WE DISCOVER, WE GROW
Girlguiding
North West England

CLEVER COGS

Challenge

Contents

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 and aircraft to bionic limbs, to name a few. The activities in this challenge 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 only 9% of the engineering workforce in the UK is female.

Despite this clear 'gender gap', women have achieved some of the greatest engineering feats of all time. Throughout the challenge pack you will be able to find out much more about some of the most famous female engineers and their achievements.

How to Complete the Challenge

This challenge contains activities that are themed around different types of engineering. Each activity has a label at the top of the page to show which engineering sector it relates to.

The Clever Clogs challenge is suitable for all sections to take part in. You can choose to complete activities as a Six, Patrol, unit... or another grouping of your choice!

We have produced a key to help identify which activities are suitable for which section and how they fit in with the programme. We've also provided ideas on how to adapt the activities for our younger sections and how to take them further for older girls. You should also feel free to incorporate your own ideas and activities, if they are relevant to the challenge.

We recommend you spend a minimum of three meetings working on the challenge. Rainbows and Brownies should aim to complete 3 - 6 activities; Guides and The Senior Section 4 - 8.

You must then choose the activity that you have enjoyed the most and produce a poster explaining what this type of engineering is all about. This could include:

- An overall description of this type of engineering
- How this type of engineering affects your day-to-day life
- Famous female engineers in this area
- The greatest achievements and challenges for this type of engineering

Leaders: At the end of each activity there is a 'Guidance for Leaders' section. This gives extra information on how to deliver the activity, as well as details of how you can adapt it to make it easier or more challenging, as appropriate to the section you're supporting with the challenge.

Remember: You, our young members, should decide which activities you would like to do. Why not get everyone together for a Rainbow Chat, Brownie Pow Wow, Patrol Meeting, Senior Section planning meeting or just a simple discussion.

This is a fun badge, not a qualification, and a flexible approach is required. As long as you have taken a full and active part in the challenge, then you should receive your badge.

Produced in conjunction with:

BAE SYSTEMS
INSPIRED WORK

CLEVER COGS Challenge
Girlguiding North West England

BAE Systems is committed to promoting diversity in engineering and proud to sponsor the engineering challenge badge.

FAQs for Leaders

Other girls are going to join the unit and some of the current members will move on to the next section throughout the year. How do I plan around this?

Remember that this is a fun badge, not an interest badge, so a flexible approach is required. As long as each girl has taken a full and active part in the challenge, please ensure that she receives her badge.

Once we've completed the challenge, how do we get our badges?

Badges are £1.00 each and can be ordered via our region online shop **here**.

Why not try some of our top tips to make this challenge printer friendly:

- Print multiple pages to one sheet - make sure you can still read it though
- Set your printer to print double-sided for optimum paper economy
- Only print the pages and sections you need
- If you don't have access to a printer, you can contact Region HQ who will be able to print out the challenge pack and post it to you (printing and postage costs will apply)

Key

Rainbows	Brownies	Guides	The Senior Section
Look	a You	d Healthy Lifestyles	i Community Action
Learn	b Community	e Global Awareness	j Out of Doors
Laugh	c World	f Skills & Relationships	k Independent Living
Love		g Celebrating Diversity	l Creativity
		h Discovery	m Personal Values
			n Fit for Life
			o International
			p Leadership

Civil Engineering

Balloon Towers

Equipment:

- Long, thin balloons
- Round balloons
- Sticky tape

Estimated Time: 30 Minutes

Method:

Rainbows and Brownies
In your group, build a tower as high as you can using only balloons and sticky tape. Your tower needs to be able to stand up by itself. See how tall you can build your tower working as a team.

Guides and The Senior Section
In your group, build a tower using only balloons and sticky tape. Like all engineering projects, there are a number of constraints which you must consider:

- 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 centimetres 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 and should try again!

