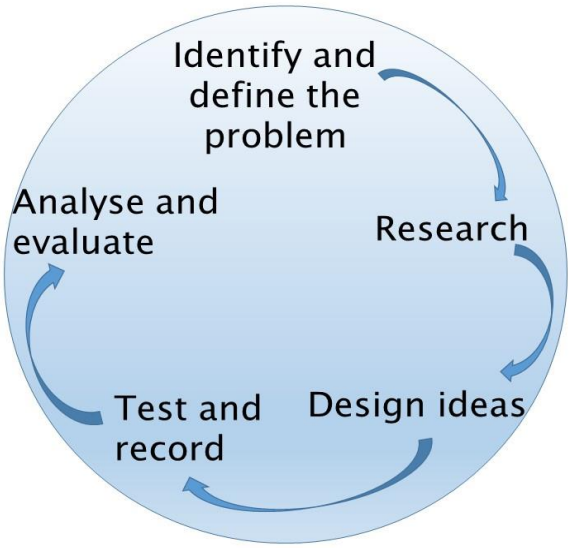
Moving Forward – Student Booklet

The Challenge

The global demand for transportation is constantly increasing. This includes aviation, trains and vehicles used for commercial, industrial, and logistical purposes, not to mention personal vehicles. In 2018, nearly a quarter of global CO_2 emissions were from transportation (Our World in Data, 2020). This means that new technologies need to be developed and employed to meet transport demand, while minimising CO_2 emissions. Due in part to this increase in demand, many governments around the world have agreed to work towards reducing their carbon emissions, some agreeing to net zero emissions by 2050.

Your challenge will be to investigate different technologies and to assess and compare their feasibility.



Background Information

In 2015, the United Nations General Assembly set up the Sustainable Development Goals, also known as the "Global Goals". These are a collection of 17 interlinked global goals designed to be a "blueprint to achieve a better and more sustainable future for all." The future of fuel for transport relates to many of these sustainability goals, and governments must consider these when introducing new legislation and approving new projects for companies developing these fuels and technologies.

Figure 1. The UN 17 Sustainable development goals. (un.org, 2015)

One of the major hurdles in meeting the sustainability goals is that the global population is expected to increase, reaching nearly 11 billion by 2100. This will, no doubt, increase the demand for vehicles, both personal and commercial.

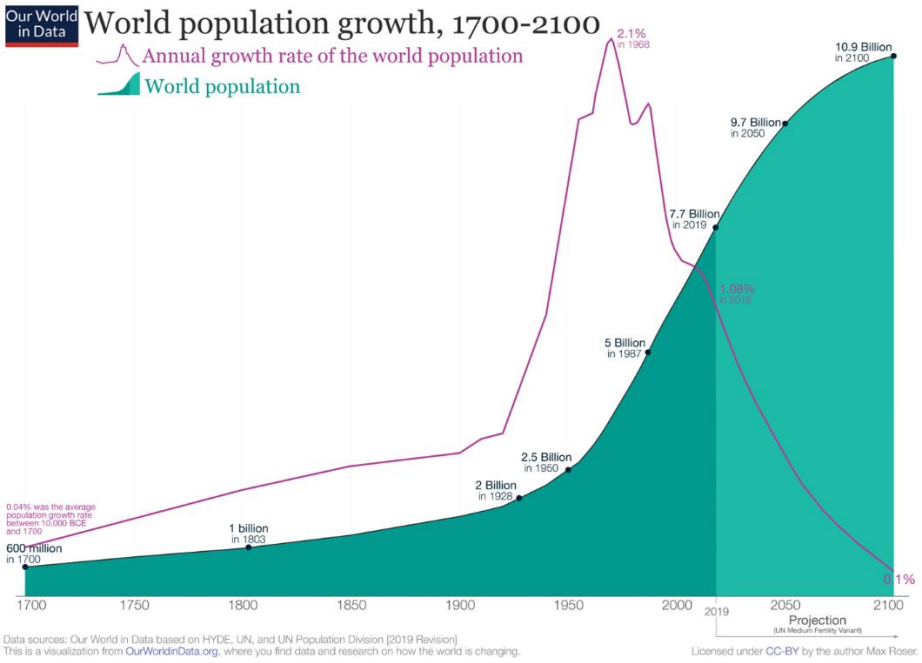


Figure 2. Past and predicted population growth of the world. (OurWorldData.org, 2022)

The race is now on between countries and companies to develop more efficient transport, which will lead to lower greenhouse gas emissions. There are already many alternatives to standard petrol and diesel vehicles on the road.
The first mass-produced hybrid vehicle was the Toyota Prius, which was launched in Japan in 1997. Hybrid vehicles use a technology which generates energy that is stored in a battery whenever the brakes are applied. However, hybrid vehicles still release CO_2.
All electric vehicles (EVs), now have much greater range than when first put on the market and this is constantly being improved upon. Their price has also dropped dramatically and will likely continue to do so as technologies advance. They are much cheaper to run than regular fuel cars. However, although the vehicles themselves do not emit CO_2, their carbon footprint will depend upon how the electricity they use is generated.
In America and other countries, biogas and hydrogen fuelled vehicles are also becoming more common. These, again, have a very varied carbon footprint depending on how the fuel is produced.

