 5

Now draw a Sankey diagram for the hair dryer.

Hint: Don't forget to have the arrows for any waste energy pointing down.

WRAP-UP

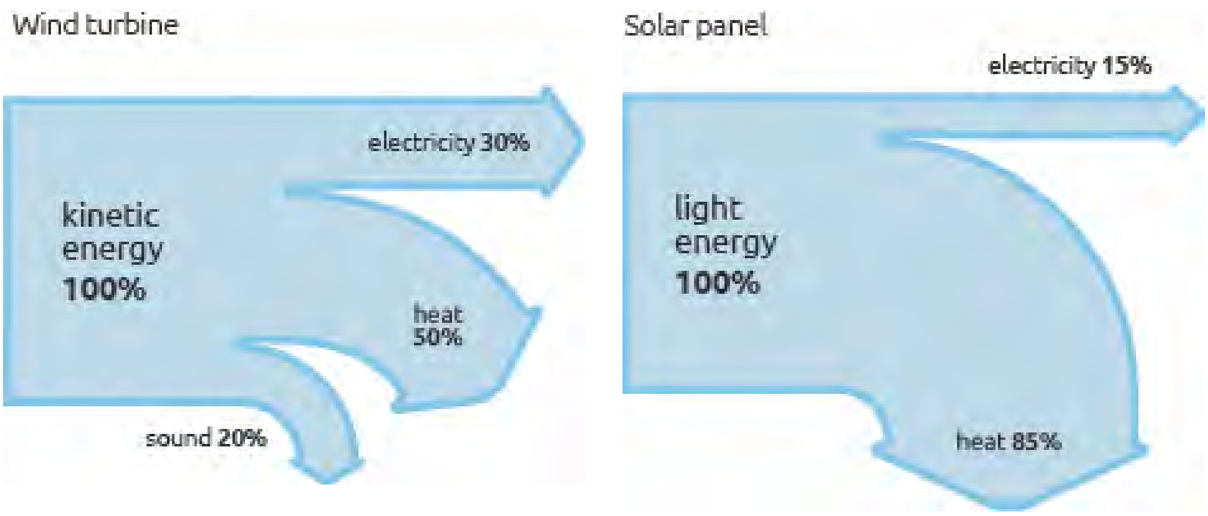
Do you know what is meant by efficiency, and how to read and draw Sankey diagrams?

Question 6

In a particular computer tablet, for every 100 J electrical energy that comes from its batteries, 65 J is transformed to light from the screen, 20 J to sound from audio and 15 J to heat.

Which of the following are true?

- ☐ 65% of the tablet's electrical energy is transformed into light energy.
- ☐ The tablet is 85% efficient.
- ☐ 15% of the energy transformed from electricity is wasted.
- ☐ The total output energy (65 J + 20 J + 15 J) equals the input energy (100 J) so the tablet is 100% efficient.



Question 7

The Sankey diagrams above represent the energy transformations that occur in a wind turbine and solar panel.

Which of the following statements are true?

- ☐ Overall, the wind turbine produces more joules of energy than it receives.
- ☐ The wind turbine converts more kinetic energy into heat than electricity.
- ☐ The solar panel is more efficient than the wind turbine.
- ☐ The solar panel transforms more light into heat than into electricity.

3 ENERGY RESOURCES AND ELECTRICITY

Many trains, including this one on the Gold Coast, Queensland, are driven by electricity.

Electricity is central to the way we live in the 21st century, so how does it work? Make some discoveries using the STELR equipment.

3.1 LESSON: FOSSIL FUELS AND GREENHOUSE GASES

KEY QUESTIONS

- What is a fossil fuel?
- What are greenhouse gases?
- What is a renewable energy resource?

FOSSIL FUELS AND GREENHOUSE GASES

Back in lesson 2.1 you watched a video called *Global Warming: Cold Facts, Hot Science.* How well can you remember some of the things you learnt?

Question 1

Burning fossil fuels – coal, oil and natural gas – produces carbon dioxide.

☐ true

☐ false

Question 2

Carbon dioxide is a greenhouse gas.

☐ true

☐ false

Question 3

Increasing the proportion of greenhouse gases in the atmosphere increases the Earth's average air temperature.

☐ true

☐ false

Question 4

Why are coal, oil and natural gas called fossil fuels?

____

____

____

Question 5

How do you use fossil fuels in your everyday life?

Coal	
Oil and oil products	
Natural gas	

RENEWABILITY

All of the resources that we use – not only energy resources – can be divided into two categories: renewable and non-renewable.

- **Renewable** resources are those that can be replaced within, roughly, a human lifetime.
- **Non-renewable** resources are those that take longer to be replaced, or they are not replaced at all.

Wheat is a renewable resource – we grow new crops every year. Rock – for concrete, roads and building – is not.

Question 6

Which of the following are renewable resources?

☐ diamonds

☐ wool

☐ sugar

☐ timber

☐ sand

Question 7

Which of the following energy resources are renewable?

- ☐ sunlight
- ☐ coal
- ☐ water
- ☐ wind
- ☐ natural gas

Question 8

People say that, in order to stop global warming, we have to change to use renewable energy sources. Why?

____

____

____

____

Question 9

How do you think we can make electricity in a more sustainable way?

____

____

____

____

3.2 LESSON: THE IMPORTANCE OF ELECTRICITY

KEY QUESTIONS

- Why is electricity so useful?
- What energy resources do we use to make electricity?
- How much electricity do we use compared to other types of energy?

WHY ELECTRICITY?

What is so good about electricity?

Question 1

Discuss in groups to make a list of all the ways you can think that we use electricity. Start with your own lives, at home, school, and anywhere else you go, but then think of other places as well.

Question 2

Now discuss what makes electricity so useful. Think of at least two reasons.

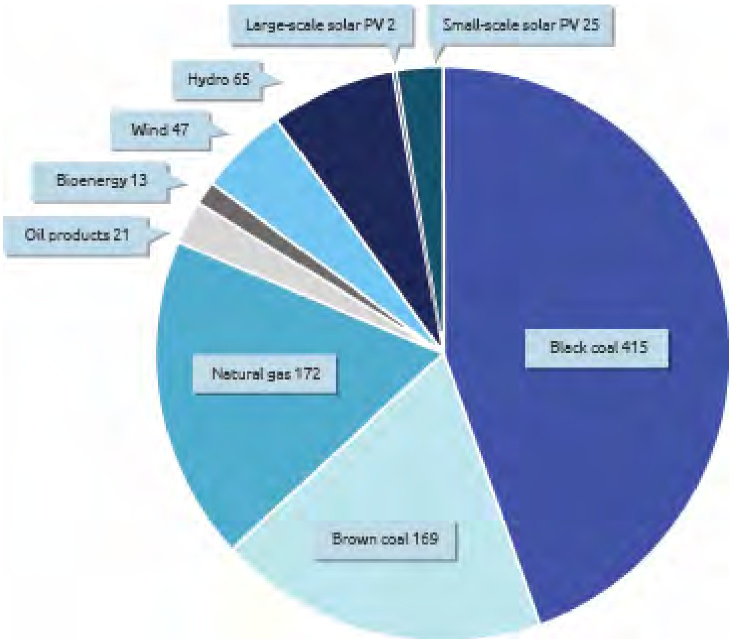
Note: If you are not sure, think about some of the ways you use electricity. Could you use coal, sunlight, gravitational energy or rubber bands instead?

HOW DO WE MAKE ELECTRICITY?

Electricity isn't a natural resource – there aren't any places on Earth where you just push in some wires and electricity flows out. We have to transform other energy sources into it. What sources do we use? The pie chart below tells you for Australia in 2016.

Question 3

On the pie chart below, use a coloured pen to draw around the border of all the segments representing fossil fuels.



Energy sources for electricity production in Australia, 2016 (PJ). Credit: Dept of the Environment and Energy, Australian Energy Statistics, Table O, August 2017.

Question 4

In Australia in 2016, fossil fuels provided ____________ of the energy that was transformed into electricity.

- ☐ less than 25%
- ☐ between 25% and 50%
- ☐ between 50% and 75%
- ☐ more than 75%

Question 5

Which of the following show the electricity energy sources in the correct order, from smallest contribution to greatest contribution?

(there might be more than one)

- ☐ small-scale solar PV, large-scale solar PV, hydro, natural gas
- ☐ small-scale solar PV, large-scale solar PV, hydro, natural gas
- ☐ bioenergy, hydro, natural gas, large-scale solar PV

Question 6

All the energy sources that are not fossil fuels are *renewables*.

In 2016, all the renewables together contributed more energy for electricity than natural gas.

- ☐ true
- ☐ false

3.3 LESSON: ENERGY RESOURCES

KEY QUESTIONS

- What factors does society need to consider in choosing energy resources?
- What energy resources do we use today?
- What is a renewable resource?
- How can we compare the outputs of electricity power stations?

There are many sources of energy available on Earth. In ancient times, food was the major source. We used it to feed the animals and people who did all the work.

Today, in the early 21st century, we mostly use machines, and they mostly get their energy directly or indirectly from fossil fuels. But the carbon dioxide produced when we burn these fuels leads to global warming. To overcome this, we need to change to energy sources that don't produce carbon dioxide.

But every energy resource poses its own problems and we have to balance many factors when we decide which ones to use.

Question 1

Discuss

Imagine you are in government with responsibility to decide what energy resources your country will use.

What factors do you have to take into account in making your decisions? After discussing in groups and/or class, list them below.

Hint: Try thinking of ways that we get or use energy now, and what is good or bad about these energy sources.

3.4 PROJECT: ENERGY RESOURCES

Research one energy resource and make a presentation of your findings to the class.

Work in groups of three or four. Each group should investigate a different resource.

Suitable energy resources include:

- PV (photovoltaic) panels ('solar panels')
- printed flexible solar panels
- solar water heating
- solar thermal power stations
- wind turbines
- geothermal power stations
- hydro-electric power stations
- pumped hydro
- biogas for generating electricity and producing heat energy
- petrol for transport
- a bio-fuel used for transport (such as bio-ethanol or bio-diesel)
- electric cars
- hydrogen fuel for transport
- tidal power
- wave power
- nuclear power stations
- coal-fired power stations
- gas-fired power stations
- coal seam gas
- gas or oil from fracking

WHAT TO FIND OUT

What is the science and technology behind the resource?

- How does this energy resource work? What devices are used?
- What are the main energy transformations and energy transfers that take place? Include a flow chart showing the energy transformations.
- Is this energy resource renewable or non-renewable? Explain.

How much is the energy resource used?

- Is this energy resource used in Australia, and if so, to what extent? Is it a large- or small-scale energy resource? Is it used in particular locations? Why or why not?
- Is this energy resource used across the world and if so, to what extent? Which countries are the main ones using it? Is there a reason why some countries are using it and others are not?

What are the benefits and problems associated with this energy resource?

- What are the main advantages of using this energy resource? Will increased use of the resource help reduce global warming?
- What health and safety concerns are associated with this energy resource?
- What environmental concerns are associated with this energy resource?

What does the community think about this resource?