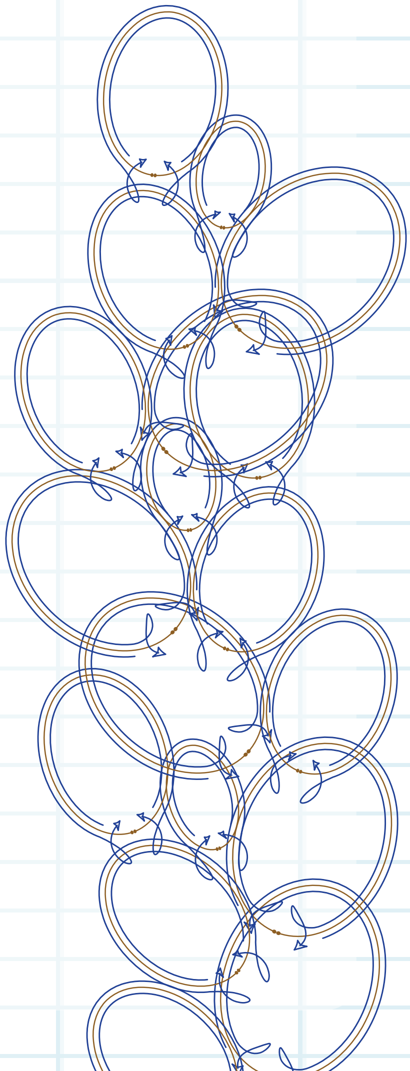
Guidance for Leaders:

If the girls are finding this challenge too easy, they could split into groups and race against each other to complete their towers. The most economic tower (or the tallest tower for Rainbows and Brownies) 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 the following examples of civil engineering to get an idea of what it 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 is over thirteen thousand miles long! The paste used to bind the stones to construct the Great Wall of China was actually made from 'sticky rice'.



Inspiring Female Engineer: Olive Dennis

- Olive Dennis was born in 1885 in Pennsylvania, US. She graduated from Cornell University with a degree in civil engineering but struggled to find work as an Engineer because of her gender.
- In 1920 Olive began work in the engineering department at Baltimore and Ohio Railroad. A year later she was promoted to 'Engineer of Service'. Her responsibility was to improve passenger service for the railroad.
- She invented and patented various devices such as air conditioning, dimmable lights and reclining seats.
- Olive became the first woman to be accepted as a member of the American Railway Engineering Association. She is recognised as having been a huge influence in the development of modern railway travel.

Civil Engineering

Earthquake Proof Buildings

Equipment:

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

Estimated Time: 20 Minutes

Method:

Rainbows and Brownies
In groups, build a tower using the spaghetti and marshmallows. Build the tower as tall as you can before it starts to fall over.

Guides and The Senior Section
As a group, build a tower as tall as possible using the spaghetti and marshmallows. You are not limited to how much spaghetti or how many marshmallows you can use, but 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 on the four corners of one piece of cardboard, and then place the second piece of cardboard on top of these.
3. Attach the two pieces of cardboard together, with the bouncy balls in between them, using the rubber bands.
4. Once you’re ready, place 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 tower would have survived a real earthquake?

Tip: You may wish to build your tower directly onto 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 it.

Guidance for Leaders:

If you have time to prepare beforehand, you could print off some images of buildings around the world which are built to withstand earthquakes. Encourage the girls to think about the design features which make buildings more stable; such as using triangles in the design.

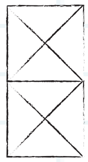
If you are supporting Rainbows or Brownies with this activity, encourage them to think about how a tower becomes less stable as it becomes taller, and how they can keep their tall tower stable; such as via the use of a larger base. If the girls are finding this too easy, you could build the shake table yourself and introduce them to the idea of an earthquake-proof building.

To make the activity more challenging for guides and senior section, set a minimum height for the tower e.g. 45cm.

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 buildings to 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:



- 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 Engineer: 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 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. Emily Roebling is widely regarded as a Civil Engineer who was key to its success.

Aeronautical Engineering

Egg Parachutes

Equipment:

- Card
- Paper
- String
- Scissors
- Sticky tape
- Cocktail sticks
- Lollipop sticks
- Straws
- Raw eggs
- Zip lock bags
- Any other construction materials you would like to use

Estimated Time: 45 Minutes

Method:

Design and build a structure that can encase an egg and protect it from shattering if it is thrown in the air or dropped from a first storey window. You may want to think about which materials will cushion the egg to stop it from breaking.

Tip: 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. Or, if you're not comfortable using a raw egg, you could always hard-boil it.

Guidance for Leaders:

Younger girls may find this activity quite challenging, but do encourage them to be creative and think about ways to keep the egg safe. To make the activity easier, you could always limit the number of materials you provide and suggest some ideas to them; such as making a parachute.

For older girls who need to be challenged more, you could suggest they increase the height from which the egg is dropped, or give them a strict time-limit in which to build their structure.

