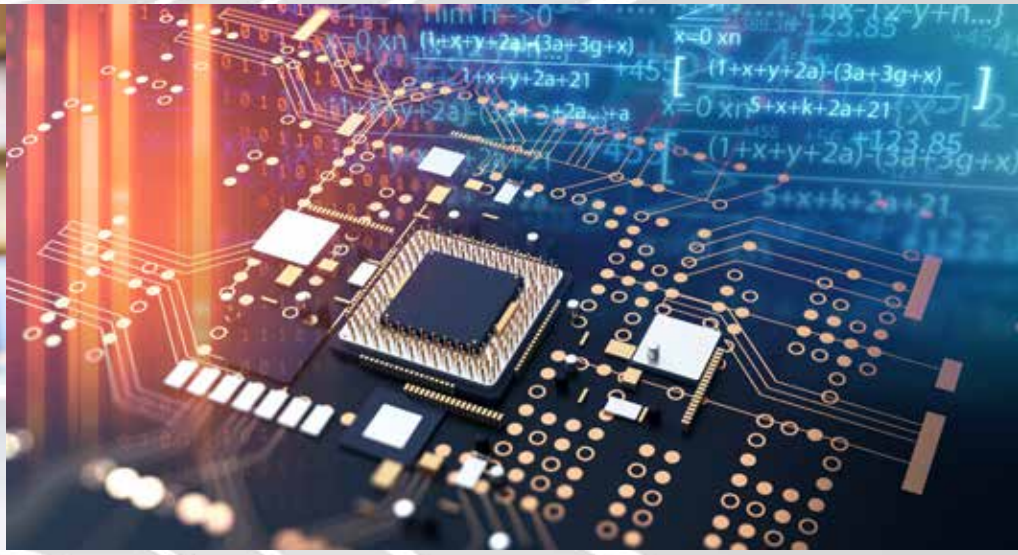
She Solves Challenge



Produced in conjunction with

BAE SYSTEMS

She Solves

Introduction

What is engineering?

Engineering surrounds us all in our day-to-day lives – even if we don't always realise it. Although it is a field that is often overlooked, without engineering the iconic pyramids, Stonehenge and even the International Space Station would not exist. There are also applications of engineering on a much smaller scale – from computer chips to medicines, building aircraft to designing bionic limbs. The activities in this book are designed to show some of the exciting and useful applications of engineering.

Women in engineering

In January 2016 the Women's Engineering Society (WES) revealed that approximately 29% of all research scientists and engineers in Singapore are female. This gender gap is apparent within the engineering industry worldwide.

Despite this gender gap, women from all over the world have achieved some of the greatest engineering feats of all time. Have a look within each section for more information on female engineers and their achievements.

How to achieve this badge

This booklet contains activities that are themed around different types of engineering. Each activity explains what engineering sector it relates to. In order to achieve the badge, you must complete:

- **Brownies** – Four activities
- **Guides and Young Adults** – Four Activities

You must then pick the activity that you have enjoyed the most and produce a poster explaining what this type of engineering is all about. Show your poster to an adult leader or young leader and describe what it means. You could include:

- An overall description of this type of engineering
- How this affects your day-to-day life
- Famous female engineers in this area
- Greatest achievements/challenges for this type of engineering
- Is this type of engineering project present in Singapore? If so, state how this engineering type has benefitted Singapore.

Leaders/teachers: At the end of each activity there is a ‚Guidance for leaders/ teachers' section. This gives extra information on how to deliver the activity, and how you can adapt it to make it easier/harder.

Balloon Towers - Civil Engineering

Equipment

- Plenty of long thin balloons and round balloons
- Sellotape

Method

In your group, build a tower as high as you can using only balloons and sellotape.
However, like any engineering project there are a number of constraints:

- Your tower must be completely freestanding (you cannot attach it to the floor or lean it against anything)
- Long thin balloons cost $10.00 each and small round balloons cost $5.00

You must try to build your tower with as little cost as possible. Once you have finished your tower, measure its height in cm and then subtract your total cost from this number. If you find your score is negative you have spent too much money on your tower!

Guidance for leaders/teachers

If the girls are finding this challenge too easy then you could split them into groups and get the groups to race against each other to complete their towers. The most economic tower can be declared the winner!

How this relates to engineering

Civil engineers are often pushed to design more complex and impressive buildings, but are limited by time and money, as well as safety constraints. Have a look at some of the following examples of civil engineering to get an idea of what this is all about:

- **Burj Khalifa** – the World's tallest building. Required special testing of materials to ensure it could withstand one hundred and sixty kilometre per hour winds. It stands at 829.8m tall.

- **The Great Wall of China** – over thirteen thousand miles long the mortar used to construct the Great Wall of China was actually made from sticky rice..

Earthquake Proof Buildings

Equipment

- Marshmallows
- Spaghetti (uncooked)
- 2 sheets of flat cardboard similar sizes
- 4 bouncy balls
- 2 large rubber bands (and spares)
- A piece of card

Estimated time: 20 minutes

Method

As a group, build a tower using marshmallows and spaghetti as high as possible. You are not limited on how much spaghetti or how many marshmallows you can use, however you must make your tower as 'earthquake-proof' as possible. You should then build a shake table in order to test your structure as follows:

1. Cut the two pieces of cardboard into two squares of the same size.

2. Place the bouncy balls in the four corners of one piece of cardboard, and then put the second piece of cardboard on top of these.

3. Attach the two pieces of cardboard together, with the bouncy balls between them, using the rubber bands.

You may wish to build your tower on a piece of card, or spare piece of cardboard so that it can be easily lifted onto the shake table when you come to test your tower. Once you're ready, you can put the tower onto the shake table and shake it as hard as you can! After thirty seconds stop and look at the damage. Do you think your building would have survived a real earthquake?

Guidance for leaders/teachers

If you have time to prepare beforehand, you could print off some images of building around the world which are built to withstand earthquakes. Encourage the girls to think about the design features which make a building more stable – for example using triangles in the design.

If you are delivering the activity to brownies, encourage them to think about how a tower becomes less stable as it becomes taller, and how they can keep their tall tower stable – for example a larger base. Get the girls to try different types of sweets and think about which work best. If the brownies are finding this too easy, you could build the shake table yourself and introduce the idea of an earthquake-proof building.

How this relates to engineering

Earthquakes can cause loss of life and many millions of pounds worth of damage. The waves of energy created by an earthquake can often cause walls to crack, foundations to move and occasionally building completely collapse.

One of the challenges faced by engineers today is to build more robust structures that can withstand earthquakes. Earthquake-proof buildings are designed to sway with the motion of the earthquake, instead of cracking and breaking under pressure. A number of design features they often include are the following:

- A cross-bracing within the structure that forms triangles (similar to a bridge)
- A large 'footprint' or base
- A tapered shape – the building gets smaller as it gets higher

Take a look at Quingdao Haiwan Bridge. Built by China in 2011, it became the longest bridge ever constructed at a massive 26.4 miles long! It is specially built to withstand earthquakes and typhoons, and took only 4 years to complete at a cost of roughly £5.5 billion.

Inspiring Female Engineers:

Marian R.Croak (PhD)

- Marian Croak is currently the Vice President of Reliability Engineering at Google, and previously worked for AT&T Laboratories.
- She joined AT&T Laboratories in 1982, where she began to develop technology to integrate voice and data communications –and she now holds over 100 patents in Voice and Information technology. This technology is used to transmit audio, such as people‘s voices, over the internet.
- Marian Croak also led the project to bring WiFi to India‘s railway system – a project which had to take account of engineering challenges such as extreme weather and high-density population areas.
- She led ‚Project Loon‘ – a project to bring internet connectivity to areas of the World which have either experienced natural disasters, or are in rural or remote locations that do not have the correct infrastructure for an internet connection.
- Project Loon provides internet connectivity by installing balloons approximately 20km above the Earth‘s surface – in a region of the Earth‘s atmosphere known as the ‚stratosphere‘, which situated on the edge of space. These balloons can withstand temperatures of as low as -80^{o}C, and are powered by solar panels.

