RSC INTEREST GROUP
APPLIED MATERIALS CHEMISTRY

The Power of Recycling

The story of a lithium-ion battery

STEM activities for 9-11 yr olds

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The Power of Recycling - The story of a lithium-ion battery

Introduction

This curriculum- linked, STEM-based resource for 9-11 year olds and their teachers, tells the story of lithium-ion car batteries and the recycling process. Through simple models and activities, the children are introduced to how these batteries work, what they contain and why they should be recycled.

The resource comprises practical activities including:

- using everyday materials to build a model of a battery
- a video featuring a young battery research scientist
- a challenge to separate a variety of everyday materials modelling real industrial processes
- an investigation
- a quiz and games

As the children complete the activities, they keep an ongoing record of what they have achieved in a ‘passport’. Once the passport is completed, they use their skills to build a model battery-powered vehicle.

Each lesson is supported by teacher notes and background information, resource list, pupils’ activity sheets, key STEM vocabulary and suggestions for additional or extension activities. There are PowerPoint presentations and animations to enrich the lessons. The activities are designed to be used individually or as part of an extended project and may be used by STEM ambassadors, science clubs or for home school projects.

How do lithium-ion batteries work?

Lithium-ion or li-ion batteries are a type of rechargeable battery; they consist of many individual units called cells. They are used in many portable devices and in electric vehicles. When in use or ‘discharging,’ lithium ions move through what is known as an electrolyte, from the negative electrode to the positive electrode and then back again when the battery is charging. As electric vehicles become more popular, more batteries will need to be manufactured to meet demand and the more used batteries there will be.

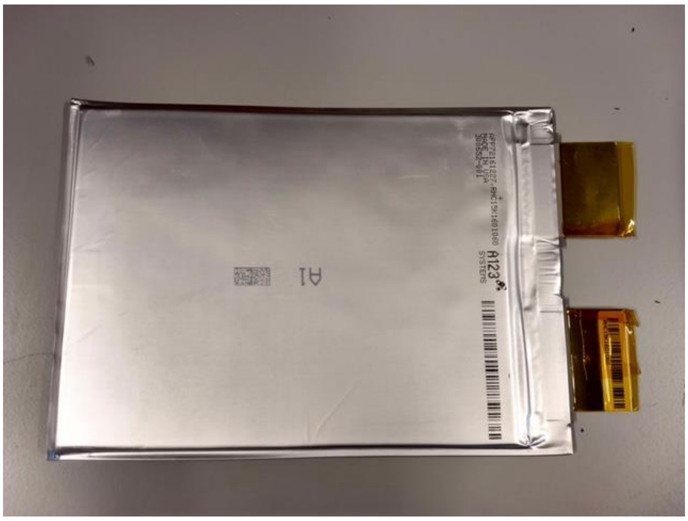
Lithium ion batteries comprise many different kinds of materials: a copper current collector, the negative electrode is lithium and graphite, the electrolyte is a lithium salt, the positive electrode usually contains metals such as nickel, manganese or cobalt and the negative current collector is aluminium. In order to be sustainable and prevent waste, it is vital that the valuable materials contained within these batteries be recovered and recycled. However, there are challenges to overcome in the recycling process.

What do lithium ion batteries look like?

There are three main types of lithium-ion batteries: cylindrical (like a Swiss roll), rectangular (known as prismatic) and pouch; each has its own characteristics according to its structure; there are advantages and disadvantages to each.

Image: Mariordo Mario Roberto Duran Ortiz, CC BY-SA 3.0 https://creativecommons.org/licenses/by-sa/3.0, via Wikimedia Commons

The opened lithium-ion battery of this electric vehicle shows many cases called modules. Each module contains lots of pouch cells.



A cell pouch. Image courtesy of Argonne Laboratories, USA.

The recycling process

At the end of their life, batteries may undergo melting or dissolving in acids, followed by recovery of some valuable materials such as metals, or they may undergo 'direct recycling' in which the anode or cathode are removed from the electrode to be reconditioned and reused in a new battery. The separation activities in this resource model the dismantling and mechanical separation and recovery of these materials.

Useful websites

General information about lithium-ion batteries

https://en.wikipedia.org/wiki/Lithium-ion_battery

A general introduction to the workings of different kinds of batteries:
https://www.explainthatstuff.com/batteries.html

How do lithium-ion batteries work?
https://www.explainthatstuff.com/how-lithium-ion-batteries-work.html

Teachers may like to watch this animation of a lithium-ion battery working
https://www.energy.gov/eere/articles/how-does-lithium-ion-battery-work

The STEM e-library has a host of resources for primary schools, all freely downloadable
https://www.stem.org.uk/resources/community/collection/12390/year-6-electricity

Access resources for primary schools on The Royal Society of Chemistry's education website:
https://edu.rsc.org/primary-science/find-resources

The Faraday Institute-Powering Britain's Battery Revolution
https://faraday.ac.uk/

01 - Inside an electric car

Context: For many years, vehicles such as cars, buses and vans have been powered by internal combustion engines. These use fossil fuels (diesel and petrol) and are responsible for a large amount of carbon dioxide emissions.

To tackle these emissions, and their contribution to climate change, vehicles are increasingly using electric motors and rechargeable batteries.

This activity helps children to understand the basic structure of an electric vehicle by constructing a layered labelled diagram.

An electric vehicle at an on-street charging point.

Resources
Cut-out diagrams (see children's worksheet)
Scissors
Glue

STEM/ vocabulary
Climate change
Fuels
Carbon dioxide
Recharge
Recycle
Electric motor
Battery pack
Cells

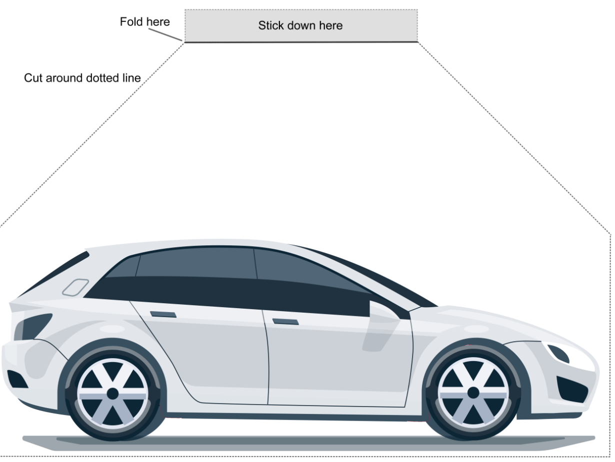
Lesson Starter:

Discuss the contribution made by vehicles to carbon dioxide emissions and climate change. *How can this be reduced?*

Talk about electric vehicles and how they use electricity stored in a rechargeable battery.

Main activity:

Children cut out and stick down the layered, labelled diagram to understand the basic lay-out of an electric vehicle.



Plenary:

Describe the various parts of the electric vehicle and the battery's role in storing electricity.

Ask the children what happens when the car gets so old that it no longer works very well. Move the discussion to the idea of recycling the valuable materials contained in the vehicle. *What materials could these be?*

Set the context for the separation activities by saying that the battery contains valuable materials and so should be recycled when the car is eventually scrapped at the end of its useful life.

Extension and further activities:

Prepare a presentation to explain how an electric car works.

Produce a piece of persuasive writing on the merits of using rechargeable battery cars.

Design an electric car of the future.

01 - Inside an electric car

Teacher Support Information

These notes are to support teachers in the delivery of the pupil activity 'Inside an electric car'.

Introduction/Background

There are broadly three types of cars:

- Internal combustion engine only (petrol or diesel).
  Drive is produced by the burning of fossil fuels and the emission of carbon dioxide as a waste gas.

- Internal combustion engine and electric motor hybrid vehicle.
  Drive is provided by both the internal combustion engine and an electric motor, powered by a rechargeable battery. When being driven, electrical energy is stored in the battery as the vehicle slows down. This 'regenerative energy' increases the vehicle's efficiency. Plug-in hybrids have the option of adding electric charge to their battery by connecting to a mains electricity charging point.

- Fully-electric vehicles.
  These only contain an electric motor, driven by a rechargeable battery. Energy can be stored during driving, as in a hybrid vehicle, but the main source of energy comes from recharging the battery from a mains electricity charging point.

Battery technology is constantly evolving but currently Lithium-ion batteries are the main type of rechargeable battery used in electric or hybrid vehicles.

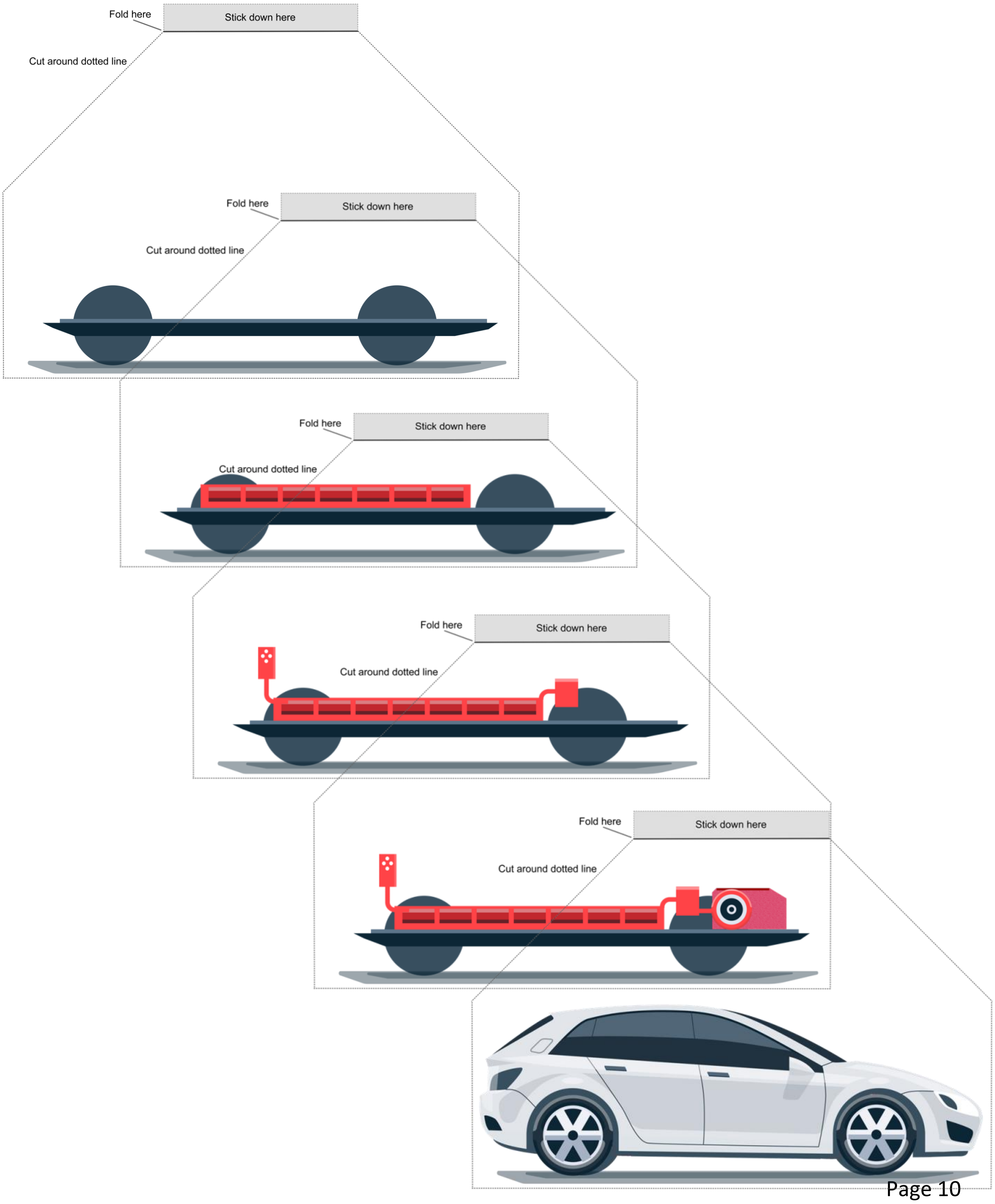
Electric vehicles are not necessarily 'zero carbon dioxide emissions'. Their real emissions depend how the electricity they use has been generated. In 2019, in the UK, oil, coal and gas accounted for 44.5% of generation; nuclear, wind, solar, hydro and other renewables accounted for 54.5%.

Activity

This activity looks at a fully-electric car. Children cut out and stick down a series of layered images (overleaf) to understand the main components that make up an electric vehicle. The components on each layer are labelled:

- Chassis - the base of the car onto which the suspension, wheels, rechargeable battery pack, interior and body shell are attached.

- Lithium-ion battery pack - contains many individual cells that can be charged and re-charged to provide the energy for the electric motor. Typically the battery would provide several hundred volts of electricity.
- Connector - to attach to the mains electricity for recharging.
- Regulator - controls the flow of electricity to the motor when driving the car or to the battery when being recharged using regenerative energy available as the car slows down.
- Electric motor - provides the forward and reverse drive for the wheels.



Advance preparation

- Copy a set of layer-diagrams for each pair or group.
- Provide scissors and glue.

Lesson starter

Discuss the emissions produced by vehicles with internal combustion engines. Ask if there are alternative fuels and guide the discussion to electric vehicles.