How this Relates to Engineering:

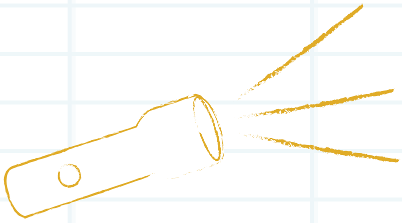
Crumple zones and energy absorbing features are often designed by Engineers for use in cars and other vehicles. The idea of absorbing the energy from an impact or crash is important in preventing injuries and saving lives. There are also lots of engineering principles that contribute to the designs you may have created; you might, for example, 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 in 1909 and was a British Aeronautical Engineer and Motor Racer.
- At the age of 14, Beatrice knew she wanted to be an Engineer and, after finishing school, worked for an electrical engineering company for three years, installing and wiring generators.
- She received a masters 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 aeroplanes, which prevented the flooding of the engine in the event of a dive.
- After completing her masters degree, Beatrice 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.

Phototonic Engineering

Signalling Challenge



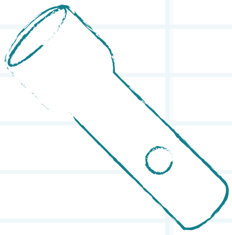
Equipment:

Rainbows and Brownies

- Torches (3 minimum)
- A large sheet
- Toys and other props

Guides and The Senior Section

- Two torches
- Two notepads
- Pens



Estimated Time: 30 Minutes

Method:

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

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 onto lollipop sticks.

At the end of the evening, perform your shadow puppet story to the other girls in your unit, or to your Leader, or parents/carers.

Remember: It is important to take care in your unit meeting place when the lights are dimmed. Take your seat and ask your Leader to turn off the lights.

Guides and The Senior Section
In your patrol or other grouping, design a code that can be used to communicate short phrases and sentences, using only light flashes.

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, but not close enough to hear each other or communicate in any other way.

Take it in turns for each group to think of a word or phrase, and transmit it to the other group using the code. 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: If you decide to use a dark outside space, ask your Leader before you leaving the meeting place.

Guidance for Leaders:

If the girls are struggling for ideas for the code, you could suggest Morse code as a starting point. Encourage them to think about how codes like this would have been useful in times where mobile phones and computers weren't available.

When completing this activity with Rainbows and Brownies, you could use the shadow puppets to introduce the idea of light, and the absence of light. Encourage 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, in addition to coding. This branch of engineering first developed in the 1960s when the laser was invented. It is now crucial in the development of fibre optics to transmit information, which provides the basis of the internet today.

In addition to this, there are lots of other applications for phototonic engineering, including:

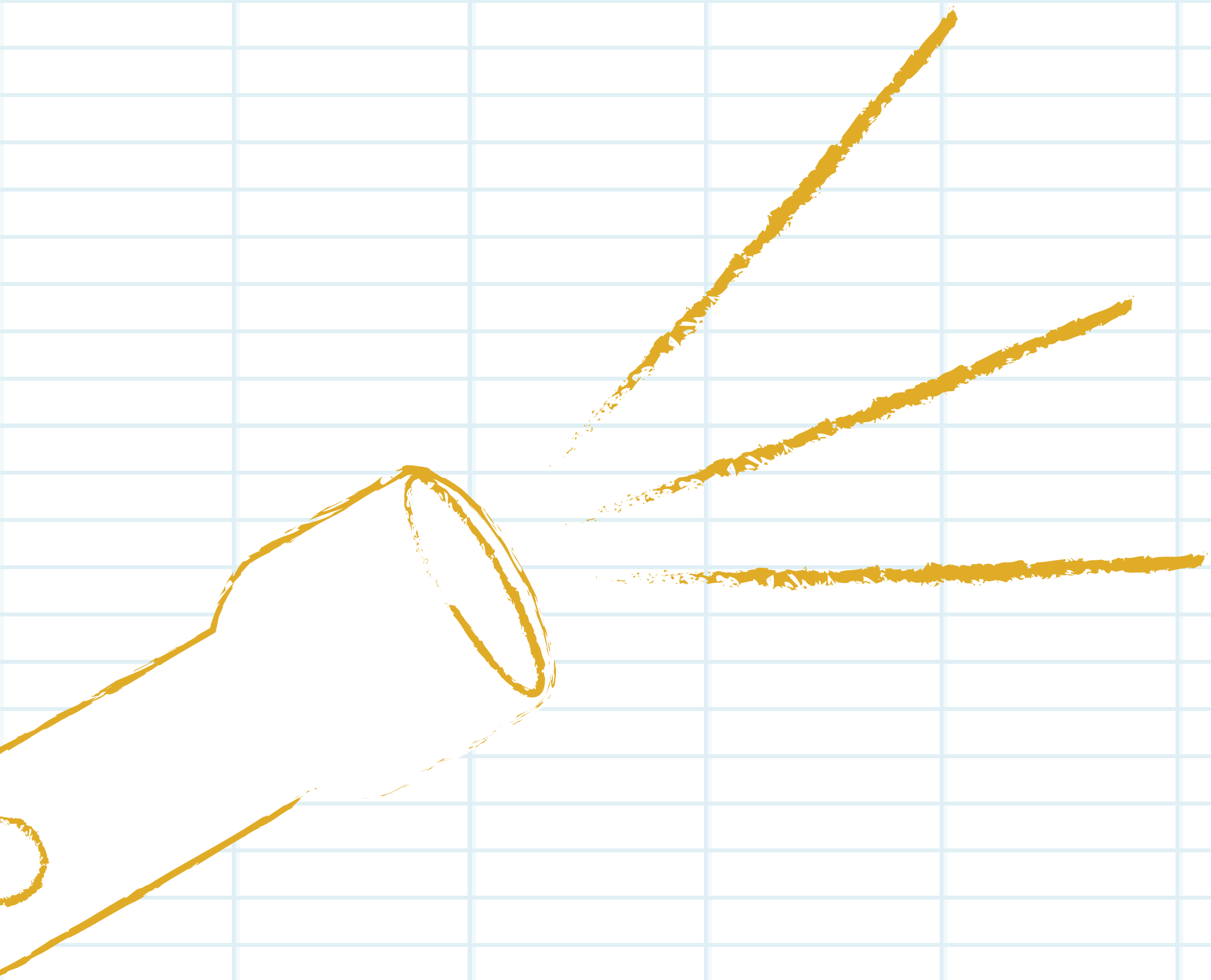
Medicine - for example in laser eye surgery or endoscopy

