Electromagnetics Challenge Badge

We need magnetic materials to help us make a greener, cleaner planet. More than 99% of all electrical energy is made using machines constructed from magnetic materials. They are the active material in electric motors, transformers, generators, sensors, data storage and many other electronic components.

If we can improve our understanding of magnetic materials, we can save electricity, reduce pollution and find new ways to recycle our waste.

Introduction to the Electromagnetics challenge badge

The Electromagnetics challenge badge is aimed at all guiding sections.
The badge is designed for all ages. It includes a selection of activities to choose from with hands-on activities, crafts, and games. All background materials and resources are provided in this pack.

The badge

To complete the challenge and earn the badge, participants must undertake the required activities and then:

- Rainbows - two more optional activities
- Brownies - three more optional activities
- Guides - four more optional activities
- Rangers - five more optional activities

The badge was designed by Designed in Tenterden;
instagram @designedintenterden www.facebook.com/DesignedinTenterden

The badges are available from the Girlguiding Cymru on-line shop and are free to Girlguiding Cymru members except for postage and packaging and are £1 each (plus postage and packaging) for members outside of Girlguiding Cymru.
www.girlguidingcymru.org.uk/challenges

Age range

At the start of each activity the symbols of the different sections indicate which age group the activity may be suitable for. Leaders are. of course. free to use activities they believe will be of benefit to their group.

Background of the Badge

This challenge was put together by Cardiff University's School of Engineering and their world-class Magnetic Materials and Applications research group (MAGMA). They wanted to share their enthusiasm for electromagnetism with Girlguiding Cymru's 20,000 young members. The badge was developed as part of a Royal Academy of Engineering Ingenious Award and launched at European Researchers' Night 2020.

Contents

	Type	Suitable for	Magnet	Page
Introduction				2
Sourcing materials				4
What is electromagnetism?				6
<u>Required Activities</u>				
Magnets in the home	Hands on		●	7
Electromagnetic People	Game			11
<u>Optional Activities</u>				
Magnetic Fishing	Craft		●	15
Magnetic Maze	Craft		●	17
3D Magnetic Maze	Craft		●	18
Guess the MRI	Game			19
Welsh National Grid game	Game			24
Make a Simple Electromagnet	Hands on			27
Electromagnetic Dancer	Hands on		●	28
Tiny Dancer – Homopolar Motor	Hands on		○	29
Make a Motor	Hands on		●	30
Inside Speakers	Hands on			31

● <u>Regular magnet can be used</u>
○ <u>Super strong magnet recommended</u>

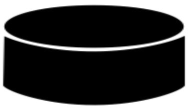
Sourcing Materials

We have provided a range of activities (including some that do not require any special equipment at all). However, there are some activities that require one or more of the following items:-

Magnets

There are several common types of magnets: -

Ferrite magnets



Most people are familiar with black ceramic magnets – these are the kind you will find on your fridge. They can be bought from craft suppliers such as www.bakerross.co.uk

Tip: Magnets with a hole in the centre (often called ring or donut magnets) are easier to attach to other objects.

Safety considerations – Ferrite magnets can break or chip if they are allowed to come together quickly – this may leave sharp edges. Use should be supervised.
Small magnets are a potential choking hazard. Keep away from young children.

Neodymium magnets

Neodymium magnets (usually a shiny silver colour) are up to 40 times stronger than ferrite magnets. They can be found in old hard disk drives or bought from specialist suppliers such as www.first4magnets.com

Safety considerations:

Neodymium magnets are especially dangerous if swallowed - keep away from young children and store safely.

These magnets snap together quickly and powerfully - this can cause injury if they pinch skin. If they shatter, they have very sharp edges which can cause cuts.

They may affect bank and other swipe cards if kept in close proximity

They may interfere with the operation of pacemakers and implantable cardioverter defibrillators in close proximity

We do not recommend activities that use neodymium magnets for children under 7. They should be kept away from pre-school children and safely stored at all times. Use your discretion for children between 7-11 and ensure they are supervised.

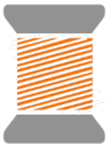
Tip: Why not use neodymium magnets as a demo rather than a hands-on activity?

Magnetic wands

For primary age children, we recommend the use of plastic magnetic wands. These avoid the risk of swallowing or breaking magnets. They can be purchased from educational suppliers such as www.tts-group.co.uk

Wire

Thin copper wire



For making motor coils you need very fine enamelled wire. The higher the gauge of a wire the thinner it is. We recommend 25 SWG wire or higher. The enamel coating needs to be removed at the ends to make an electrical connection. The easiest way to do this is to sandwich it between a small folded piece of fine sandpaper and rub.

Try www.rapidonline.com/unistrand-enamel-copper-wire-36swg-500gm-05-0200

Stiff copper Wire

Some activities require wire that needs to hold its form when shaped. If buying online you will need between 14 SWG (thicker, harder to bend) to 19 SWG (thinner, easier to shape but more likely to be bent out of shape). You can also harvest copper wire from an old power lead by stripping off the insulation.

Try https://www.rapidonline.com/unistrand-enamel-wire-18swg-500gm-05-0245

Copper is very good at conducting electricity. However, you could try a different type of wire e.g. a steel paperclip and see if that will work instead.

What is electromagnetism?

During this challenge you are encouraged to play with magnets and see how they can be used to create electricity. Similar experiments over 150 years ago, led to the invention of the electric motor, generator and telecommunications we depend on every day.

How exactly do electric and magnetic forces travel through space?
Although people worked out that magnets could do powerful things, they couldn't understand how. This made it difficult to work out how to fix problems such as overheating wires

It turns out that a changing magnetic field causes a changing electric field, which then causes another changing magnetic field, which causes an electric field and so on. It's this 'disturbance' or wave that travels through space. This answer helped to solve another big mystery – what exactly is light made of? These waves travel at the same speed as light. Or to put it another way, light acts like an electromagnetic wave.

We now know that there is a whole spectrum of electromagnetic waves – from gamma waves to radio waves. This has helped us develop all kinds of new technologies such as infra-red cameras and telescopes, UV watermarks, lasers, microwaves, radar, x-rays and MRI scans.

Today, we are surrounded by things that rely on electromagnetism – wifi, mobile phones, tv, radio, remote controls, sat navs, credit card readers, washing machines, vacuum cleaners, electric cars, smart meters.

The future of electromagnetics

Engineers have helped to transform our lives but there is still lots we don't understand.
The MAGMA research team at Cardiff University are particularly interested in improving soft magnetic materials – 'soft' is used to describe materials that react very strongly to a magnet but they don't become permanently magnetised themselves. (They actually feel hard to touch!) An example of a soft magnetic material is iron with a little bit of silicon in it.

One of the major uses of this material is in electric motors and generators. Electric motors use magnets to change electricity into movement. Generators do the reverse by using magnets to change movement into electricity. If we can make these more efficient, we'll be able to make more green energy from wind and tidal turbines, electric cars will be able to go further without charging and we can reduce pollution by using fewer petrol and diesel engines.

Another place where better soft magnetic materials could make a big difference is in our electricity grid. A lot of energy is lost moving electricity from the power station to the sockets in your house. Transformers are a key part of the process. A typical transformer has a coil of wire wrapped around a soft magnetic material. This soft magnetic material needs to able to handle changing magnetic fields without getting hot. The less energy is lost by heat, the more energy can get to our homes as electricity.

Required Activities

1. Magnets in the home – 30mins

The challenge starts with an exploration of the magnetic materials in the home. We have suggested several additional experiments that you can do depending on your age and interest.

Leader notes
Use magnets appropriate for the age of the group. See p.4 for details.

What you will need
- Magnet
- Paperclip

(check that the paperclip is magnetic using your magnet)

Instructions
1. Go around your house with a magnet – write or draw a list of all the things that pull towards the magnet.
2. Do the items on your list also pull on your paperclip?
3. If they pull on both the magnet and the paperclip - label them as a magnet. If they only pull on the magnet but not the paperclip – label them as magnetic.