Main activity

Children cut out and paste the layers down in order (see children's worksheet below).

Plenary

Describe the various parts of the electric vehicle and the role of the battery in storing electricity.

This activity helps to set the context for the recycling and separation activities to come. Explain that the battery contains valuable materials and so should be recycled when the car is eventually scrapped at the end of its useful life.

Activity Sheets 1a-c Inside an electric car

Electric cars do not use petrol. They have an electric motor instead of an engine.

Use the cut-outs to see the main parts inside an electric car.

Cut on the dotted line on each picture. Keep them in order and stick each tab one on top of the other. Then open the layers to see inside the car.

Fold here

Stick down here

1 – Base layer

Cut around dotted line

The chassis holds the wheels and suspension. All the parts attach to the chassis.

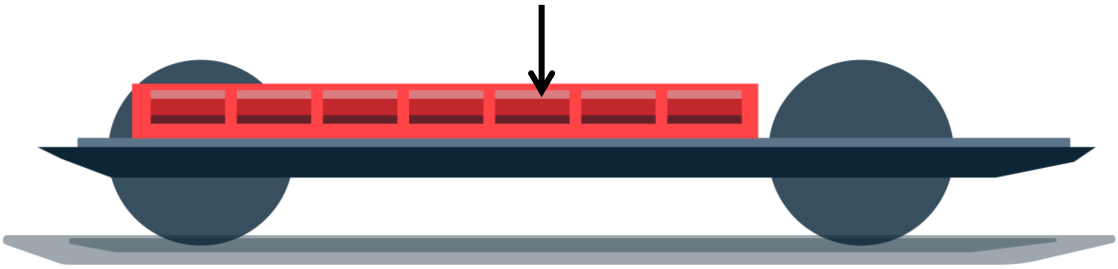
Fold here

Stick down here

2

Cut around dotted line

The lithium-ion battery pack holds the electricity to drive the car. Each battery pack contains many separate cells and can be recharged.



Fold here

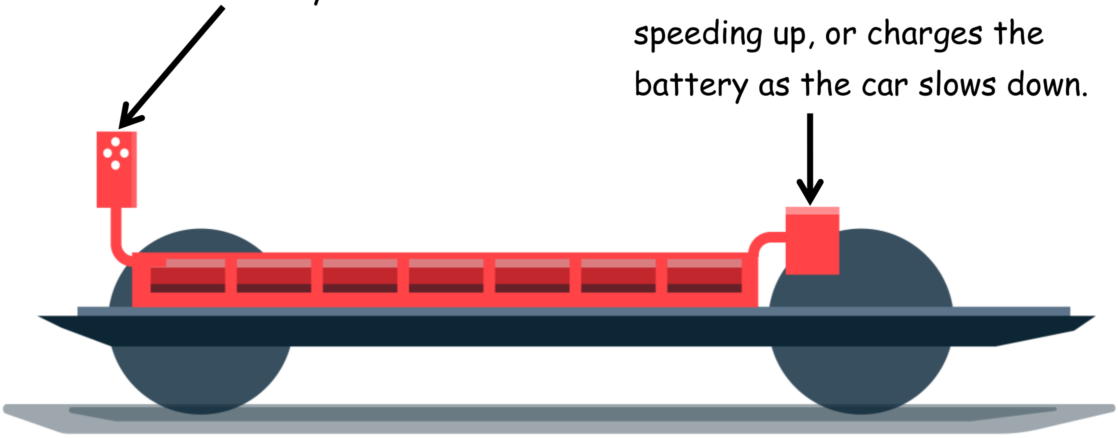
Stick down here

3

Cut around dotted line

A connector allows the battery to be plugged in and recharged from mains electricity.

The regulator sends electricity to the electric motor when the car is speeding up, or charges the battery as the car slows down.



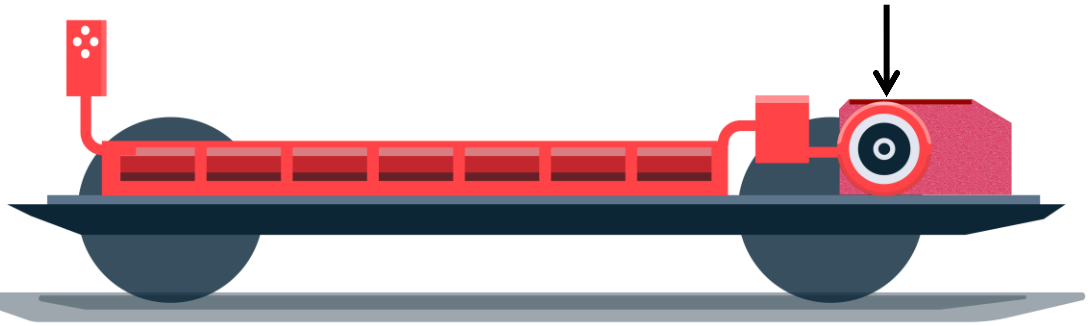
4

Fold here

Stick down here

Cut around dotted line

The electric motor connects to the wheels and drives the car.



5

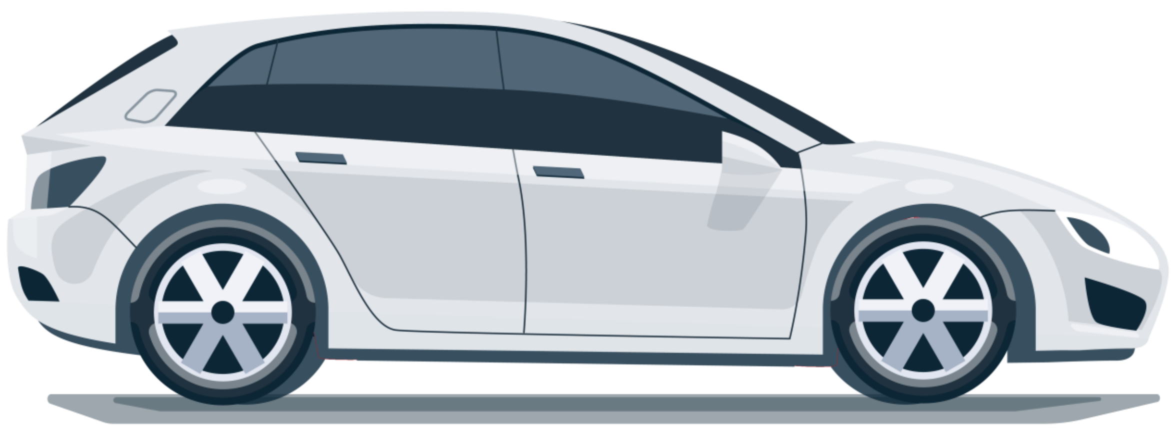
Fold here

Stick down here

Cut around dotted line

What is inside an electric car?

Lift the flaps to see.



02 - Model lithium-ion battery

Context: Rechargeable batteries are used in many devices, from mobile telephones and tablets to electric vehicles. These batteries are made up from individual cells which can take-in and store charge when they are connected to an external charger. When in use, they can release this electricity to drive components including computer processors, lights and the motors that drive electric vehicles.

In this activity, children see how a rechargeable cell works and model a lithium ion battery.

Resources

- Scissors
- Sticky tape
- Modelling dough or plasticine
- Black card and red card
- String
- Empty and clean crisp packets
- Children's activity sheet (attached)

Some batteries are thrown away when they have been fullyused. This is a waste of resources. Rechargeable batteries can be used over and over again.

Lesson Starter:

Use the PowerPoint presentation (notes in the presentation and teacher notes) to show the components in a lithium ion cell. Use the buttons on slide 5 onwards to show that electricity can be put into the cell using a charger. This electricity is stored and then used to light a bulb when connected in an electric circuit.

Main activity:

Children make a model of a lithium ion cell and then connect their cells together to make a battery. This models the structure of the battery in an electric car, where many cells are joined together to produce a very high voltage.

Each group places its cell inside an empty and clean inside-out crisp packet, to represent the electrically-insulated pouches that hold each cell. Groups then join their cells together using the connector wires (loosely tie strings). Joining the positive to negative terminals cause each cell voltage to be added together. The battery has the combined voltage of all cells.

Plenary:

Children consider the electrical devices they use and how many of them are powered by batteries. *Which devices use rechargeable batteries and which one use disposable ones?*

Discuss the advantages of using rechargeable batteries and recycling batteries at the end of their use.

STEM/ vocabulary
Cell
Battery
Electricity
Circuit

Extension or further activity

Children use the internet to find out about the different types and sizes of batteries used in a range of devices. For example:

- mobile phone
- hand-held torch
- wrist watch
- television remote control

Children can make a table showing the type of battery and the voltage it produces.

02 - Model lithium-ion battery

Background information

For many years, small devices such as torches, radios and TV remote controls, have used disposable batteries. These contain chemicals which can react to produce electricity. When they are depleted, they cannot be recharged and are thrown away. Useful materials can be recovered from these batteries and their recycling should be encouraged.

More recently, rechargeable batteries have been developed which are able to store and release electricity through a series of charge and discharge cycles. These batteries are made up from a number from cells that contain a lithium-ion matrix. It is this matrix that can effectively take in electricity and store it when the battery is connected to an external charger. The electricity is then released when the battery is connected to an electric circuit.

Such batteries can be used and re-used many times before they reach the end of their useful life. Furthermore, by separating their component parts, their useful materials can be recycled when the battery is no longer useful.

This activity has two parts:

- PowerPoint presentation which introduces batteries and shows how lithium-ion batteries can be used and then recharged.
- Children use empty clean crisp packets turned inside-out, card, string and plasticine or modelling dough to make a model lithium-ion battery.

Curriculum links and skills

- Cells, batteries and electric circuits
- Use tools and equipment to perform practical tasks (cutting, shaping)

Resources per group

Scissors

Sellotape

Plasticine or modelling dough

Red card (10cm x 2cm)

Black card (10cm x 2cm)

String

Small, clear, clean crisp packet (turned inside-out)

Advance preparation

Print out the accompanying children’s work sheet (see lesson notes).

Lesson starter

Use the PowerPoint presentation to introduce batteries and show how lithium-ion batteries can be used and then recharged.

These notes accompany the presentation and are also available in the *Notes* section of the presentation.

Slide 2

Batteries are used to power devices like mobile telephones, tablets and torches. Some very big batteries can even power vehicles.

There are, broadly-speaking, two types of batteries.

Some batteries cannot be recharged and can only be used until their charge runs out. These are disposable batteries (though they should still be recycled).

Other batteries can be discharged and recharged many times. One type of rechargeable battery is a lithium-metal oxide battery (also called a lithium-ion battery or Li-ion).

Discuss with children where they would use batteries and the advantages of having rechargeable batteries that can be used many times.

Slide 3

A cell is a single unit – a battery is a series of cells joined together.

This is a very simplified diagram. The Lithium-metal oxide matrix actually contains three separate layers: lithium metal oxide, plastic separator and lithium-carbon layer. Lithium ions are able to move between these layers and either take in electric charge (electrons) when being charged, or release electric charge (when being used).

An animation of this is shown on the following slides.

Slide 5 (and repeats)

During charging, the charger is connected to a source of electricity (typically the household mains supply). This provides the electrical energy to push charge into the lithium-metal oxide matrix, where it is stored.

Slide 6 (and repeats)

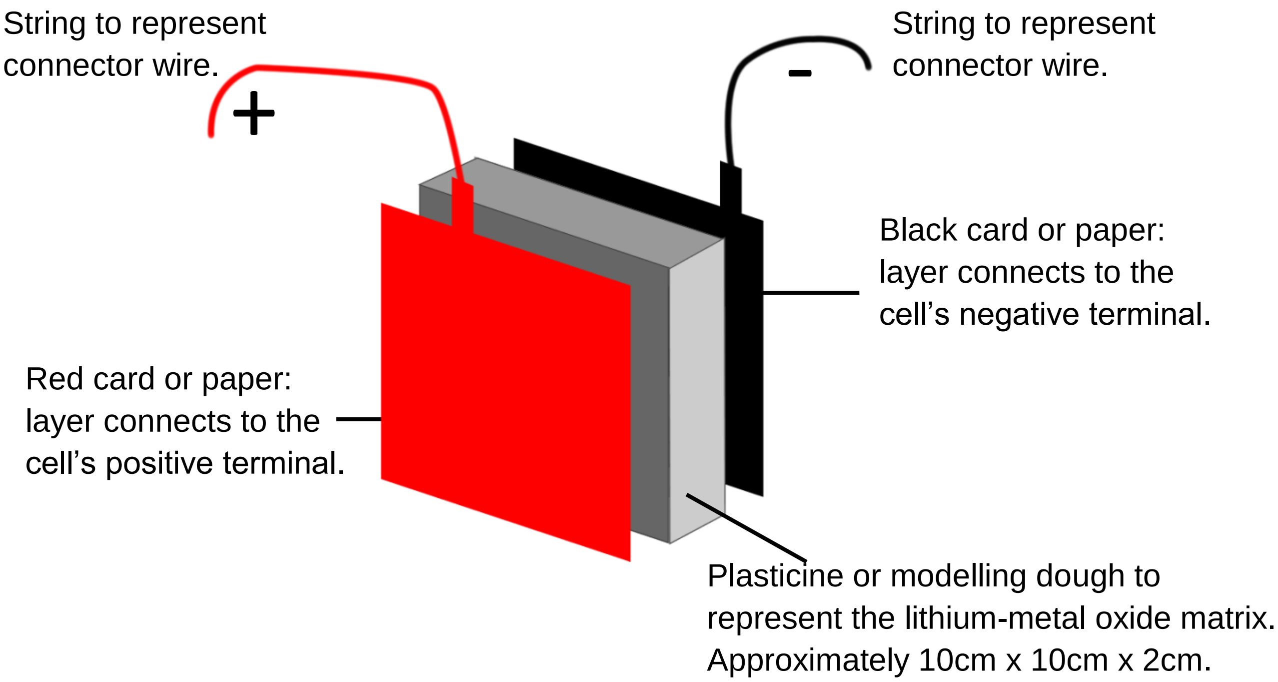
During discharge the electrical charge stored in the lithium-ion cell flows out and around the circuit. The energy in this electric charge is used to drive the components in the circuit, and gradually the cell discharges. It needs to have this energy replaced, and so it is once more connected to the charger.