Phototonic Computing - Using light to link computers and control boards together and allow them to communicate.

Aeroplanes/Aviation - Developing phototonic gyroscopes which are used for navigation

Inspiring Female Engineer: Hedy Lamarr

- Hedy Lamarr was born in 1914 and was an Australian and American film Actress and Inventor.
- During the Second World War, she developed a radio guidance system for the allied torpedoes involving 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.



Programming a Computer

Equipment:

- Cones, masking tape or string
- A blindfold (or, you can use your neckers as blindfolds, if you have them)

Estimated Time: 20 Minutes

Method:

Using one of the materials above (cones, masking tape, string or something else), mark out a path on the floor to create a maze. Make the maze as complicated or easy as you would like, as appropriate to your section.

Nominate one person from your group to be the 'computer'. The 'computer' should stand at one end of the maze and then place the blindfold over her eyes. The rest of the team must then direct the 'computer' to the other side of the maze by giving 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:

If you are struggling to make a maze inside, you could take the group outside and suggest they draw the maze onto the floor using chalk.

Remember: Make sure these will wash away easily!

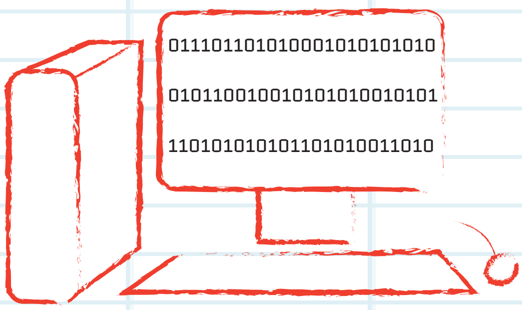
How this Relates to Engineering:

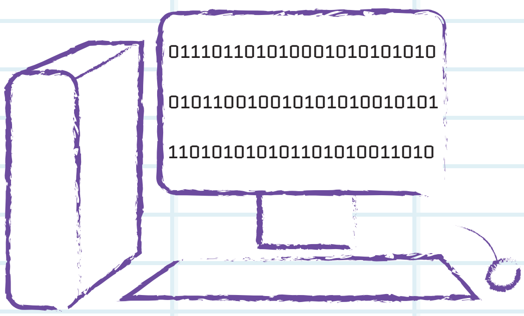
To carry out different tasks, computers are programmed to follow specific sets of 'instructions'.

What happened in the task above if you gave your 'computer' 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?

Inspiring Female Engineer: Ada Lovelace

- Ada Lovelace was born in 1815, and is generally recognised as the first ever computer programmer (male or female).
- Ada 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 an 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 would always be limited by the instructions they are given. Alan Turing disagreed with Ada, theorizing that artificial intelligence is achievable. What do you think?