Emily Roebling

- Emily Roebling was born in 1843 and was married to Washington Roebling – the chief engineer on the Brooklyn Bridge.
- Washington became the master bridge builder after his father, John Roebling died. In order to assist Washington, Emily began to study civil engineering and topics such as maths, strength of materials and cable construction.
- In 1872 Washington was left bedridden as a result of an illness he developed, and was unable to continue as chief engineer on the Brooklyn Bridge.
- Whilst Washington was ill, Emily took over the management of the construction of the Brooklyn Bridge, and effectively assumed the role of chief engineer.
- The Brooklyn Bridge was completed in 1883 and is one of the largest engineering projects in American history, and Emily Roebling is widely regarded as a civil engineer who was key to its success.

Egg Parachutes – Aeronautical Engineering

Equipment

- Card
- Paper
- String
- Scissors
- Sellotape
- Cocktail sticks
- Lollipop Sticks
- Straws
- Raw eggs
- Zip lock Bags
- Any other construction materials you may decide to use

Estimated time: 45 minutes

Method

Design and build a structure that can protect an egg form shattering when it is thrown in the air or dropped from a first story window. Wrap your egg in a zip lock bag before you build your structure around it, so that if the egg does break it will not cause a mess. You may wish to incorporate features such as:

- 'Crumple Zones'
- Energy Absorbing Structures
- Cushioning for the egg passenger

Guidance for leaders/teachers

Brownies may find this activity quite challenging, but encourage them to be creative and think about ways to keep the egg safe (if you're not comfortable using a raw egg then you could always hard-boil it). To make the activity easier for them you could always limit the number of materials you give them and suggest some ideas to them, for example a common idea is to make a parachute.

For older girls who need to be challenged more you could increase the height that you drop the egg from or give them a strict time-limit to build their structure.

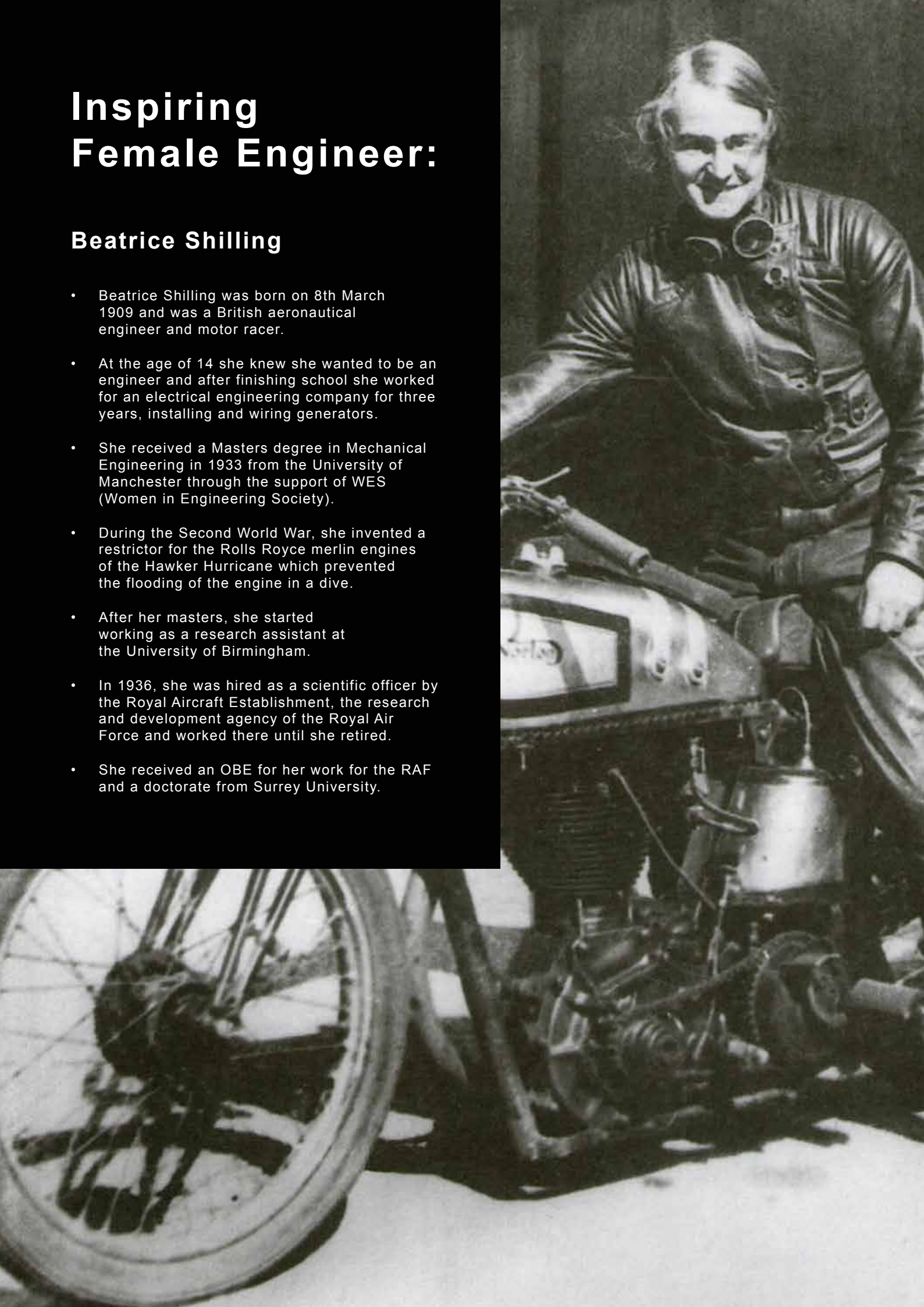
How this relates to engineering

Crumple zones and energy absorbing features are often designed by engineers for use in cars or similar. The idea of absorbing the energy from an impact or crash is important in preventing injuries and saving lives. There are also lots of engineering principles that contribute to the designs you may have created – for example you might have found it useful to use triangles in your design – this is because they are recognised as being a strong shape.

Inspiring Female Engineer:

Beatrice Shilling

- Beatrice Shilling was born on 8th March 1909 and was a British aeronautical engineer and motor racer.
- At the age of 14 she knew she wanted to be an engineer and after finishing school she worked for an electrical engineering company for three years, installing and wiring generators.
- She received a Masters degree in Mechanical Engineering in 1933 from the University of Manchester through the support of WES (Women in Engineering Society).
- During the Second World War, she invented a restrictor for the Rolls Royce merlin engines of the Hawker Hurricane which prevented the flooding of the engine in a dive.
- After her masters, she started working as a research assistant at the University of Birmingham.
- In 1936, she was hired as a scientific officer by the Royal Aircraft Establishment, the research and development agency of the Royal Air Force and worked there until she retired.
- She received an OBE for her work for the RAF and a doctorate from Surrey University.



Signalling Challenge – Phototonic Engineering

Equipment

- Two torches
- Two notepads
- Pens

Estimated time: 30 minutes

Method

Guides & Young Adults:

In your patrol, design a code that using only light flashes can be used to communicate short phrases and sentences. Once you have designed your code, split into two groups and each take a torch. Either in a dark room, or in a dark outside space, position your two groups so that they are within sight, however not close enough to hear each other or communicate in any other way. Take it in turns for one group to think of a word or phrase, and transmit it using the code to the other group. The other group must try to decipher the word and write down what they think it is. At the end of the activity, both groups should get together and compare their answers. Is there any way you could improve your code to make it more reliable? What challenges do you think those working with codes face?

Remember to ask your leader before you leave your meeting place.

Brownies:

In your group, find a quiet space where you can turn the lights off and hang a large sheet over the backs of some tables/chairs to create a screen. Next, set up a torch, or a few torches which point at the screen.