Main activity

Model lithium-ion cell

We tend to refer to all batteries in the same way, but strictly speaking the single unit is a ‘cell’ and several cells joined together form a battery. A lithium-ion cell is typically 3.7 or 4.2 volts. A battery, with many cells, can have a much higher voltage.

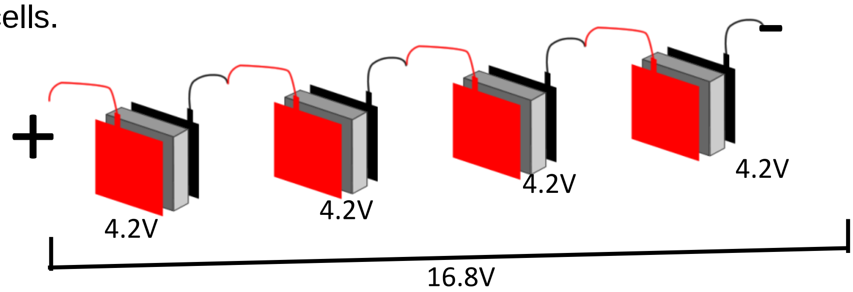
Children use the instructions on the activity sheet to make a cell and then groups join their cells to produce a battery.



From cells to a battery

Electric vehicles typically have batteries that produce several hundred volts. This is achieved by joining lots of cells together, positive to negative in series.

To model an electric car battery, each group places its cell inside an inside-out crisp packet, to represent the electrical insulation between cells. Groups then join their cells together using the connector wires (loosely tie strings). Joining the positive to negative terminals cause each cell voltage to be added together. The battery has the combined voltage of all cells.



Plenary

The children consider the electrical devices they use and how many of them are powered by batteries. *Which devices use rechargeable batteries and which one use disposable ones?*

Discuss the advantages of using rechargeable batteries and recycling batteries at the end of their use.

How can children reduce the number of disposable batteries that they use?

Extension or further activity

Have children use the internet to find out about the different types and sizes of batteries used in a range of devices. For example:

- mobile phone
- hand-held torch
- wrist watch
- television remote control

Children can make a table showing the type of battery and the voltage it produces.

Activity sheet 2 Make a model lithium-ion cell and battery

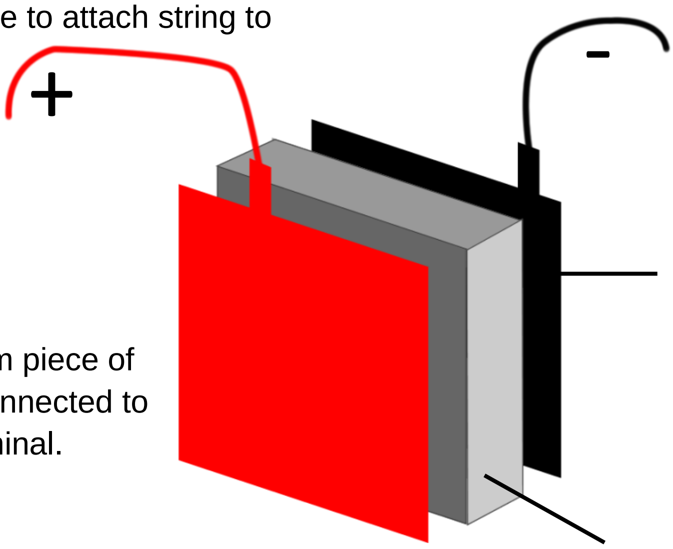
Use card, scissors, plasticine and sticky tape to make a model of a lithium-ion cell.

Positive connector wire

Use sticky tape to attach string to the red card.

Negative connector wire

Use sticky tape to attach string to the black card.



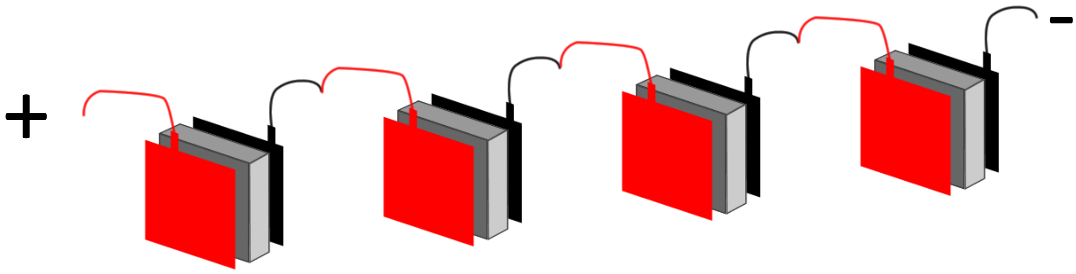
10cm x 10cm piece of black card. Connected to negative terminal.

10cm x 10cm piece of red card. Connected to positive terminal.

Lithium-ion matrix

10cm x 10cm x 2cm piece of plasticine.

You have made a single cell. Now put it into an inside-out crisp packet and join your cell with other groups' cells to make a battery.



03 - Lemon-powered battery

Context: Batteries contain a number of cells that can each generate an electrical voltage. In this activity children see that the reaction between the acids in the lemon juice, and two metals (copper and zinc) can produce electricity to light a light-emitting diode (LED).

This activity has often used small light bulbs in the circuit but these need more current to glow brightly and so using an LED can often give better results.

Resources per group

Three lemons
Connecting wires (with crocodile clips if available)
Copper coin
Zinc-galvanised nail
LED
PowerPoint presentation

Lemons, copper and zinc can be used to generate electricity to light an LED.

Lesson Starter:

Ask children if they think electricity can be generated from a lemon. If they say no, ask why not?

Revisit where we get electricity from (both mains electricity and also portable battery power). Explore the processes that produce electricity, such as burning fossil fuels and renewable sources such as wind turbines. See if children think we could generate electricity using lemons! Then show the presentation.

Use the slides to see if they can spot the pattern of voltage when lemon cells are joined to form a battery (voltage adds together when connected in series).

Use the final slides to show how children should make their circuits if each group is going to make one.

Main activity:

Children use the image on the slide to set up their lemon-powered circuit. Stress that they need to take appropriate care when pushing the zinc nails into the lemon.

Into each lemon, children push a copper coin and a zinc galvanised roofing nail. Make sure these do not touch inside the lemon and that enough protrudes above the skin to be able to connect wires to them. To make the battery, children connect the nail on the first lemon to the copper coin on the second lemon. Then connect from the nail on the second lemon to the copper coin on the third. This is most easily done using wires with crocodile clips attached.

Complete the circuit by connecting the LED using wires from the copper coin of the first lemon to the nail on the third.

An assembled circuit is shown in the teacher support notes.

Note: if the LED does not light, try reversing the connecting wires (the LED positive and negative need to be the correct way round) or add another lemon cell to the battery.

Plenary:

Discuss how children could investigate which parts of the lemon are responsible for producing the electricity. *Would it work if it was just the skin? How could this be checked?*

Have children draw a diagram, using the appropriate symbols, to show their circuit.

STEM/ vocabulary
Cell, battery, electricity, circuit, electric symbol

Extension and further activity

Children can investigate batteries and circuits made using different fruits, vegetables and metals.

For example, could a potato or a carrot produce a battery? Would using different metals or materials to replace the coin and nail have an effect?

03 - Lemon-powered battery

Teacher Support Information

This activity could be done as a demonstration, or groups of children can make their own lemon-powered battery.

Introduction / Background

Disposable batteries are able to produce electricity because of the chemical compounds they contain. This can also be shown using lemons, a copper coin and a zinc galvanised nail.

In this type of cell, there is a chemical reaction between the acid in the lemon, the zinc on the surface of the galvanised nail, and copper in the coin. This reaction generates an electric voltage and allows a current to flow when connected to make a circuit.

When connected in series, the voltage produced by each lemon cell is added together. The presentation shows the voltage measured by a digital volt meter. Use the presentation to see if children can see the pattern as cells are connected to make a battery.

Curriculum links and skills

- Cells, batteries, electric circuits and symbols.
- Identifying patterns and trends in data.

Resources per group

- Three lemons
- Three copper coins
- Three zinc-galvanised nails (roofing nails)
- Four short pieces of wire (with crocodile clips at each end if possible)
- One light emitting diode (LED)

Advance preparation

- Cut one small slit into each lemon skin to allow the copper coin to be easily pushed in.
- Perform a suitable risk assessment and ensure appropriate care is taken when handling the zinc nails.
- Load the accompanying PowerPoint presentation.

Lesson starter

Revisit where we get electricity from (both mains electricity and also portable battery power). Explore the processes that produce electricity, such as burning fossil fuels and renewable sources such as wind turbines. See if children think we could generate electricity using lemons! Then show the presentation.

Use the slides to see if they can spot the pattern of voltage when lemon cells are joined to form a battery (voltage adds together when connected in series).

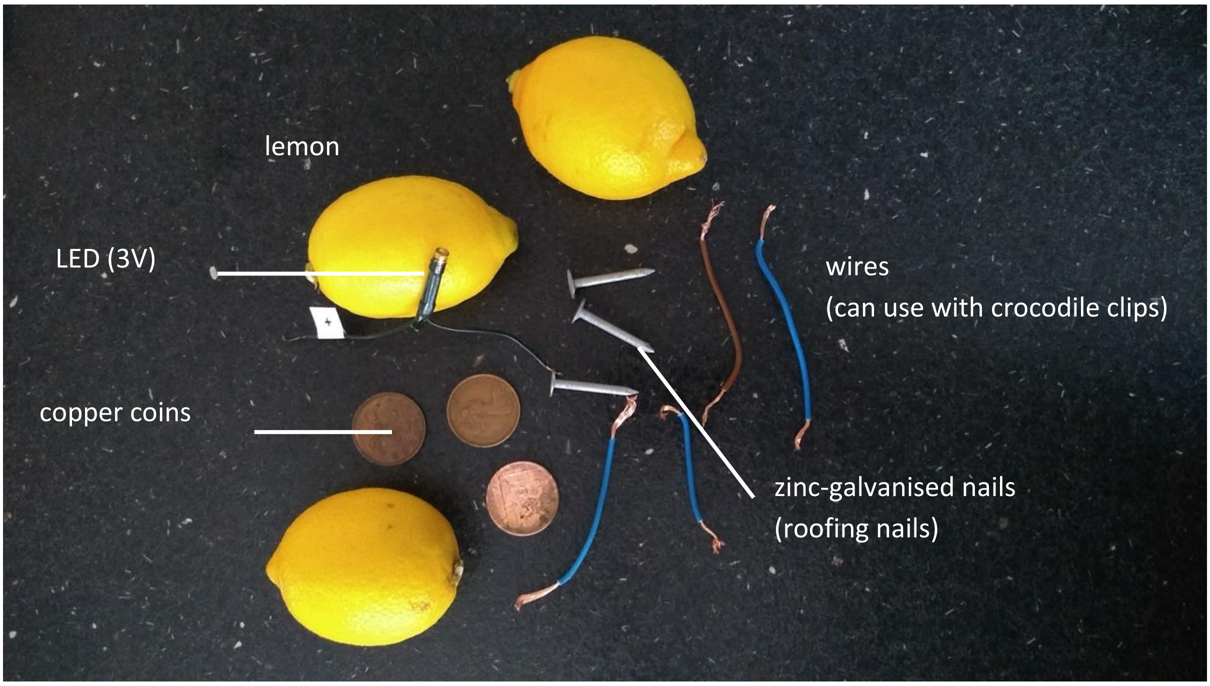
Use the presentation to pose the question, “Can electricity be generated from a lemon?” Go on to prove that it can.

The voltmeter shows that each lemon in this circuit produces 1.11volts (V). Use the slides to see if children can identify that as cells are connected in series, the voltage that they produce is added together.