When considering how sustainable a fuel or energy type is, it is important not only to think about the emissions, but the full 'cradle to grave' life cycle. This considers factors such as production of the fuel, transportation of the fuel and efficiency. This means that some fuel or energy types may be more suited to different countries and transport uses, and that there may not be a one size fits all approach.

Background Research

1. Which state or territory in Australia has the highest recorded number of EV car sales per 10,000 vehicles? Suggest why this may be the case.
   Suggested website: https://www.budgetdirect.com.au/car-insurance/research/electric-car-sales-australia.html

2. Hydrogen is generally described in terms of colours, this relates to how it is produced. Explain how each of the types of hydrogen are produced, in the table below.
   Suggested website: https://www.nationalgrid.com/stories/energy-explained/hydrogen-colour-spectrum

Green	
Blue	
Grey	
Black and Brown	
Pink	
Turquoise	

Yellow	
White	

3. Why is it important to consider the colour coding of hydrogen when determining how sustainable a fuel type is?
   Suggested website: https://rac.com.au/travel-touring/maps-and-guides/ev-chargers

4. Complete the table below to show the energy mix in Australia in 2021?

	%
Gas	
Coal	
Renewables	

Suggested website: https://www.energy.gov.au/news-media/news/2021-australian-energy-statistics#:~:text=The%202021%20data%20shows%20renewables,mix%20in%20calendar%20year%202020.

5. Why is this energy mix relevant to considering the use of electric cars?

6. Consider the UN sustainability goals and discuss how the future of fuels used for transportation may impact these goals.

Sustainability Goal	How future fuels used in transport can impact this goal
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

11	
12	
13	
14	
15	
16	
17	

Hydrogen fuel

Background information

Hydrogen is being trialled as a fuel of the future, and infrastructure is being built and developed with this goal in mind. Hydrogen can be created through splitting water into its two components, hydrogen and oxygen, through a process called hydrolysis. Many hydrogen production facilities, such as Woodside Energy's H2TAS, will be designed to create green hydrogen and ammonia.

Figure 3. BMW 7 series prototype, powered by hydrogen. (Creative commons).

Job Alert

Chemists and chemical engineers play a vital role in the resources industry. Part of their role can involve investigating the efficiency of reactions and how to generate the highest yield of the desired product.

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Objective

The aim of this investigation is to determine the relationship between electrolyte concentration and hydrogen production during hydrolysis (electrolysis of water) and consider how this could affect production yield.

Background research

Suggested websites:

- Video: What is Electrolysis
- BBC Bitesize: Electrolytes and electrolysis
- MIT School of Engineering: How does a battery work?

1. What are the main factors which can increase the rate of a chemical reaction?

2. What does the term cation mean?

3. What is a cathode?

4. What does the term anion mean?

5. What is an anode?

6. What is the purpose of the battery/applied voltage during electrolysis?

7. What is an electrolyte and what is its purpose?

8. What is the chemical formula of water?

9. What is the ratio of oxygen atoms to hydrogen atoms in water?

_____

10. Considering your answers to Q8 and 9, would you expect more oxygen or hydrogen to be produced during hydrolysis? Explain your answer.

_____

_____

_____

Hypothesis

As the concentration of the electrolyte increases, the volume of hydrogen produced will _____. This is because_____

Equipment

- Small clear plastic container (e.g., takeaway container)
- 9V battery
- 2 silver-coloured (steel) drawing pins
- 2 graduated measuring cylinders (recommend 25 mL capacity and plastic)
- Stopwatch
- 2 elastic bands
- Books, blocks or plasticine
- Bicarbonate of soda
- 1 L measuring beaker
- Measuring teaspoon
- Stirring rod