Places to explore
- Recycling bin
- Kitchen utensils
- Electronic Gadgets
- Home appliances
- Furniture and fixings
- Stationary drawer
- Toys and games
- Coins (see notes below)

Be very careful around bank cards and swipe cards. The black stripe along the back is made of a magnetic material that can store information. When you swipe the card, an electronic device reads the magnetic data and converts it into words and numbers. Holding a strong magnet close to the card could scramble the data and stop it working properly.

What's happening?

Actually, everything in your house is magnetic - including you! However, the force is far too weak for it to be noticeable. The things that you found around your house that did not react to your magnet might be paramagnetic materials, such as aluminium, or diamagnetic materials, such as water, copper, or carbon.

The only type of magnetism that is strong enough for us to observe using our magnets at home is ferromagnetism. Ferromagnetic materials have iron, nickel or colbalt in them and they are strongly pulled towards magnets. Paperclips, scissors, screws, nuts, and bolts are just a few of many objects that are ferromagnetic and contain iron.

Some of the things on your list might be a magnet themselves and the paperclip will stick to them. A lot of permanent magnets can be found around the house, such as fridge magnets, in speakers and headphones, in computer hard drives, in electric motors (for example your vacuum cleaner) and all sorts of sensors.

You may have even found some electromagnets. An electromagnet is a magnet that is created by electricity. This means that they can be switched on and off. For example, in your toaster, the switch might be held down by an electromagnet until it is ready to pop!

Required Activities

Take it further

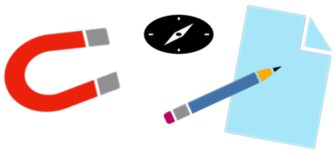
Here are some extra activities for you to try as part of your investigation.

Making magnetic fields visible

Try drawing the magnetic field lines. A magnetic field is the area around a magnet where a force acts on a magnetic material or another magnet.

What you will need

- Magnet
- Magnetic compass
- Paper and pencil



You may have found some nails in your house that are magnetic but what about the ones on your hand? Buy some magnetic nail polish and explore magnetic fields. www.physicscentral.com/explore/action/nailpolish.cfm

Instructions

1. Place your magnet on a piece of paper.
2. Place a compass nearby and mark the direction that the compass is pointing
3. Move the compass to another spot and see it change direction as it lines up with the magnetic field. Mark the direction it's pointing again
4. Keep doing this until you have another marks to see a pattern of fieldlines around the magnet.

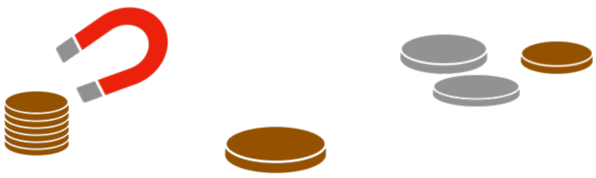
If you don't have a compass, try this online magnetic field simulator from the University of Colorado
phet.colorado.edu/sims/cheerpj/faraday/latest/faraday.html?simulation=magnets-and-electromagnets

Magnetic money

Are coins magnetic or not?

What you will need

- Magnet
- Lots of small coins



Instructions

1. Test each of the coins with a magnet.
2. Sort the coins into those that are magnetic and those which aren't.

What's happening?

You may notice something strange. Some denominations are sometimes magnetic and sometimes not. Looking at the dates of the coins might give you a clue. The materials used to make coins has changed over time. Many new coins are made from steel and coated with other metals. Steel is made from iron so it is ferromagnetic. Pennies have been made from copper-coated steel since 1992. Older coins that are made from copper alone are not ferromagnetic.
Check out www.royalmint.com for more information about the materials used in coins.

Required Activities

Even your food

Magnetic cornflakes

If you read the back of your cereal packet you might find it is fortified with iron – this means it is also ferromagnetic! Can we prove this?

What you will need

- Fortified cereal such as cornflakes or rice puffs
- Magnet
- Plastic ziplock sandwich sized bag or similar
- Water
- Washing up bowl

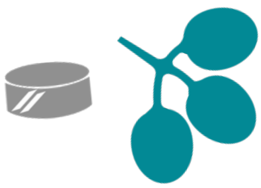
Instructions

1. Place a small amount of the cereal into the bag and crush it up into tiny pieces.
2. Keeping your magnet on the outside of the bag, move it slowly over the pieces and see if they respond.
3. Try crushing the cereal to a powder, add water to the bag and seal it.
4. Place the magnet in your washing up bowl and place the sealed bag on top.
5. Leave it to settle for 15mins
6. Carefully pick up the bag and magnet together and turn it over so the magnet is on top. Allow the cereal to float down. You might find some grey powder stays by the magnet. This is the iron that's been added to the cereal. We need some iron in our diet to keep us healthy.

If you are using a super strong magnet you can try floating a piece of cereal in water and see if it follows the magnet.

Magnetic Fruit!

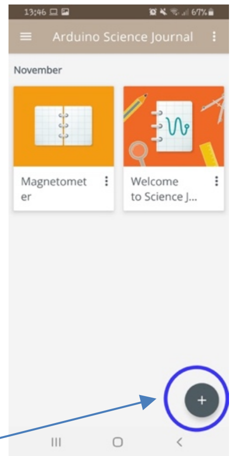
If you have access to a super strong magnet (such as a neodymium one) you might even be able to demonstrate diamagnetism - using fruit!
www.exploratorium.edu/snacks/magnetic-fruit



Magnets are used to make electricity but did you know that electricity is used to make magnets?
www.youtube.com/watch?v=qed4ynPYVIA

Required Activities

Take it even further



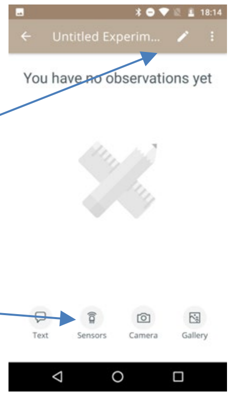
If you are able to borrow a suitable smart device you can use it to explore the strength of the magnets that you found and create sounds!

What you will need

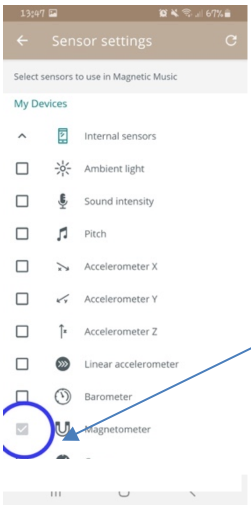
- Iphone, Ipad or similar device. (Unfortunately, cheaper smartphones and tablets do not contain an inbuilt magnetometer. Check your device beforehand)
- Items that contain magnets or electromagnets

Instructions

1. Download Google's Science Journal app in the Google Play or Apple store (it's free)

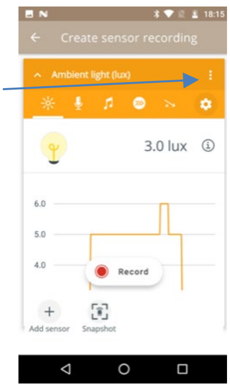


2. Open the app and click the plus button in the bottom right corner. You can then click on the pencil on the top right of the screen to name your experiment and add a photo if you would like. Click the tick to save.



3. Now click on the sensors icon at the bottom.

4. Click on the cog (settings) icon and untick everything apart from Magnetometer



5. Go back to the main screen and click on the 3 white dots. Select 'Enable Audio.' Then click on 'Audio Settings' and select 'Scale.'

6. You are now ready to go! Try and find various magnetic items and see what happens!

Even when the phone isn't near anything the magnetometer reading isn't zero. This is because the earth behaves like a giant magnet. The geomagnetic field is created by electric currents in the liquid metal flowing around the Earth's core. This means the Earth is actually an electromagnet.