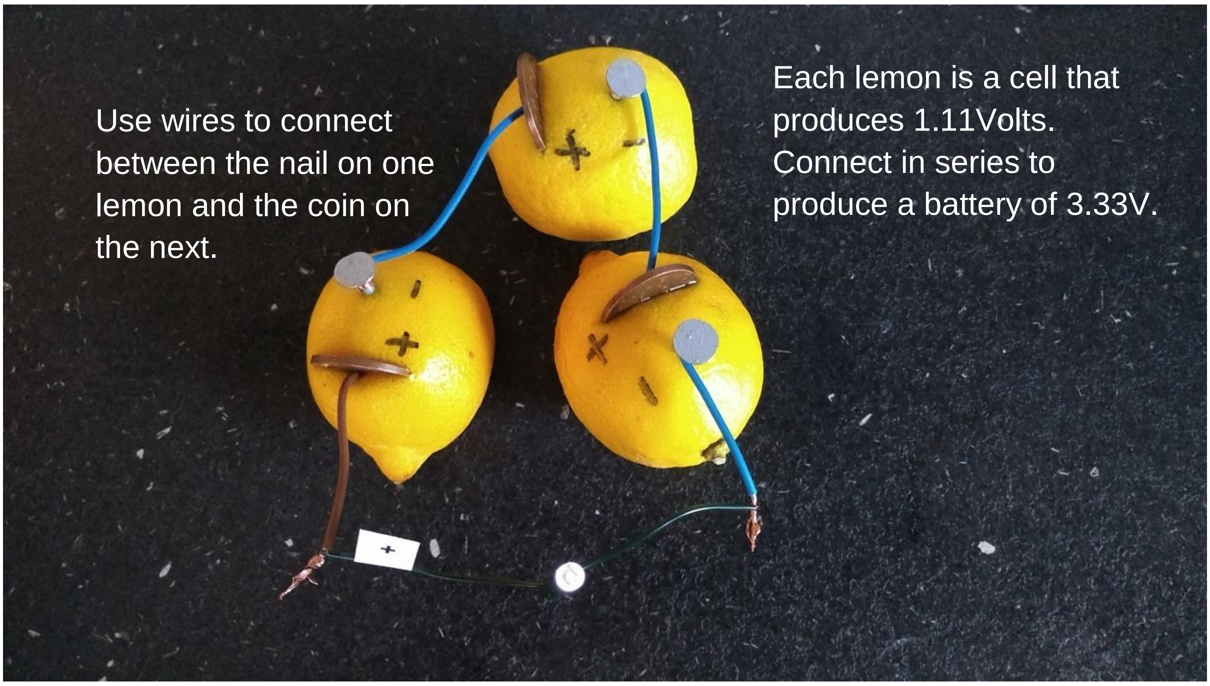
Leave the final photograph on display so that children can use it as a reference to make the circuit.

Main activity

Construct the circuit as shown in the photographs. Use an LED that will light with around 3volts and take care to connect the LED with the correct polarity. If it does not light, reverse the connections or add another lemon.



Cut a small slit into the skin of each lemon so that the coin can be inserted easily. Do not allow the coin and nail to touch inside the lemon.



Plenary

Have groups demonstrate their batteries and circuits in action. *Can they explain where the electricity is being generated?* Have children use circuit symbols to draw a diagram of the circuit they have produced.

You can challenge children to investigate which particular component of the lemon is the essential one. *Is it the skin or the juice?*

Extension and further activity

Children can investigate using different fruits, vegetables and metals or materials for their battery. *Would a potato be able to generate a voltage? How good is it compared with the lemon or other fruits? What is the outcome if different metals are used?*

04-Video with Dana Thompson

University of Leicester

In this short video, (recorded during the Covid 19 pandemic) Dana explains that when she was little, her dad was her role model and always encouraged her to try new things. She developed an interest in chemistry at high school and really enjoyed experiments and investigations. She decided to study Chemistry at Leicester University where she developed an interest in Clean Energy. Her work is fun and there is a variety of things to do, working with chemicals in the lab and with different machines. Her work is important in the fight against climate change. Petrol and diesel cars use valuable fossil fuels and so the key is to move to electric vehicles.

She explains that when electric car batteries reach the end of their life, we need to recover some of the valuable materials they contain, so that they may be used again. She tells the children that in the future, we need young people like them, with the right skills, to help us to solve problems such as how best to recycle old batteries and find ways of separating the useful materials obtained.

She sets the separation challenges for the children:

"It is very important that we scientists find ways of recovering valuable materials from electric car batteries. However, when we recycle the batteries, we can end up with lots of materials all mixed up together. We have to use different ways of separating the materials so we can use the useful ones again. Today, you are going to be scientists. Can you use your science skills to separate the different materials? Finally, can you use what you have discovered to solve a final separation challenge and find the best way to separate a mixture of materials?"

She invites the children to record their results, maybe in a table, by drawing or taking photos.

05-Separations

Context: Recycling lithium-ion batteries recovers valuable materials that can be used again, avoiding waste. Initially, the batteries must be safely dismantled and some materials need to be separated before recycling can begin. Finally, after shredding, some materials are separated by using flotation, magnetism for attracting metals, dissolving some and filtering others. In this activity, the children are introduced to the reasons for battery recycling before using their science skills in a circus of eight separations based on real industrial processes but using child-friendly materials.

Image: Lithium-ion battery Nissan Leaf: Wiki Creative Commons Attribution-Share Alike 4.0 International, Author Gereon Meyer

Resources

- Paper shredder for demonstration
- Power Point+ Video of scientist
- Set up a circus of 8 separation activities
- Activity sheet 5
- Disposable transparent cups
- Spoons
- Timers

Separations 1-8	Resources
Pepper from salt using static charge.	Salt, pepper **sealed in a plastic petri dish**, plastic ruler, wool cloth
Nuts and bolts Plastic from wire	Timer, nuts, bolts, wire
Plastics in water (Separation by density)	Pieces of polyethylene (PE) from milk bottles and PET plastic from ready meal trays
Plastics in water (density)	Pieces of **polystyrene** and PET or PVC, salt
Dancing raisins (Floating increasing bouyancy	Raisins, effervescent tablets
Magnetic	Aluminium small foil pieces (some flat, some rolled into balls) and ferrous metals, magnets
Dissolving, filtering and evaporating	Salt, aquarium grit, filter funnel, filter paper, dish
Sieving	Plastic pieces and small spheres aluminium foil, sieve

Lesson Starter: *Can the children think of gadgets they own that contain batteries? How long do they last? What happens when they no longer work?*
Explain that electric car batteries are very expensive and contain lots of useful materials that could be used again, avoiding waste. *How would you get these materials from the batteries?*
The accompanying Power Point slide 2 shows an image of a lithium-ion car battery. So that we can recycle the car battery, first it has to be removed from the car. All the fixings such as nuts and bolts must be undone and any wires removed and separated from their plastic insulation. *What happens next?* Explain that 'mechanical shredding' is the next stage of the process. Model this by feeding paper through a shredder, to represent the crushing, mixing and mashing of the remaining components of the battery producing a "soup" of ingredients.

Main activity

Watch the accompanying video of scientist Dana Thompson explaining that after the battery and its contents has been shredded, scientists need to find a way to separate all the different materials so they can be used again. She challenges the children to try to separate eight sets of materials, shown on slide 4 and Activity sheet 5. The safe materials they are using represent valuable, useful and sometimes hazardous battery materials. The groups try the eight separations. Encourage the children to make careful observations and keep a record in the form of drawings, photos, video or text, of what they discover. Further details and how the separation methods link to the actual recycling process are in the Teacher support notes.

Plenary

Discuss the different separations. *Can the children describe and explain what they discovered in each activity?* End the session by following the stages of the recycling of a lithium ion car battery in the diagram on slide 5 of the matching Power Point. *Can they match any of their separations with the recycling process?* (Refer to the table in the Teacher support notes)

Extension and further activities:

Challenge the children to separate further mixtures of two or three materials.

Investigate whether replacing water with other liquids such as salt water or cooking oil affects the floating or sinking of different plastics.

Can other materials that sink in water, be made to float adding effervescent tablets?

Use dictionaries to check the meaning of key vocabulary used in the activities.

Lithium-ion battery recycling process

Dismantle safely the electrical conductors and cells.

Break apart different components.

Separate by using **mechanical** methods, chemicals or heat.

Mechanical sorting uses magnets, shaking, filtering gravity or flotation.

Separation produces plastics, casings, metal foils from electrical conductors plus active materials.

Metals can be extracted by heating or dissolving and concentrating.

Useful materials recycled.

STEM/ vocabulary

Separate, charge, static electricity, float, sink, density, flotation, effervesce, gas, magnetic, iron, ferrous, dissolve, solution, filter, evaporate, sieve

06 - Separations Challenge

Context:

There are several processes employed when recycling lithium ion batteries and many challenges, such as separating the various plastics from metals. In this activity, the children are set a new challenge: to plan how to separate a mixture of several materials before trying out their ideas. They choose how to record their results before producing a report of their investigation.

Resources per group

Activity sheet 6
Disposable transparent cups
Bag of mixed materials (See teacher notes)
Spoons
Piece of netting/sieve
Filter funnel
Filter paper
Magnet
Salt

Advance preparation

Upload PowerPoint+video
Prepare the bags of materials

Lesson Starter:
Start the session by reminding the children of the last activity. *Why do we need to recycle batteries? Can they recall the separations? Can they name two materials that floated?* Show the two materials, (pieces of plastic and balls of aluminium foil) and ask *'How did we separate these materials from one another? What equipment could we use?'* After discussion and feedback, ask for volunteers to demonstrate one or two ideas. Play again the final section of the video in which the scientist explains that recycling produces a mixture of many materials that must be separated. Today, they will take on a challenge to use their science skills to plan the best way to separate not just two, but several different materials, using a variety of methods.

Main activity

Distribute the bags of materials representing all the bits of the battery mixed together in a big ‘soup’. Slide 6 on the PowerPoint lists the materials to separate. Groups first discuss their ideas and suggest the stages of separation. They read the statements provided on Activity sheet 6 and sort them into a sequence.
The groups decide which equipment they will need and then follow their planned sequence of separations.

After removing the floating materials they separate them using a method and resources of their choice, including sieving, shaking or rolling the materials. Finally they set up a small sample of the salt solution and leave it in a shallow dish to evaporate. They record their results in drawings, writing, photos or a combination of methods.

Plenary The groups give feedback, describing how they separated the materials. They show the recovered materials and the ‘cleaned soup’. *Did their sequence work? Would they change the sequence of their separations and if so, how and why?* Show the sequence on slide 7 in the Power Point and remind the children of the links to the actual recycling process. *What advice would they give to the scientists to help them in their recycling work?*

Extension and further activities:
Can the children design a new separation challenge?
Design a set of separation challenge sequence cards with drawings or diagrams replacing text.
Identify everyday plastics using the recycling codes.

Put all the materials into a transparent cup. Add water until the cup is about ¾ full.

→ Remove the metals with the magnet.

→ Use a spoon to remove the materials that float on the water.

→ Add a spoonful of salt to the water and stir until it dissolves. Repeat until pieces of plastic begin to float.

→ When pieces of plastic float after adding salt, scoop them out with a spoon.

→ After removing all the floating materials, you could use a sieve to separate them.

→ Filter to separate the grit from the salty water.

→ Place a spoonful of the salty water on a dish. When the water has evaporated, look for salt crystals.

Image: Recycled material for battery production. Wikimedia Creative Commons attribution: share alike

05 - Separations and 06 - Separation Challenge Teacher Support Information

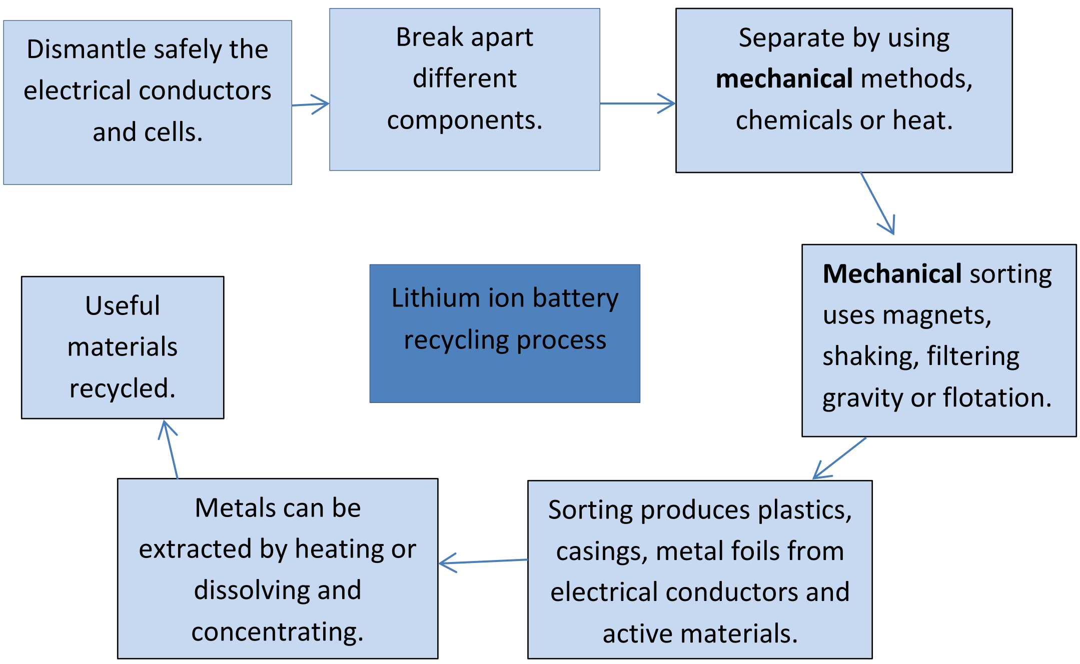
These notes are to support teachers in the delivery of the pupil activities 'Separations' and 'Separation Challenge'. They provide background information, tips for advance preparation, how the activities link with the recycling process and suggestions for extension and further activities.