Using yourselves, or other props and toys create a story which you can tell using shadows. You could make your own shadow puppets by cutting card out into different shapes and sticking these shapes on lollipop sticks. At the end of the evening, perform your shadow puppet story to the other girls in your unit, or to your leader.

Guidance for leaders/teachers

If the girls are struggling for ideas for the code, you could suggest Morse code as a starting point. Ask them to think about how they think codes like this would be useful in times where mobile phones and computers weren‘t available.

When completing this activity with brownies, you can use the idea of shadow puppets to introduce the idea of light, and the absence of light. Get them to think about where their shadow comes from, and how it changes if they move the angle of the torch.

How this relates to engineering

Phototonics has many uses as well as coding. This branch of engineering first developed in the 1960s when the laser was invented and is crucial now in the development of fibre optics to transmit information. This provides the basis of the Internet today.

Inspiring Female Engineers:

Hedy Lemarr

- Hedy Lamarr was born on 9th November 1914 and was an Austrian and American film actress and inventor.
- During the Second World War, she developed a radio guidance system for the allied torpedoes which involved technology using frequencies to prevent the enemies from intercepting messages.
- The principles of her work are now used in modern Wi-Fi and Bluetooth technology systems.
- This work led her to be placed in the National Inventors Hall of Fame in 2014.

Ada Lovelace

- Ada Lovelace was born in 1815, and is generally recognised to be the first computer programmer ever (male or female).
- She worked with Charles Babbage on the analytical engine, and designed the first algorithm (a set of instructions that can be followed by a computer).
- As well as being a celebrated mathematician and computer scientist, Ada also shared in interest in poetry with her father, Lord Byron – a famous yet unstable poet at the time.
- Ada theorized that a computer could never achieve artificial intelligence – she believed that computers will always be limited by the instructions they are given. Alan Turing disagreed with Ada, theorizing that artificial intelligence is achievable. What do you think?

Programming a Computer – Software Engineering

Equipment

- A large piece of paper or lots of small pieces of paper attached together
- Pens
- A blindfold

Estimated time: 20 minutes

Method

Draw a maze onto the large piece of paper – make it as complicated or easy as you would like. Nominate on person from the group to be the ‘computer’. The computer wears the blindfold and starts at one end of the maze. The rest of the team must then direct her to the other side of the maze by telling her instructions.

Take turns for each member of the group to be the computer, and make the maze more difficult if you find it too easy.

Guidance for leaders/teachers

If you don‘t have any paper big enough to hand or the girls find this too easy you could get them to create an obstacle course out of items you have lying around. Alternatively, you could take them outside and get them to draw the maze onto the floor with chalks (make sure these will wash away easily).

How this relates to engineering

To carry out different tasks computers are programmed to follow specific sets of ‘instructions’. What happened in the task above if you gave your team member too many instructions at once, or weren’t clear enough in your instructions? Do you think this is similar to the way a computer gets ‘confused’ or slow if you try to carry out too many tasks on it at once?

Design a New Sport – Biomechanical Engineering

Equipment

- Pens
- Paper

Estimated time: 30 minutes

Method

You must invent a new, active sport that is suitable for someone with a disability. This can be an adaptation of an existing sport or it can be something entirely new. You should try to avoid using ideas that have not yet been invented – however imagine that you have an unlimited budget and build capability. Consider the following when designing your sport:

- What are the rules, scoring system and winning criteria?
- How is it specifically suited to those with a disability?
- Will players require any specialist equipment?
- Where will your sport be played?

Once you have finished designing your sport either explain its rules to your leader or have a go at playing it!

Guidance for leaders/teachers

Brownies may need for this activity to be a bit more hands-on to make sure they don‘t lose interest. Rather than coming up with an entirely new sport, you could think of a few adaptations to a game/sport they like to play and get them to try it out. For example, can they think of a way to play ‚Splat!‘ with their eyes closed?

How this relates to engineering

Biomechanical engineers study the way in which the human body functions, and use this understanding to design new technologies to improve day-to-day lives. This can commonly include the improvement of surgical practices and prosthetics, or improving quality of life for those with disabilities.

Inspiring Female Engineers:

Bonnie Dunbar

- Bonnie was born in Washington, US in 1949, and received a doctorate in biological/ mechanical engineering.
- She studied the effects of space flight on the human body, including bone strength and hormonal and metabolic activity.
- She later became a senior engineer with Rockwell International Space Division and developed thermal protection for the space shuttle.
- Following this, Bonnie accepted a position with NASA, and trained as an astronaut. She travelled to Space five times and studied the biomechanics of her fellow crew members, and how they adapted to space travel

Ruzena Bajcsy

- Ruzena Bajcsy was born in May 1933 and is a Professor of Electrical Engineering and Computer Science. In the 1970s she worked on developing new systems for robots that allowed them to explore their environments more effectively.
- She used the idea of ‚active perception' – programming robots to move their cameras and sensors to gather as much data about their surroundings as possible.
- Ruzena also helped to develop ‚elastic matching' – the ability for a computer to identify points on organs and body parts which are unique to individuals and spot any anomalies or problems. This has been used in medical science and was a big step to diagnosing patients more effectively.

One Minute Timer – Systems Engineering

Equipment

- Pen
- Paper
- Sand/Water
- Variety of different sized bottles and containers
- String
- Sticky tape
- Measuring jug/cup
- A Marble
- Card
- Pipe cleaners
- Lollipop sticks

Estimated time: 1 – 1 ½ hours

Method

Guides and Young Adults:

Using only the materials listed above design a system that is capable of timing one minute exactly. Use the pen and paper to create your design and then as a team build and test your timer. After your first test think about design changes you could make in order to make your timer more accurate. At the end of the evening get your leader to test your timer and see how accurate you managed to be. What problems did you face when building your timer and how did you overcome them?

Brownies:

Using household items and recycled materials design a marble run. Try to include as many interesting features as you can e.g. loops and see-saws! Make your marble run as long as you can in the time you have been given, and at the end of the session test your marble run to see if it works and how fast it is!

Guidance for leaders/teachers

If you are doing the activity with guides, encourage them to think about reproducibility – how do they know that when they do their final test they will get the same result in their previous tests?

If you are doing the activity with brownies, you could show them some incredible marble runs on the internet that people have created, to get them inspired.

Encourage the girls to be creative with this activity! Engineering is about innovation, and thinking of exciting new ideas. Sometimes ideas that seem crazy at the time are the ones that change the world!

How this relates to engineering

A big part of engineering is using science and maths to solve problems and make people‘s lives easier/ safer. Although as an engineer you might not be building one minute timers, a lot of your work would probably be spent finding solutions to problems and thinking of new ways to do things. You will often be limited by materials and cost and so must find a way to make the best of what you have.

Exploding Volcano – Chemical Engineering

Equipment

- Baking soda
- Vinegar
- Warm water
- Jug
- Deep baking tray (if inside)
- A 500ml plastic bottle
- Food colouring
- Newspaper
- PVA glue
- Washing-up liquid
- Paints

Estimated time: 1 ½ hours

Method

Remove the lid from the plastic bottle and put your bottle in a baking tray (if you are using one).You will then need to begin building up the body of your volcano around the plastic bottle, using papier mâché with the newspaper and glue. You might want to screw up newspaper to form the shape and then papier mâché over this. Once your papier mâché is dry (you may need to come back to this at a later meeting) you can paint the volcano.

Using the jug, pour the water into the bottle which is inside your volcano. Carefully add a squirt of vinegar and a squirt of washing up liquid into the bottle. If you would like the ‚lava' to be coloured you can add a few drops of food colouring at this point. When you are ready to erupt your volcano, add 2 teaspoons of bicarbonate of soda and step away quickly.