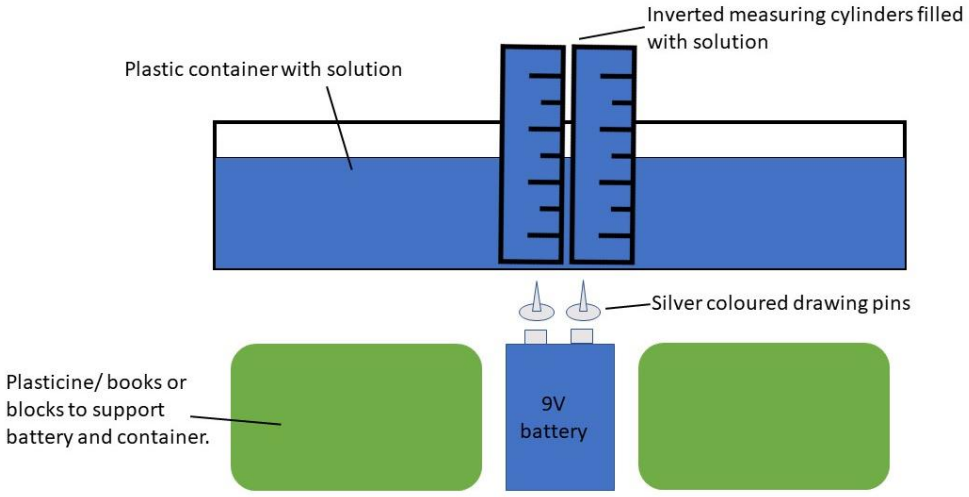


Figure 4. Suggested set-up for the equipment. Us the elastic bands in a cross shape to help stabilise and secure the inverted measuring cylinders.

Method

1. Place plasticine/books/blocks next to a 9V battery to create a support for it and the container that will sit above it.
2. Place the two drawing pins on top of the terminals of the battery, spike side up. Put the container on top, pushing down slowly and gently until they poke through the bottom of the container. This will ensure the pins are the same distance apart as the terminals.
3. Place the container on the worksurface with the pins still in the bottom.
4. Create the electrolyte: Pour 500 mL water into the measuring beaker, add 1 level teaspoon of bicarbonate of soda and stir, using the stirring rod, until it has dissolved.
5. Place the elastic bands around the container, so that they create a slight cross shape over where the drawing pins are.
6. Pour the solution into the container until it is around ¾ full and make a note of the volume used from your jug. *Ensure you use the same volume in future trails.*
7. Submerge the measuring cylinders in the solution to fill them, and carefully stand them upside down over the pins, trying not to release any solution. Use the elastic bands to help keep them in place. *You may need assistance for this step.*
8. Gently lift the container with the upturned measuring cylinders onto the set up so that the drawing pin heads are on top of the terminals of the battery.
9. Start the stopwatch.
10. After 30 seconds measure how much gas has been displaced in each gradated measuring cylinder and record this in the results table. (Your teacher may ask you to conduct the "pop test" to work out which measuring cylinder contains hydrogen – the other will contain oxygen)
11. Repeat the experiment increasing the concentration of the solution each time, by increasing the number of teaspoons of bicarbonate of soda to the same volume of water.

Results and Analysis

1. Complete the table below with your results. If you have not conducted the gas tests, recall your previous answers regarding if more hydrogen or oxygen will be produced during hydrolysis to assist your decision as to which measuring cylinder contains which gas.

Number of spoons of bicarbonate of soda in solution	Volume of oxygen collected in measuring cylinder (mL)	Volume of hydrogen collected in measuring cylinder (mL)

2. Plot a graph to show the relationship between the number of spoons of bicarbonate of soda added (x-axis) and the volume of hydrogen gas produced (y-axis).

3. Describe the relationship between the amount of bicarbonate of soda added and the volume of hydrogen gas produced.

4. Was the volume of oxygen collected what you expected compared to the volume of hydrogen collected?

Evaluation

1. How did your results compare to your hypothesis?

2. Were there any potential sources of error in your investigation? (Hint: consider what other variables may increase the rate of reaction in this experiment)

3. How could you improve this investigation?

4. How does this investigation relate to hydrolysis of seawater?

5. Considering the main factors which can increase the rates of reaction, outline any ideas you have to research the rate of hydrogen production, through hydrolysis, further.

Biogas Production

Background information

Biogas is produced by the breakdown of organic matter. Biogas can be generated on a small or large scale. Some households and farms have their own digesters to create biogas, which is used for heating. Across Australia more local councils are starting to collect food waste to generate electricity (City of Cockburn, 2022). Biogas can also be used as a fuel for transport.

Job Alert

The role of a **chemist** can include investigating yield production. In the case of biogas, this would involve trialing different organic materials to determine which ones create the most biogas. **Environmental engineers** and **scientists** may then consider the impacts of biogas on the local environment where it is produced, monitoring potential hazards from freshwater contamination. An **environmental advisor** can use the research to help in creating policy and provide feedback to local councils and parliament, enabling them to make safe decisions regarding biogas production plants.

Objective

To determine which type of organic matter creates the most biogas.