- What are the views of members of the community to use of this resource? If possible, get opinions from within your school and/or local community about reactions if a resource of this kind were to be established nearby.

What is the likely future of the resource?

- Is the energy resource likely to be a useful and widely used energy source for Australia and across the world in the future? Why?

HOW TO PRESENT YOUR PROJECT

The main product of your project is the class presentation, but upload any files that you use in the project space below:

- copy text into the text widget, so your teacher can read it in Stile;
- upload presentation files (e.g. PowerPoint) with the files and media widget;
- upload photographs of posters, models or other static material;
- if possible, upload a video of your presentation.

Think about the best way to present your information so that it engages your audience. For example, use:

- photographs;
- diagrams, models, flow charts and maps;
- tables and graphs of data;
- video clips;
- posters;
- your own recordings of interviews and site visits;
- a PowerPoint presentation.

RESOURCES YOU CAN USE

- experts in the field – it will help your project a lot if you can ask someone working in the industry questions about it;
- see the subject resources menu on the STELR website; and
- books and/or websites, but be sure to use trustworthy sites. Ask your teacher if you are not sure.

Important: You must include a bibliography, showing where you got all your information.

Answer the following question after you have seen all the other project presentations for your class.

Question 1

You should have learned a lot about your energy resource and quite a bit about other resources as well from other students' presentations.

What more would you like to find out about energy resources?

4 BATTERIES

Batteries come in many shapes and sizes and they can be a convenient way of 'storing' electrical energy.

Batteries contain chemicals that can produce a flow of electrons when connected to a circuit. They are a 'store' of electrical energy. Batteries vary in size from those small enough to fit in a hearing aid, to ones that are the size of a shipping container. Some batteries can be recharged using electrical energy to reverse the original chemical reaction.

One of the largest batteries in the world was built at Hornsdale in South Australia to store excess energy generated by nearby wind turbines.

4.1 LESSON: WHY USE BATTERIES?

KEY QUESTIONS

- Why do we use batteries?
- What have batteries got to do with renewable energy?

Question 1

Make a list of all the batteries that you use in your everyday life. Discuss the list with others in the class and include as many as you can.

When the list is complete, make two groups: rechargeable and non-rechargeable batteries.

Rechargeable	Non-rechargeable

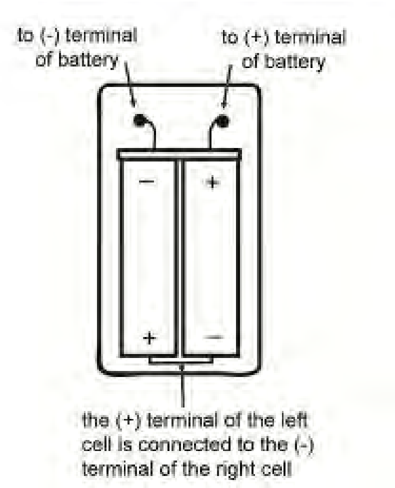
Question 2

Imagine what your life would be like if batteries had not been invented. What would be the most important changes?

4.2 PRAC: CONNECTING BATTERIES

KEY QUESTIONS

- What happens when you add more batteries to a circuit?
- What are volts and how do we measure them?
- What is the difference when batteries are connected in series or in parallel?



BATTERIES AND CELLS

Scientifically speaking, a single battery is called a cell. If there are two or more cells together in a circuit, it is called a battery. The STELR battery contains two 1.5V (double A) cells.

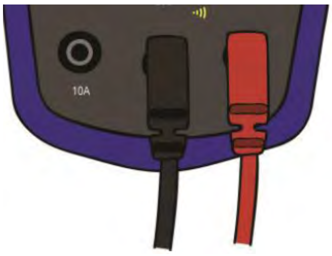
Single household cells usually deliver 1.5 volts when fully charged. Unfortunately, they do not deliver enough power to run most devices, which is why you usually have to use more than one to get them to work.

Materials

- 2 x STELR batteries
- STELR testing station
- STELR multimeter
- connecting cables
- STELR switch

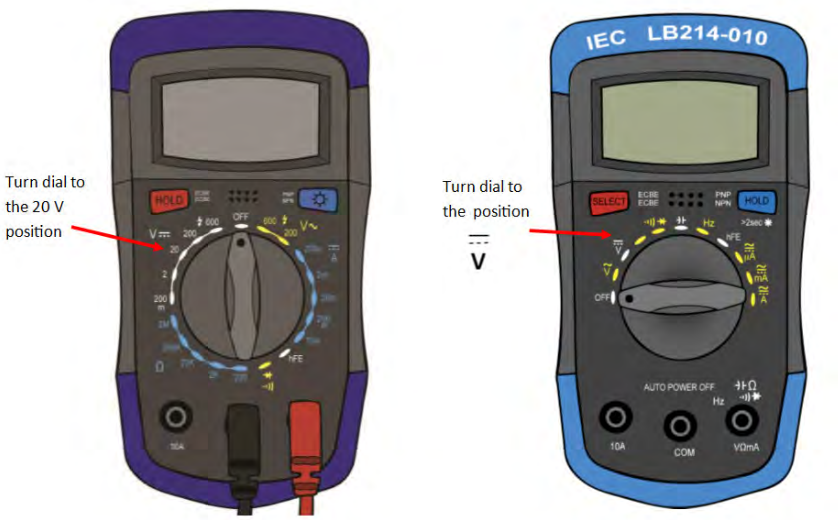
4.2.1 TESTING THE BATTERIES

WHAT TO DO



To measure the voltage, use the middle socket of the multimeter for the negative terminal and the right-hand socket for the positive terminal.

There are two different STELR multimeters. Look at the pictures below to determine which one you have. When you are ready to measure the voltage, turn the rotary switch to the position shown on the picture.



Label one of your STELR batteries 'A' and the other 'B'.

Connect battery 'A' to the multimeter as shown in this diagram.

Measure and record the voltage. Repeat with battery 'B'.

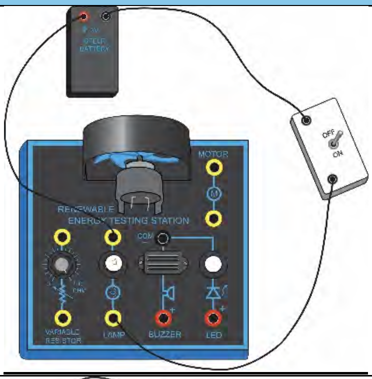
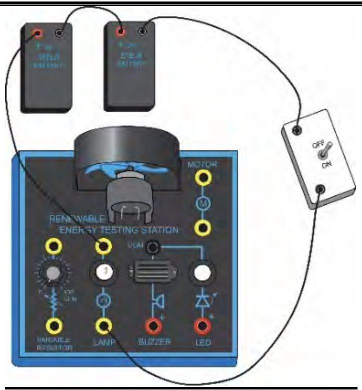
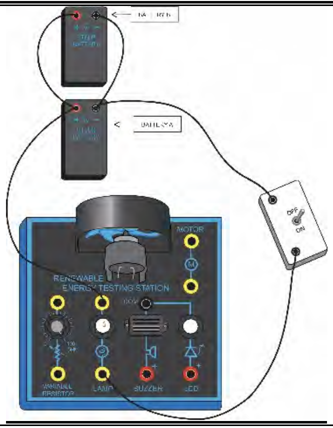
Voltage for Battery A	Voltage for Battery B

NOTE: The rest of this experiment will work best if both batteries measure close to 3 volts. If this is not the case, ask you teacher for a replacement battery and re-test it.

4.2.2 ADDING IN BATTERIES

WHAT TO DO

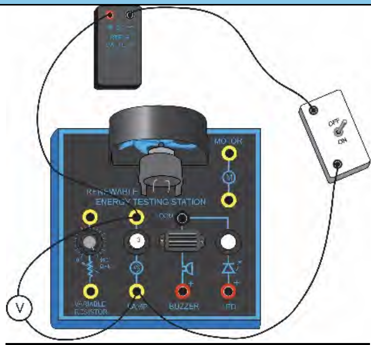
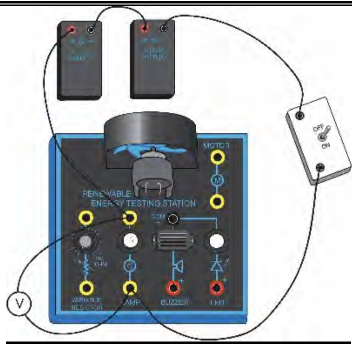
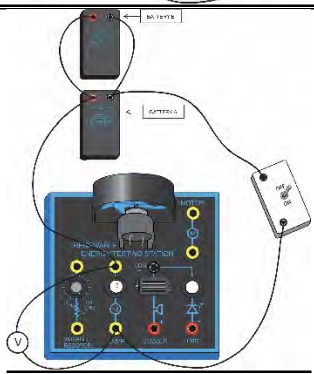
Connect up the circuits that are illustrated below and notice what happens to the brightness of the lamp when the second battery is added.

	Set-up	Brightness of the lamp
One battery		
Two batteries in series		
Two batteries in parallel		

VOLTS: ENERGY IN A CIRCUIT

The circuit above gets its energy – electrical energy – from chemical reactions in the battery. The energy is transferred around the circuit through the cables, and transformed into light and heat at the lamp. Energy in electrical circuits is often measured in terms of **volts**, symbol **V**.

A volt is not a basic measure of energy but for our purposes we will use volts to measure electrical energy in circuits.

	Set-up	Voltage
One battery		
Two batteries in series		
Two batteries in parallel		

You may have noticed that when the two batteries are connected in parallel, they deliver a similar voltage to the single battery.

Connecting a second battery in **series** will make the globe brighter but the batteries will run out of energy quickly.

Connecting a second battery in **parallel** does not affect the brightness of the globe but it will glow for twice as long.

4.3 LESSON: BATTERY TECHNOLOGY

KEY QUESTION

- What are the useful features of different types of batteries?

Making smaller and lighter batteries that last longer is a developing technology.

This picture is of one of the first types of mobile phones. It is pictured next to an apple so you can see how big it was. It was so big because most of the size was the battery. These batteries could be recharged but they became less and less effective each time they were recharged.

Over the years, scientists and technologists have developed smaller and more powerful batteries for phones.

Question 1

Imagine you were designing a better battery for each of the following situations.

Describe the features of the battery that are important in each case. Consider the importance of the following:

- size;
- weight;
- the amount of energy needed and how often it is used;
- how long it needs to last;
- if it need to be rechargeable;
- if changing the battery is difficult; and
- if cost is an issue.

Situation	Battery features
Battery for a hearing aid	
Battery to store electricity generated by a wind farm	
Battery for an electric car	
Battery for the TV remote control	
Battery to store excess electricity generated by solar panels in a house	
Battery for a lap-top computer	
Battery to power a space station	

5 WIND ENERGY

The 140 MW Woolnorth Wind Farm on the far north-west coast of Tasmania. Credit: Hydro Tasmania

There are many sources of energy that we can use. Each one has benefits but brings problems with it too. Which ones should we use, and how do we get the best out of them?