Background

At the end of their life, batteries may undergo:

1. High temperature melting or
2. Dissolving in acids, followed by recovery of some valuable materials such as metals or
3. They may undergo 'direct recycling' involving reconditioning of the anode and cathode for reuse. Direct recycling recovers most materials, avoiding waste.

Lithium ion batteries comprise many different kinds of materials. Initially, the batteries must first be safely dismantled and some materials need to be separated before recycling can begin. There are several processes employed and many difficulties, such as dealing with the different glues used to bond the cells together or separating the various plastics from the metals. Finally, after shredding, some materials are separated by using flotation, magnetism for attracting metals, then dissolving some and filtering others.



The activities in this section mimic the mechanical methods used in this process and allow children to apply a range of separation techniques.

Activity 05: Separations

Context: In the Separations activity, the children learn that lithium ion batteries are made from a wide variety of materials, some valuable and why these batteries should be recycled. They use their scientific skills to separate a selection of child-friendly materials, each separation representing a method used in the industrial recycling process.

The table below outlines the separations and their link with industrial processes.

Separation activity	Link with industrial process
1. Separation of pepper from salt using static charge.	Represents the method of removing dust from materials recovered from the batteries.
2. Undoing nuts and bolts. Observe the single strand plastic coated copper wire.	This is the first phase of the process. The batteries have their wires and fixings physically separated from their battery casings before the crushing of remaining parts begins.
3. Observe what happens when two kinds of plastics of different density are submerged in water.	Plastics of different densities may be separated in liquids. Some float because they are less dense than the surrounding liquid; others, being denser sink.
4. Raisins in water.	Over 90% of anode material from li ion batteries can be recovered using the froth flotation technique. Air is bubbled through the liquid containing the anode material; the anode material then floats and is scooped from the surface.
5. Magnetism.	Magnetism is used to remove ferrous metals in the mechanical processing of batteries.
6. Separating a mix of insoluble grit and dissolved salt in water by filtering and evaporation.	The recycling process after crushing and dissolving can produce a black liquid soup of materials containing carbon (graphite) represented here by grit. Filtering will remove the carbon as it is not soluble. The liquid remaining may contain valuable salts which can later be recovered.
7. Separating (by adding salt) pieces of **polystyrene** and **PVC (or PET)** plastics that both sink in water.	Different plastics in the recycling process may be separated by density. Some (for example polystyrene in this activity), may sink in water but become buoyant if salt is dissolved in the water, increasing its density.
8. Children try to find a way to separate pieces of plastic and small balls of aluminium foil, by sieving or shaking.	After shredding and grinding of battery components, the finer materials are sieved to separate fine powders from coarser shredded particles. Coarser particles are separated by gravity to remove lighter debris from heavier metallic particles.

The separation activities

*Health and Safety. *Teachers should risk assess each of the activities before the lesson. Ensure that the salt and pepper are sealed in a plastic petri dish or similar, to avoid pepper being inhaled or causing irritation to eyes. Care should be taken when handling wires or plastic pieces in case of sharp edges.*

1. Salt and pepper
Mixture of table salt and fine ground pepper
Plastic petri dish
Plastic ruler/piece of PCVU pipe
Wool cloth

The separation of salt and pepper involves using ‘charge’ or static electricity. Substances can gain or lose electrons to become negatively or positively charged. Rubbing the plastic ruler (or try a piece of PVCU pipe) with a wool cloth causes electrons to move from the wool to the ruler. The negatively charged ruler if held close to, but not touching the salt and pepper, will attract positively charged particles. Pepper being lighter than the salt will jump towards the ruler.

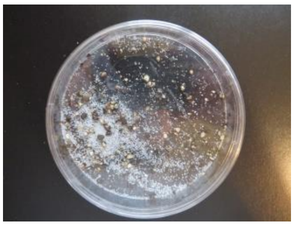


Image shows salt and ground pepper sealed inside a plastic petri dish.

2. Wires, nuts and bolts
Single strand copper wire, plastic coated
Nuts and bolts
Timer
Wire strippers (for teacher demo).

The children can time how quickly they can separate the nuts from the bolts. They can handle the single core wires and suggest how the plastic coating could be removed. Demonstrate the use of wire strippers to remove the plastic coating.

3. Plastics in water
Few pieces each of polypropylene and PET or PVC plastic
Cup
Spoon

The separation of plastics involves plastics of different densities; one less dense than water will float, whilst the second, more dense than water, will sink. Some such as polyethylene PE (plastic milk bottles) or polypropylene PP (food packaging or cups) float; others eg PET (pop bottles) or PVC (blister packs) will always sink as they are denser than water.

Plastics carry identification codes stamped inside a triangle for recycling purposes. Check the chart below when sourcing plastic for the activities and test them prior to the investigations.
Choose one plastic that will float and one that will sink. Ensure that the children push the pieces below the surface of the water before releasing them, to avoid surface tension affecting the results.

Plastics recycling identification codes

Name of plastic	Code number	Float/sink
Polyethylene terephthalate or PET	1	Sinks
High density polyethylene or HDPE	2	Floats
Polyvinylchloride or PVC	3	Sinks
Low density Polyethylene or Polythene or LDPE	4	Floats
Polypropylene or PP	5	Floats
Polystyrene or PS (usually transparent. Some PS is white)	6	Sinks in water but floats in salty water

4. Raisins in water
Raisins
Cup
Effervescent tablets
Transparent cup

The children place a few raisins into a cup of water, add small pieces of effervescent tablets and make careful observations in this ‘dancing raisins’ activity. The rough surface of the raisins attracts bubbles of carbon dioxide released by the effervescent tablets; their overall density is reduced, increasing their buoyancy. When the raisins have collected sufficient bubbles they will float; when bubbles burst at the water surface, the raisins lose buoyancy and sink.

5. Magnetism
Aluminium foil cut into small pieces x3
Aluminium foil rolled into small spheres x 3
Ferrous metals x3 eg nut, bolt, screws, paper clip
Magnet

Aluminium is a non-magnetic metal. If flat pieces of aluminium foil are submerged in water they will sink. If rolled into spheres, they will float, as they contain air and are less dense than water. Place a few flat pieces of foil and iron-containing metals such as nuts, bolts screws or paper clips in the water. Hold the magnet against the outside surface of the cup. The ferrous metals will be attracted to the magnet.

6. Dissolving and filtering

Grit eg aquarium grit x ½ cup
Table salt x ½ cup
Teaspoon
Filter funnel
Filter paper
Cup x 2

This is an opportunity to talk about dissolving. Mix grit such as aquarium grit with table salt. Children add a couple of teaspoons of the mix to water and stir until the salt dissolves. Filtering the mixture will remove insoluble solids such as grit, but soluble or dissolved solids in solution will pass through the filter paper. Investigate recovering the salt by leaving shallow dishes of salt solution and waiting for the water from the solution to evaporate. The more concentrated the salt solution, the more salt crystals will be produced.

7. Plastics in water

Polystyrene plastic pieces x 3
PVC or PET plastic pieces x 3
Salt x ½ cup
Spoon
Cup

Remind the children to push the plastic pieces below the surface of the water, to ensure that surface tension does not affect the investigation. Choose two different plastics that will sink in water; one **must** be **polystyrene**. Polystyrene (**not** the white foam version called ‘expanded polystyrene’, found in insulated hot drinks cups or food containers) is an interesting example of a plastic whose density is slightly greater than that of water. It will sink in water but will float if the density of the water is increased by adding salt. Add salt a teaspoon at a time, stirring until dissolved. Repeat if necessary but stop when the polystyrene begins to rise. Ensure the plastics are tested prior to the activity.

8. Sieving
Pieces of plastic
Aluminium foil spheres
Sieve/piece of net
Lid or tray
Piece of card

Have available a suitable sieve or small piece of netting for the children to use to separate the plastic pieces from the aluminium balls. The holes in the net or sieve must be large enough to allow **either** the foil spheres or plastic pieces to fall through. Placing the two materials on a tray and tilting one end so that the balls roll away from the plastic, or gently shaking from left to right the materials on the tray are other possible methods. Try the methods in advance! The children could make their own sieve from card.

Advance preparation

- If possible, have a paper shredder and wire strippers available for the demonstrations.
- Provide copies of Activity sheet 5.
- Load the accompanying Power point and video.
- Set up the circus of eight separation activities described above. Resources could be rotated around the groups to reduce the materials required. Prepare additional resources to replenish as required.

Curriculum links and skills

- Making observations, problem solving and working scientifically.
- Using   knowledge of solids, liquids and gases to decide how mixtures might be separated, including filtering, sieving and evaporating.
- Properties of materials: Compare and group together everyday materials on the basis of their properties, including their response to magnets.
- Know that some materials will dissolve in liquid to form a solution, and describe how to recover a substance from a solution.

Lesson starter

Can the children think of gadgets they own that contain batteries? How long do they last? What happens when they no longer work?
Explain that electric car batteries are very expensive and contain lots of useful materials that could be used again, avoiding waste*. How would you get these materials from the batteries?*

The accompanying Power point shows an image of a lithium ion battery from an electric car. So that we can recycle the battery, first it has to be removed from the car. All the fixings such as nuts and bolts must be undone and any wires removed and separated from their plastic insulation. *What happens next?* Explain that ‘mechanical shredding’ is the next stage of the process. Model this by feeding paper through a shredder, to represent the crushing, mixing and mashing of the remaining components of the battery producing a “soup” of ingredients.

Main activity

Watch the video of scientist Dana Thompson explaining that after the lithium-ion car battery and its contents has been shredded, scientists need to find a way to separate all the different materials so they can be used again. She challenges the children to try to separate the eight sets of materials using similar methods to those used in the recycling industry. The safe materials they are using represent valuable, useful and sometimes hazardous battery materials. Introduce each of the separations shown on the children’s Activity sheet 5 and explain what the children need to do. The children work through the eight separation activities. Replace materials as required. Fresh water will be required for each group completing activities four, six and seven. Encourage the children to make careful observations and keep a record of what they discover in the form of drawings, photos, video or text.

Plenary

Discuss the different separations. *Can the children describe and explain what they discovered in each activity?* End the session by following the stages of the recycling of a lithium-ion car battery in the diagram on the matching Power Point. *Can they match any of their separations with the recycling process?* (The links between the activities and the actual recycling process may be found in the table earlier in the Teacher support notes).

Extension and further activities:

- Challenge the children to separate further mixtures of two or three materials.
- Investigate whether replacing water with other liquids such as salt water or cooking oil affects the floating or sinking of different plastics.
- Can other materials that sink in water, be made to float adding effervescent tablets?
- Use dictionaries to check the meaning of key vocabulary used in the activities.

Activity 06: Separation Challenge

In the activity ‘Separation Challenge’, the children plan the stages of separation and recovery of a mixture of several materials, before trying out their ideas.

Resources per group
Activity sheet 6
Magnet
Salt ½ cup
Spoon
Transparent cup x 2
Sieve x 1
Filter funnel x1
Filter paper x 1
Shallow dish or lid

Bag containing:
Ferrous materials eg paper clips, screws, nuts, bolts x 4
Pieces of polypropylene or polyethylene plastics x 3
Pieces of **polystyrene** x3
Spheres of aluminium foil x 3
Grit x 3 teaspoons

Advance preparation

- Prepare bags of materials for each group.
- Print copies of pupil Activity sheet 6.
- Load the accompanying video.
- Test the buoyancy of the sample plastic pieces and ensure that they are correctly identified. The polypropylene or polyethylene should float. The polystyrene should sink in water but float when salt is added to the water.

Lesson starter

Start the session by reminding the children of the last activity. *Why do we need to recycle batteries? Can they recall the separation methods? Can they name two materials that floated?* Show two materials (pieces of plastic and balls of aluminium foil) and ask *‘How would we separate these materials from one another? What equipment could we use?’* After discussion and feedback, ask for volunteers to demonstrate one or two ideas. Play the final section of the video in which the battery scientist explains that recycling produces a mixture of many materials that must be separated. Today, they will take on a challenge to use their science skills to plan the best way to separate not just two, but several different materials, using a variety of methods.

Main activity

Show the mixture of materials representing all the bits of the battery mixed together in a big 'soup'. Groups first discuss their ideas and suggest the stages of separation. They read the statements provided on Activity sheet 6 and sort them into a sequence. Next provide each group with a bag of materials and have available all the required resources for the groups to select.
The groups follow their planned sequence of separations. After removing the floating materials (pieces of PE or PP plastic and the balls of aluminium foil), they must find a way to separate them. Possible methods might include those tried in the previous lesson: placing them on a lid or tray gently raising one end so that the foil balls roll away; they might use a piece of netting or perhaps make a sieve from cardboard with holes large enough for one of the materials to pass through. Finally they set up a small sample of the salt solution and leave it, to allow the water to evaporate before looking for salt crystals. They choose an appropriate way to record and report their results.