Background research

Suggested websites:

- https://www.nationalgrid.com/stories/energy-explained/what-is-biogas

1. What does the term anerobic digestion mean?

   _____

2. Give some examples of the sort of waste products that can be used to produce biogas.

   _____

Hypothesis

The _____ will produce the most biogas. This is because_____

_____

Equipment

- 5 conical flasks
- 5 gas syringes, with connection tubes feeding into bungs that fit the conical flasks
- 5 different waste products to test (e.g., grass, berries, straw, oats, apple)
- 5 retort stands with clamps
- Pestle and mortar (or food processor)
- Weighing scales
- Funnel

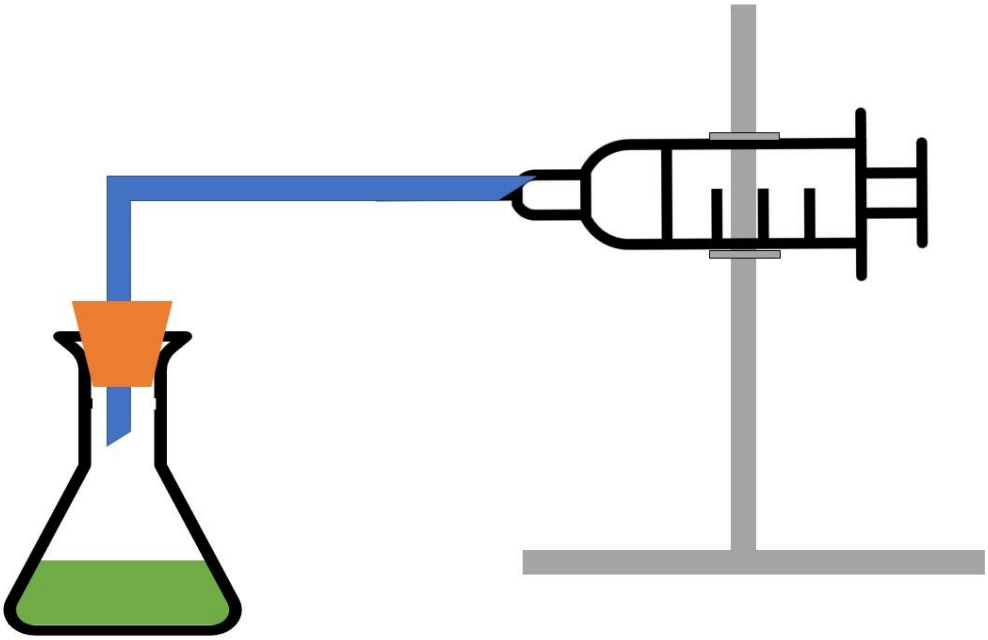


Figure 5. Equipment set up to measure the volume of biogas produced from different waste products.

Method

1. Use the pestle and mortar to break down each waste material into a smooth puree (ensure these are done separately). You may need to add a little water to get the right consistency.
2. Place the funnel into a conical flask and put this on the weighing scales. Carefully add one type of food waste and record its weight.
3. Gently secure the gas syringe in a horizontal position, and fully compress the syringe so that there is no air in it.
4. Carefully push the bung into the conical flask so that there is now a closed system (as pictured above).
5. Wash the funnel and then repeat steps 2 – 4 for each waste material. Ensure that each conical flask has the same weight of waste material in it. (*Each flask should only contain one type of waste material*)
6. Record the volume of gas collected each day in the results table below, until the reaction has stopped, or the cylinder is full.

Results and Analysis

1. Complete the table below adding your results – you may need to track for longer in colder weather as it will take more time for the material to break down and create gas.

Waste material	Volume of biogas collected in the syringe (mL)					
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6l

2. Plot a graph, using a different colour for each waste material, to show the volume of biogas collected (y-axis) each day (x-axis).

3. Which waste material produced the most biogas over the whole experimental period?

_____

4. Which waste material produced the least biogas over the whole experimental period?

_____

5. Were there any trends in the data, for example, the rate of gas production was linear/ exponential/ inverse exponential?

_____

_____

_____

Evaluation

1. How did your results compare to your hypothesis?

2. Were there any potential sources of error in your investigation? (Hint: consider what other variables may increase the rate of reaction in this experiment)

3. How could you improve this investigation?

4. What does this investigation show you about the production of biogas?

5. Outline any more ideas you have to take this research further. Consider factors which could increase the rate of reaction.

Resistance in the Grid

Background information

With many countries, such as the UK, announcing that they will ban the sale of new cars powered wholly by petrol and diesel (BBC, 2020) in the not-so-distant future, many people are beginning to purchase electric cars instead. This in turn may lead to people considering how they get their electricity.

Most households have their energy supplied by the national grid. This is a network of cables which distribute electricity around the country from a variety of sources such as coal-and-gas fired power plants, solar arrays and wind farms. You can also feed any excess electricity your household generates (from solar panels etc.) back into the grid.

People can also live "off grid" which means that they produce all their own electricity. This may be via solar panels which would also require battery storage and/ or a back-up generator.