5.1 LESSON: WIND TURBINES

KEY QUESTIONS

- What energy transfers and transformations occur in a wind turbine?
- Where does the wind blow most in Australia?
- What are the advantages and disadvantages of wind turbines?

In Australia, wind turbines are the fastest growing renewable energy resource.

At the end of 2018, there were 94 wind farms with just over 2,056 turbines. Another 24 wind farms were under construction at this time. These wind farms produced over 16,000 gigawatt hours (GWh) of electricity.

HOW WIND TURBINES WORK

Watch the video *How a wind turbine works*.

VIDEO *How a wind turbine works*
https://youtu.be/57NFcXLd9BA

Question 1

Increasingly, wind farms are being built coupled with massive batteries that store electricity when the turbines produce more than is needed, and supply it when the turbines are not producing enough.

Write in the boxes to complete the description of the transfers and transformations that occur when a wind turbine charges a battery. Use the following words:

electrical | transferred | kinetic | transformed | mechanical | transferred
transformed | chemical

Wind has ______ energy. This energy is transformed, becoming ______ energy of the turbine. This is ______ along the main shaft to the generator where it is ______ into ______ energy. This energy is then ______ through cables to the battery where it is ______ into ______ energy.

Question 2

Wind turbines take about half of the wind's kinetic energy. Of that, most is converted into mechanical energy, with a little lost as heat and sound. Then, most of the mechanical energy is transformed into electrical energy, again with small losses to heat and sound.

Draw a Sankey diagram showing the transformations that occur. (Do not include the kinetic energy that remains in the wind.)

- **Easier option:** start with the wind energy and only show the final outputs.
- **Challenge option:** make the diagram longer by showing the mechanical energy stage.

WHERE TO PUT WIND TURBINES?

Obviously, the best place to put a wind turbine is where it is windy. Turbines work best in smooth air flows, so they should be placed away from obstructions such as tall buildings or rugged landscapes, which break up the air flow. In addition, the higher you go up the stronger the wind, so engineers make turbines as high as they can.

Some wind farms are built offshore, in the ocean. These cost more, but winds are generally stronger, and people do not object to them spoiling the landscape.

Where in Australia, on land or off the coast, are the best locations for wind farms?

Open the website below and navigate to Australia. Where are the strongest winds now? If you click on a location the wind speed is shown in the box at the bottom left of the screen.

Earth
https://earth.nullschool.net/#current/wind/surface/level/orthographic

Question 3

On the map below, in one colour:

- draw circles around the three areas where the winds are strongest;
- write in the top, beside the circles, the wind speeds in those areas;
- write in a map key in the bottom left corner of the map:
  a. the name the pen colour you are using; and
  b. beside it, 'Most wind' and the date.

Write in small letters because you will soon add more information to the map.

Now, go to this website:

Australian Renewable Energy Mapping Infrastructure

https://nationalmap.gov.au/renewables/

(Click 'I agree' to see the map. Then click 'Add data', choose 'Renewable Energy', then choose 'Average Wind Speed at 100 metres'.)

This map shows the average wind speeds 100 m above the ground all around Australia – dark blue areas have the lowest average speeds and red areas the highest. To get accurate readings, zoom in and click on a location – the average wind speed there is displayed in a text box.

Question 3 continued...

Now, using another colour, add the following to the map on the previous page:

- Circle the three areas with the highest average wind speeds.
- Beside the circles, write in the average wind speeds at those locations.
- To the map key:
  a. add the name of the pen colour; and
  b. write 'Highest average wind speeds'.

Question 4

Compare the wind speed data today with the average wind speed information in your map:

- Did the areas that you circled overlap at all? Explain.
- How do the wind speeds today compare to the averages for the areas?

Question 5

Wind turbines need average wind speeds of 6 metres per second (m/s) or more to operate effectively.

Looking at the average wind map, what proportion of Australia has enough wind to support wind turbines?

- ☐ less than 25%
- ☐ between 25% and 50%
- ☐ between 50% and 75%
- ☐ more than 75%

Question 6

Discuss

If wind speed was the only factor involved in deciding where to build wind farms, we would put them in the areas where the average wind speeds are highest.

Looking at the wind map, can you think of reasons why these might not always be good places for wind farms?

____

____

____

____

____

____

ADVANTAGES AND DISADVANTAGES OF WIND POWER

Discuss

There are many factors to consider when deciding how we should produce electricity. Some are listed in the table that follows.

- In small groups, discuss how wind power stands with respect to each factor, and then summarise the main points you decide on. Sometimes there might be several points relating to a factor.
- Based on the points you have made, rank wind power as good (Y), bad (N) or somewhere in the middle (–).

Factor	Discussion – how is wind power with respect to this factor?	Y, N or –
Carbon dioxide		
Renewability		
Cost		
Pollution		
Environment		
Reliability		
Suitable locations		
Community acceptance		

5.2 LESSON: WIND TURBINE DESIGN

If you want to transform the energy in the wind into electricity, you want machines that do this as efficiently as possible – at least within your cost limits.

There are many factors that contribute to the efficiency and cost-efficiency of wind turbines, such as the materials used and the height of the towers. Some factors you can test with the STELR wind turbine.

Question 1

Brainstorm all the factors that you can think of that could affect the energy output and cost-effectiveness of wind turbines.

Question 2

Now look at the STELR wind turbine equipment. Which of the above factors do you think you could test using the STELR equipment?

Question 3

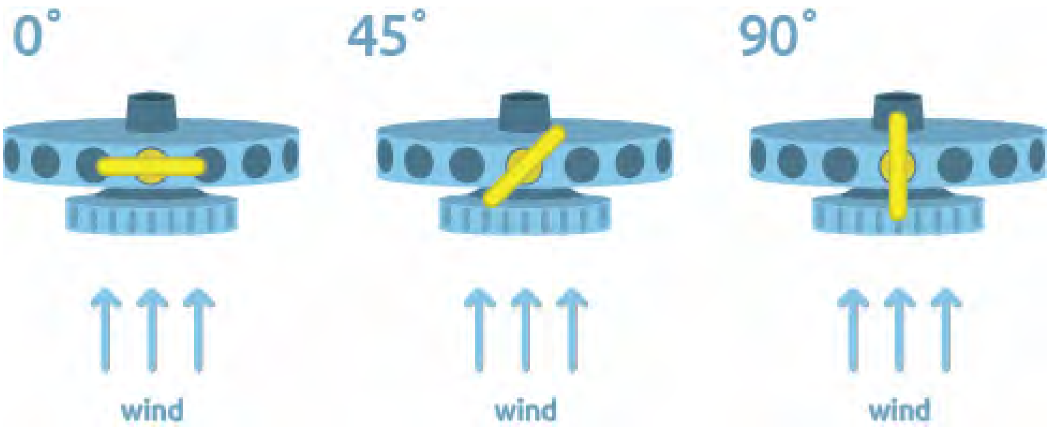
Make a guess at what you think would be the best design for a STELR wind turbine.

5.3 PRAC: WIND TURBINE BLADE ANGLE

KEY QUESTION

- Which blade angle on the STELR wind turbine produces the greatest voltage?

First, check the diagram below to see which angle we're measuring.



The videos listed below demonstrate two ways of setting blade angles. Your teacher will provide you with a STELR protractor if they want you to use it.

Setting blade angle using hub marks
https://youtu.be/j4Vg3mubQlM

Setting blade angle using STELR protractor
https://youtu.be/8ov2zqosyxg

The photo of the wind turbine hub to the right clearly shows the 15° marks around the blade sockets.

EXPERIMENT SETUP

Aim

Based on the key question at the start of the prac, write an aim for your investigation.

Hypothesis

Before you start, predict which blade angle you think will produce the highest voltage. Explain why you think this.

Materials

- STELR model wind turbine and hub
- 2 × STELR 150 mm turbine blades
- retort stand
- STELR testing station
- STELR multimeter
- connecting cables
- three-speed electric fan
- tape measure or ruler
- STELR hub protractor

Risk assessment

Complete the following risk assessment.

Fact	Risks	Precautions
The STELR wind turbines are fragile		
Objects can fly out from things that are spinning fast		
Electric fans spin fast		

Variables

In any experiment, it is essential to know what the variables are, and to control them appropriately. This ensures that the experiment addresses the experiment aims and gives a meaningful result. You will need to consider the:

- **independent variable:** the variable you change to see the difference it makes;
- **dependent variable:** the variable you measure to see if/how it changes when you change the independent variable;
- **controlled variables:** other factors that you keep constant, so they don't have any impact on the dependent variable.

Identify which of the following variables are independent, dependent and controlled:

voltage | length of blades | distance between fan and wind turbine
angle of blades | fan setting | number of blades | angle of wind turbine to fan

Independent variable:____

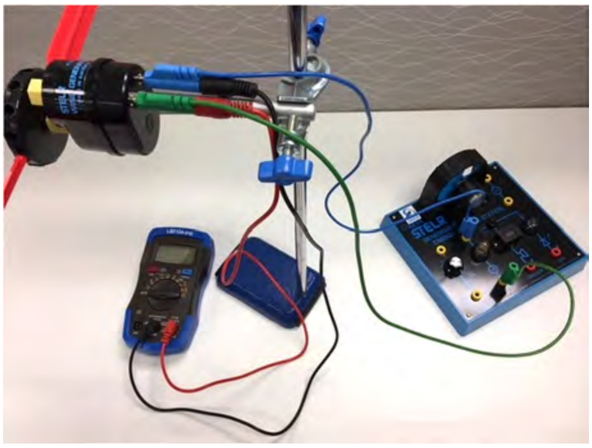
Dependent variable:____

Controlled variables:____

Procedure

1. Attach the wind turbine body to the retort stand.
2. Make a circuit with the wind turbine and lamp in series.
3. Connect the multimeter so it can read the voltage across the turbine. Don’t turn it on yet.

The photo below shows how to connect the circuit. Draw a circuit diagram for it in the blank space on the right. Use a G in a circle to represent the wind turbine (G is for generator).

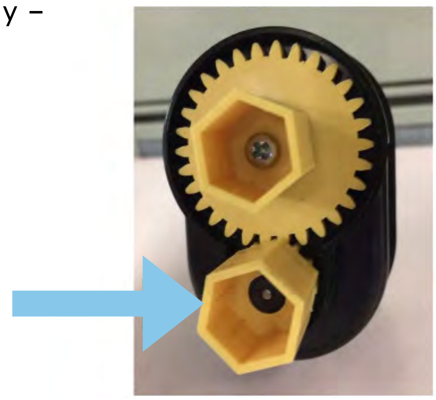


Procedure cont...

4. Attach two blades to the hub of the wind turbine:
    a. Position the blades opposite each other.
    b. Insert each blade at 30° (each mark around the slot rim is 15°, or use the STELR hub protractor).