Variations:

If you are working in your patrol, you could build a number of volcanoes in your group. You could try the following combinations to see the effect of the water temperature and the washing up liquid:

1. Warm water and no washing up liquid
2. Cold water and no washing up liquid
3. Warm water and washing up liquid
4. Cold water in washing up liquid

How do you think that the temperature of the water and adding the washing up liquid affected the volcano? Which was the best volcano?

Guidance for leaders/teachers

If you are doing this activity with brownies, you might want to ask the girls to step back and add the bicarbonate of soda yourself. Bear in mind that you will need parts of two guide meetings to do this activity – one to papier mâché the volcano and then the other to actually erupt the volcano.

How this relates to engineering

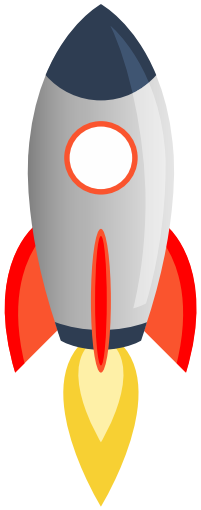
Biomechanical engineers study the way in which the human body functions, and use this understanding to design new technologies to improve day-to-day lives. This can commonly include the improvement of surgical practices and prosthetics, or improving quality of life for those with disabilities.

Inspiring Female Engineers:

Jacqueline Barton

- Jacqueline Barton is an American Chemist who was born in 1952 and raised in New York City.
- She studied at Columbia and earned her PhD in inorganic chemistry, then worked at Bell Labs and taught at Hunter College, City University of New York, before returning to Columbia as a Professor.
- During her career as an educator and researcher she has trained more than 100 graduate and postdoctoral students, about half of whom moved into academic positions.
- Jacqueline studies the chemical and physical properties of DNA and their roles in biological activities. She spent her time studying the electrical conductivity of DNA and was among the first to demonstrate this property. She has shown that certain DNA molecules do not conduct electricity and as damaged DNA can cause many kinds of cancer, she hopes that her discovery will one day help doctors detect damaged DNA before cancer results.
- Jacqueline received the National Medal of Science in 2010 from President Barack Obama and was elected to the National Academy of Sciences in 2002.

Slingshot Rockets – Astronautical Engineering



Equipment

- A straw
- A rubber band (and some spares)
- Paperclip
- Card
- Sticky Tape
- A lollipop stick/craft stick
- Scissors
- Small amount of modelling clay

Estimated time: 30 minutes

Method

The straw is going to form the body of your rocket, and the card will be used to create ‚fins' to attach to the straw. The first thing you need to do is decide on the size and shape of these fins, and cut them out of the card. Different sizes and shapes will cause your rocket to fly differently, so think carefully about your design!

Once you have cut out your fins, you can attach them to the straw using sticky tape. Next, take the paperclip, and bend the big end of the paperclip over (about a length of 1cm), so that it is at 90 degrees to the rest of the paperclip.

Hold the long section of the paperclip against the straw (at the opposite end to your fins) and use the sticky tape to secure it in place. Next shape the modelling clay into a small nose-cone and attach it to the end of the rocket with the paperclip.

Finally, to make the launcher, use the sticky tape to secure the elastic band to the top of the lollipop stick. The slingshot rocket is now ready to use! Simply hook the bent over section of the paperclip into the elastic band, pull pack on the rocket, and take aim and fire!

In your group you could try different designs of the rocket, such as differently sized or shaped fins or bigger/smaller nosecones to see which rocket flies the best!

Guidance for leaders/teachers

If you don't have any paper big enough to hand or the girls find this too easy you could get them to create an obstacle course out of items you have lying around. Alternatively, you could take them outside and get them to draw the maze onto the floor with chalks (make sure these will wash away easily).

How this relates to engineering

Astronautical engineers work on equipment that is specifically used outside of the earth's atmosphere, for example the design of the international space station, or the development of equipment used by astronauts.

Oil-Spill Clean-Up – Environmental Engineering

Equipment

- A large, deep tray
- Vegetable oil
- A medium sized rock
- Materials of your choice for the clean-up
- A stopwatch

Estimated time: 30 minutes

Method

In this activity, you will be seeing some of the problems that an oil-spill can cause and how tricky it can be to clean a spill up. Before beginning you should get together with your patrol and think of some ideas of how you might clean up your oil-spill and what materials/tools you might need to do this.

Once you are ready to start and have gathered your materials fill the tray approximately half full with water and place the rock in the centre of the water. Pour a small amount of oil into the water away from the rock and immediately start the stop-watch.

You now need to try to remove the oil from the water as quickly as possible, without causing further damage to the ‚habitat'. You cannot remove large portions of water and if the oil touches the rock (representing land) you should start again, as oil spills often cause the most damage when they reach land and beaches.

If you are stuck for ideas here are a few techniques you could try:

- Skimming the oil off the surface of the water
- Soaking the oil up
- Adding detergent to the water to break up the oil

After you have finished the activity think about the following questions:

- Which of the methods you tried do you think worked the best?
- What do you think the problems could be with doing this on a much larger scale?
- Do you think that any of the methods you tried could have caused more damage to wildlife and the ecosystem?
- Did any of the methods you used completely clear up the oil?

Guidance for leaders/teachers

Brownies might need a bit more help with this activity. You could provide a selection of materials at the start of the evening and discuss their ideas with them before they start.

How this relates to engineering

Oil spills can cause huge amounts of damage to wildlife and habitats, and this damage can last for many years. When oil enters water it sits on the surface and can spread out, often travelling towards land. If it reaches the land a lot of damage can be caused, killing animals and plants that live near to the coast.

One of the most difficult issues with an oil spill is how to clear the spill up – there is no easy method to remove the oil from the water without causing more damage. Environmental engineers work on problems such as this, designing solutions to environmental issues.

Inspiring Female Engineers:

Katherine Johnson

- Katherine Johnson was born on 26th August 1918 and is an African-American Mathematician whose calculations were critical in the success of the USA manned spaceflights.
- Katherine was enrolled directly into the second grade when she started school and by the age of 18, she graduated from West Virginia State College with degrees in both Mathematics and French.
- Katherine was the first black woman to be accepted into West Virginia University as part of the state's newly-integrated graduate school program, however, she had to drop out when she discovered that she was pregnant.
- Katherine started her career as a research Mathematician and went on to join NACA (superseded by NASA) in 1953 where she worked as a 'computer' completing complex manual calculations. Due to the state racial segregation laws in the USA at the time, Katherine was required to work and eat separately from her white peers, however, in 1958 NASA removed segregation and went onto use digital computers which Katherine helped with training employees to use them for calculations.
- Katherine's calculations enabled Astronaut John Glenn to complete three orbits of Earth in 1962 and she went onto play a significant role in producing calculations for the Space Shuttle Programme and helped with the plans for a mission to Mars.
- In 2015, president Barack Obama awarded Katherine the Presidential Medal of Freedom and in 2016 she was included as the main character in the film 'Hidden Figures' which detailed her life and work at NASA. More than 75 years after she dropped out of West Virginia University, she was awarded an honorary doctorate for her contribution to her field.

Susan Murcott

- Susan Murcott is an environmental engineer, with a particular focus on water and sanitation problems. It is estimated that almost one billion people worldwide don't have access to clean water – and as an environmental engineer Susan Murcott is working to change this.
- In 2005 Murcott was involved in setting up a non-profit company called Pure Home Water, to sell ceramic filters.
- These filters remove bacteria and dirt from water in order to make it safe to drink.
- Pure Home water has set up a factory in Northern Ghana, to produce and sell these filters. They cost around $10 each, and so far 16,000 filters have been sold. This could have provided clean water to up to 100,000 people

Mini Activities – Materials Engineering

Try two of the mini-activities below to complete this clause on materials engineering.