Job Alert

The role of an **electrical engineer** often involves working with large scale systems, such as designing an efficient national grid. An electrical engineers' responsibilities can include undertaking research, creating test procedures and writing reports. Electrical engineers need to have a good understanding of physics and material science, particularly conductivity and resistivity of materials. They also need to be competent mathematicians, to enable them to present and interpret data.

Objective

To determine the relationship between the length of a wire and resistance, relating this to energy loss in the grid and what this means for electric vehicle recharging.

Hypothesis

As the length of the wire increases the resistance will _____. This is

because _____

Equipment

- Wooden metre rule
- Ammeter
- Voltmeter

- Connection leads (wires)
- 2 x crocodile clips
- Duct tape
- Power supply
- 1.1 m nichrome wire

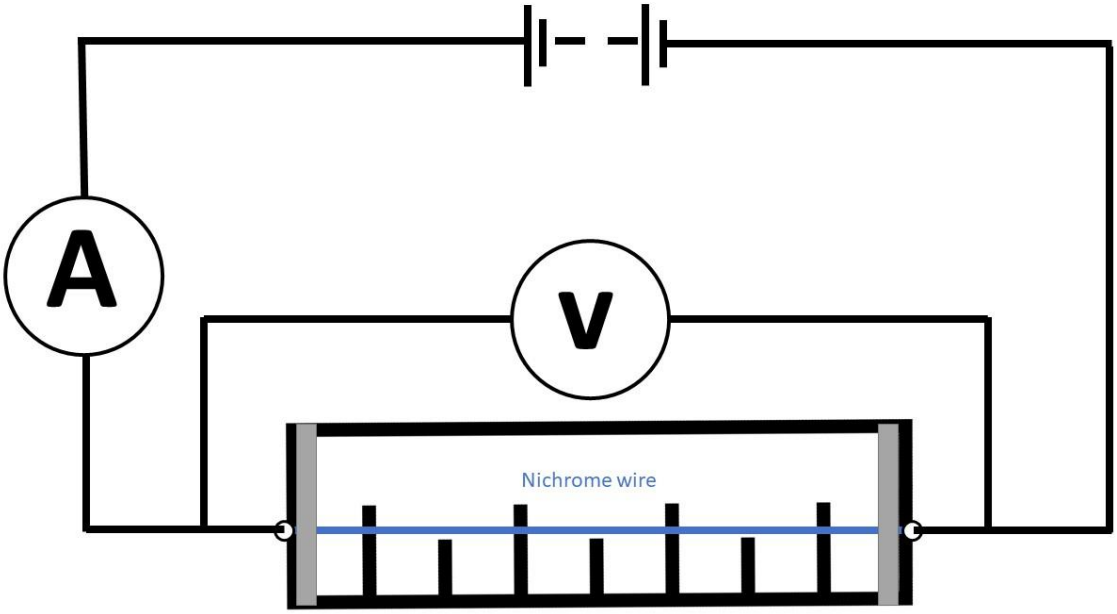


Figure 1. Equipment set up to determine the resistance of a wire for varied lengths. Connect the voltmeter in parallel and the ammeter in series.

Method

1. Stretch the nichrome wire out over the metre rule and secure each end down with a little duct tape so that it cannot move.
2. Create a series circuit with the ammeter, power supply and nichrome wire, using the crocodile clips to connect to a 1m length of nichrome wire (see diagram above).
3. "Piggyback" the voltmeter onto the connection leads with the crocodile clips on it, so that the voltmeter is connected in parallel and will take voltage readings across the length of nichrome wire.
4. Turn on the power supply and quickly record the voltmeter and ammeter readings in the results table, turning the power supply back off again. The readings will fluctuate, so take the reading as quickly as possible. The power supply must be DC, and we do not recommend using over 3V. The nichrome wire will start to heat up quickly, so you must not leave the power on for more than a few seconds at a time.
5. Repeat the investigation using shorter lengths of nichrome wire, by moving one of the crocodile clips to a new position, recording your readings in the results table. Allow time for the wire to cool between readings.

Results and Analysis

1. Complete the table below adding your results and by calculating the related resistance.

Length of nichrome wire (cm)	Voltage (v)	Current (A)	Resistance (Ω) R = V / I
100			
80			
60			
40			
20			

2. Plot a graph to show the relationship between the length of wire (x-axis) and the resistance (y-axis).

3. What is the relationship between the length of wire and the resistance?

4. Using any prior understanding of how current flows, explain your results.

5. Use your results from this experiment to explain what happens the further an energy source is away from a customer.

6. Would it be more **efficient** to charge an electric car using the energy produced at your house, e.g., rooftop solar, or to use energy distributed from the national grid? Explain your answer referring to your experimental results.

Evaluation

1. How did your results compare to your hypothesis?

2. Were there any potential sources of error in your investigation? (Hint: consider what other variables may increase the resistance of a wire in this experiment)

3. How could you improve this investigation?

4. What does this investigation show you about the efficiency of electricity transmission?

5. Outline any ideas you have to take this research further.

Extension

Which other careers might involve researching electrical energy transmission and efficiency?