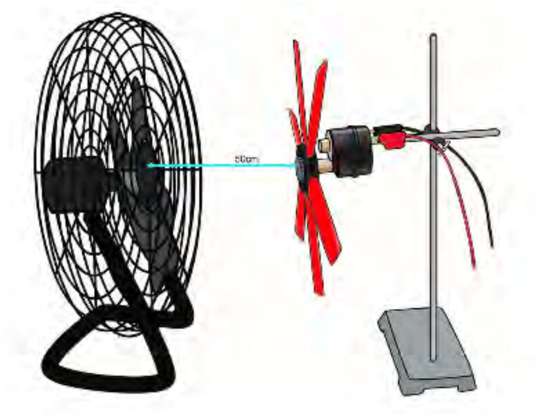
Note: Ensure you tighten the hub firmly once your blades are in place.

5. Attach the hub to the *ungeared* connection on the turbine body – with the *small* cog wheel.



Attach the hub to the small, ungeared connection on the turbine.

6. Position the turbine 50 cm in front of the fan, measured from hub to hub:
   a. Ensure that the turbine and fan are angled so the turbine faces the fan front on.
   b. Adjust the height of the turbine so its hub is the same height as the fan's hub.
7. Ask your teacher to check your setup. **Proceed when you have permission**.



8. Set the multimeter to 20 in the white 'V' range, or the white V (depending on your model multimeter) to measure voltage.
9. Turn the fan to its highest setting and measure the voltage across the wind turbine.

   Enter the voltage in the results table below.

   Note: The reading on the multimeter is likely to vary. Estimate what you think the average reading would be.
10. Turn off the fan and multimeter.

Repeat for other blade angles

- Remove the wind turbine hub and change the blade angles.
- Tighten the blades and replace on the turbine body.

  Ensure that the positions of the wind turbine and fan haven't changed.
- Turn the fan on to full and read the voltage.
- Repeat for 15°, 45°, 60° and 75°.
- Based on your results, try other angles to find which one gives the highest voltage.

Try it out!

While you have the equipment set up, try out some other angles...how about 0° and 90°? Or, what happens if the blades have the same angle but are in opposite directions?

RESULTS

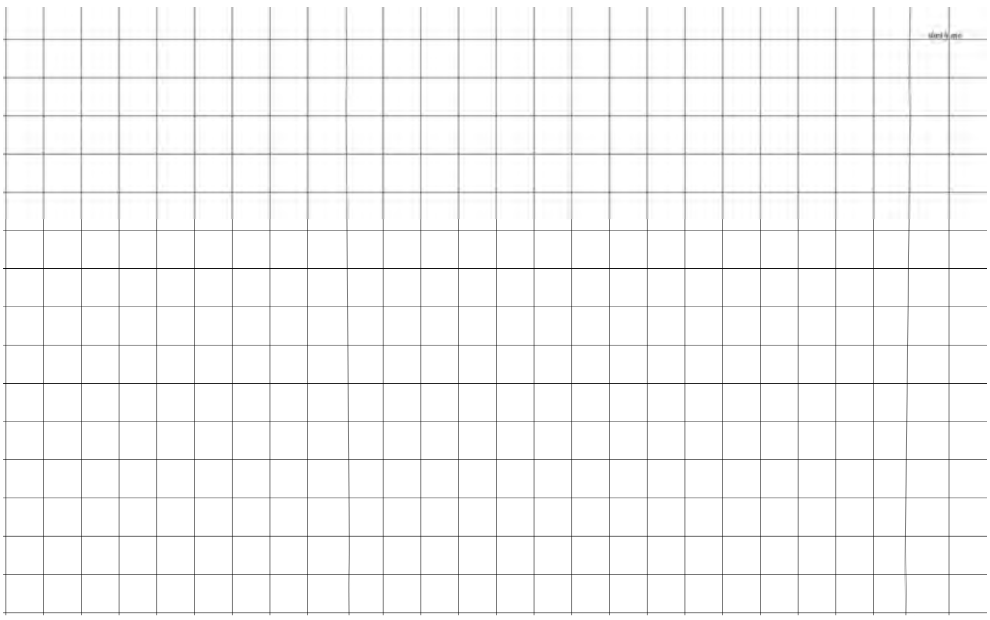
Record your results in the table below.

Angle (°)	Voltage (V)
15	
30	
45	
60	
75	

Plot your results on the graph below. *Note: You will need to add numbers to the axes.*

STELR wind turbine: voltage vs. blade angle

Voltage (V)



Blade angle (°)

What blade angle produced the highest voltage?__________________________________

DISCUSSION

Did the results from your experiment match your prediction?

- If so, do you think this is for the reason you gave? Explain.
- If not, what do you think explains the results that you got?

Did you have any practical difficulties carrying out the experiment? If so, how did you resolve them?

Conclusion

Write a conclusion to your experiment.

Hint: Go back to check your experiment aim. Your conclusion should be a short statement that addresses this.

5.4 PRAC: NUMBER OF BLADES

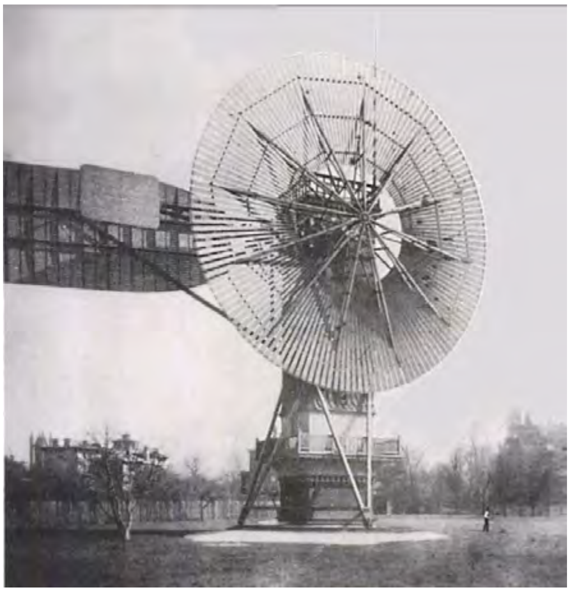
KEY QUESTION

- How many blades give the greatest voltage on the STELR wind turbine?

How many blades should a wind turbine have?

Charles Brush, from Ohio, USA, made one of the world's first electricity-generating wind turbines in 1888, shown at right. Clearly, he thought the answer to the question was, 'a lot'.

In this prac, you'll find out what the answer is for the STELR wind turbine.



Charles Brush's wind turbine, Cleveland, Ohio, 1888.

EXPERIMENT SETUP

Aim

Based on the key question above, write an aim for your investigation.

___

___

Hypothesis

Before you start, predict which number of blades (2, 3, 4, 6 or 12) will produce the highest voltage.

Explain why you think this.

___

___

___

Materials

- STELR model wind turbine and hub
- STELR 150 mm turbine blades
- retort stand
- STELR testing station
- STELR multimeter
- connecting cables
- three-speed electric fan
- tape measure or ruler

Risk assessment

Complete the following risk assessment.

Fact	Risks	Precautions
The STELR wind turbines are fragile		
Objects can fly out from things that are spinning fast		
Electric fans spin fast		

Variables

What are the independent, dependent and some important controlled variables in this experiment?

- **independent variable:** the variable you change to see the difference it makes;
- **dependent variable:** the variable you measure to see if/how it changes when you change the independent variable;
- **controlled variables:** other factors that you keep constant, so they don’t have any impact on the dependent variable.

Identify which of the following variables are independent, dependent and controlled:

voltage | length of blades | distance between fan and wind turbine
angle of blades | fan setting | number of blades | angle of wind turbine to fan

Independent variable:____

Dependent variable:____

Controlled variables:____

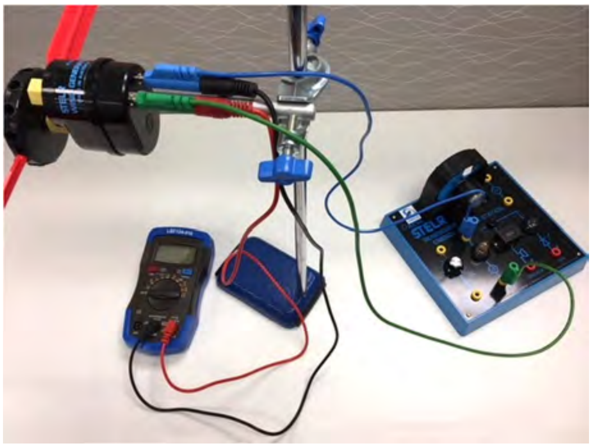
____

____

Procedure

1. Attach the wind turbine body to the retort stand.
2. Make a circuit with the wind turbine and lamp in series.
3. Connect the multimeter so it can read the voltage across the turbine. Don't turn it on yet.

The photo below shows how to connect the circuit. Draw a circuit diagram for it in the blank space on the right. Use a G in a circle to represent the wind turbine (G is for generator).

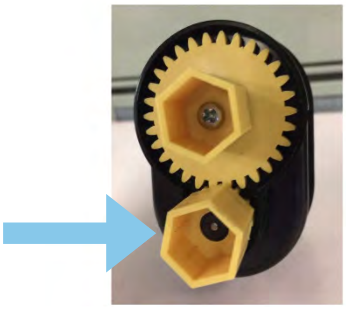


Procedure cont...

4. Attach six blades to the hub of the wind turbine:
   a. space the blades evenly around the hub;
   b. insert each blade at 45° (each mark around the slot rim is 15°).

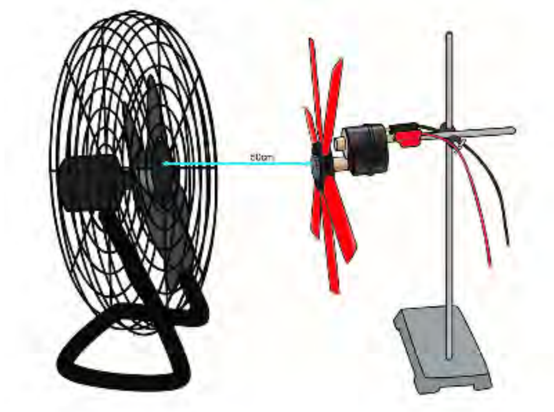
   Note: Ensure you tighten the hub firmly once your blades are in place.

5. Attach the hub to the *ungeared* connection on the turbine body – the connection with the *small* cogged wheel.



Attach the hub to the small, ungeared connection on the turbine.

6. Position the turbine 50 cm in front of the fan, measured from hub to hub. Ensure that the turbine and fan are angled so the turbine faces the fan front on.



7. Adjust the height of the turbine so its hub is the same height as the fan's hub.
8. Ask your teacher to check your setup. **Proceed when you have permission**.
9. Set the multimeter to 20 in the white 'V' range, or the white V (depending on your model multimeter) to measure voltage.
10. Turn the fan to its highest setting and measure the voltage across the wind turbine.

    Enter the voltage in the results table on the following page.

    Note: The reading on the multimeter is likely to vary. Estimate what you think the average reading would be.
11. Turn off the fan and multimeter.

Repeat for other blade numbers

- Remove the wind turbine hub and change the number of blades.
- Tighten the hub to secure the blades and replace on the turbine body.
- Ensure that the blade angles are 45°.
- Ensure that the positions of the wind turbine and fan don't change.
- Turn on the fan to full and take the voltage reading.
- Repeat until you have readings for 2, 3, 4, 6 and 12 blades.