Biomechanical Engineering

Design a New Sport

Equipment:

- Pens
- Paper

Estimated Time: 30 Minutes

Method:

You must invent a new, active sport that is suitable for someone with a disability. This could be an adaptation of an existing sport or something entirely new. You should try to avoid using ideas that have already been invented, but imagine that you have an unlimited budget and build capability.

You should consider the following things 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, explain its rules to your Leader or have a go at playing it!

Guidance for Leaders:

Rainbows and Brownies may need this activity to be a bit more 'hands-on'. Rather than coming up with an entirely new sport, they could think of a few adaptations to a game or sport they like to play and try them 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 Engineer: Bonnie Dunbar

- Bonnie Dunbar was born in Washington, US in 1949, and received a doctorate in biological and mechanical engineering.
- Bonnie 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.

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:

Rainbows and Brownies

Using household items and recycled materials, try designing 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!

Guides and The Senior Section

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?

Guidance for Leaders:

To support Rainbows and Brownies with their activity, you could show them some incredible marble runs on the internet, to get them inspired.

For the Guides and The Senior Section, you could encourage them to think about reproducibility - how do they know that, when they do their final test, they will get the same result as their previous tests?

Encourage the girls to be creative with these activities! 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:

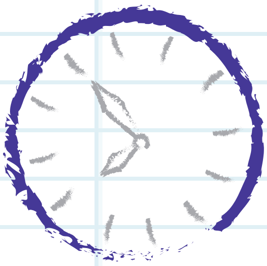
A big part of engineering is using science and maths to solve problems and make people's lives easier and safer. Although as an Engineer you might not be building one minute timers, a lot of your work would probably be spent finding solutions to problems and thinking of new ways to do things. You will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

Inspiring Female Engineer: Ruzena Bajcsy

- Ruzena Bajcsy was born in 1933 and is a Professor of Electrical Engineering and Computer Science.
- In the 1970s, Ruzena 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 to spot any anomalies or problems. This has been used in medical science and was a big step towards diagnosing patients more effectively.

1:00

60



60000

6e+7

6e+10

Exploding Volcano

Chemical Engineering

Equipment:

- Baking soda
- Vinegar
- Warm water
- Jug
- Deep baking tray to prevent spillage (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 place your bottle on to a baking tray (if you are using one). You can then begin building the body of your volcano around the plastic bottle, using papier mâché with the newspaper and glue. You might want to screw the newspaper up 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 forms the inside of 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. Or, Rainbows and Brownies, ask your Leader to add this while you stand back and watch.

Guides and The Senior Section:
If you are working in small groups, you could build a number of volcanoes. 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 and 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:

If you are supporting Rainbows and Brownies with this activity, you might want to ask the girls to step back and add the bicarbonate of soda yourself. Bear in mind that you will need two parts of a meeting to do this activity - one to papier mâché the volcano and an other to decorate/paint and erupt the volcano.

Why Does the Volcano Explode?
The vinegar used in the volcano is an acid, and the baking soda is an alkali. When these two are mixed together, a chemical reaction takes place very quickly. This chemical reaction produces carbon dioxide, which rises to the surface of the water in the same way as the bubbles in a fizzy drink. Using warmer water gives more energy to the reaction, so the lava is produced more quickly. The washing-up liquid helps to make the 'lava' foamy.

How this Relates to Engineering:

Chemical Engineers use raw materials and chemicals to create useful products, many of which we use on a daily basis. There can be a lot of challenges when creating materials on a large-scale, and Chemical Engineers work out processes to make these products. When you tried different mixtures of chemicals in your volcano to decide which mix gave the best eruption, you were actually refining a process, in the same way a Chemical Engineer might. As a Chemical Engineer, you might use these skills in water management, energy production, pharmaceutical development or food manufacturing.

Inspiring Female Engineer: Jacqueline Barton

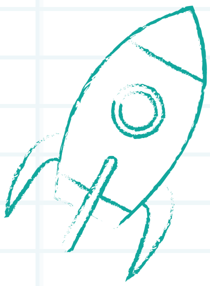
- Jacqueline Barton is an American Chemist who was born in 1952 and was raised in New York City.
- Jacqueline studied at Columbia University and earned her PhD in inorganic chemistry. She then worked at Bell Labs and taught at Hunter College, City University of New York, before returning to Columbia 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 forms.
- Jacqueline received the National Medal of Science in 2010 from President Barack Obama and was elected to the National Academy of Sciences in 2002.

Astronautical Engineering

Slingshot Rockets

Equipment:

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



Estimated Time: 30 minutes

Method:

Rainbows and Brownies
Using the straw and card, make your own rocket. First, cut off the bendy part of the straw so you are left only with the straight tube. This can then be used to form the body of your rocket. Cut the card into fins and attach these to one end of your straw, using sticky tape, as shown in the diagram.