Job title	Role and responsibilities

Regenerating Energy

Background information

Automotive designers and engineers will consider factors to increase a vehicle's efficiency and assist with car design. Many hybrid and electric vehicles make use of regenerative braking systems. When a driver removes their foot from the accelerator, or applies pressure to the brake, the motor spins in the opposite direction and thus acts as a generator, which creates electricity to help recharge a battery. The energy is also used to assist the braking system, to help slow the car down.

A generator generates electricity and can be a relatively simple device. There are three main components required for a generator: a magnet, a coil of conductive metal wire and a force. When the force is applied to the magnet, to make it move in and out of the coil of wire (or the coil moves over the magnet), then a current is generated.

Objective

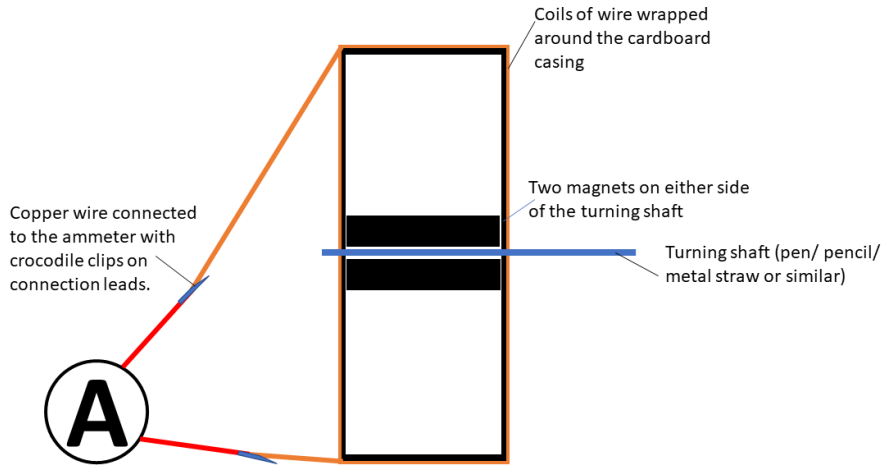
To create a simple generator and determine the relationship between the magnetic field strength (number of magnets) and the current induced.

Hypothesis

As the number of magnets in the generator increase the current induced will _____. This is because_____.

Equipment

- 6 bar magnets
- 1 large piece of strong corrugated cardboard
- A ruler
- A shaft (this could be an old pen/metal straw or something of similar length and shape)
- Copper wire
- Sandpaper
- Glue
- Plasticine/Blu tack
- Ammeter
- Connection leads
- Crocodile clips
- Masking tape
- Record player (optional)