RESULTS

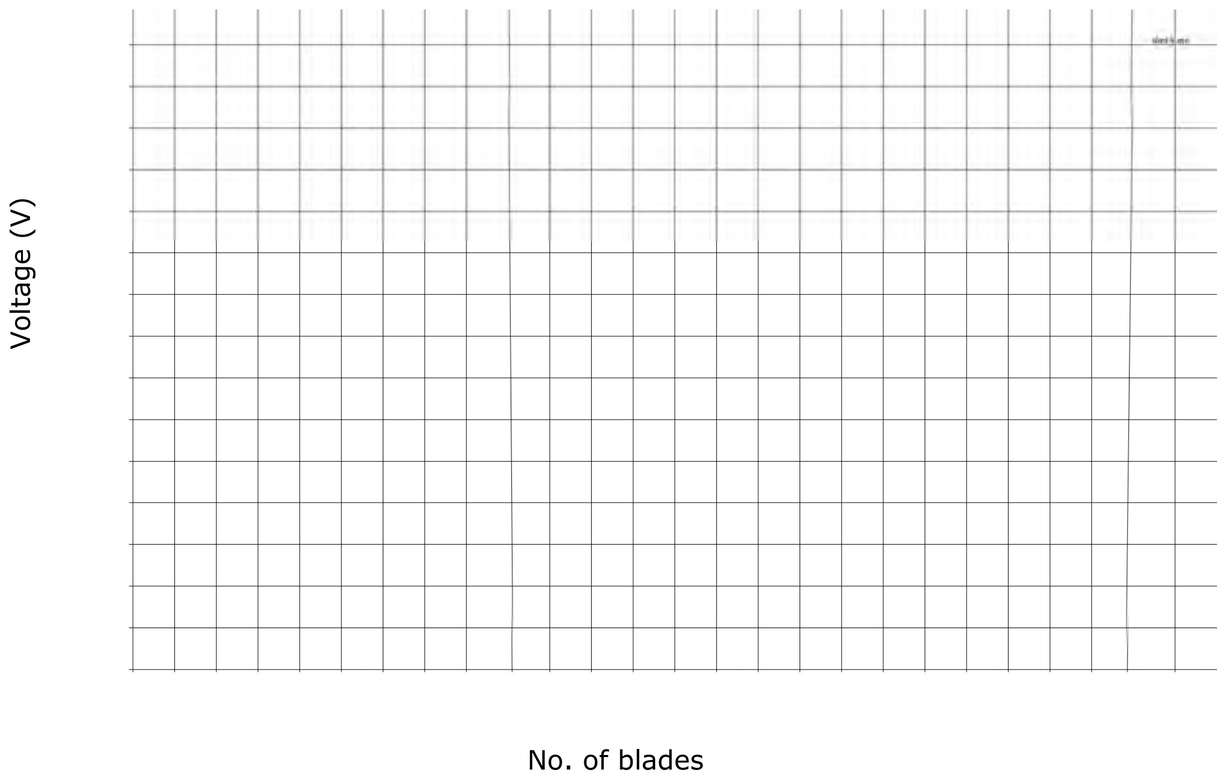
Record your results in the table below.

No. of blades	Voltage (V)
2	
3	
4	
6	
12	

Plot your results on the graph below.

Note: You will need to add numbers to the axes.

STELR wind turbine: voltage vs. no. of blades



Swap results

Swap your results data with two other groups. Add their results to your graph.

You should graph your results with points – do not join the points to make a line graph.

Explain why you think this is.

DISCUSSION

Did the results from your experiment match your prediction?

- If so, do you think this is for the reason you gave? Explain.
- If not, what do you think explains the results that you got?

How did your results differ from those of the groups that you swapped results with? For example, did you agree on the best number of blades?

Describe the main differences in the three results sets.

Why do you think that the results from the three groups differ as they do?

Hint: We identified some of the variables involved in this experiment in a previous question. Were the controlled variables successfully controlled? Could there be other variables that had an effect on the results?

Why do you think that this experiment didn't test 1, 5, 7, 8, 9, 10 or 11 blades?

Did you have any practical difficulties carrying out the experiment? If so, how did you resolve them?

Conclusion

Write a conclusion to your experiment.

Hint: Go back to check your experiment aim. Your conclusion should be a short statement that addresses this.

SUMMARY

Summarise your findings from the two experiments. First for blade angle:

Number of blades:

6 SOLAR PANELS

Solar 'farms' are large paddocks of solar panels. Some solar farms even have sheep or cattle grazing under the panels.

At the end of 2018, one in five houses in Australia had rooftop solar panels and 59 large-scale solar projects were being built.

Typical household rooftop installations have a capacity of 1–3 kW. Any electricity not used in the house can be sold into the electricity grid or stored in household batteries.

Many commercial buildings such as schools, universities, factories, shopping centres and markets are also installing solar panels.

In 2019, Australia's largest solar farm in Coleambally, New South Wales, had capacity to produce 150 MW, which is enough to power 52,000 homes.

6.1 LESSON: HOW SOLAR PANELS WORK

KEY QUESTIONS

- How are solar panels made?
- How do solar panels work?
- Where does the sun shine most in Australia?

WHAT DO YOU KNOW ABOUT SOLAR PANELS?

Solar panels are common on roof tops in Australia, but how much do you know about them?

Work in small groups to put together everything you know, or think you know, about solar panels.

Include these questions:

- What do they do?
- What is another name for them?
- What is the difference between a solar *cell* and a solar *panel*?
- What are they made out of?

Question 1

List all the things you know, or think are true, about solar panels.

What do solar panels do?

Solar panels transform the energy of sunlight directly into electricity.

- They produce no carbon dioxide when they operate, so provide us with usable energy without contributing to global warming.
- They are a renewable energy technology because the sun replaces the energy that they use every day – at least, if it is not cloudy.

Question 2

Most solar panels are less than 20% efficient, producing heat as waste energy.

Draw a Sankey diagram to represent the energy transformations that occur in a solar panel.

What is another name for solar panels?

Solar panels are also known as *photovoltaic* (PV) panels:

- 'photo' means light;
- 'voltaic' refers to electricity.

Question 3

Using a different text colour, add the words 'photo' and 'voltaic' to your Sankey diagram above, placing them close to the words that they mean.

What are solar panels made of?

Watch this video to see...

VIDEO *Bosch Solar How it's Made* (1)
https://youtu.be/B6rjm9bk5qs

Question 4

Solar cells are made from the element __________________. This is extracted from

__________________. The extracted material is made into a rectangular shape then

sliced into__________________, which are __________________ thick.

What's the difference between a solar cell and a solar panel?

Watch the rest of the video, although – be careful – the narrator talks about solar *modules* instead of solar *panels*.

Bosch Solar How it's Made (2)
https://youtu.be/NdMwOuCD7nI

Question 5

Each solar __________________is stamped with a metal coating to transport the

electricity. After testing, they are assembled. They are connected so that the

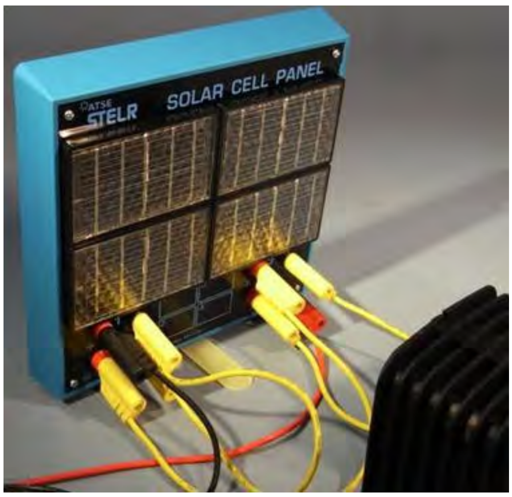
__________________ accumulates. There are 60 solar cells in a __________________.

Actually, not all solar panels have 60 cells – some commercial ones have 72 cells.

Question 6

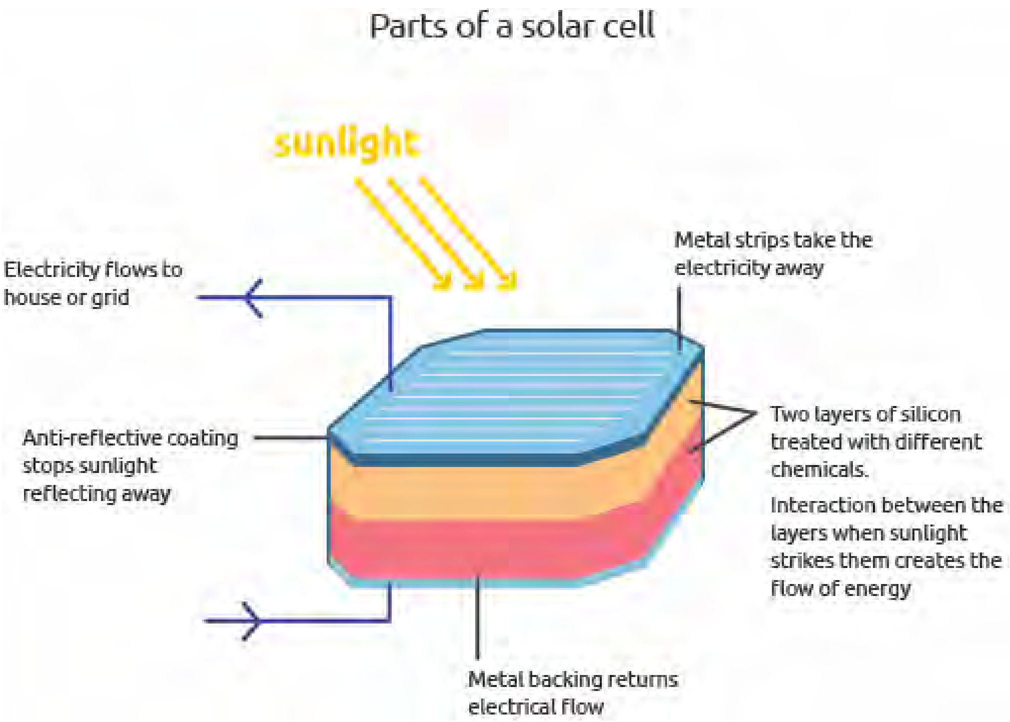
How many solar cells are there on the STELR solar panel?

____



HOW DO SOLAR CELLS WORK?

The heart of a solar cell is two thin layers of silicon pressed together. The layers are almost pure, but have had small amounts of different chemicals mixed into them. When sunlight penetrates into them, the interaction between the two layers creates an electrical flow. Metal layers on the top and bottom of the cell take and return the flow of electricity that is created.