Why not look at different types of rocket designs on the internet to get some inspiration for your rocket. Before making it, try thinking about how well your rocket would fly and what might help it to fly the furthest.

Guides and Senior Section
Use the straw to form the body of your rocket. Make sure you cut off the bendy part of the straw, so you are left only with a straight tube. The first thing you need to do is decide on the size and shape of the fins for your rocket. Cut the card into the "fins" and attach these to one end of the straw, using sticky tape, as shown in diagram 1. Different sizes and shapes will cause your rocket to fly differently, so think carefully about your design! Next, take the paperclip and pull the inside loop out so that it forms an elongated 's' shape, as shown in diagram 2. Then, bend the paperclip about 1cm from the top, 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, as shown in diagram 3. Finally, to make the launcher, use the sticky tape to secure the elastic band to the top of the lollipop stick, as shown in diagram 4.

The slingshot rocket is now ready to use! Simply hook the bent-over section of the paperclip into the elastic band and pull back on the rocket. Take aim and fire by letting go of the rocket and flicking the lollipop stick forward.

Tip: Rainbows and Brownies could just throw your rockets, rather than use the slingshot.

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!

Diagram 1

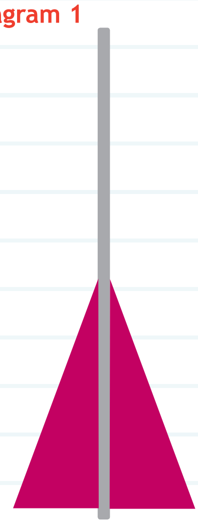


Diagram 2

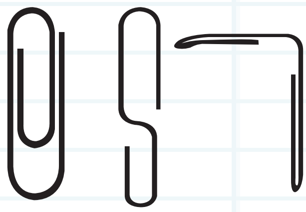


Diagram 3

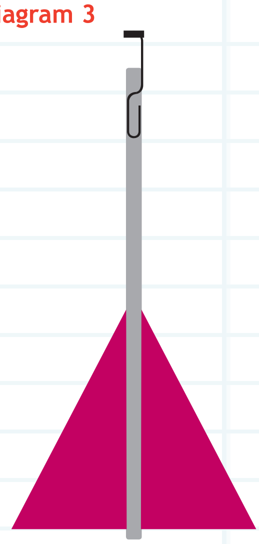


Diagram 5

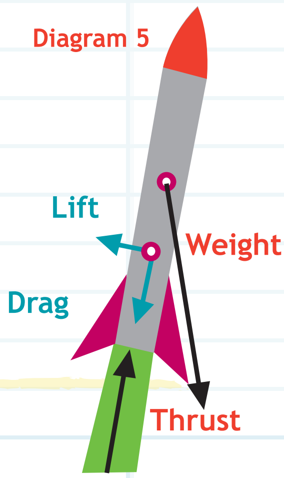
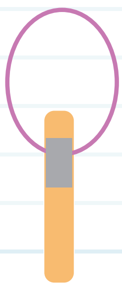


Diagram 4
Launcher



Guidance for Leaders:

Younger girls may find making the 'launcher' for the rocket challenging. If your Rainbows and Brownies really want to have a go at launching their rocket however, you might like to have a look at the method for 'Guides and The Senior Section' and try making the launcher yourself.

Encourage the girls to experiment with different sizes and shapes of rockets. Try cutting the straw to different lengths, changing the size of the nose cone or changing the size and shape of the fins. You could have a competition at the end of the activity to see which rocket flies the furthest and which is the most accurate.

Encourage the girls to think about the forces that act on a rocket according to Diagram 5:

Drag - A force which is going to slow the rocket down, as air particles are colliding with the nose of the rocket. Ensuring that the nose is 'streamlined' can help to reduce this.

Thrust - In a real rocket, this force is provided by the burning of fuel, however in this activity the force is provided by the slingshot. Pulling the elastic band back further will increase the thrust.

Weight - This is the force of the rockets mass, combined with gravity which is trying to pull the rocket back to the ground. Generally, the heavier the rocket is, the greater this force will be and the less likely your rocket is to be able to fly. Small amounts of weight however, for example the nose cone, can help the rocket to fly straight.