Why does your phone need to measure magnetic fields? Phones that have a magnetometer can work out accurately the direction they are facing and this is useful for navigation apps.

2. Electromagnetic People – 15-20mins

Introduction

This is a group activity to get you thinking about the diverse range of careers and people who work in jobs linked to electromagnetism. This is not about getting the right answer but how you approach a challenge.

What you will need

- Job descriptions and People profiles cards (1 set per subgroup)

Instructions

1. Split into smaller groups of 6-12. Each group needs a set of people and jobs.
2. Try to match the people to their role.
3. Talk about your thinking process and guesses with the other groups before finding out the correct answers.
4. Who do you think is most like you? If you had to choose one of the jobs, which would you pick and why?

Online version

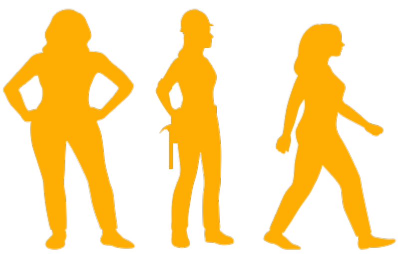
If you are meeting online you can adapt the activity as follows.

Instructions

1. Make a Powerpoint slide with the pictures of all of the people on it alongside words to describe them and their hobbies. Screenshare this with everybody.
2. Your leader can read out the job information and ask you to vote on the person you think does that job.
5. Discuss your guesses as you go along. Who do you think is most like you? If you had to choose one of the jobs, which would you pick and why?

Possible Voting methods

- Your leader reads out the names and you put your hands up to vote
- Write the name (or number) of the person in the chat
- Say the name the person, their number or their colour out loud
- Screen annotation - you can use the stamp tool to put a mark on a person.



Leader notes

Remember to check that screen annotation is enabled for participants beforehand and clear the screen between slides.

Required Activities

<u>Leader notes</u>
This activity can be used as an icebreaker and an opportunity to practise critical thinking skills with older groups.

- Remember to emphasise that this is a very difficult challenge and it's more about how they approach a problem than getting the right answer. Engineers face challenges all the time so they need to develop lots of different strategies.
- Engineers also need to be ok with getting it wrong sometimes because working out what doesn't work will get them closer to a solution more quickly than being afraid of trying.
- Studying science and maths is often thought to limit career options but in reality, it provides many transferable skills that can be useful in any role.
- Ask for evidence – how and why did they make their choices? What strategies did they use, e.g. process of elimination, looking for commonalities, patterns of speech etc.
- Encourage debate - ask if others agree/disagree and why? How did they come to a group decision?
- If there is disagreement, point out that often in engineering there isn't only one solution and people may disagree over which direction they should go. People may have different priorities when looking at the information available.
- Emphasise the problem-solving skills developed by studying STEM subjects.
- Challenge attitudes - if girls express views that indicate stereotyping, this is a good opportunity to sensitively challenge unconscious bias.

Here are the correct answers
Ayse = A
Fatemah = D
Tattiana = B
Clara = C
Angharad = F
Beth = E

I'm Clara. Growing up, I loved reading books by Carl Sagan. He was a fantastic science communicator and really inspired me. I love hiking in the Swiss countryside and swimming in Lake Geneva. I like to spend time with my friends and family. I like to go running, I have run three marathons in the past. I'm also really into crafting, so I crochet, knit and do cross stitch.

I'm Ayse. All my family are engineers! My Dad is an engineer and he is my hero, which is why I chose to study engineering. I like to spend time with my friends, we will have a nice drink, and go shopping together. I also like going to the theatre and to the cinema. I enjoy outdoor sports and being able to travel is one of my favourite things to do.

I'm Beth. I always had an interest in medicine and wanted to be a doctor when I was at school. When I was younger I trained with disabled athletes and was fascinated by their prosthetic limbs and how it made a difference to their performance and what I could do to make it better. I love running, walking and dancing. I also love the beach and taking photos.

I'm Tattiana. When I was younger I wanted to be an aircraft pilot. I also learned about accounting, which is very helpful when trying to understand if a solution to a problem will cost too much money. I enjoy going out and talking with my friends, watching movies, climbing, yoga and being outdoors in general. There's nothing better than a nice sunset.

I'm Fatemah. In high school I was good at maths and physics and loved learning about electro-magnetism. My family said I should study medicine but I decided to study engineering because I love learning how things work. I have a 3 year old son and we do cooking and baking together. I enjoy travelling and learning about other cultures.

I'm Angharad. I enjoyed maths and physics in school because it was logical and I found it interesting being able to explain why things were the way they were. I am very sporty, I play netball with a local team and enjoy going to the gym. I also enjoying cooking and going out with friends.

A. I find the idea that we can communicate between the sky and the ground very exciting. I studied electronic and communication engineering and my work involves 5G technology – this uses super high frequency electromagnetic waves. What I like most about it is that I am connecting people by helping establish a communication link. I enjoy working with other engineers and scientists to discover and create something new. I like that in engineering you can help solve the small problems that people think are impossible and make a difference. Sometimes you need to be patient, as you may find it hard but never give up. Some words which describe me are: Practical, Creative, Out-going,

B. In my work I am finding ways to improve tidal turbines. These are similar to wind turbines but located under the sea. If we can make turbines work at low speed, more countries could use them to generate their electricity. I believe it is one of the solutions to the energy problem in the world. Whilst doing my degree I fell in love with renewable energy and turbomachinery, the next logical step was to study tidal energy. I have developed more technical skills that have improved my problem-solving skills. Engineering has taught me other skills too such as, patience, teaching, networking and project leading skills. Some words which describe me are: Understanding, Cooperative, Resourceful.

C. I'm a Particle Physicist at CERN - a laboratory that runs experiments using particle accelerators. These use electric fields to speed up and increase the energy of a beam of particles, which are steered and focused by magnetic fields. I study top quarks which are the heaviest particle in our recipe book of particles. This can help us look for dark matter. Part of my job is teaching computers to look for information about these particles in our data. We have to be inventive and think up new ways to solve the problems and this means that we can be wrong but wrong is good because you are still learning and you will eventually find the solution. I have moved around the world for my work I have lived In France, Germany, the Netherlands, the UK, Singapore and the USA. Some words which describe me are: Self-motivated,, Resourceful, Curious

D. I'm a Radio Frequency Engineer and I help industry find useful applications of new technologies that are being developed. I mostly work on antenna - these are the parts of mobile phones, laptops, and medical devices that connect wirelessly to other devices. We are always looking for ways to make things smaller, lighter, and cheaper. Something I have learnt is that everyone brings something from their own experience and culture which is why diverse teams are important. My work moves very fast and is always changing so there are lots of things to learn. I have three patents and I am proud that I am making a difference and an impact on the world. Some words which describe me are: Sociable, Caring, Kind

E. I'm a Medical Engineer. I use a big machine that looks like a doughnut called an MRI machine (Magnetic Resonance Imaging). It allows me to see inside the body and even see inside of the brain! My work helps companies develop or improve medical devices. My favourite part of my job is being able to travel the world and make new friends from some really cool places - so far I have been to Japan, South Africa, America, Australia, and Europe. I enjoy the variety of my work; every day is different. There are lots of challenges and always something exciting to work on. My Job has taught me how to communicate with lots of people, of all ages and from different cultures (sometimes in different languages!). I've learnt to accept failure as well as success! Some words which describe me are: Friendly, Inventive, imaginative

F. I'm an Electrical and Electronics PhD Student. My research focuses on the microwave part of the electromagnetic spectrum and how they can be used to diagnose and kill bacteria. I find my work incredibly interesting and exciting. I get to learn, while potentially developing something that could change society for the better. I did a project into a potential new cancer treatment. This made me realise how much of an impact I could have by having a career in engineering. The project was so interesting and I felt like I was genuinely making a difference. I have already learnt so much in such a short space of time including new computer software. Don't listen to people who say that maths and science aren't cool, because they are, VERY! Some words which describe me are: Witty, Helpful, Logical

Optional Activities

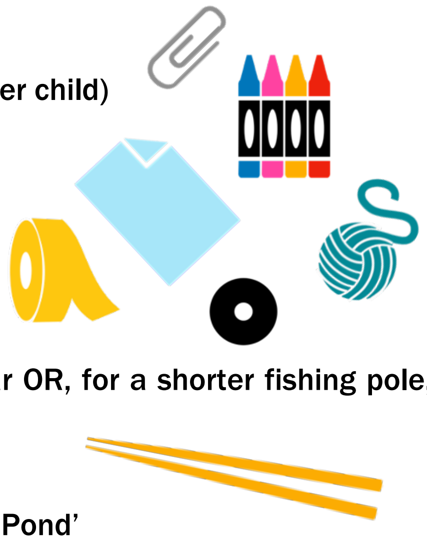
Magnetic Fishing - 30 mins

Introduction

Make a magnetic fishing game and learn about magnetism. See activity 1 for more background information on magnetism.