Question 7

In a solar cell, electricity is created by the interaction between:

- ☐ the metal strips and anti-reflective coating
- ☐ the two metal layers at the top and bottom
- ☐ the two silicon layers
- ☐ mechanical energy
- ☐ the bottom silicon layer and the metal backing

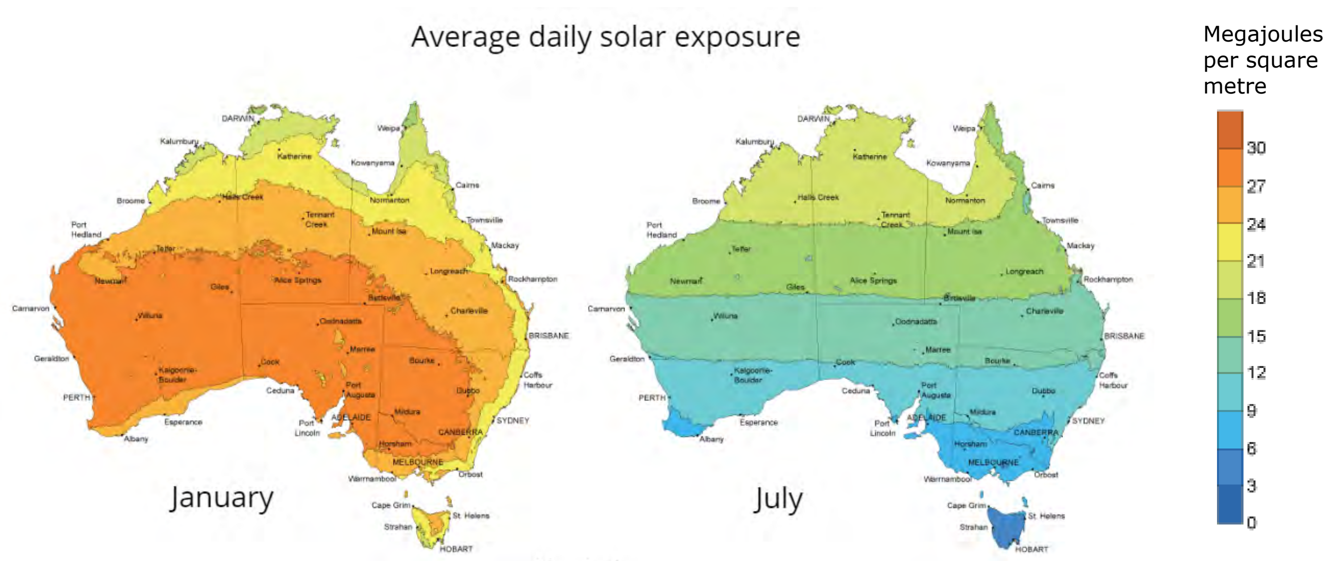
Question 8

Solar panels have to be connected into a circuit in order to provide useful energy.

- ☐ true
- ☐ false

SOLAR POWER IN AUSTRALIA

Solar panels on the Sydney Town Hall, and the 53 MW Broken Hill Solar Farm, which covers 140 hectares.



The maps above show how much sunlight different parts of the country get in January – mid summer – and July – mid winter. Use them to answer the questions that follow.
(Source: Bureau of Meteorology www.bom.gov.au/climate/data/index.shtml)

Question 9

Which of the following statements are true?

- ☐ In January, Adelaide gets more sunlight than Darwin.
- ☐ Darwin gets about the same amount of sunlight per day in January as in July.
- ☐ On average, Perth gets more than twice as much sunlight per day in January compared to July.
- ☐ On average, Brisbane gets over 20 megajoules per square metre of sunlight per day in July.

Question 10

Make a true statement of your own shown by one or both of the maps.

Question 11

The units used in the maps are megajoules per square metre (MJ/m^2).

How would you explain what these units mean to a grade 6 student?

Hint: Your answer will need to include the words energy*,* area *and* day*.*

NEW SOLAR TECHNOLOGIES

Photovoltaic technology is advancing at a rapid rate. Some emerging technologies include flexible solar cells that can be put into fabrics and solar cells integrated into building materials, for example roofing and windows, as shown below.

Question 12

Using the photos above as a prompt, think of a new product that could use solar cells in an interesting and useful new way.

Draw a sketch of your idea and label to help explain your idea.

Question 13

Look at another student's answer. Provide some constructive comments on it, including:

- Who might be interested in the product?
- How much might it cost to make?
- How useful is it going to be?

6.2 PRAC: EXPLORING SOLAR PANELS

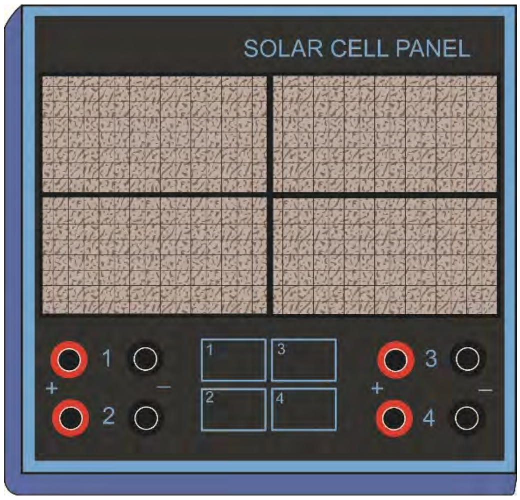
KEY QUESTION

- What voltages does the STELR solar panel produce when the cells are connected in series and parallel?

The STELR solar panel has four solar cells, as shown at right.

The cells are numbered – shown in the key at the bottom of the panel – and the connectors for each cell identified.

In this activity you will compare the voltages delivered by the panel's cells in series and parallel, but first, measure the voltage from a single cell, to provide a basis for the comparison.



Aims

- To measure the voltage delivered by a single STELR solar cell.
- To measure the voltage delivered by a STELR solar panel with the four cells in series.

Hypothesis

What do you predict the voltages of the four cells will be when they're in series?

Mark how many times the voltage of a single solar cell on the scale below.

Materials

- STELR testing station
- STELR multimeter
- 2 x halogen lamps
- STELR solar panel
- connecting leads
- STELR A.C. power supply

Risk assessment

Complete the following risk assessment.

Fact	Risks	Precautions
Multimeters are sensitive instruments		
The halogen lamps get very hot		
The halogen lamps use a power pack connected to mains electricity		

Variables

Identify:

- the independent variable – the variable you change to see the difference it makes;
- the dependent variable – the variable you measure to see if/how it changes when you change the independent variable;
- three controlled variables – other factors that you keep constant, so they don't have any impact on the dependent variable.

Note: There are many variables that you should control – pick ones that you think will make the most difference if you don't control them (for example, where the halogen lamps are pointing).

independent variable:	
dependent variable:	
controlled variable 1:	
controlled variable 2:	
controlled variable 3:	

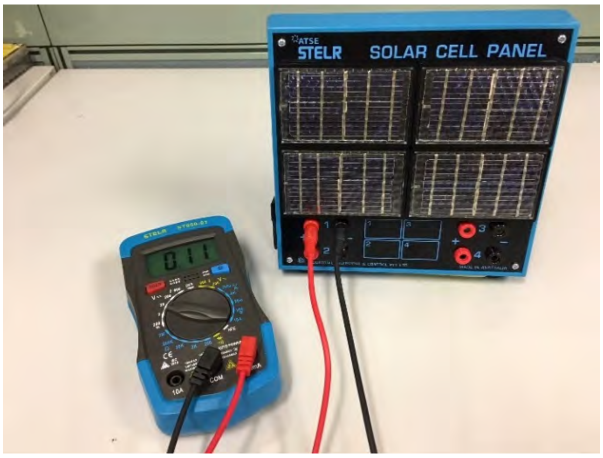
READ THE VOLTAGE OF A SINGLE SOLAR CELL

For electricity to do anything it must be in a circuit, but the voltage of electricity sources, like batteries and solar cells, can be measured when they're not in a circuit. We'll do this in this experiment.

First, connect the multimeter to solar cell 1 on the STELR solar panel, as shown:

- connect the cell **1 +** connector on the panel to **VΩmA** on the multimeter;
- connect the cell **1 –** connector on the panel to **COM** on the multimeter;
- turn the multimeter to **20** in the **white V** range or the **white V** (depending on your multimeter).

You should get a small voltage reading from the light in the room.



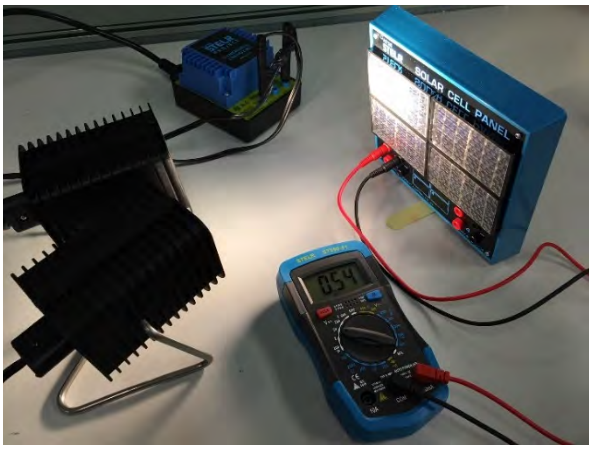
Try moving the panel or pass your hand over the cell – see the difference it makes.

Now set up the halogen lamps and shine them directly on solar cell 1.

The halogen lamps produce a light similar to sunlight.

- Connect each halogen lamp to the **0 V** and **12 V** connectors on the power supply pack.
- Plug the power supply into a wall socket and turn on.

Read the voltage across the cell and record below.



Check all the solar cells

Attach the multimeter cables to each of the cells in the panel, direct the halogens onto the cell, and read the voltage it produces.

Fill in your voltage readings in the table below, and then work out the average.

Solar cell no.	**1**	**2**	**3**	**4**	**Average**
Voltage (V)					

With both halogen lamps directed at a cell it should produce over 0.5 V (if any of your cells are less than this, let your teacher know).

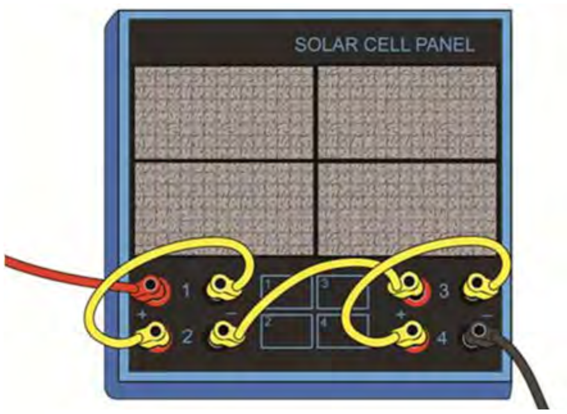
FOUR CELLS IN SERIES

Now to measure the voltage of four solar cells in series. You will compare this with the same cells connected in parallel.

To make sure that the comparison is fair, ensure that all the variables – except the one you are testing – stay the same.

Now connect the solar cells in series, as shown at right:

- connect the **–** connector of cell **1** to the **+** connector of cell **2;**
- connect the **–** connector of cell **2** to the **+** connector of cell **3;**
- connect the **–** connector of cell **3** to the **+** connector of cell **4;**
- connect the multimeter to cell **1 +** and cell **4 –.**



The 4 solar cells connected in series

Place the panel in position in front of the halogen lamps and turn them on. Read the voltage and record it in the results section to follow.

Note: It may be more convenient to connect the cells from the back of the panel instead of the front.