Plenary

The groups give feedback, describing the methods and the sequence they used to separate the materials. They show the recovered materials and the 'cleaned' soup. *Did their sequence work? Would they change the sequence of separations used and if so, how and why? What advice would they give to the scientists to help them in their challenge?* Show the sequence on slide 7 of the Power point and remind the children of the links to the actual recycling process.

Put all the materials into a transparent cup. Add water until the cup is about ¾ full.

→ Remove the metals with the magnet.

→ Use a spoon to remove the materials that float on the water.

→ Add a spoonful of salt to the water and stir until it dissolves. Repeat until pieces of plastic begin to float.

→ When pieces of plastic float after adding salt, scoop them out with a spoon.

→ After removing all the floating materials, you could use a sieve to separate them.

→ Filter to separate the grit from the salty water.

→ Place a spoonful of the salty water on a dish. When the water has evaporated, look for salt crystals.

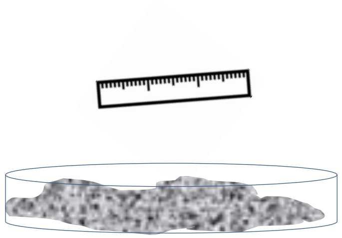
Extension and further activities:

- Can the children design a new separation challenge?
- Design a set of separation challenge sequence cards with drawings or diagrams replacing text.
- Identify everyday plastics using the recycling codes.

Activity sheet 05 Separations cards

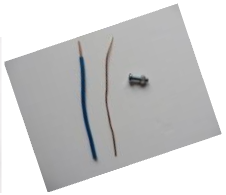
1.Salt and pepper

Rub a plastic ruler with a dry wool cloth.
Hold the ruler over the mixture.
What do you notice?



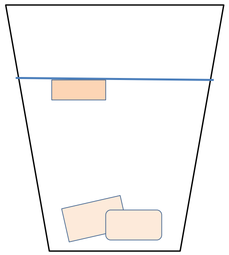
2.Wires, nuts and bolts

How quickly can you separate the nuts and bolts?
How might you separate the plastic from the wires?



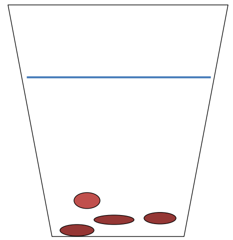
3.Plastics in water

Push all the plastic pieces under the water. What happens? Why?



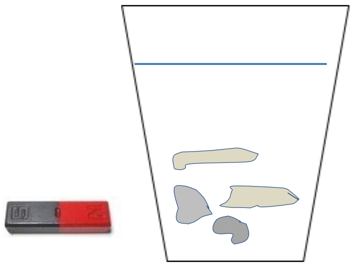
4.Raisins in water

Add the fizzy tablet to water. Look carefully. Can you explain why some raisins come to the surface?



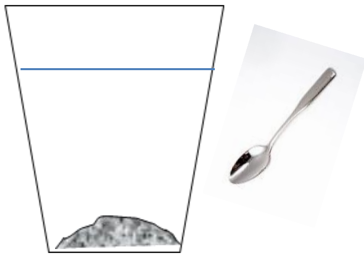
5.Magnetism

Use the magnet to separate the metals. What did you discover?



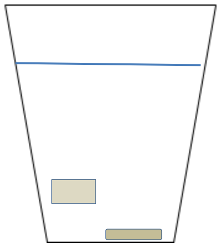
6.Dissolving

Add 3 teaspoons of a salt and grit mixture to water. Stir until the salt dissolves. Filter. How will you recover the salt?



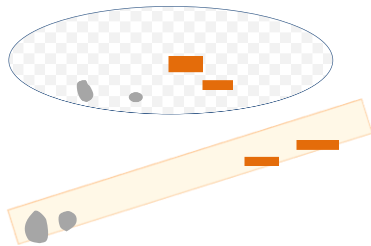
7.Plastics in water

Push the two types of plastic under the water. What happened? Now add a teaspoon of salt. Stir. Repeat until you notice a piece beginning to float. Can you think why?



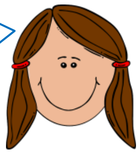
8.Sieving

Use the sieve to separate the two different solids. Can you think of another way?

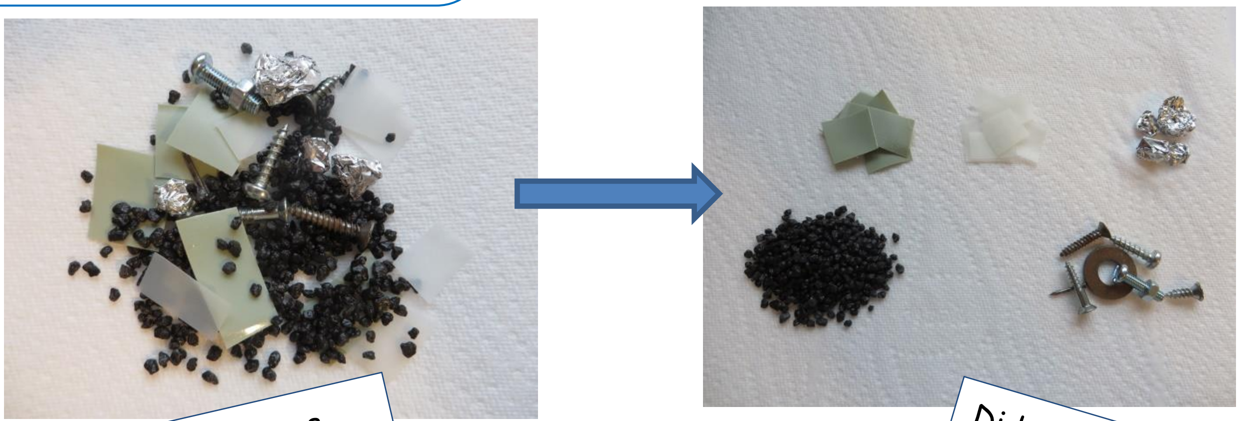


Activity sheet 06 Separation challenge

Different materials from an electric car battery have been mixed together. Can you help the scientists to find the best way to separate them?



What methods should they use? Put the ideas into the right order. Then have a go!



Did you know that some plastics sink in water but float in salty water?

Did you know that some metals are magnetic but some are not?

Remove the metals with the magnet.	Filter to separate the grit from the salty water.
Add a spoonful of salt to the water and stir until it dissolves. Repeat until pieces of plastic begin to float.	Put all the materials into a transparent cup. Add water until the cup is about $\frac{3}{4}$ full.
Use a spoon to remove the materials that float on the water.	After removing all floating materials, you could use a sieve to separate them.
Place a spoonful of the salty water on a dish. When the water has evaporated, look for salt crystals.	When pieces of plastic float after adding salt, scoop them out with a spoon.

07 - A Sticky Problem

Context: In this guided investigation, the children learn that electric car batteries contain lots of individual units known as 'cells'. Using strong glues, each cell is sealed inside a packet called a pouch, shiny inside-a bit like a crisp packet! These seals have to be broken in order to recover the valuable materials inside but strong glues can make this difficult. The children are challenged by battery scientists to use their science skills to investigate the effectiveness of several glues. Using child friendly glues and crisp packets to represent cell pouches, they consider which glue might be best at sealing the cells and pouches but also allow them to be separated for recycling.

Image: Lithium-ion cell pouch. Courtesy of Argonne Laboratories USA

Resources

- Activity sheets 7a, 7b
- PowerPoint
- Crisp packets, clean and dry x 8
- PVA glue
- Glue stick
- Glue spatula
- Teaspoon
- Disposable cups x 3
- Parcel tape
- Scissors
- Marbles (of same size)
- Box

Glue	Number of marbles in packet supported by glue bond			Average
Glue stick	16	16	16	16
PVA	23	21	22	22
1 spoon PVA and 1 spoon water	18	18	18	18
2 spoons PVA and 1 spoon water	20	21	21	21

Table shows sample results

Lesson Starter: Show the accompanying Power Point. Slide 2 has an image of an electric car battery and Slide 3 shows the battery with its cover removed. Explain that an electric car battery is made from lots of individual units we call 'cells' and each cell is sealed inside a pouch. Slide 4 shows a pouch containing an individual cell. Explain that to recover valuable materials such as those shown on Slide 5, electric car batteries at the end of their life need to be dismantled before recycling can begin. However, lots of different glues are used in different batteries and some are so strong that it can be difficult, sometimes impossible, to pull the cells and pouches apart. Read the email from the battery scientist on Activity sheet 7a and on slide 6 of the Power Point, which explains that scientists are trying to find a glue that will allow them to be pulled apart more easily for recycling but will be strong enough to stick the cells and pouches together.

Main activity Show the children the crisp packet and point out its shiny inner coating and its similarity to the cell pouches used in electric car batteries. Today, the crisp packets will be taking the place of cell pouches from a battery! They are going to test four glues to see how effective they are but instead of gluing real cell pouches, they will be using crisp packets!

The children suggest glues they might use. They consider how they will measure the effectiveness of the glue samples and discuss and share their ideas. Explain that **one way** of testing the strength is to measure how much weight the glue seal can support. Demonstrate by first firmly attaching a crisp packet to the edge of a table with a strip of parcel tape across its top; glue and firmly press the second packet to the first. Add a label to show which glue was used. Now, place the marbles very gently one by one into the outer bag. Stop when the glue seal breaks and the outer bag drops away from the first. Place a box underneath to catch the bag and marbles when they fall. *Ask "How can we make this a fair test?"* Suggestions might include: using the same amount of glue, marbles of same size, spreading the glue evenly, spreading on only one surface and placing the marbles in gently each time. The groups test all four glues and record the weight each type of glue supported before the bond was broken. They may use their own ideas for recording, including tables, drawings, photos or text. A recording table is provided on Activity sheet 7b if preferred. They discuss which glue would allow cells to be separated for recycling but strong enough to seal them together for battery use. They decide which glue they would recommend and why.

Plenary: The groups share their results. *Did they have any problems? How did they try to make sure they carried out a fair test? Which glue supported most weight? Did all groups agree? Which glue was the weakest? Which one would allow the cell pouches to be separated most easily for recycling? Would they recommend this glue? Why? Why not? Would they improve their investigation and in what way?*

Crisp packets or 'cell pouches' attached to table edge.

Extension and further activities:
Test other glues or concentrations of PVA.
Investigate different methods of testing the strength of the glues suggested by the children.
Plot a graph of time versus number of marbles supported by the glue bond, for each type of glue.
Design a poster to explain their investigation.

STEM/ vocabulary
Cell, battery, glue, seal, adhesive, bond, separate, recover, recycle, data

07 - A Sticky Problem Teacher Support notes

Background information

As electric cars become more popular, the number of lithium-ion batteries requiring recycling has begun to rise. Recycled materials could be used to make new batteries thus reducing waste and the impact on the environment. However, lithium-ion batteries are complex and not designed to be disassembled. They consist of large numbers of cells bonded together. Strong adhesives are used and these bonds must be broken before the recycling process can begin. Scientists are searching for solutions to tackle such challenges.

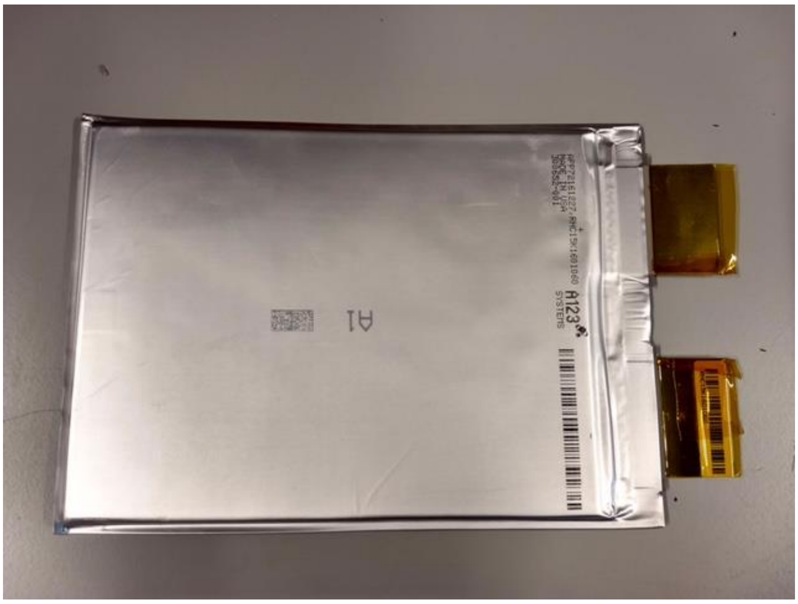


Image 1 shows a lithium-ion cell pouch.

Image 2 shows a pouch cell and materials recovered during the recycling process. Courtesy of Argonne Laboratories.

In this guided investigation, the children learn that electric car batteries contain lots of individual units known as 'cells'. Using strong glues, each cell is sealed inside a packet called a pouch, shiny inside-a bit like a crisp packet! These seals have to be broken in order to recover the valuable materials inside but strong glues can make this difficult.
The children are challenged by battery scientists to use their science skills to investigate the effectiveness of several glues. Using child friendly glues and crisp packets to represent cell pouches, they consider which glue might be best at sealing the cells and pouches but also allow them to be separated for recycling. They report their results and recommendations.