Build your own Lava Lamp

Equipment

- A clear jar or glass
- Vegetable oil

Estimated time: 15 minutes

Method

Fill the jar/glass about 2/3 full with water. Add a few drops of the food colouring to this water to give your lava lamp some colour. Next, fill the cup up almost to the top with vegetable oil. You should see that the oil sits on top of the water. Finally, add a teaspoon of salt on top of the vegetable oil, and watch your lava lamp work! When the lava lamp stops working, you can add more salt on top of the oil to start the process again.

- How do you think the lava lamp works?
- What do you think the salt does?
- Could you use other things instead of salt?

Does an orange float?

Equipment

- A deep container that you can fill with water
- An orange

Estimated time: 5 minutes

Method

Fill the container with water and place the orange on the surface of the water. Does the orange sink or float? Next take the orange out of the water and peel it, then place it back on the surface of the water. Does the orange sink or float now?

Did peeling the orange make any difference to the result?

Why do you think this was the case?

Mini Activities – Materials Engineering (cont.)

Make your own slime

Equipment

- A large plastic container
- Cornflour
- Water
- A spoon for mixing the ingredients

Estimated time: 15 minutes

Method

Put one cup full of cornflour in the plastic container and add half a cup full of water to it. Mix this up using the spoon – you could also add a few drops of food colouring to change the colour of your slime.

Try mixing the slime quickly and slowly – does this change the slime?

If you squeeze the slime hard in your hand is this different to letting it run through your fingers?

Why do you think the slime behaves differently?

Guidance for leaders/teachers

Try to encourage the girls to think of their own explanations as to why these materials act the way that they do. Ask them about how they think materials with these properties could be useful. The explanations for why each material acts the way it does are below:

- **Lava Lamp:** The oil and the water do not mix, so the oil will form a layer on the surface of the water. When you add the salt, the salt will dissolve in the water and sink to the bottom, carrying droplets of oil with it. When the salt is completely dissolved the oil will float to the surface again, giving the ‚lava lamp' effect.
- **Floating Orange:** The peel of the orange contains small air pockets, which allow it to float. When the peel is removed these air pockets are gone and the orange is denser than water so it will sink.
- **Slime:** When the cornflour and the water are mixed together, particles of cornflour are suspended in the water. They are packed very closely together, but when you stir the mixture slowly they can move past each other. If you put a sudden strain onto the mix, however, the water will move away but the cornflour particles stay still, because they don't have time to move past each other. This means that it seems like a solid

How this relates to engineering

Material engineers research, design and develop new materials to create new technologies and products. A materials engineer studies the different properties of materials and the different ways that they behave. As a materials engineer you could work in all sorts of different roles, from cutting edge medical research to sports, designing carbon limb replacements for people with disabilities.

Inspiring Female Engineers:

Stephanie Kwolek

- Stephanie Kwolek was born in 1923 in Pennsylvania. When she was 23 years old she graduated with a degree in Chemistry.
- After nine years working as a research chemist she made a huge breakthrough, with the discovery of Kevlar. She was initially trying to find a material to be used in car tyres – but Kevlar turned out to be so much more than that.
- Kevlar is strong but also lightweight, which makes it the perfect material for protective clothing, such as bulletproof vests.
- Today, Kevlar has all sorts of applications, but its use in body armour is arguably the most important. Countless lives have been saved all as a result of the discovery that Stephanie Kwolek made.

Stephanie Lacour

- Stephanie Lacour is a research project manager based at Cambridge University.
- Before this, she was a researcher at Princeton University, where she developed semiconductors which are able to stretch. Semiconductors are small electronic devices, and this was a breakthrough in research to create „electronic skin“.
- There are hopes that her research could help create implants which surgeons can use to repair nerve damage, for example if someone was paralysed.
- There are also hopes that these semi-conductors could be used to create a skin which could cover prosthetic limbs. This skin could be connected to the person‘s nerves, allowing them to feel the limb again.

Build a Mechanical Hand – Biomechanical Engineering

Equipment

- A piece of cardboard (one each) around the size of an A4 piece of paper
- 5 straws each
- Scissors
- String
- Stickytape

Estimated time: 30 minutes

Method

Using the materials above you are going to design a simple mechanical hand, which works in a similar way to your own hand. Firstly, place your hand on the piece of cardboard and draw around it. Then use the scissors to cut out the shape you have drawn. Looking at your own hand, decide where you think the fingers should bend and draw lines where you think these bends should be. You should expect to draw three lines on each finger and two lines on the thumb.

Using the scissors, score along each of the lines you have drawn to allow the paper to fold. Lay a straw along each of the fingers of the cardboard hand and cut the straw into sections which will fit between the score lines. Also cut a larger section of straw which runs from the bottom of the finger to the wrist.

Once you are happy with the size and position of the straws you can use sticky tape to stick them to the cardboard hand. Finally, cut five pieces of string which are about twice as long as your hand. Using one piece of string for each finger, thread the string through the straws on the finger. Tape the top of the piece of string to the top of the finger, to stop it from pulling through.

Once all of the pieces of string are threaded through the straws, you can tie all of the pieces of string together near to the wrist.

Your mechanical hand is now complete! Try pulling on the string to make the fingers bend.

What do you think the straws represent?

What do you think the strings represent?

What problems would there be if one of the straws or the pieces of string broke? What do you think this would mean if it happened in real-life to someone‘s hand?

Guidance for leaders/teachers

If you think this activity might be too difficult for your brownies, you could adapt the activity slightly. Instead of the strings, you could print out a diagram of the bones and tendons in a hand. Get them to cut out the shape of their hand from cardboard and draw on the bones and tendons, then decorate the hand as they like. Talk to them about what the bones and tendons do, and how we are able to move our hands.

How this relates to engineering

Biomechanical engineering is all about understanding systems within the body, and applying an understanding of mechanical engineering to these systems. For example, understanding how the hand works, and the engineering principles behind tendons, bones and skin allows biomechanical engineers to help figure out solutions when things go wrong.

Cipher Wheel – Cyber Security Engineering

Equipment

Brownies:

- Decoder print-out
- Coded message print-out
- A-Z alphabet printed on A4 sheets of paper
- Lemon Juice
- White Paper
- Paint Brush
- Small Pot (to hold lemon juice)
- Heat source (e.g. lightbulb/radiator)

Guides:

- Printed cipher wheel template
- Split Pins
- Coded message print-out
- Blue tack
- Paper
- Pens

Young Adults:

- Printer cipher wheel template
- Split pins
- Paper
- Pens
- Coded message print-out

Estimated time: 1.5 – 2 hour

Method

Brownies (Instructions for leaders/teachers):

1. Before the activity, cut out the coded message letters. Hide the letters around the meeting place. Display the ‚decoder' and ‚coded message' in a visible place in the meeting room.

2. When the girls arrive, get them to search the meeting place and find the hidden letters – there should be enough for each girl to have at least one letter.

3. As a group, use the decoder to translate the coded message. E.g. If the first number on the code is ‚18', encourage the girls to look at the decoder and realise that this number corresponds to an ‚R'. Find a girl which has an ‚R' and place this letter underneath the 18. Continue in this way until the entire message is translated.

4. Once you have finished the group activity, explain to the girls that they're now going to have a go at coding their own names. Give each of the girls a pen, paper and a copy of the decoder.

5. Get the girls to write their names using the decoder to translate from letters to numbers – they may find it easier to write their names out in letters then write the numbers underneath.

6. Explain to the girls that coding is a way to hide a message, to keep the message secret. There are other ways to do this – for example by using invisible ink.

7. Get the girls to write their names in the code, on a piece of paper using the lemon juice and paint brushes.

8. One at a time, let help the girls to hold their message close to (not touching) a heat source, and watch as their message appears.

(Continued over)

Cipher Wheel – Cyber Security Engineering (cont.)

Method

Guides (Instructions for Guides):

1. Divide into small groups. Each group will need one of the coded message print-outs, and each of you will need three coding wheels – one of each size, a split pin and a small piece of blue tack.