What you will need:

- Paperclips (at least one per child)
- Sticky tape
- Coloured paper or card
- Pens or colouring pencils
- Scissors
- Fish shape templates
- Doughnut magnets
- String
- A bamboo cane or similar OR, for a shorter fishing pole, chopsticks



Optional:
A hula hoop or bucket to be the ‘Pond’
A stopwatch or timer to see who can fish the most against the clock

Leader notes

Use magnets appropriate for the age of the group – see p.4 for details.
Ensure the magnets are strong enough to work through the paper.
Take about fishing rod safety, i.e. not above your head, be aware of other people around you and don’t ‘whip’ or ‘flick’ the magnet end around quickly.

Carrying out this challenge safely

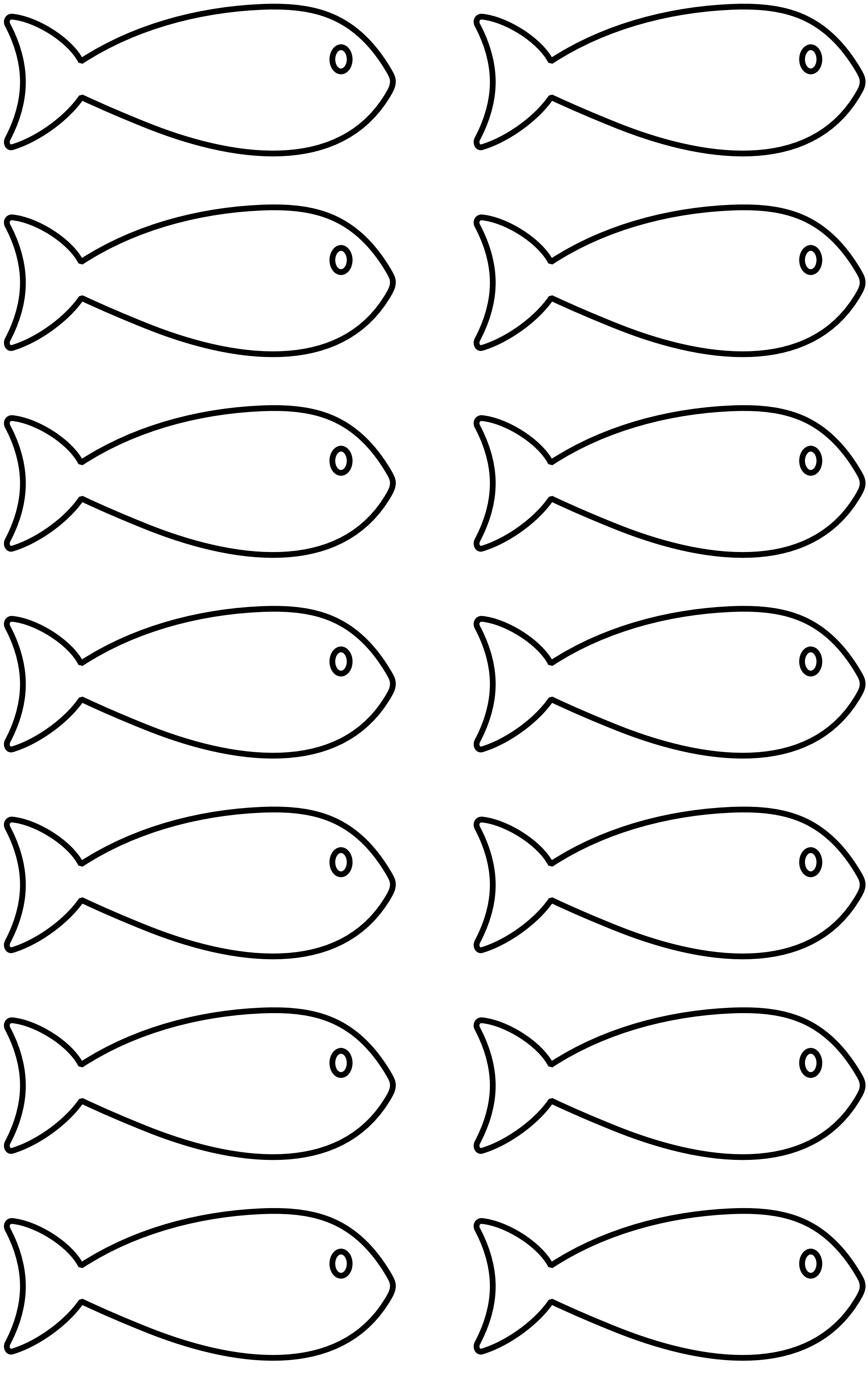
Keep your magnet safe at all times and do not lose it. Never put it in your mouth and keep it away from electrical devices and bank cards.
Be careful when using scissors. Do not run while carrying them, and remember scissors are a tool not a toy. Your magnet may attract your scissors so be careful.
Have fun and ask your grown-up helper if you get stuck!

Instructions

1. Get the paper, pens and colouring pencils you need to draw a fish. Take a fish template and draw round it. Next you need to colour in your fish!
2. Take your paper clip and stick it to the back of your fish.
3. Take a doughnut magnet and tie it to the string. Check with your grown-up helper that it is tight!
4. Next you need to attach the other end of the string to the bamboo cane. Again ask your grown-up helper to check the knot is tight.
5. Decide where the pond will be, place all the fish in the pond and get fishing!

Take it further

https://www.youtube.com/watch?v=zNdTnAywCBI



Optional Activities

Magnetic Maze - 30 mins

Introduction

Create a maze and challenge your friends to solve it. You will be designing a maze and moving a paper clip through the maze using a magnet. Learn about problem-solving and magnets and challenge yourself to develop your skills.

What you will need:

A paper plate (1 per person)
A magnet and paperclip
(1 each per person)
Blu tack or sticky tape
Scissors
Coloured pens/pencils
A maze design

Leader notes

Use magnets appropriate for the age of the group – see p.4 for details. Ensure that they are strong enough to move a paperclip through the paper plate and that your paper clips are magnetic. There are lots of maze patterns available online to download, print and then stick to the paper plate.

Carrying out this challenge safely

Keep your magnets safe at all times and do not lose it. Never put it in your mouth and keep it away from electrical devices and bank cards.
Be careful when using scissors. Do not run while carrying them, and remember scissors are a tool not a toy. Your magnet may attract your scissors so be careful.
When you have finished the activity dispose of your maze responsibly.
Have fun, and ask your grown-up helper if you get stuck!

Instructions

1. Draw your maze onto your paper plate or draw it on to a piece of paper then stick it to your plate. You can add a prize to the middle of your maze if you like.
2. Think carefully about the design of your maze, make sure that it can be solved!
3. Now you have designed your maze, you can design a character to stick to your paperclip. Draw your design on paper, and stick this to your paperclip
4. Test your maze! Place your paperclip character at the start of the maze, and using the magnet under the plate, carefully drag your paperclip through the maze.