Curriculum links and skills

- Work scientifically, making observations, conducting fair tests and using their data to draw conclusions.
- Give reasons, based on evidence from comparative and fair tests, for the particular uses of everyday materials.
- Writing for a purpose, producing a report of their results

Resources per group

Activity sheets 7a, 7b
Crisp packets, clean and dry x 8
PVA glue
Glue stick
Glue spatula
Teaspoon
Disposable cups x 3
Parcel tape
Scissors
Marbles of similar size
Box

Advance preparation
Print Activity sheets 7a, 7b.
Load the Power Point 'A Sticky Problem'.
Collect crisp packets in advance. Invert the bags and wash, rinse and dry to ensure they are free from grease.

Lesson Starter

Show the accompanying Power Point. Slide 2 has an image of an electric car battery and Slide 3 shows the battery with its cover removed. Explain that an electric car battery is made from lots of individual units we call 'cells' and each cell is sealed inside a pouch. Slide 4 shows a pouch containing an individual cell. Explain that to recover valuable materials such as those shown on Slide 5, electric car batteries at the end of their life need to be dismantled before recycling can begin. However, lots of different glues are used in different batteries and some are so strong that it can be difficult, sometimes impossible, to pull the cells and pouches apart. Read the email from the battery scientist on Activity sheet 7a and on slide 6 of the Power Point, which explains that scientists are trying to find a glue that will be strong enough to stick the cells and pouches but also allow them to be pulled apart for recycling.

Main Activity

Show the children the crisp packet and point out its shiny inner coating and its similarity to the cell pouches used in electric car batteries. Today, the crisp packets will be taking the place of cell pouches from a battery! They are going to test four glues to see how effective they are but instead of gluing real cell pouches, they will be sticking crisp packets together.

Can they suggest any types of glue that they could test in their investigation? Ideas may include PVA and glue sticks. Diluting the PVA increases the range of the investigation. The groups could try the following initially:

1. Glue stick
2. PVA
3. 1 teaspoon of PVA mixed with 1 teaspoon of water
4. 2 teaspoons of PVA and 1 teaspoon of water.

They must measure how strong the glues are. *How might we do this? How could we measure glue strength?* The children discuss and share their ideas. Explain that **one way** of testing the strength is to measure how much weight the glue seal can support. Demonstrate by first firmly attaching a crisp packet to the edge of a table with a strip of parcel tape across its top, so that the packet hangs from the edge. Next, spread glue over the entire surface of a second crisp packet and firmly press the second packet onto the first. Flip the packets back onto the table top and apply gentle pressure across the surface of the bags to ensure a secure bond. Add a label to show which glue was used. Now, place the marbles very gently one by one into the outer bag. Stop when the glue seal breaks and the outer bag drops away from the first. Place a box underneath to catch the bag and marbles when they fall.

Ask *“How can we make this a fair test?”* Suggestions might include: using the same amount of glue, spreading the glue evenly, spreading on only one surface each time and placing the marbles in gently each time.


Image 1

Image 2

Image 1: Two crisp packets glued together, attached to and hanging from, the edge of a table.

Image 2: The second, outer crisp packet is glued onto the first but left open at top. Marbles may be gently placed into this outer packet.

The groups test all four glues and record the number of marbles each type of glue supported before the bond was broken. They may use their own ideas for recording, including tables, drawings, photos or text. A recording table is provided on Activity sheet 7b if preferred. They discuss which glue would allow cells to be separated for recycling but would be strong enough to seal them together for battery use. They decide which glue they would recommend.

The table below shows sample results for four glues. Each glue was tested three times and the average number of marbles supported was calculated.

Glue	Number of marbles supported in crisp packet before glue bond gave way			Average
Glue stick	16	16	16	16
PVA	23	21	22	22
1spoon of PVA 1 spoon of water	18	18	18	18
2 spoons PVA 1 spoon of water	20	21	21	21

Plenary

The groups share their results. *Did they have any problems? How did they try to make sure they carried out a fair test? Which glue supported most weight? Did all groups agree? Which glue was the weakest? Which one would allow the cell pouches to be separated most easily for recycling? Would they recommend this glue? Why? Why not? Would they improve their investigation and if so, in what way?*

Extension and further activities

Test other glues or concentrations of PVA.
Investigate different methods of testing the strength of the glues suggested by the children, for example:

- Attach a bulldog clip to the bottom of the outer crisp packet and hook a plastic cup to it. Add weights to the cup.
- Use a Newton meter to measure the force required to pull one bag away from the other

Collect data in a different way, such as the time taken for the glue seal to hold e.g. five, ten, fifteen marbles before it gives way.
Plot a graph of time versus number of marbles supported by the glue bond, for each type of glue.
Design a poster to explain their investigation.

Activity sheet 07a A Sticky Problem

From: Professor Andy Abbott@leicester

To: Pupil scientists

Subject: Glue testing

Dear Pupil Scientists

So that the materials from electric car batteries can be recovered, the cells inside need to be separated. Each cell is glued into a case called a pouch; you can see one in the photo I have sent you. Usually the glues used to stick them together are very strong and separating the cells is difficult. However, the glue needs to be strong enough to hold the cell pouches together when the battery is being used.

We are trying to find a new type of glue that will make separating the cells easier for recycling. Today we would like you to use your science skills to test the effectiveness of four different types of glue.

Scientists often test their ideas by setting up investigations using everyday materials. Instead of real cells from a battery, you could use crisp packets, as the cell pouches in the batteries are made from a similar material!

You will have to make sure the crisp packets are clean and not greasy. You will also need to think of a way of measuring how strong each type of glue is.

As good scientists, you know that it is important to keep a record of your investigation results.

We look forward to hearing all about your investigations and finding out which glue you recommend.

Good luck!

Andy Abbott
Professor of Chemistry
University of Leicester

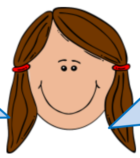
Activity sheet 07b   A Sticky Problem

To recycle electric car batteries, the cells inside have to be separated. If the glue used to join them is too strong, the cells cannot be pulled apart. Can you test glues to find one that is just right?

Use sticky tape to stick a crisp packet to the edge of a table. Glue another crisp packet to it. Gently place marbles one by one into the second packet until the glue seal gives way. Record the number of marbles held. Repeat 3 times.

Type of glue	Number of marbles the crisp packet holds before the glue seal 'unsticks'.			Average
Glue stick				
PVA				
1 spoon of PVA+ 1 spoon of water				
2 spoons of PVA + 1 spoon of water				

Did you know?
Electric car batteries contain lots of individual 'cells'. Each cell is inside a packet called a pouch, shiny inside-a bit like a crisp packet!



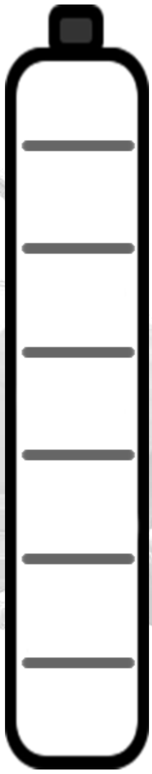
How will you make sure your test is fair?
Are your results reliable?
Can you think of any other sticky materials to try?

Which glue allows the packets to separate most easily? Would it be strong enough? Tell the battery scientists what you have found out and which glue you recommend.

08 Lithium-ion battery passport

Name

Model electric car.
Battery snakes and ladders.
Separation challenge.
Why we need to recycle lithium-ion batteries video.
Lemon-powered battery
Lithium-ion battery
Inside an electric car



Complete the challenges.

Colour in the charge bars to get a full battery.

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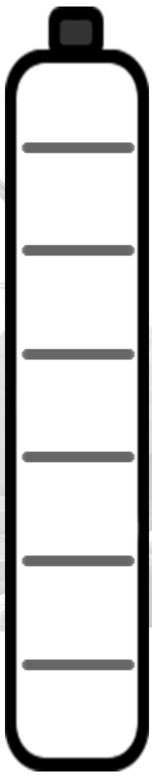

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09 - Lithium-ion Snakes and Ladders

In this game children play snakes and ladders and test their understanding of lithium-ion batteries and how they are recycled.

The attached sheet has the board that the children use. Print it off either as an A4 or A3 sheet. Also use counters and a dice to allow children to play the game.

As part of the game, a player can land on Question squares (shown with a Q). A set of question cards is provided. Another member of the group takes a card and asks the question. If the player answers correctly, they can take the bonus, avoid the snake drop or climb the ladder. If they get it wrong then they stay where they are.

The correct answer is given and the card goes to the bottom of the pile. It does not matter if questions come around for a second time.

Question cards

Cut out so that each group has a full set of cards.

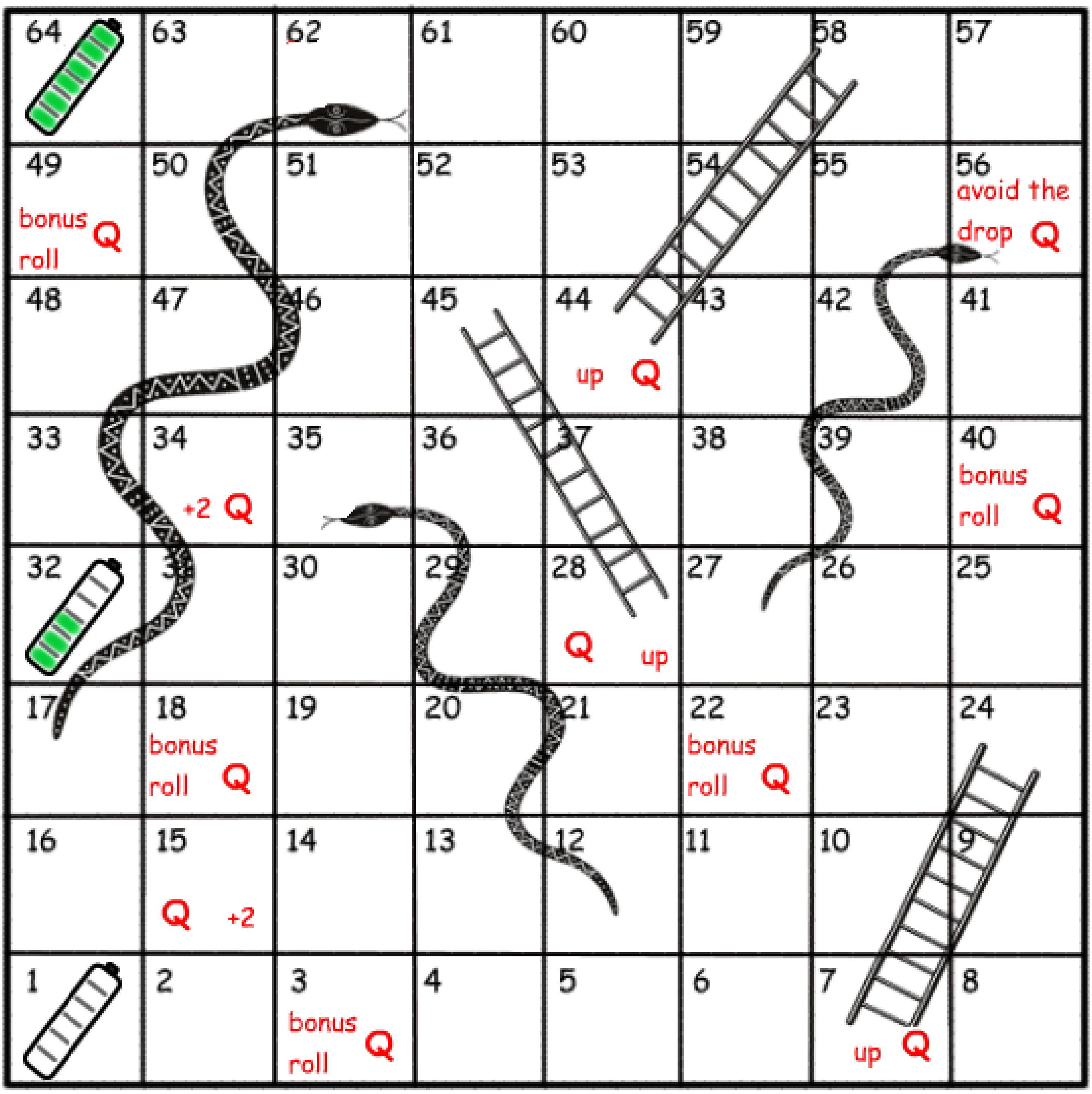
What material is used to make rechargeable batteries? A. Wood B. Lithium ✓ C. Sodium D. Paper	What type of battery can you re-use many times? A. Disposable battery. B. Static battery. C. Rechargeable battery. ✓
What does the battery do in an electric car? A. Stores electricity to drive the electric motor. ✓ B. Keeps the seats warm. C. Helps to stop the car. D. Starts the petrol engine.	In an electric car, how is the battery charged? A. By plugging it into the mains. B. When the car slows down. C. Both of these ways. ✓
Which one of these is part of a lithium-ion cell? A. Cathode ✓ B. Positive matrix C. Series layer D. Filament	Which one of these is part of a lithium-ion cell? A. Gathering foil B. Positron C. Lithium-metal oxide matrix ✓ D. Distributor cap