2. Assemble each coding wheel by placing the largest wheel on a flat surface, then the smaller wheel on top of it. Pin them together through the centre of the wheels using the split pin.

3. The outer circle of this coding wheel represents the coded letters – and the inner wheel is the de-coded letters. These wheels can be used to code and decode messages – however first both the person sending and receiving the messages need to know how the wheels should be lined up. To do this, we use a ‚crib', which tells you which three letters should line up. All of the messages below are coded using the crib ‚NI'. To set-up your cipher wheel, make sure that the ‚N' on the outer wheel is lined up with the ‚I' on the inner wheel. Once you have correctly aligned the wheels use blue-tack to hold them in place.

4. As a group, use the aligned cipher wheel to decode the messages provided. Look at the letter you wish to decode on the outer wheel, and then look at the inner wheel to find out what the decoded letter is.

5. Once you have decoded your message have a go at choosing your own crib, and sending coded messages to each other. You could do this as a group, in pairs or individually.

Young Adults (Instructions for Young Adults):

1. Follow steps 1 – 4 of the guide activity listed above.

2. Imagine you have intercepted a secret message which you wish to read. You don't know what the crib is, but you need to figure out a way to decode the message. The message reads:

PGDUZS // FTQ // RUDEF // IADXP // IMD //, SUDXSGUPQE // IQDQ // QZFDGEFQP // ME // GZPQDOAHQD // EBUQE // FA // OMDDK // OAZRUPQZFUMX //, OAPQP // YQEEMSQE //. MF // RUDEF //, FTUE // FMEW // IME // SUHQZ // FA // FTQ // NAK // EOAGFE //, NGF // UF // EAAZ // NQOMYQ // MBBMDQZF // FTMF // FTQK // IQDQ // FAA // NAUEFQDAGE // MZP // FMXWMFUHQ // RAD // FTQ // FMEW

3. Try to figure out a method to decode the message. If you're struggling, here are a few hints:

- The most common letter in the English language is ‚E'
- Hint: Focus on two-letter words like ‚FA' and ‚UF' to figure out the crib!
- Cheat: Answer is at the bottom of the page if you get really stuck

(Continued over)

During the First World War, Girlguides were entrusted as undercover spies to carry confidential, coded messages. At first, this task was given to the boy scouts, but it soon became apparent that they were too boisterous and talkative for the task.

Cipher Wheel – Cyber Security Engineering (cont.)

Guidance for leaders/teachers

The instructions for the Brownies activity are aimed at the leaders/teachers, whereas the instructions for the Guides and the Young Adults are aimed at the girls themselves. Therefore, print out the instructions for the Guides and Young Adults and hand them out if you'd like them to do the activities themselves.

The decoded passage for the Young Adults is written at the bottom of the page that it is on, just in case the girls get stuck!

How this relates to engineering

Cyber Security Engineers undertake many different tasks in their job. They are problem solvers, and use their problem solving skills to develop secure network solutions, protect against threats and manage security technology. This task is a basic step in understanding decryption and coded messages. This task helps to form a basic understanding of how letters and numbers can be used interchangeably in many ways to encrypt, store and transfer data.

Brownies coded message

3 25 2 5 18 // 19 5 3 21 18 9 20 25 // 5 14 7 9 14 5 5 18 19 // 8 5 12 16 // 20 15 // 11 5 5 16 // 21 19 // 19 1 6 5 // 15 14 // 20 8 5 // 9 14 20 5 18 14 5 20!

Guides coded message

1. **RFWNJ // HZWNJ // BFX // YMJ // KNWXY // UJWXTS // JAJW // YT // BNS // YBT // STGJQ // UWNEX**

2. **FQNHJ // UJWWD // BFX // YMJ // KNWXY // BTRFS // YT // LWFIZFYJ // BNYM // F // IJLWJJ // NS // JSLNSJJWNSL // NS // YMJ // PF // - NS 1906!**

Brownies: Cyber security engineers help to keep us safe on the internet!

Guides:

1. Marie Curie was the first person ever to win two Nobel prizes, and created the theory of radioactivity
2. Alice Perry was the first woman to graduate with a degree in engineering in Great Britain, in 1906

Inspiring Female Engineer:

Kira Radinsky

Kira Radinsky is a coding specialist, who developed a new type of predictive software. The predicted software uses algorithms that search the internet for information, and then use this information to predict future World events e.g. riots or diseases. In 2012, her software predicted the first Cholera outbreak that had occurred in Cuba in 130 years – months in advance. She now works as the director of data science at eBay.

Binary Activities – Cyber Security Engineering

Brownies: Binary Necklaces

Equipment

- Thread (you can use ribbon or string too)
- 16 beads – 2 packs of different colours
- Piece of paper
- 2 different coloured pens

Estimated time: 15-20 minutes

Method

In the diagram below, the black boxes represent 0s and the white boxes represent 1s (on and off signals). Each letter below has its own sequence of on and off signals within the binary alphabet.

Letter	Pattern
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	
M	

Letter	Pattern
N	
O	
P	
Q	
R	
S	
T	
U	
V	
W	
X	
Y	
Z	

On a piece of paper, write down your initials using the white and black boxes (binary code) above. For example, if your initials are LE then you will write it down as:

L	
E	

Binary Activities – Cyber Security Engineering (cont.)

- You will need 16 beads in order to create your necklace.
- Choose one coloured bead to place on top of the black boxes and another coloured bead to place on top of the white boxes that spell out your initials.
- Place your different coloured beads on top of the white and black boxes on your piece of paper that spell out your initials.
- With your leader‘s help, measure a piece of thread that fits your neck comfortably for a necklace and cut it leaving a little extra in order to tie knots at both ends.
- Tie a knot at one end of thread and then thread the beads onto your piece of thread in the correct order to spell out both letters of your initials.
- After you’ve threaded all of your beads, ask your leader to help you with tying both pieces of thread together whilst you’re wearing the necklace.

How this relates to engineering

Cyber Security Engineers undertake many different tasks in their job. They are problem solvers, and use their problem solving skills to develop secure network solutions, protect against threats and manage security technology. This task is a basic step in understanding decryption and coded messages. This task helps to form a basic understanding of how letters and numbers can be used interchangeably in many ways to encrypt, store and transfer data.

Inspiring Female Engineer:

Grace Murray Hopper

- Grace Hopper is often referred to as a ‘pioneer computer scientist’ who was known for creating COBOL (Common Business-Oriented Language) – the first computing language.
- She earned a PhD in Mathematics from Yale University, worked at the Havard University Computation Laboratory and went onto become a rear admiral in the Navy.
- In 1969, she was named ‘Computer Science Man of the Year’ by the Data Processing Management Association
- In 1991, she was the first woman to be awarded the National Medal of technology – the highest honour within engineering and technology in the United States.
- Throughout her life, she helped assemble computer compilers, systems which translate programming languages and codes. She spent her time trying to make programming more understandable to non-experts and as a result more businesses were able to utilise computer technology.

Binary Activities – Cyber Security Engineering (cont.)