Further information

https://thestemlaboratory.com/magnetic-paper-plate-maze/

Optional Activities

3D Magnetic Maze - 30 mins

Introduction

Design a maze and move a paper clip through it using a magnet. You can also challenge your friends to solve it. Learn about problem-solving and magnets and develop your skills.

What you will need:

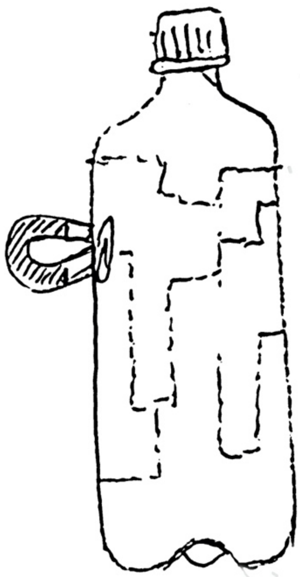
- A clean, dry, plastic bottle with a lid (1 per person)
- A magnet and paperclip (or other magnetic objects) (1 each per person)
- Permanent marker

Carrying out this challenge safely

Keep your magnets safe at all times and do not lose it. Never put it in your mouth and keep it away from electrical devices and bank cards.
Be careful when using scissors. Do not run while carrying them, and remember scissors are a tool not a toy. Your magnet may attract your scissors so be careful.
When you have finished the activity dispose of your maze responsibly.
Have fun, and ask your grown-up helper if you get stuck!

Instructions

1. Draw your maze onto the outside of your plastic bottle with permanent marker pen. You can add a prize to the end of your maze if you like.
2. Think carefully about the design of your maze, make sure that it can be solved!
3. Now you've designed your maze you can drop your paperclip inside the bottle and screw the lid on.
4. Test your maze! Bring your magnet to the outside of the bottle, and your paperclip will be attracted to the magnet. Guide your paper clip through the maze. You could time your friends and see who can go fastest or who drops the paper clip the least.



Leader notes

Use magnets appropriate for the age of the group – see p.4 for details.
Check that your paperclips are magnetic and your magnets are strong enough to move a paperclip through the plastic bottle.

Optional Activities

Guess the MRI - 20 mins

Introduction
A Magnetic Resonance Imaging (MRI) machine is tube shaped and is made up of a ring of electromagnets. It is one of the most powerful ways to look inside the human body without causing any harm. Can you work out which foods have been scanned using the MRI?

Leaders notes
If the guides or rangers are going to create their own quiz to test other members discuss internet safety with them.

What you will need:
MRI pictures of foods (see below).

Instructions
1. Using the MRI pictures of food, ask the girls to guess what they might be. Optionally, you can play snap, matching an inside to an outside
2. Some of the foods are the same but have been imaged in the opposite direction which makes them look very different.

Further Information
All MRI Images come from Inside Insides and the Copyright is owned by Andy Ellison
http://insideinsides.blogspot.com/
https://futurism.com/guess-the-food-from-the-mri

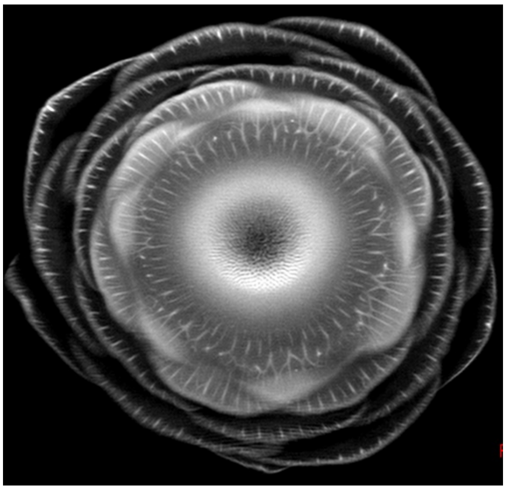
What's happening (in an MRI machine)?
We are mostly made of water, which is made of hydrogen and oxygen. At the centre of each hydrogen atom is an even smaller particle called a proton. Protons are like tiny magnets and are very sensitive to magnetic fields.

When you lie in the magnetic field generated by the MRI scanner, the protons in your body line up in the same direction. Just like how the needle of a compass lines up with the Earth's magnetic field.

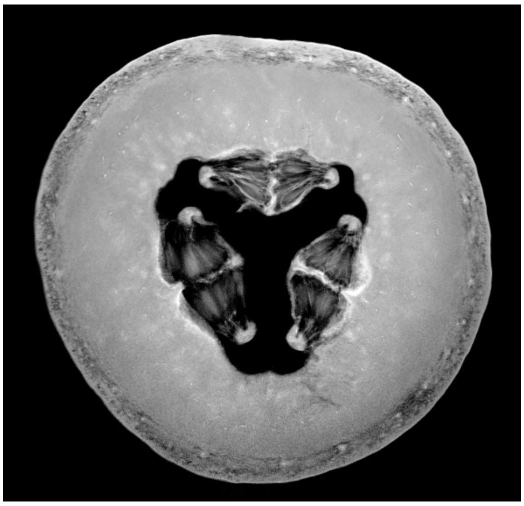
Short bursts of radio waves are then used to knock the protons out of alignment. When the radio waves are turned off, the protons realign. This sends out radio signals, which are picked up by receivers. These signals provide information about the exact location of the protons in the body. They also help to distinguish between the various types of tissue in the body, because the protons in fat, muscle, bones and other tissues realign at different speeds and produce distinct signals.

In the same way that millions of pixels on a computer screen can create complex pictures, the signals from the millions of protons in the body are combined to create a detailed image of the inside of the body.