RESULTS

Fill in your results below.

Average voltage of a single solar cell (V):	
Voltage produced by 4 solar cells in series (V):	

Compare results with other groups. Share your data to fill in the table below.

Copy your results and results from four other groups into the table below, and work out the averages.

		Voltages (V)	
Group no.	**Students in group**	**Single cell (avg)**	**4 cells in series**
1			
2			
3			
4			
5			
Average	**N/A**		

Summarise the class's results. How do the average voltages for four cells compare to the average single-cell voltage?

DISCUSSION

Discuss the questions below in your groups before answering.

Did the results agree with your hypothesis? If so, repeat your hypothesis here, and if not, describe how the results differed.

Can you explain the results?

It is highly unlikely that the results of the different groups were the same. Give two reasons why there might have been differences.

Why do you think the class data was averaged?

If one group had very different results from all the other groups, do you think you should exclude their results? Explain.

Assess the experiment as carried out by your group. For example, did it go well, and do you think it was a fair test? (Reasons it might not have been include that the basic design was flawed, or you had practical difficulties carrying it out.)

Conclusion

Write a short summary of the experiment addressing its aims.

6.3 PRAC: ANGLE TO LIGHT

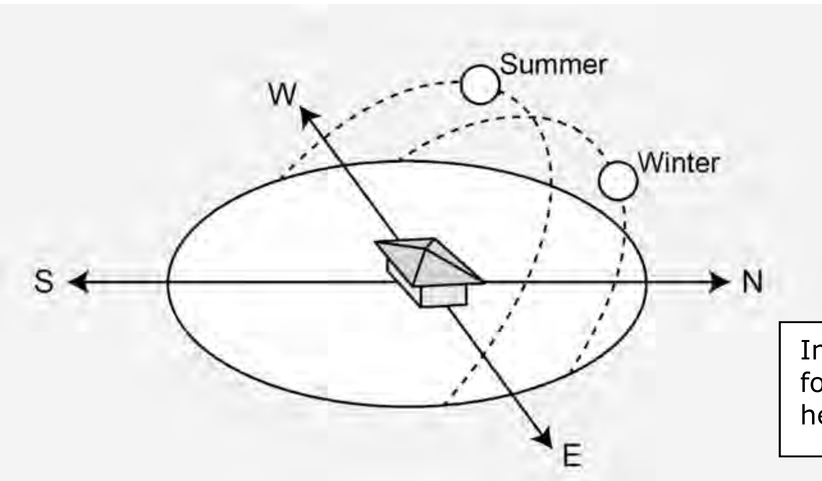
KEY QUESTION

- How does the angle that light strikes a solar panel affect the voltage?

Some solar panels, like the ones pictured above, are mounted so that they twist about to follow the sun, but most are fixed in one position. Engineers need to know the angles to point the panels to produce the most electricity. This isn't simple because the sun moves in two different ways:

- daily – across the sky from east to west;
- yearly – the daily path shifts from south to north and then back again.

So, where the sun is in the sky depends on the time of day and the time of year. It also depends on where you are on the planet.



Important: This diagram is for the southern hemisphere.

Every day, the sun goes from east to west (the dotted paths), but in summer the path is closer to the south, making the sun higher at noon (in the southern hemisphere), and in winter the path is more to the north, making the sun lower in the sky at noon.

The purpose of this prac is to find out how much difference the angle of the light to a solar panel makes.

Use the STELR equipment to investigate this, but beyond that, you will have to decide in your groups how you design, conduct and report the experiment.

MEASURING ANGLES

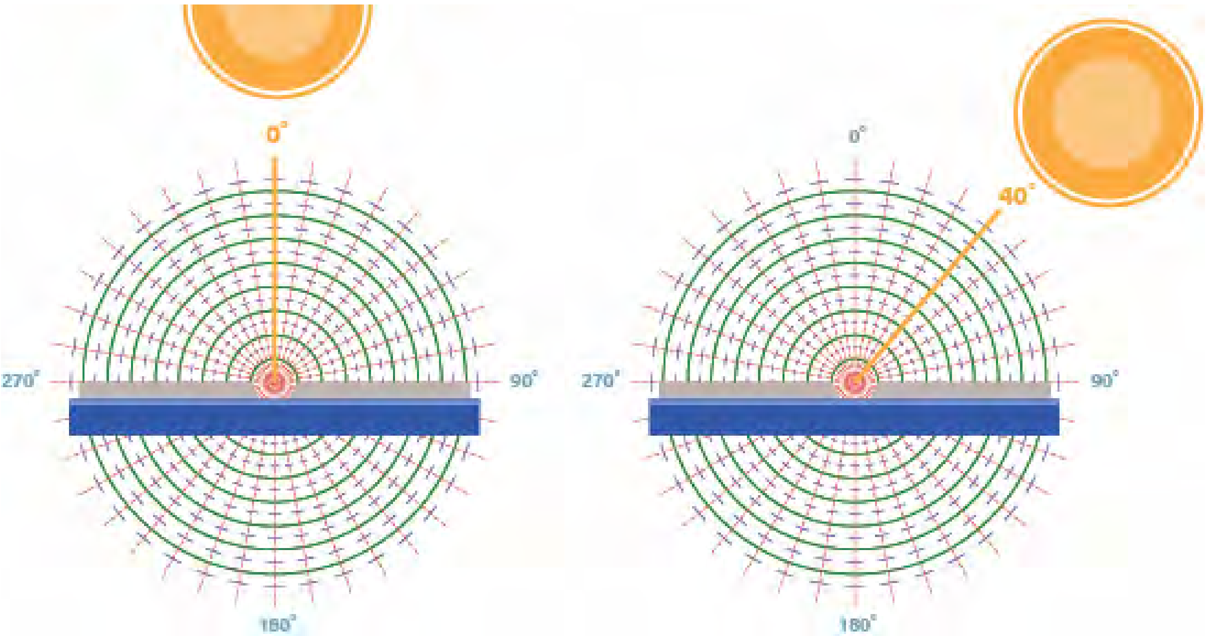
So that you can compare results around the class, everyone should use the same method to measure the angles of the light to the solar panels.

Use the alignment circle provided, as illustrated below.

- 0° is when the light source is directly in front of the panel.

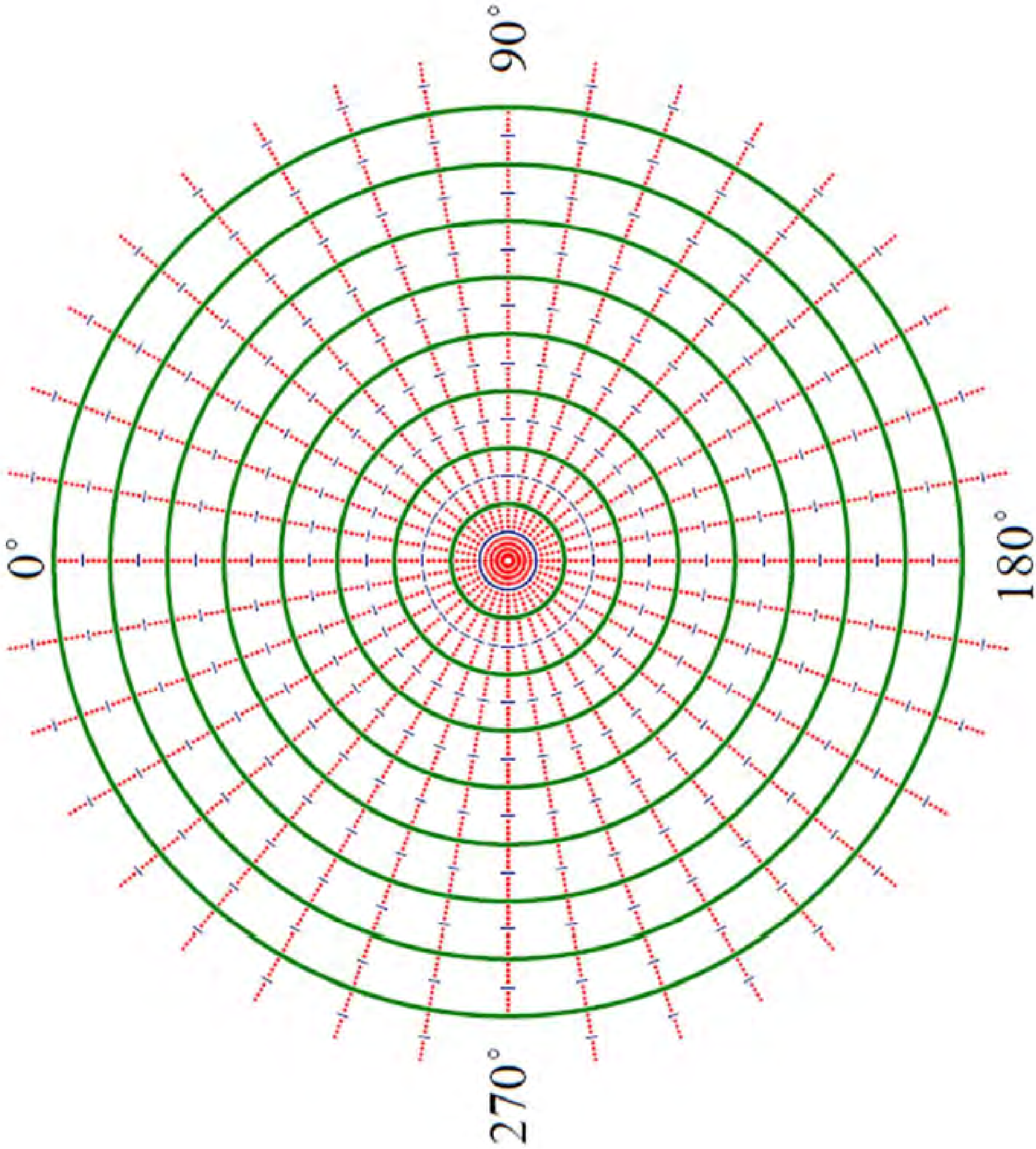
Some questions:

- Should you test between 90° and 270°? That puts the light source behind the panels.
- If you test between 0° and 90°, should you test between 270° and 0°?



How to use the STELR alignment circle to measure the angle of light to the solar panel. The solar panel is shown from above.

STELR solar panel alignment circle



DESIGN AND RUN THE EXPERIMENT

Write up your experiment.

You must include:

- aim;
- hypothesis;
- materials;
- method (consider including diagrams or photographs of your setup);
- risk assessment;
- variables (note: it is important to keep all variables except the independent variable at the same levels, to make your test fair);
- results, presented clearly (is it possible to graph them?);
- conclusion (addressing the aim).

Your teacher may give you the STELR investigation planner to help with design of the investigation.

Important! Have your teacher check your preparation before you carry out the experiment.

There are pages below to write up the experiment – use your own paper and attach if this is not enough.

There are some discussion questions to finish.

DISCUSSION

Did your results agree with your hypothesis? If so, repeat the hypothesis here, and if not, describe how the results differed.

Can you explain the results?