Guides & Young Adults: Braille Alphabet

Equipment

- Scarf or material to be used as a blindfold
- 12 tennis balls
- Two muffin trays – 6 holes
- Paper
- Pens
- Stopwatch
- Braille alphabet diagram print-outs

Estimated time: 20 minutes

Method (instructions for the girls)

- Within your unit, split yourselves into two groups of equal size and decide which team is team one and which is team two. Make sure you sit away from the other team so they can't see your paper.
- Within your teams, think of a word that you want to spell out using braille. Write down this word a piece of paper and make sure to keep this word out of sight from the other team.
- Make sure that your muffin tray is the correct way up with 2 holes across and 3 holes down.
- Using the braille alphabet diagram to spell out the first letter of your word by placing the tennis balls in the correct holes.
- When both teams have spelt out their first letter using the tennis balls, nominate one person from team one to take the tray into the middle of the room, ensuring that the tray is the right way up for team two to feel.
- Nominate one person from team two to be blindfolded and taken into the middle of the room where the tray is. The blindfolded person needs to feel the tennis balls in the tray and memorise the order they are laid out in.
- The blindfolded person then needs to be taken back to their team and they need to describe the pattern to the group and use the braille alphabet diagram in order to determine which letter they think the other team was spelling out.
- Now it's the other team's turn to have a go, nominate one person from team two to take the tray into the middle of the room, ensuring the tray is the right way up for team one to feel.
- Nominate one person from team one to be blindfolded and taken into the middle of the room where the tray is. The blindfolded person needs to feel the tennis balls in the tray and memorise the order they are laid out in.
- The blindfolded person then needs to be taken back to their team and they need to describe the pattern to the group and use the braille alphabet diagram in order to determine which letter they think the other team was spelling out.
- This process needs to be repeated for both teams until both of the words have been spelled out.
- After this round, you could try to spell more difficult words using letters from the braille alphabet that require more tennis balls to be used each time. If you want to make it even harder then you could put a time limit on how long each person is allowed to feel the tennis balls on the tray. By using more complicating letters or by reducing the time allowed, it will be more difficult for the person on the other team to memorise the layout of the tennis balls.

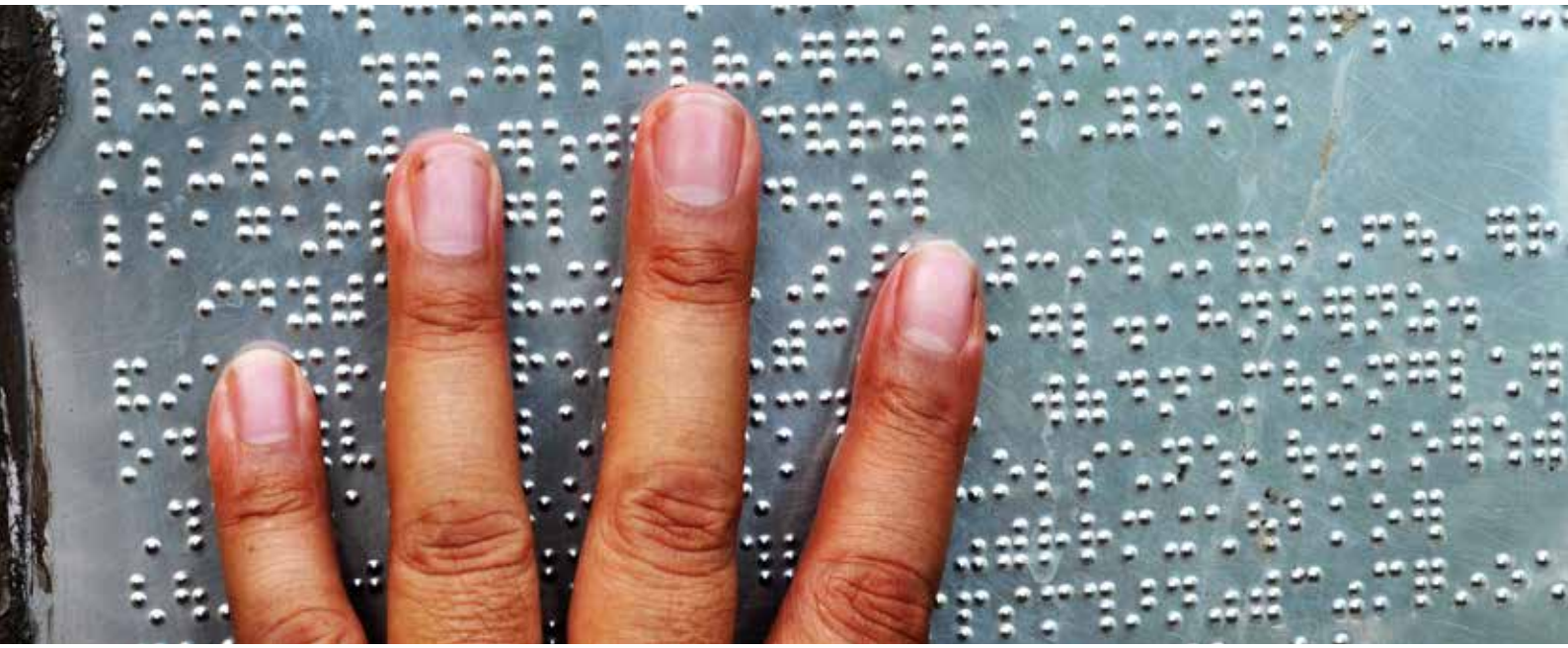
Binary Activities – Cyber Security Engineering (cont.)

How this relates to engineering

Computers are used to store and view data; they process data by using electrical signals which are either on or off. All of the data that needs to be processed by a computer must be converted into binary format; it's a language which the computers can understand.

Binary code represents text, computer instructions or any other data using a two-symbol system (1s and 0s). The binary code assigns a pattern of binary digits, also known as bits, to each instruction.

Braille is a type of binary code that is widely used by blind people to read and write by touch, named for its creator, Louis Braille. This system consists of grids of six dots each, three per column, in which each dot has two states: raised or not raised which is similar to how binary code works for computers by being in an on or off state.



Guidance for leaders/teachers

In order to support your Brownies with the binary necklaces, you could print off a piece of paper with 2 rows of 8 boxes so that the girls can colour in the boxes that should be black to fit with their initials. By doing this, it will help the girls to be able to place their beads on top of the black and white boxes so that they can thread their necklaces in the correct order.

In order to support your Guides and Young Adults with the braille alphabet challenge, you could help time both teams when they are blindfolded trying to feel the tennis balls to ensure that both teams get the same amount of time to determine the pattern for each letter.

Remember to print out the Braille alphabet for the girls for the braille challenge!

If-Then –
Cyber Security Engineering

Equipment

- No equipment needed

Estimated time: 20 minutes

Method

For each round, nominate one person in the group to be the ‚Programmer', and the rest of the group are Computers.

Round 1: The Programmer stands in front and commands the Computers: ‚If I [fill in blank] Then You [fill in blank]'. As an example, the Programmer says ‚If I sit down, Then You sit down'. The Computers copy the Programmer and sit down when the Programmer does. This stage gets across the basic concept of the If-Then statement used in computer programming.

Round 2: To make the activity a little more difficult, the Programmer gives the Computers a command such as ‚If I raise my left leg, Then You sit down'. This still keeps things simple in terms of the actual movement, but complicates the statement a little.

Round 3: The next adaption introduces the Else part of the If-Then statement. The Programmer could say ‚If I jump, Then You raise your left hand, Else sit down. This makes the group think a little more about the command and what they have to do. This stage can be used to explain the relevance to computer programming. In this round, if the Programmer doesn't raise their left hand (or do anything), the Computers should sit down.

Throughout the rounds, you could get the Computers to sit down if they get a command wrong and ‚break'.

All rounds can be repeated with different members of the group being the Programmer and getting to tell the others what to do.

Guidance for leaders/teachers

Brownies, Guides and Rangers should be able to handle all of the rounds. You could even add a While Loop in if you think they could handle it, where you could say something like ‚While I am sitting down: If I raise my hand, Then You sit down, Else raise your left leg'. So they should only follow the command if the Programmer if sitting down in the first place – if not, nothing in the rest of the statement should happen.

How this relates to engineering

In computer programming, the programmer has to give a set of instructions to the computer so that it can carry out a task. Once a piece of code has been written, it can run behind the scenes to make things happen (for example, there's code running in your computer every time you click a button – the code is written to tell the computer what to do when the button is clicked). This exercise introduces the very basic concept of computer programming and logic statements.