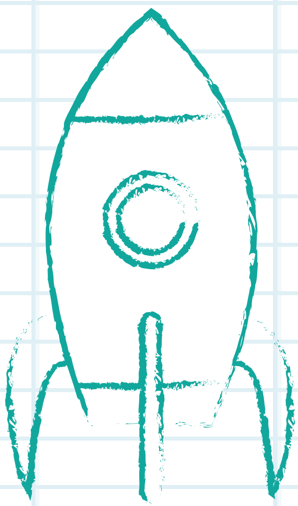
Lift - This force acts upwards against the rocket, helping to hold it in the air. This force is generated when a solid object moves through a gas. The bigger the lower surface area which is in contact with the air is, the greater the lift.

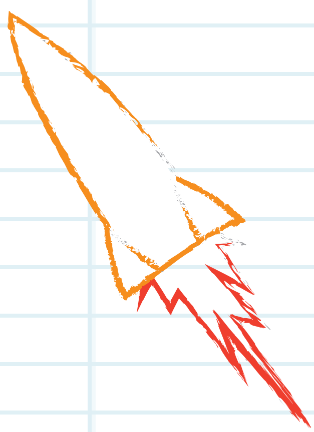
How this Relates to Engineering:

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.

Inspiring Female Engineer: Caroline Herschel

- Caroline Herschel was born in 1750 in Hannover, Germany, and moved to England with her brother William Herschel in 1772.
- Caroline became her brother's assistant and helped him by writing down his observations and assisting him in producing reflective telescopes.
- She studied astronomical theory and mastered algebra and formulae for calculation and conversion as a basis for observing the stars and managing astronomical distances.
- She was appointed a Royal Astronomer Assistant at the court at Windsor and worked alongside her brother. She received £50 for the year of work and this was the first salary that a woman had ever received for scientific work.
- Between 1786 and 1797 she discovered eight comets and fourteen nebulae (clouds of gas and dust in outer space).
- She was awarded the 1828 gold medal of the Royal Astronomical Society and, in 1846, at the age of 96, she was awarded the gold medal of the Prussian Academy of Sciences.

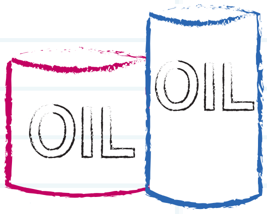




Oil-Spill Clean-Up

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:

Get together with your group and think of some ideas of how you might clean up an oil-spill and what materials and tools you might need in order to do this. Through discussion, you will identify some of the problems that an oil-spill can cause and how tricky it can be to clean up.

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; oil spills often cause the most damage when they reach land and beaches.

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

- Skimming the oil off the surface of the water
- Soaking up the oil
- 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 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:

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

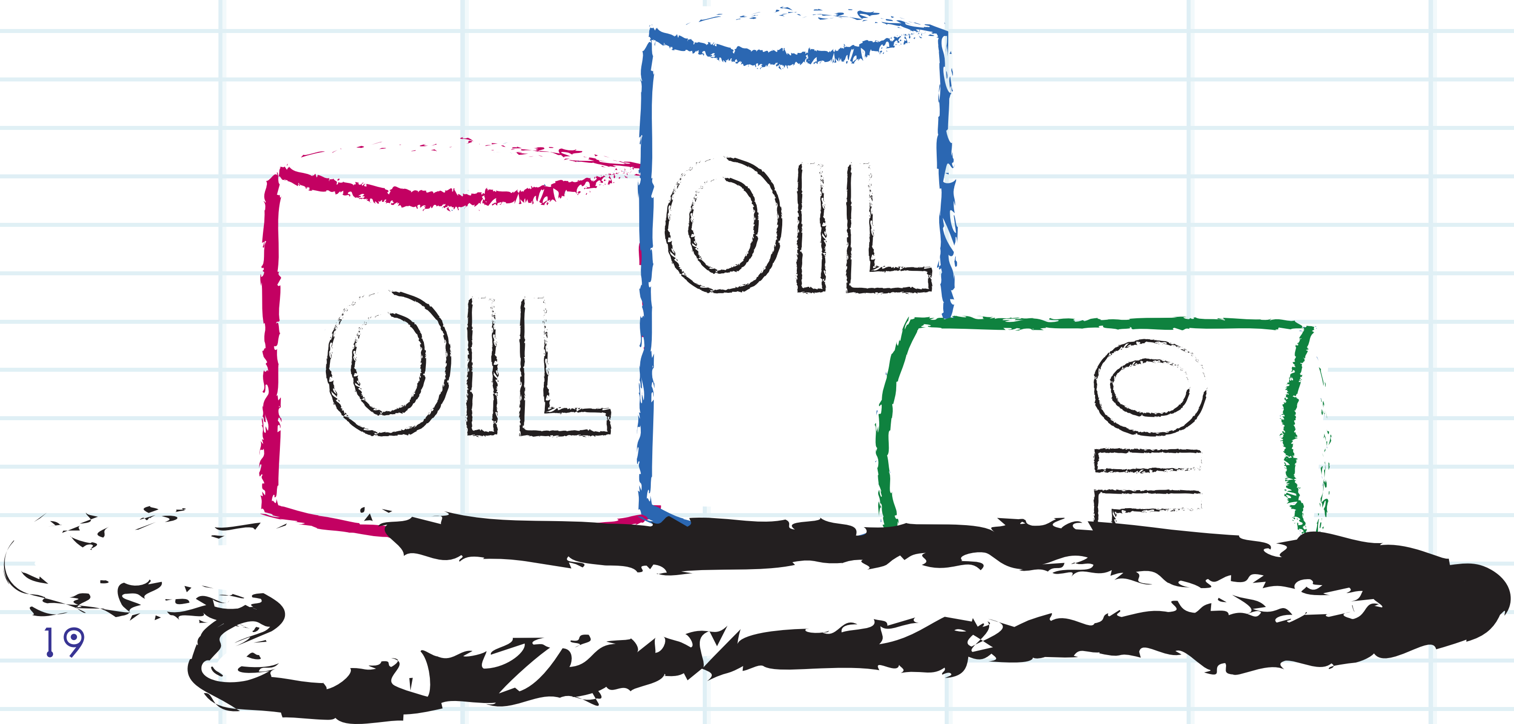
How this Relates to Engineering:

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 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 it up. There is no easy method to remove oil from water without causing more damage. Environmental Engineers work on problems such as this; designing solutions to environmental issues.

Inspiring Female Engineer: 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, Susan 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 for up to 100,000 people.

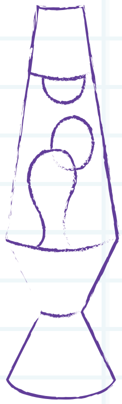


Materials Engineering

Mini Activities

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

Build your own Lava Lamp



Equipment:

- A clear jar or glass
- Vegetable oil
- Salt
- Food colouring

Estimated Time: 15 minutes

Method:

Fill the jar or glass about 2/3 full with water. Add a few drops of the food colouring to the water to give your lava lamp some colour. Next, fill the cup 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
- 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?

Guidance for Leaders:

Try to encourage the girls to think of their own explanations as to why these materials act the way 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: Oil and water do not mix, so the oil will form a layer on the surface of the water. When you add 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.

Make your own Slime

Equipment:

- A large plastic container
- Cornflour
- Water
- A spoon (for mixing the ingredients)
- Food colouring

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, then mix it 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:

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. Please find the explanation below as to how the materials in the slime work:

- 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 in which they behave. As a Materials Engineer, you could work in all sorts of different roles; from cutting edge medical research to designing carbon limb replacements for people with disabilities.

Inspiring Female Engineer: Stephanie Kwolek

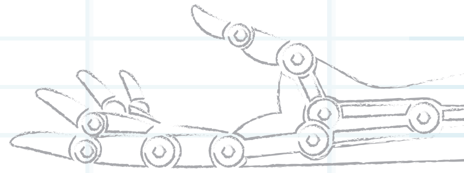
- Stephanie Kwolek was born in 1923 in Pennsylvania. When she was 23 years old she graduated with a degree in Chemistry.
- After nine years working as a Research Chemist, Stephanie made a huge breakthrough, with the discovery of Kevlar. She was initially trying to find a material to be used in car tyres, 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.

Build a Mechanical Hand

Biomechanical Engineering

Equipment:

- A piece of A4 cardboard
- 5 straws
- Scissors
- String
- Sticky tape



Estimated Time: 30 minutes

Method:

Using the materials above, design a simple mechanical hand, which works in a similar way to your own hand. You can use the diagram on the next page to help you with this. 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 cardboard 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. Then, cut a larger piece of straw to run from the bottom of each 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, from the top of each finger, down to the wrist. Tape the top of the piece of string to the top of each 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 pieces of string broke? What do you think this would mean if it happened in real-life to someone's hand?

Guidance for Leaders:

If you think this activity might be too difficult for Rainbows or 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. Help them to draw around their hand on cardboard and then carefully cut it out. Then, encourage them to draw on the bones and tendons and 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.

Inspiring Female Engineer: 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 could use to repair nerve damage, if someone was paralysed for example.
- 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.

Diagram