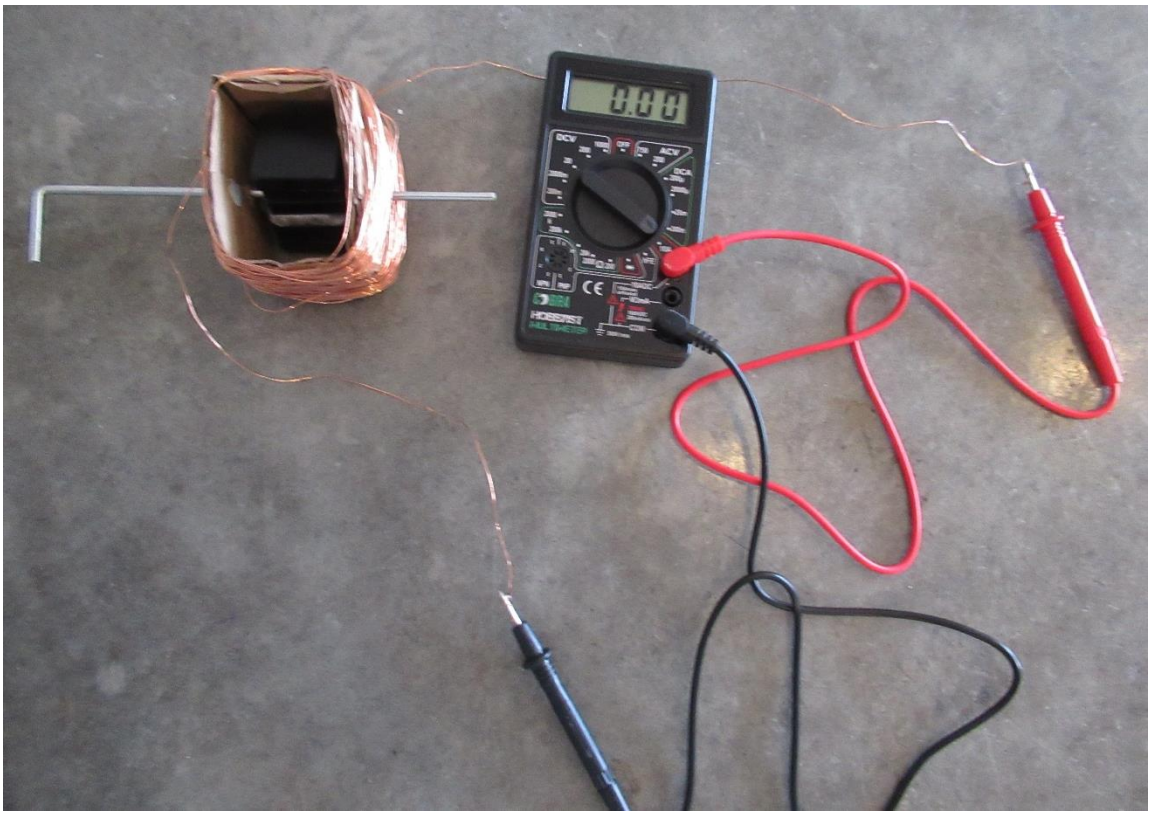


Figure 4. Diagram and photograph to show the setup of the generator end on. With the magnets in the middle facing each other, separated by the turning shaft. Copper wire has been coiled around the outside of the cardboard casing in two sections, enabling the shaft to turn.

Method

1. First you need to make the casing of the generator from the cardboard. This will be a hollow rectangular prism in which the magnets will spin. To do this you will need to measure the length (l) and width (w) of the magnets and create a net as per the diagram below (figure 4). Fold along the dotted lines to create the case and check that your magnet fits inside. It will need to be able to spin freely inside the case without hitting the sides yet be relatively close to the sides. Once you are satisfied, you can secure the frame with some masking tape.

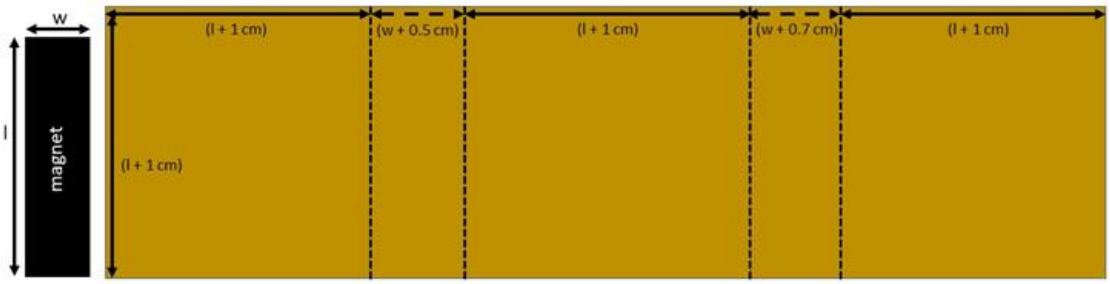


Figure 5. To make the frame create a net which is slightly larger than the magnet and wider, so that the magnet can spin inside it freely once it is constructed.

2. Next, push your shaft through the exact centre of the frame – you can draw a cross on one of the faces to find where this is.
3. Place magnets either side of the shaft inside the frame.
4. Start to wind the copper wire around the frame tightly (but not so tight that you squeeze the frame so the magnets can no longer rotate). You will need about 300 turns of wire, so if you have a partner then ask them to hold the wire as you turn the frame to make it easier. Try to have an even amount of turns either side of the shaft and avoid crossing the wires as much as possible.