Inspiring Female Engineer:

Reshma Saujani

Reshma is an American lawyer and politician, and founded the tech organisation Girls Who Code in 2012. Girls Who Code is a non-profit organisation with the aim of increasing the number of women in computer science and changing perceptions of what a computer programmer looks like. The organisation is run through the academic year to teach high school girls computing skills, such as programming, robotics and web design.

Appendix 1 –
Brownies coded letters

C	Y	B	E	R	S
E	C	U	R	I	T
Y	E	N	G	I	N
E	E	R	S	H	E
L	P	T	O	K	E
E	P	U	S	S	A
F	E	O	N	T	H
E	I	N	T	E	R
N	E	T			

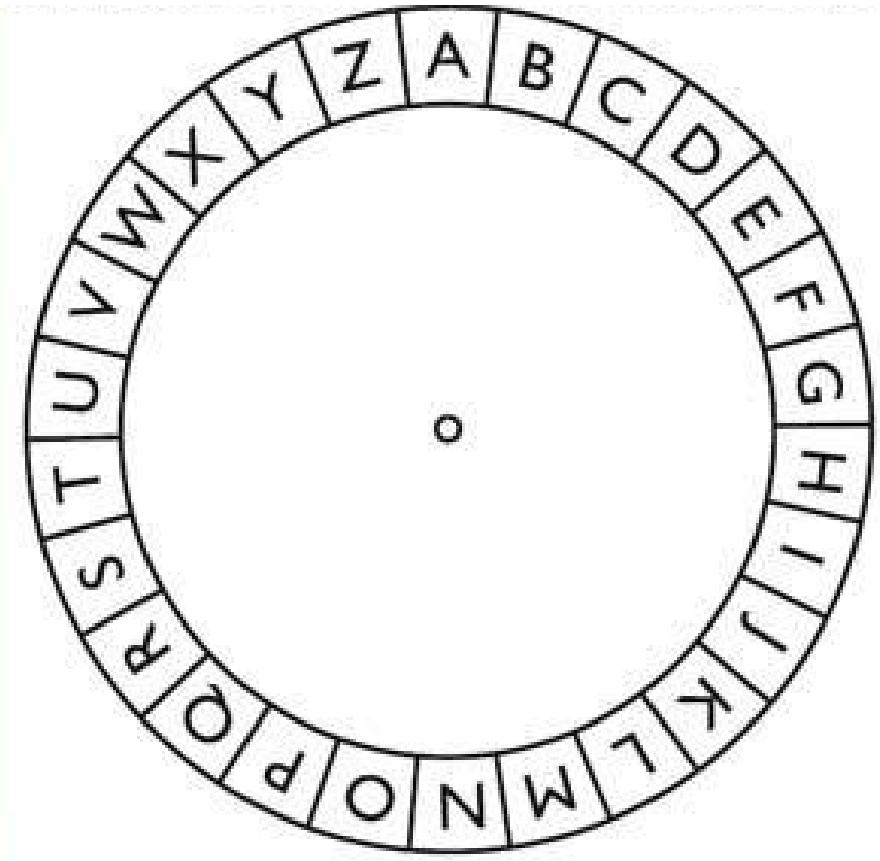
Appendix 2 –
Brownies decoder

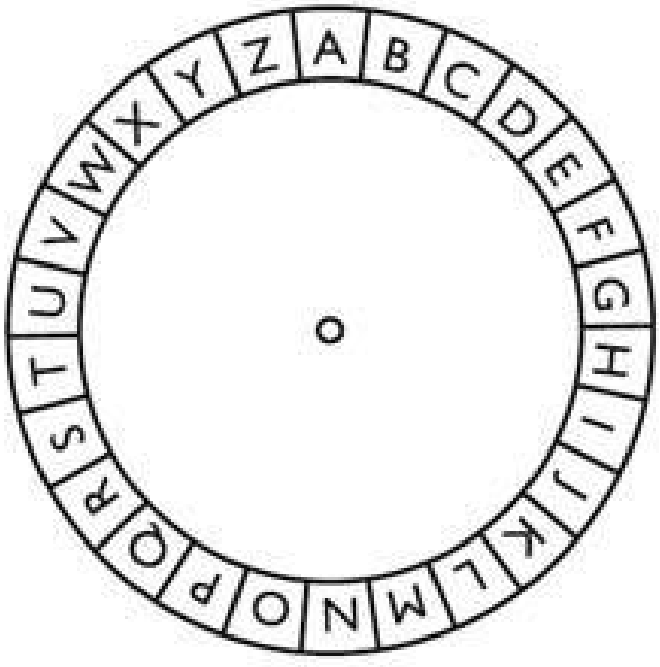
A	B	C	D	E	F	G	H	I
1	2	3	4	5	6	7	8	9

J	K	L	M	N	O	P	Q	R
10	11	12	13	14	15	16	17	18

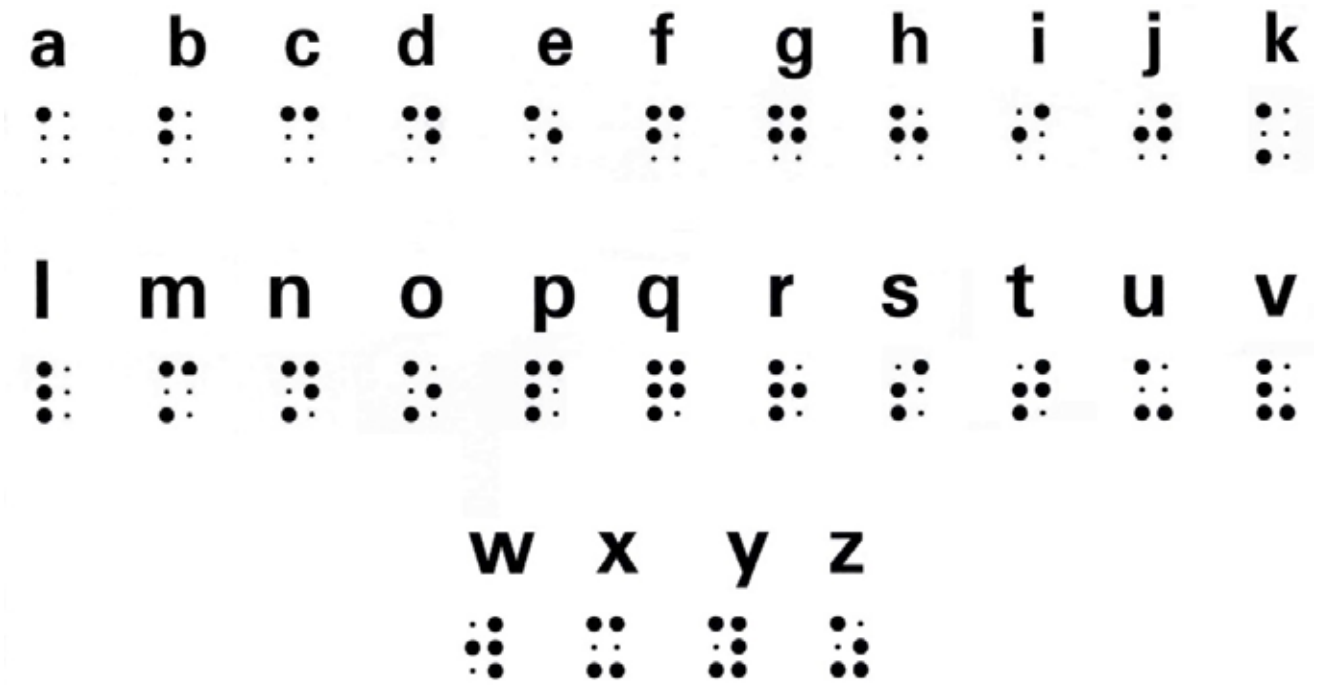
S	T	U	V	W	X	Y	Z
19	20	21	22	23	24	25	26

Appendix 3 – Guides/Young Adults cipher wheel print out





Appendix 4 – Braille alphabet



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