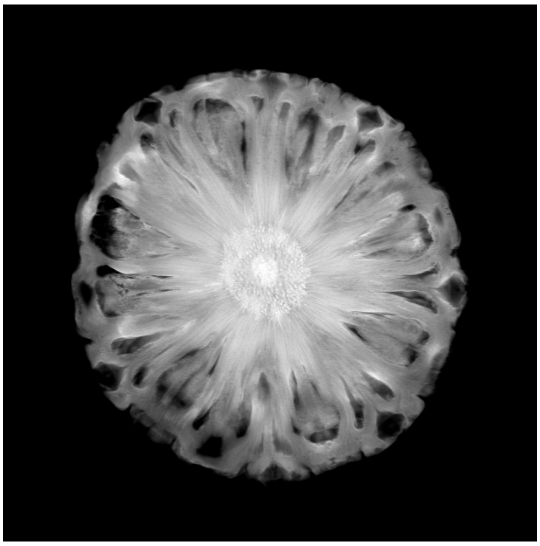
Optional Activities



Artichoke

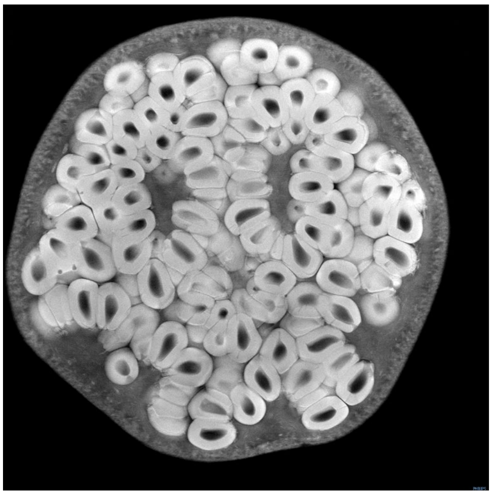
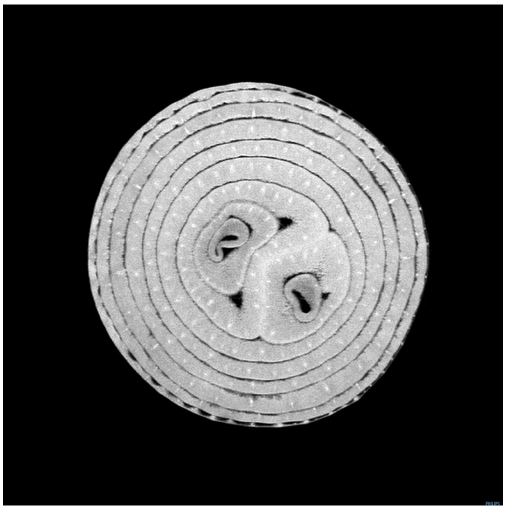
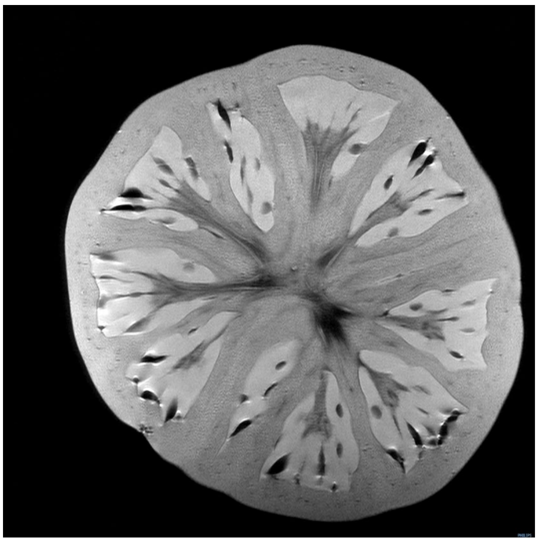


Melon



Pineapple

Optional Activities

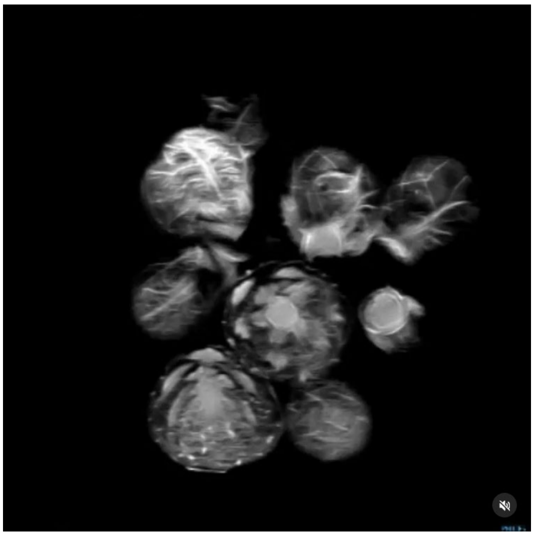
	Pomegranate 
	Onion 
	Tomato 

Optional Activities

	Cucumber 
	Pear 
	Corn on the cob 

Optional Activities

Peas



Brussels Sprouts

Star Fruit

Optional Activities

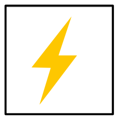
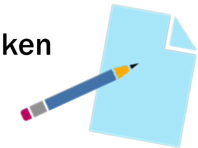
Welsh National Grid Game – 45mins

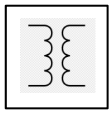
Introduction

Our electricity is distributed by the national grid. The grid relies on transformers to move electrical energy from one circuit to another. Transformers are among the largest users of soft magnetic materials and they are very efficient. Despite this around 10% of the electricity is lost - mostly in their magnetic core. This is estimated to cost the UK £700 million per year. Developing better magnetic materials will reduce some of the losses and create a more efficient national grid. It will reduce the amount of energy needed to power Wales and we won't need to rely on renewable energy sources as much.

What you will need for 2-6 players

- Dice
- Counters – 1 per player
- 20 x Electricity tokens per person
- 2 x Transformer tokens per person
- National grid map print out
- Pen and paper to keep score



Electricity Token



Transformer Token

Instructions

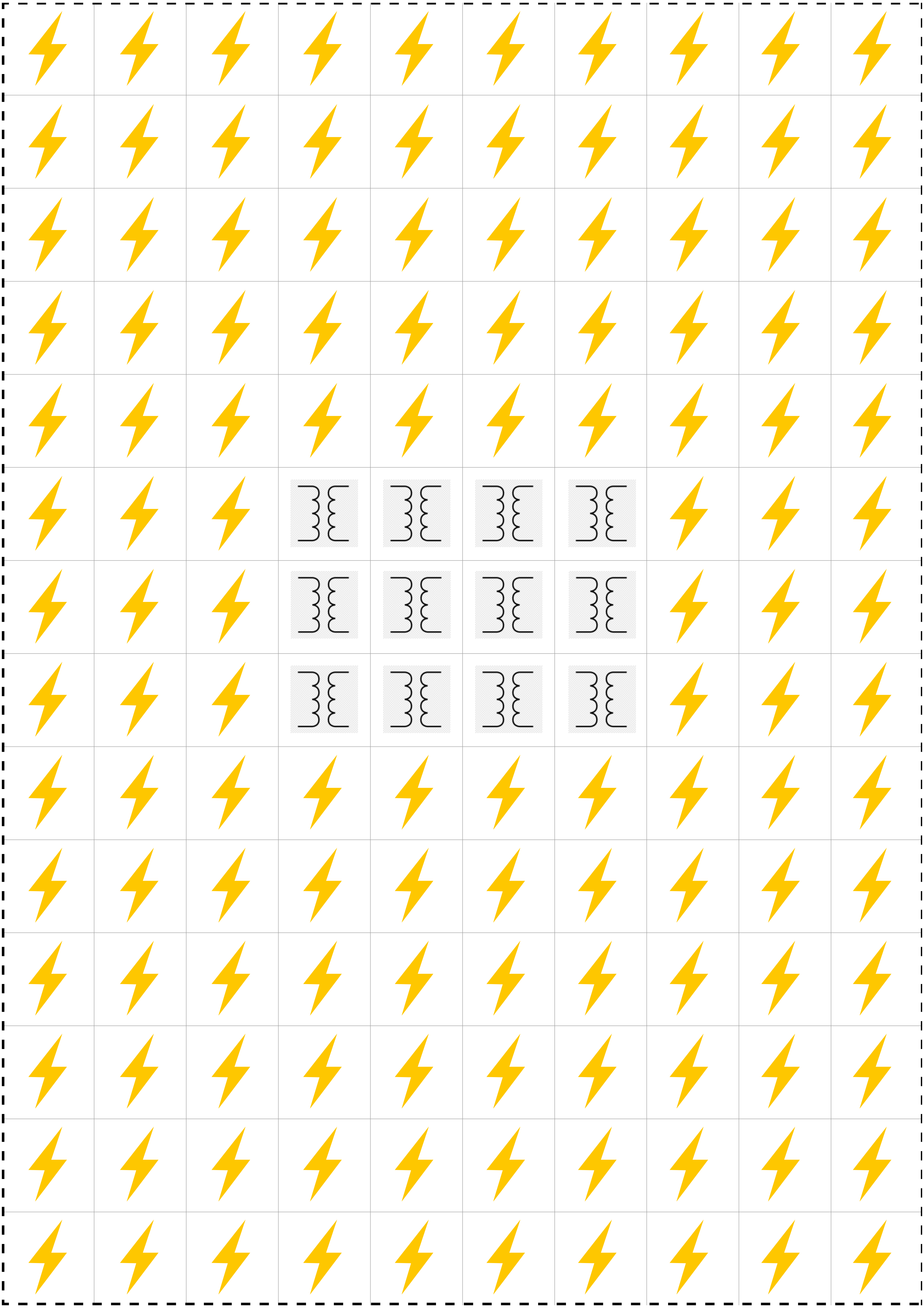
Wales are playing England in the Rugby World Cup final. At half time it is anticipated that there will be massive surge in electricity as people switch on their kettles. Dinorweg power station has the capacity to deal with such a surge in power requirements.