Which one of these is part of a lithium-ion cell? A. Diode B. Capacitor C. Odometer D. Anode ✓	Is this statement true or false? “A battery contains a number of individual cells connected together.” A. True ✓ B. False
If a lithium-ion cell produces 3 volts, how many volts will two cells connected in series produce? A. 1.5 volts B. 4.5 volts C. 6 volts ✓	What happens when a lithium-ion battery is being charged? A. Electricity flows into the battery. ✓ B. Electricity flows out of the battery. C. Electricity stays in the circuit. D. Electricity leaves the circuit.
What happens when a lithium-ion battery is being used to power a circuit? A. Electricity flows into the battery. B. The circuit gets colder. C. The battery gets heavier. D. Electricity flows out and around the circuit. ✓	In an electric car, what does the regulator do? A. Controls the electricity going to the electric motor and the battery. ✓ B. Regulates how fast the car goes. C. Controls the car’s temperature.
What symbol is used to identify the positive terminal on a battery? A. Minus sign (-) B. Circle C. Plus sign (+) ✓ D. Triangle	How does an electric car battery produce a very high voltage? A. It has one very big cell. B. It can be charged from the mains. C. It contains many cells connected together. ✓
What symbol is used to identify the negative terminal on a battery? A. Minus sign (-) ✓ B. Circle C. Plus sign (+) D. Triangle	Which of these devices contain lithium-ion batteries? A. Mobile phone B. Tablet computer C. Electric car D. All of them ✓

Recycling a battery can produce which of these materials? A. Metals B. Plastics C. Salts D. All of these ✓	How would you separate metals containing iron from a mixture during battery recycling? A. Filter B. Attract with a magnet ✓ C. Use a sieve D. Dissolve in water
Which method is the best way to recover salt from salty water? A. Filter the salty water B. Use a magnet C. Evaporate the water ✓ D. Shake the salty water through a sieve	When recycling a car battery, which of these would happen first? A. Crush the battery B. Sieve the mixture C. Unscrew the bolts on the battery case ✓ D. Dissolve the battery

Recharge Your Battery
Snakes and Ladders

Fully-charged

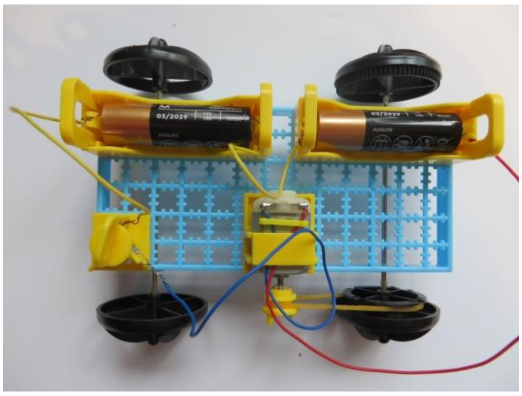


Empty battery

If you land on a question square (one with a Q) you will be asked a question. If you answer correctly, you can take the prize described in the square you are on. If you are wrong, you can't take that prize and you may go down a snake or get stuck at the bottom of a ladder.

10 - Build a battery-powered car

This activity involves using a simple kit to arrange several components on a base board and complete a circuit to build a battery-powered car. The accompanying PowerPoint has images and step-by-step instructions for children to follow to construct their vehicles.



The kit used in this example, “Evolution Energy Experiment Car” by Artec, is one sourced from TTS educational suppliers. Its components may be arranged in a variety of ways, providing an opportunity to see how batteries can be used to power a motor and also to construct a series or parallel circuit containing a bulb. In addition, the children can investigate the use of either a pulley wheel with a rubber band or a gear wheel to produce motion. Teachers may prefer to use alternative kits or components. Point out that in this activity, cylindrical, disposable batteries are being used, rather than lithium-ion batteries.

*Health and safety

Care should be taken when using batteries in practical activities. Rechargeable batteries, including lithium ion batteries, should not be used as they may become very hot in a short circuit. The children should be taught how to safely connect components to avoid a short circuit.

Resources

Class sets of battery-powered vehicle construction components may also be sourced from YPO educational suppliers: www.ypo.co.uk

TTS educational: www.tts-group.co.uk

Activity Sheet 10 Build a battery-powered car

Example shown features “Evolution Energy Experiment Car” by Artec, supplied by TTS

Connecting plug from wire B.

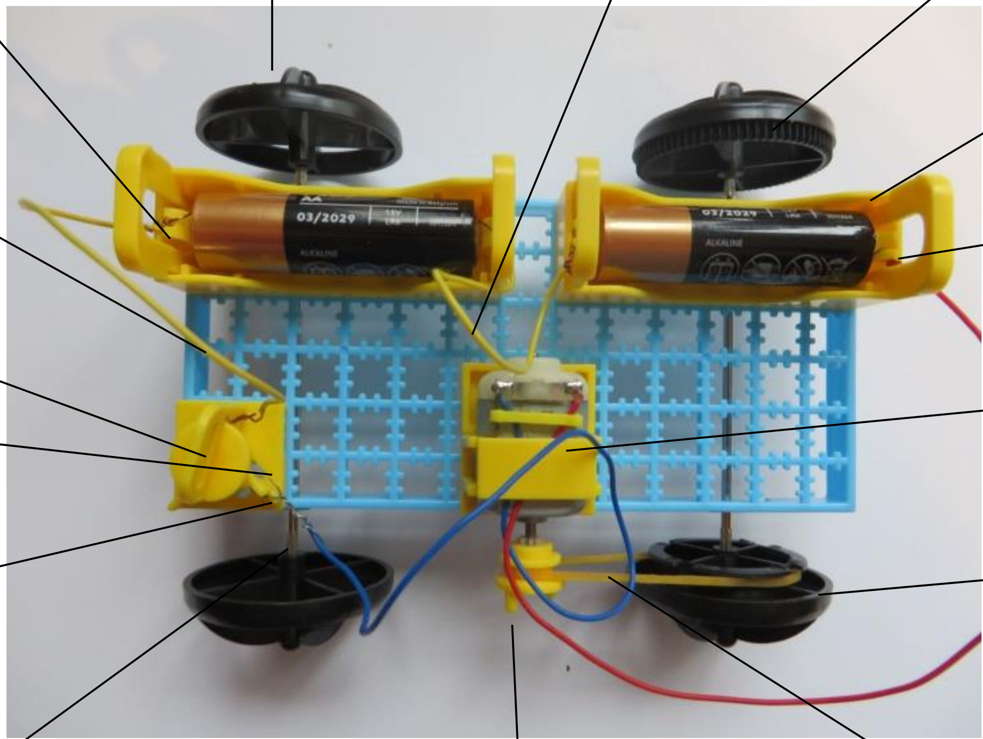
Wheels pushed onto the end of the axle.

Wire A to a connecting two battery holders.

Gear wheel

Battery holder

Wire B connected to the upper switch.



Upper switch pushed into the lower switch

The connecting plug from the red motor wire.

The lower switch attached to the body.

The motor, mount plus motor holder attached to the body.

Blue motor wire connected to the lower switch.

The pulley wheel attached to the axle.

The rubber band around the pulley wheel and the pulley.

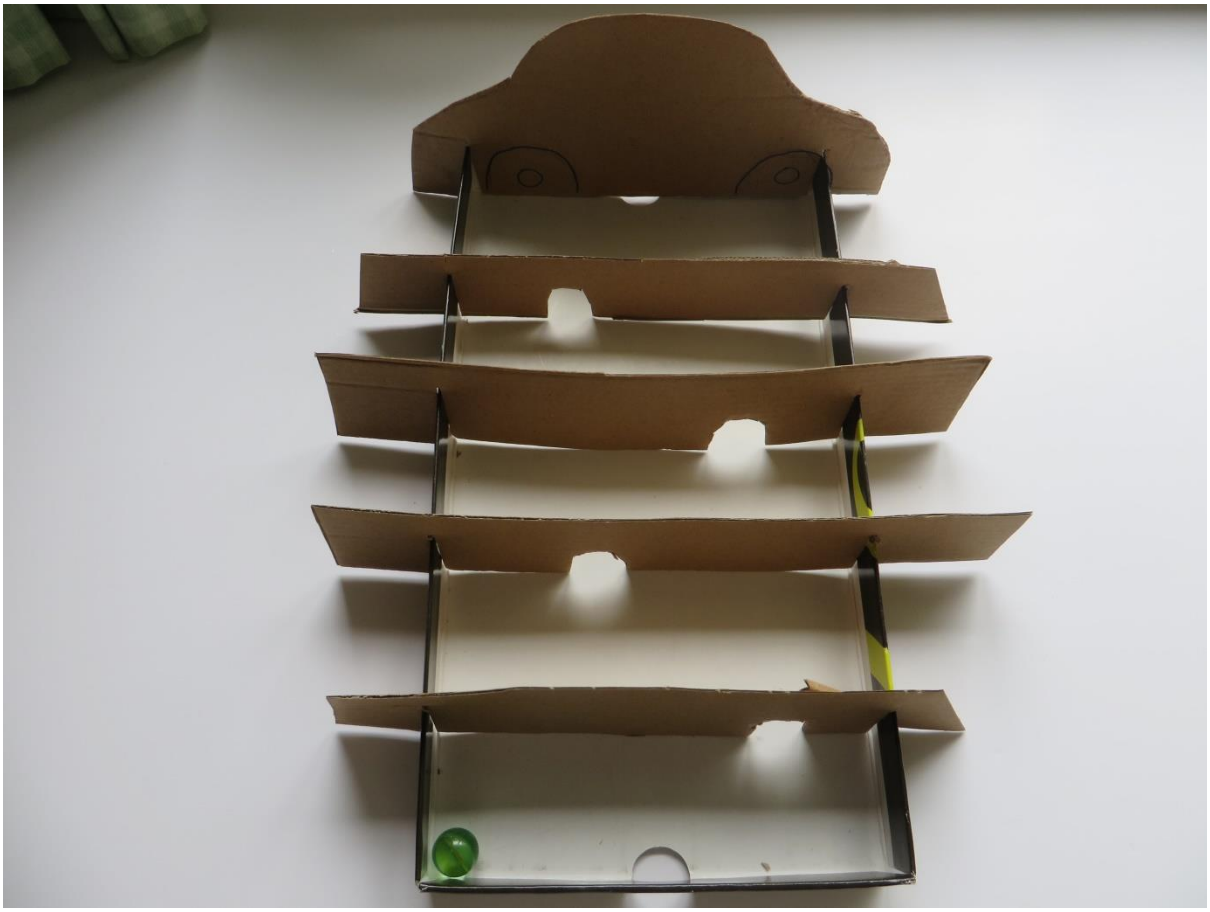
The axle pushed through the holes under the main body.

The pulley pushed onto the motor.

11 - Charge Your Battery game

The most common types of batteries in electric vehicles are lithium ion batteries; they have a high energy density compared to weight. They can be discharged and recharged daily.

When a battery charges or absorbs power, lithium ions move one way; when the battery is discharging or supplying power, the ions move in the opposite direction. This light-hearted game uses a model to demonstrate in a simple way the charging of a lithium ion battery! Each player, in turn, times how long it takes to steer a marble through the gaps in the partitions, from the starting position to the end, thus ‘charging’ the battery. The player with the shorter time is the winner!



Resources

You will need:
A cardboard box or shoe box lid
Stiff cardboard for partitions
Marbles x 3
Scissors
Straws (optional)
Glue
Stopwatch or timer.

How to make the game

Measure a rectangle of thick cardboard wider than the box width, to make a partition. In this model, the rectangle measured approximately 25cm x 4cm.

Cut two slits in the cardboard rectangle, the distance between the slits matching exactly the width of the box.

Cut a small gap in the partition, slightly wider and higher than a marble.

Place the partition across the width of the box and gently push it downwards so that it just touches the base.

Make three or four more partitions in a similar way but changing the position of the marble gap each time.

The maze can be made more challenging by:

- glueing pieces of drinking straws onto the box lid between the partitions, to impede the marble's route
- increasing the number of marbles used

To play the game

The first player places the marble at the starting point .Start the timer. Guide the marble across the route through the gaps in the partitions. Switch off the timer when the marble has reached the finishing point and record the time it took to 'charge' the battery.

The winner is the player with the shortest 'charging' time.

Extension

The children could design and build a marble maze ‘charge the battery’ game to challenge a partner.

Design a pressure switch that would complete a circuit and light a bulb when the marble reaches the end of the run, activating the switch.

12-Appendix Meet a battery research scientist

Lizzie Driscoll
Battery Researcher at the University of Birmingham

I'm a current Chemistry Doctoral Researcher working on developing new materials which we can use in Lithium-ion batteries. But what is a doctoral researcher? You might have heard it called a PhD student instead, but ultimately it involves 3-4 years researching into a specialist topic and it's a post-graduate degree. For me I'm supervised by Professor Peter Slater and on the successful completion of the degree, I can call myself Dr Liz, which is quite a nice touch. My day-to-day role in the lab involves making new materials. Being a solid state chemist, this would sometimes involve mixing powders together and heating to high temperatures. We can then use a technique called X-ray diffraction to see if we've made a new material. If we're successful, we can then make the powder into an ink, coat it onto foil and make into a working battery. I always think it's crazy how we can take a material and make it into a functioning device!

How did I get to where I am though? After the completion of my A-levels, I joined the University of Birmingham in 2013 to do my undergraduate degree in Chemistry with Industrial Experience. I have always found the topic of energy so fascinating and relevant, and there's plenty more work to be done!