Assess the experiment you carried out. For example, did it go well, and do you think it was a fair test? (Reasons it might not have been include that the basic design was flawed, or you had practical difficulties carrying it out.)

Do you think that your results have implications for the placement of solar panels on buildings and in other locations? If not, why not, and if so, what implications? Explain.

If you were given the opportunity, what further investigation would you carry out to build on what you learned from this investigation?

You have learned some of the background about solar energy – now it is time to investigate it in action using the STELR solar panel:

- What difference does it make connecting solar cells in series and in parallel?
- How does the angle that light strikes a solar panel affect its energy output?

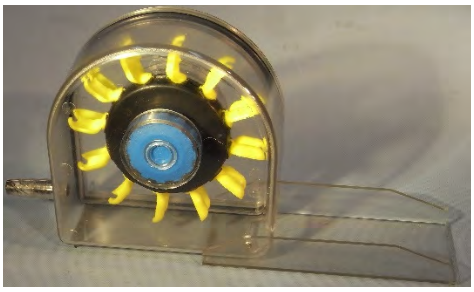
SUMMARY

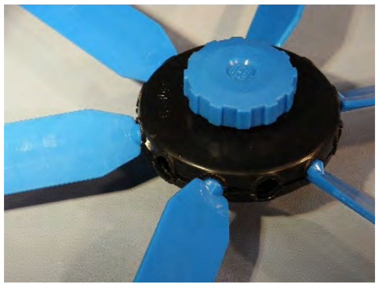
Summarise the results of your experiments.

Series vs. parallel

Angle of light

7 OPEN INQUIRY





In groups, conduct your own investigation with the STELR solar panel or wind turbine.

There are some suggestions below, but try to think of your own ideas. Of course, you'll have to agree on your investigation as a group.

You must design, conduct and report on your investigation, using the same format as in previous experiments.

Important: Get permission from your teacher before you carry out your experiment.

Possible inquiry questions:

Solar panel

- What is the effect of clouds on the energy delivered, or dust or leaves?
- Does temperature have any effect on energy output? If so, how?

Wind turbine

- Will combinations of different blade lengths and/or angles generate more electricity?
- How does blade surface area relate to energy output?
- How do gears and gear ratios affect the output of a wind turbine?

Pelton Wheel

- How does flow rate of water affect the output of a hydro power station?

PLAN, CARRY OUT AND REPORT

First, plan your experiment. You will need to include enough information in your plan to convince your teacher that you are ready to go ahead. Use the investigation planner on the following page.

When you have permission, carry out the experiment. It may not work properly straight away – you may need to change materials and/or procedure before you take your data readings.

Finally, record your data and present it in a meaningful way. Then discuss what it shows.

In your final report, make sure you include:

- inquiry question (also, because this is your own question, include any background discussion to explain why you are interested in this question);
- aim;
- hypothesis;
- variables;
- materials;
- procedure;
- risk assessment;
- data table and, if appropriate, a graph;
- discussion, including:
    - a) how the experiment went, including any problems encountered and whether they were overcome;
    - b) if the results agreed with your hypothesis;
- conclusion.

INVESTIGATION PLANNER

What are you investigating?	
What are you going to investigate?	What do you think will happen? Explain why.
What is your hypothesis?	What is the aim of your investigation?
Designing your experiment	
What variables might affect the outcome of your investigation?	What variable(s) will you test?
How will you make your tests fair?	What observations and measurements will you need to take?
How will you ensure that your measurements are reliable?	What calculations (if any) will you need to make?
What risks might there be? What safety precautions do you plan to take?	What materials and equipment will you need?

Your results	
How will you record your observations and measurements?	What graphs can you draw? What spreadsheets can you design to display your results?
Conducting your investigation	
Once your teacher has approved your plans and you have the materials, conduct your investigation. Record how the investigation was performed. Include any modifications that you made and why you made them.	
Analysing your results: your conclusions	
Examine your results. Use them to answer your aim.	From your conclusions, were your predictions and hypothesis correct? Does your hypothesis need to be modified? Discuss.
Evaluating the investigation	
How reliable do you think your results were? Discuss.	How could you modify your procedure to make your results more reliable?
If you were given the opportunity, what further investigation would you carry out to build on what you learned from the investigation?	

8 STEM AT WORK

There are many careers in STEM-related fields (science, technology, engineering and mathematics) – and not always as scientists, technicians, engineers or mathematicians. Renewable energy is a particular growth area.

Watch the video below and choose one person from the STELR *Career Profiles, Renewable Energy* web page. Then answer the questions that follow.

VIDEO *Sheena Ong, graduate engineer*
http://stelr.org.au/career_profiles/sheena-ong/

STELR Career Profiles, Renewable Energy
www.stelr.org.au/career-profiles-renewable-energy/

Question 1

Fill in some basic information about Sheena and the person you chose from the STELR website.

	Person 1	**Person 2**
Name	Sheena Ong	
Organisation & what it does		
Role		
High school subjects		
Other qualifications		
Job duties		
What they like about the job		

Question 2

In the video, Sheena talks about her interest in *humanitarian engineering*.

- What do you think this term means?

Describe two possible engineering projects, one humanitarian and the other not. Explain what makes the difference, in your opinion.

Question 3

All of the people profiled carry out a variety of tasks within their jobs, often mixing fieldwork, office work on the computer, and liaising with a diverse range of people.

- From the two profiles that you have looked at, which type of task would you like best?

How could you train yourself to be better at this type of task?

Question 4

Do you think there will still be jobs like the two you have looked at in 20 years? If not, do you think your two career profile people will be well equipped to adapt? Explain.

GLOSSARY

Word or term	Meaning

The Australian Power Insititute (API) proudly supports science, technology, engineering and maths education in Schools.

ENGINEERING THE FUTURE

Engineers in the Energy Industry help to:

- Provide the "bridge" between science & community
- Take up climate change challenges
- Address technological challenges
- Transition to a renewables future
- Implement energy efficiency initiatives
- Continue providing essential service to community
- Raise living standards & tackle poverty in developing countries.

ABOUT API

The API is a not for profit organisation established by the energy industry companies in Australia to facilitate the provision of tomorrow's technical leaders equipped to deliver Australia's energy future through initiatives such as:

- API Bursary Program to support students at university study engineering and technology courses
- Support for programs to encourage young female students to study STEM and pursue engineering and technology careers.

CONTACT US

www.api.edu.au info@api.edu.au

API SOLAR CAR CHALLENGE

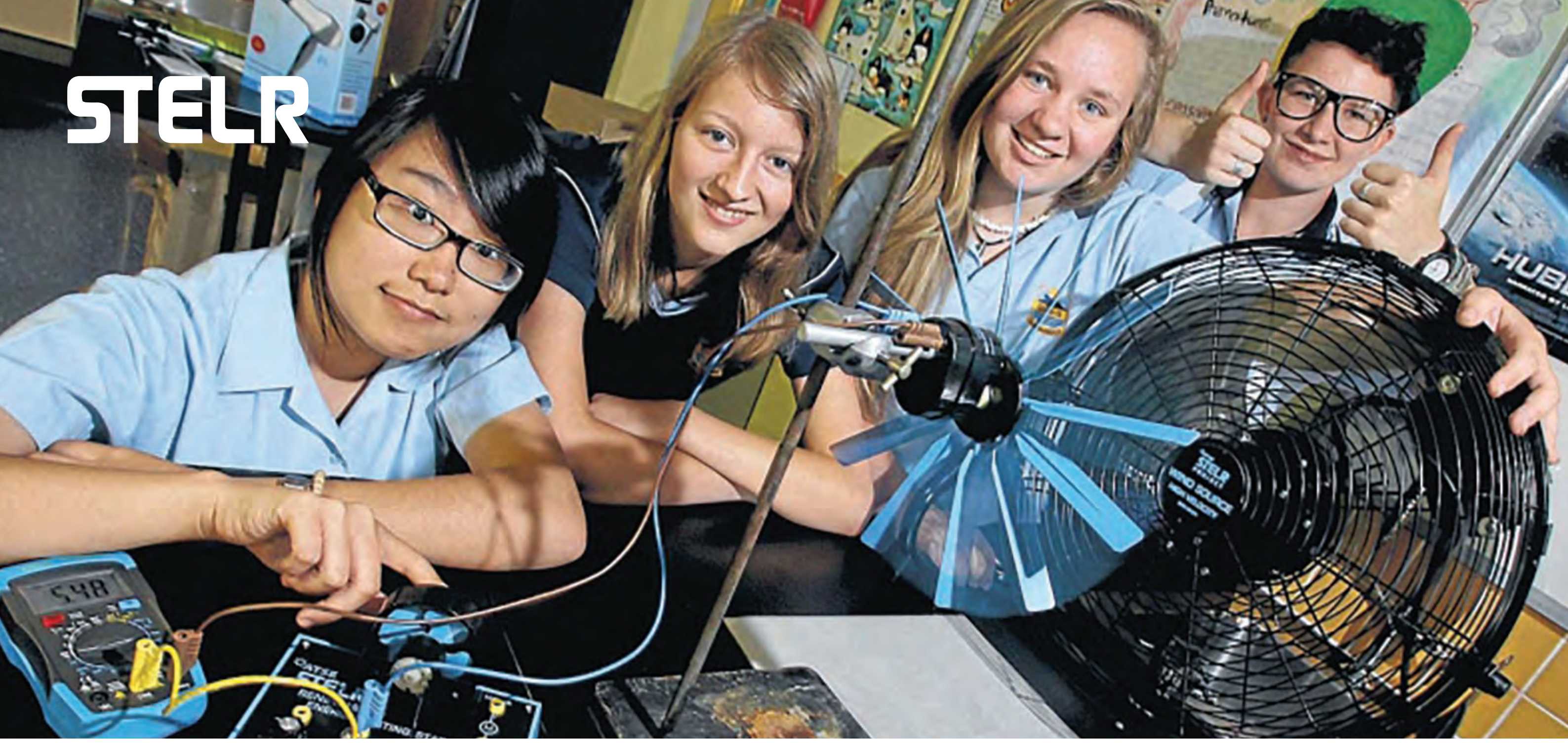
As API is committed to improving STEM education, API provides part funding for STELR, which is an initiative of The Australian Academy of Technological Sciences & Engineering (ATSE). API supports this program by providing class sets of re-usable model solar car kits to over 250 schools Australia wide using the Science and Technology Education Leveraging Relevance (STELR) Renewable Energy Module.

API also encourages involvement between university undergraduate engineering students by sending an API Bursary Holder to a participating high school to deliver a presentation about careers related to the renewable energy and power industry. During these visit the young undergraduate engineers also assist with solar car construction, judge the cars, and award prizes. The API, the high school teachers and students consider the Solar Car Challenge a great program to be invlolved in!

API BURSARY PROGRAM

As The API is constantly working to support the education and professional development of engineers & technologists in the energy industry across Australia, API offers scholarships to engineering & technology students with an interest in areas of engineering relevant to the electric power industry. The bursaries provide financial assistance over 4 years plus the opportunity where available for paid employment with member companies during the univeristy summer vacations.

Applications open February-May 2020 via API website.



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