1. Starting at Dinorweg, you must provide power to as many locations in Wales as possible. Each location you power will give you points as per the list. The scores are based on the population size in each place.
2. Each player starts with 20 electricity tokens representing 1000 kilowatts of electricity and 2 transformers tokens. All players start at Dinorweg.
3. You get the points for a location by completing a continuous grid from Dinorweg to a location. The first player to that location gets the points.
4. On a player's turn they first roll a die. If they roll an odd number, they can use 1 electricity card. If they roll an even number, they can use 2 electricity cards. If they roll a 6, they can either use 2 electricity cards or 1 transformer.
5. The player uses their electricity tokens to connect up the grid. For example, you can use 2 electricity tokens to connect up Dinorweg and Porthmadog.
6. You can partially connect up the grid. For example, if you roll an odd number, you can place 1 electricity token between Dinorweg and Welshpool. You can then finish the grid on subsequent turns.
7. Your grid must be continuous starting from Dinorweg. For example, you cannot start a grid from Swansea to Haverfordwest if you have not already created a grid to Swansea.
8. Placing a transformer limits electricity loss, so you can pick up another 5 electricity tokens. If you roll a 6, you can use a transformer or place 2 electricity cards. You cannot do both.
9. The game ends when a player has run out of electricity cards or all locations have been completed. The winner is the player with the highest score.

Welsh National Grid Game

<u>Location Scores</u>

10 - Cardiff
8 - Swansea
6 - Bridgend
6 - Newport
5 - Wrexham
5 - Rhyl
4 - Bangor
4 - Aberystwyth
4 - Llandudno
4 - Haverfordwest
3 - Holyhead
3 - Newtown
2 - Welshpool
2 - Llandrindod Wells
1 - Monmouth
1 - Machynlleth
1 - Porthmadog
1 - Brecon



Optional Activities

Make a Simple Electromagnet - 20 mins

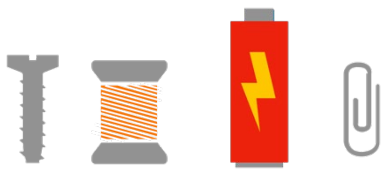
Introduction

When electric current flows through a wire, it creates a magnetic field. The magnetic field around a straight wire is not very strong. But if the wire is wrapped in a coil, the fields produced in each turn of the coil add up to create a stronger magnetic field. When the coil is wrapped in the shape of a cylinder, it is called a solenoid.

If an electromagnet consists only of coiled wire (if it has nothing but air in its middle) then the magnet will not be very strong. However, if you place a piece of iron in the middle of the coil (the core) it will make the magnetic field much stronger. This is because iron is ferromagnetic. Create an electromagnet and then test it out by seeing what magnetic things you can pick up.

What you will need:

A 1m length of thin copper wire (one each)
An AA battery (one each)
A bolt (one each)
Paperclips

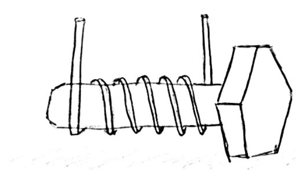


Carrying out this challenge safely

Batteries and wires can get hot – only connect the battery for short intervals and DO NOT tape together permanently

Have fun and ask your grown-up helper if you get stuck!

Instructions



1. Take your bolt and wire. Wrap the wire around the bolt at least 50 times leaving a straight piece at each end (about 15cms long).
2. Using your sandpaper, rub the wire at each end to get the insulation off. Pulling the last 1cm of the wire through a pinched piece of sandpaper works best.
3. Hold one end of the wire on the end of the battery and place the other end of the wire on the other end of the battery. You have created an electromagnet!
4. Test your electromagnet by trying to pick up paper clips or other small magnetic items with the bolt.

Further Information

https://www.youtube.com/watch?v=na_FpTXLFa8
https://www.youtube.com/watch?v=_odHVX4mUAQ

Troubleshooting:-

- Check the bolt with a magnet to ensure that it is ferromagnetic.
- A higher density of wire wraps will create a more powerful magnet. Using thinner wire, ensuring it is wrapped closely and tightly and the coils are not too criss-crosssed will help.
- Make sure your batteries are fully charged – using them in this way quickly drains them.
- Check that the coating has been fully removed at the ends to make a good connection.

Optional Activities

Electromagnetic Dancer – 45mins

Introduction

Use your electromagnet to make a paper dancer

Leader notes

For younger ages you can use this as a demonstration. If you do not have the materials for an electromagnetic, you can use a number of permanent magnets to create a chaotic pendulum dancer instead
https://www.exploratorium.edu/snacks/strange-attractor

What you will need:

For dancer

- String
- Lego of K'Nex or others items to build a frame.
- Doughnut magnets
- A base, this could be a piece of wood or a plastic tray
- Paper and pens to make your dancer
- Blu tack and/or sticky tape
- Scissors

For electromagnet

- Bolt - 1 per person
- 1m of thin enamelled copper wire (see p.5 for details)
- Small piece of sandpaper
- AA battery – fully charged

Troubleshooting:-

- Check the bolt to ensure that it is magnetic (stainless steel will not work.)
- A higher density of wire wraps will create a more powerful magnet. Using thinner wire, ensuring it is wrapped closely and tightly and the coils are not too criss-crosssed will help.
- Make sure your batteries are fully charged – using them in this way quickly drains them.
- Check that the coating has been fully removed at the ends to make a good connection.

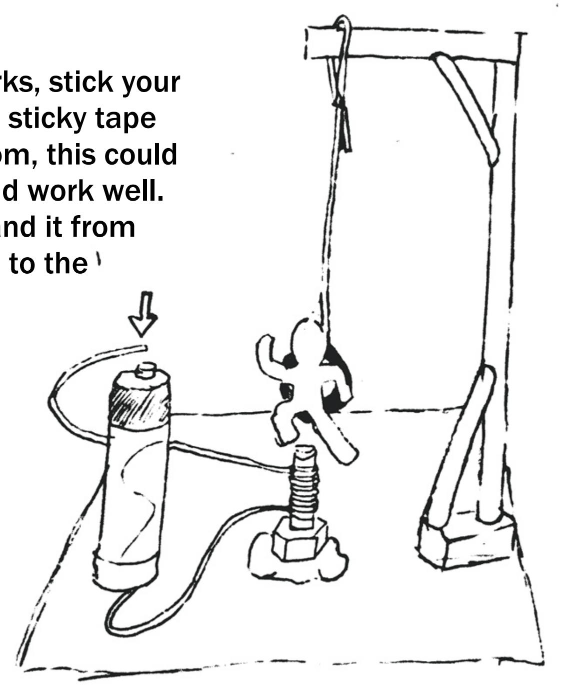
Carrying out this activity safely

Batteries and wires can get hot – only connect for short intervals and DO NOT tape together permanently

Be careful when using scissors. Your magnet may attract your scissors so be careful.
Have fun and ask your grown-up helper if you get stuck!

Instructions:

1. Follow the instructions from the 'Make a simple electromagnet' activity
2. Once you are happy that your electromagnet works, stick your bolt down onto your board with either blu tack or sticky tape
3. Build a stand which you can dangle a magnet from, this could be any sort of frame or stand. Lego or K'Nex could work well.
4. Tie some string to your doughnut magnet and hand it from your frame. You need to get the magnet as close to the electromagnet as possible without touching.
5. Draw your dancer so that they will be able to stick to your magnet with blu tack. Once you have finished your dancer, stick it carefully to your magnet.
6. Tape one end of your electromagnet wire to the bottom of the battery. What happens when you touch the other end of the wire to the battery?



Optional Activities

Tiny Dancer - a Homopolar Motor - 45 mins

Introduction

See if you can make a homopolar motor and create a twirling dancer!