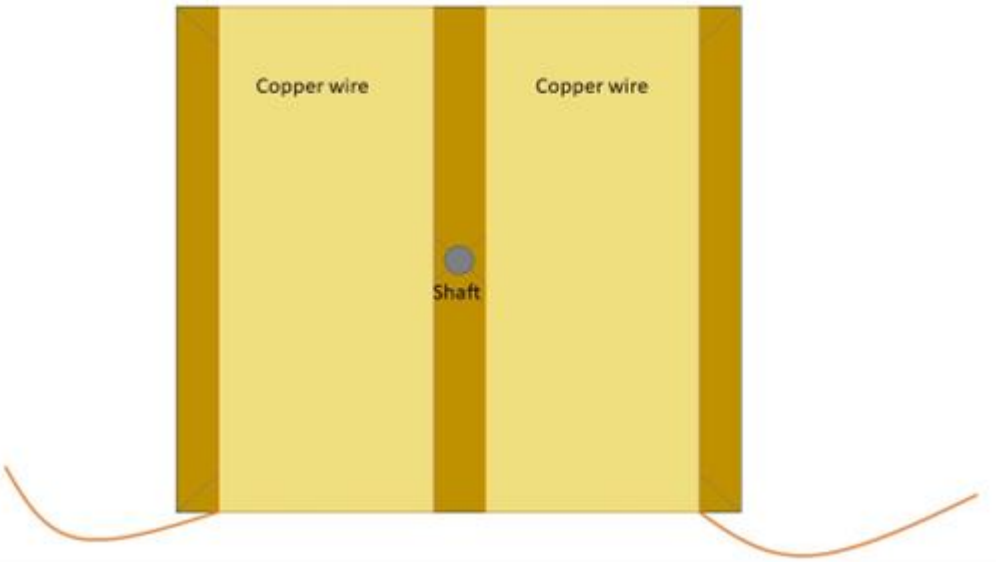


Figure 6. Neatly wind the copper wire around the frame, ensuring you leave a "tail" at each end to connect the ammeter to.

5. Use the sandpaper to rub off any enamel at the ends of the copper wire, and then connect the ends to the ammeter using the crocodile clips and connection leads.
6. Turn the shaft so that the magnets rotate. Try to keep a quick, regular speed and record the highest current induced in the results table. If you have a record player, you could put the shaft on top of the spindle in the middle and place the generator on top of a record, making sure the head shell and stylus are out of the way.
7. Repeat the investigation, increasing the number of magnets each trial, as indicated by the results table.

Results and Analysis

1. Complete the table below.

Number of magnets used	Maximum current induced (A)
2	
4	
6	

2. Plot a graph to show the relationship between the number of magnets (x-axis) and the maximum current (y-axis).

3. What is the relationship between the number of magnets used and the maximum current?

4. Hybrid cars are recommended for city driving, but less so for freeway travel. Explain why this is the case considering the purpose of regenerative braking and changes in velocity during city travel versus freeway travel.

5. Explain why brake pads on a hybrid car will last longer than brake pads on a regular car?

Suggested website: https://auto.howstuffworks.com/auto-parts/brakes/brake-types/regenerative-braking.html

Evaluation

1. How did your results compare to your hypothesis?

2. Were there any potential sources of error in your investigation?

3. How could you improve this investigation?

4. Outline any ideas you have to take this research further.

Extension

When do hybrid cars become value for money?

1. Complete the table below to compare the cost of two hybrid cars with comparably equipped non-hybrid cars from the same manufacturer.

Car make and model	Cost of hybrid model	Cost of equivalent non-hybrid model

2. Compare the specifications of the hybrid and equivalent non-hybrid model for each car.

Car make and model	Type	Cost of 1L of fuel (current prices)	Combined (average) fuel consumption (L/100 km)	Average fuel cost to travel 100 km
	Hybrid			
	Fuel			
	Hybrid			
	Fuel			

Suggested websites: https://rac.com.au/car-motoring/info/hybrid-cars-australia, https://www.fueleconomy.gov/

3. Calculate how many kilometres you would have to travel before the hybrid car started to save you money (how long until the additional cost of the hybrid version is covered by fuel savings). Hint: don't forget the calculated cost above is per 100 km.

4. What other factors may you want to research before deciding if a hybrid would work out to be more economical for you/your family?

Cars of the World

Objective

To discuss the pros and cons of different vehicle fuel types for cars and explain which one you would choose for yourself

a) Living where you currently live
b) If you lived in London (or another city of your choice, outside of Australia)

Background research

Complete the table to compare the different vehicle fuel types:

	Hybrid	Electric (EV)	Hydrogen	Biogas
Cost and availability of cars now in Australia Suggested websites: https://www.budgetdirect.com.au/car-insurance/guides/car-buying/how-much-does-it-cost-to-run-an-electric-car.html https://www.racv.com.au/royalauto/transport/cars/hydrogen-cars-explained.html#:~:text=How%20much%20do%20hydrogen%2Dpowered,%24118%2C000%20and%20A%24484%2C000%20respectively.				
Cost and availability of cars now in UK Suggested websites: https://www.autotrader.co.uk/?refresh=true				

The cost to use this fuel/style and availability now in Australia Suggested website: https://rac.com.au/travel-touring/maps-and-guides/ev-chargers				
The cost to use this fuel/style and availability now in the UK Suggested website: https://www.zap-map.com/live/ http://www.hydrogenbatteries.org/Where_Can_I_You_Buy_Filling_Up_With_Hydrogen_In_The_UK_Nearest_Service_Station.htm				
Efficiency of the fuel type				
Maximum range of the average vehicle using this fuel type				
Safety of the fuel type Suggested website: https://www.cnbc.com/2022/01/29/electric-vehicle-fires-are-rare-but-hard-to-fight-heres-why.html https://www.volvocars.com/uk/support/manuals/v90/2018w17/starting-and-driving/bi-fuel-information/vehicle-gas-bi-fuel				

Other information				

You may wish to present this as an essay, table, video, slideshow or through some other means, as directed by your teacher.