> **Leader notes**
>
> This is a project for older children who can understand the precautions and adult supervision is recommended.

What you will need:

- Thicker copper wire (14-19 SWG - See page 5 for details)
- Neodymium Disc Magnets (approx. 12mm diameter, such as www.first4magnets.com/circular-disc-rod-c34/12mm-dia-x-6mm-thick-n42-neodymium-magnet-4-3kg-pull-p3488#ps_0_3587|ps_1_718
- AA Battery
- Pliers or wire cutters
- Crepe or tissue paper
- Blu Tack or sticky tape

Carrying out this challenge safely

If running continuously the wire and battery may become very hot! Handle with care. Do not leave unattended in use and separate the magnet from the battery when not in use.

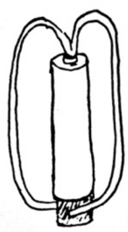
Neodymium magnets are especially dangerous if swallowed - keep away from young children and store safely.

These magnets snap together quickly and powerfully - this can cause injury if they pinch skin. If they shatter, they have very sharp edges which can cause cuts.

They may affect bank and other swipe cards if kept in close proximity

They may interfere with the operation of pacemakers and implantable cardioverter defibrillators in close proximity

Instructions



1. Cut a piece of wire about 25 cm long. Fold it in half to find the centre. Then bend each half back using the pliers to make a heart shape. It does not need to be perfect but try to be symmetrical.
2. Place a neodymium magnet on the negative side of your battery and stand on a flat surface. The magnet should be at the bottom.
3. Balance your wire on top and adjust the shape until the ends of the wires touch either side of the magnet. Using sandpaper removes any coating from the wire at the central
4. point where it touches the battery and the two ends touching the magnet.
5. Balance it on top again and let go. If it is properly constructed it should spin.
6. Using very light paper, create a little dancer shape and stick it to the top of your wire.

> **Troubleshooting**
>
> - If the motor does not work try turning your magnets upside down and reversing the direction.
> - The batteries burn out quickly! If turning the magnets upside down doesn't work, try replacing your battery with a new one.
> - Make sure that the bottom section of wire is lightly touching the magnet. If it doesn't your motor will not work. If it is too close it may stop the wire turning.

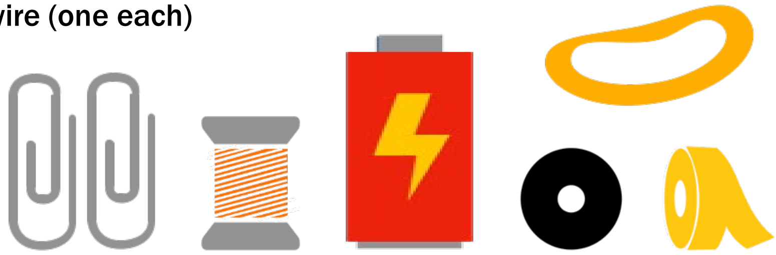
Further information - https://www.youtube.com/watch?v=p29gy0OBaY8

Optional Activities

Make a Motor – 45 mins

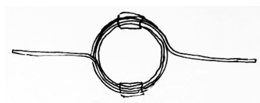
Introduction
We use electric motors all the time. They are found in our washing machines, microwaves, vacuum cleaners and increasingly in buses and cars. They work on the very simple principle that a magnet will exert a force on a current carrying wire. You can make a your own motor and explore electromagnetic induction as follows.

What you will need:
1m of thin enamelled copper wire (one each)
A D battery (one each)
Sticky Tape
Blu Tack
Sandpaper
Elastic Band (one each)
Doughnut magnet (one each)
Large Paper clips (2 each)



Carrying out this challenge safely
If running continuously the wire and battery may become very hot! Handle with care. Do not leave unattended in use and separate the magnet from the battery when not in use.

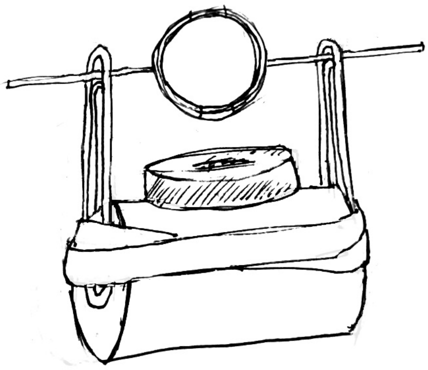
Instructions
1. Make a coil by winding your wire around the battery ten times. Make sure you leave a straight bit at each end. Slide your coil off the tube and secure it with sticky tape.
2. The wire has a layer of insulation on it which needs to be removed at the ends to create good electrical contact. Fold the sandpaper in half over the wire (scratchy sides together) around the ends of the wire and rub it gently to remove this layer. Make sure the coating is removed at the points where the wire makes contact with the paperclips.



3. Use an elastic band to hold a paperclip onto each end of the battery. This can be a bit tricky so try wrapping the elastic band first then sliding the paper clips between the elastic band and the battery.
4. Attach a magnet to the battery using the Blu Tack. Then carefully balance the coil on the two paperclips, with a little push it should spin rapidly!

Further information
https://www.youtube.com/watch?v=WIOpGkOMMhg

Optional Activities



Leader notes
This is a project for older children who can understand the precautions and adult supervision is recommended.
It can be tricky to get the coil to spin freely if it is not neat or well balanced. If the coil catches on the magnet you can try holding the motor upside down or adjusting the position of the paperclips.

Optional Activities

Speaker insides - 15 minutes

Introduction

Take apart an old pair of headphones and see how they use electromagnetism to turn electricity into sound._

What you will need:

- Old pair of broken earbuds
- Scissors or craft knife and cutting mat
- Optional:
- Paper and pencil
- Pliers/screwdriver

Leader notes

This activity potentially involves the use of sharp tools and may require close supervision.
Larger headphones may have screws or other fastenings hidden behind the foam coating.

Carrying out this challenge safely

Be very careful when using tools, particularly those with blades.
Work on a stable surface and use a cutting mat or surface protector.
Keep craft knives retracted when not in use.
Always keep your body and fingers behind the blade as you cut.
Avoid talking or looking away when cutting.

Instructions

1. Cut the wire close to one of the earbuds using a sharp pair of scissors or craft knife.
2. Find the seam that runs around the earbud. Carefully prise or break the end cap off.
3. Try to Identify and separate the following parts
   a. The magnet – this should stick to your scissors/knife.
   b. Diaphragm – this is made of very thin plastic or paper with a tiny copper coil attached
4. Draw a picture of how the parts go together.

What's happening?

Earphones are miniature loudspeakers. They work by sending electrical signals through the tiny copper coil. This turns the coil into an electromagnet which reacts with the permanent magnet. As the coil is pushed and pulled by the changing magnetic field, it makes the diaphragm move back and forth, thus making the air vibrate and creating sound. Microphones are speakers in reverse – they turn the soundwaves into an electrical signal.

Take it further

You can use the wire you cut off from the headphone to make your own speaker using some magnets, a cup and some very thin copper wire
https://www.exploratorium.edu/snacks/cup-speaker

Girlguiding Cymru
The Coach House,
Broneirion,
Llandinam,
Powys SY17 5DE
Tel: 01686 688652

Email: waleshq@girlguidingcymru.org.uk
www.girlguidingcymru.org.uk
@GuidingCymru
www.facebook.com/GirlguidingCymruWales

Girlguiding Cymru is a registered charity, no. 521209

MAGMA
School of Engineering
Cardiff University
Newport Road
Cardiff CF24 3AA

Tel: +44 (0)29 2087 4411
Email: magma-project@cardiff.ac.uk
www.cardiff.ac.uk/engineering
Twitter: @CardiffUniMAGMA

Cardiff University - Registered charity no. 1136855

With thanks to our funders:-

This and project has received funding from the European Union's Horizon 2020 Research Innovatio programme under grant agreeme