



WE DISCOVER, WE GROW

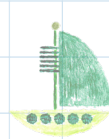
Girlguiding

North West England

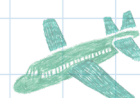
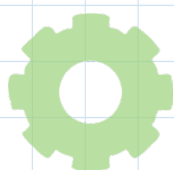
BAE SYSTEMS

CLEVER COGS CHALLENGE GOING PLACES

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Introduction

About this Challenge

This challenge is an extension of the popular Clever Cogs Engineering Challenge, and is themed around Transportation Engineering. Each activity will give you a taste of a different kind of engineering that you might find with the field of Transportation Engineering. Clever Cogs - Going Places has been designed to complement the 'Have Adventures' theme of the new programme. Each activity is based on a different method of transport, and you'll read about some incredible female explorers who have been somewhere amazing using these modes of transport along the way! As you complete the activities, think about how engineering has made these adventures possible, and what kind of adventures you could go on using these transport methods!

What is Transportation Engineering?

Transportation Engineering covers so many different things. It is when science is applied to the design, development, analysis, operation, and management of transportation systems for many different modes of transport e.g. roads, buses, air, rail, and marine. Transportation Engineering provides the capability for people and goods to move around the world safely.

Transportation Engineering is a sub-discipline of Civil Engineering; it focusses on a similar theme of designing and implementing infrastructure. It looks into forecasting future demand for travel, engineering traffic to make sure it provides the more effective solution, and ensuring roads are designed and laid out appropriately. It also includes designing airports and bridges - things that facilitate transportation.

Transportation Engineers solve complex problems by analysing data and using innovative solutions. Most Transportation Engineers would work in an office, but there's also some field work involved to visit construction sites and assess progress.

Women in Engineering

According to a survey done by the Women's Engineering Society (WES) in 2017, the percentage of female engineers within the UK has increased in recent years, and is currently 11.8%.

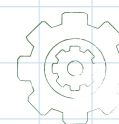
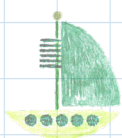
Despite this gender gap, women have achieved some of the greatest engineering feats of all time. Throughout this challenge, you will be able to find out much more about some really inspiring engineers, and also some adventurers!

Produced in conjunction with:

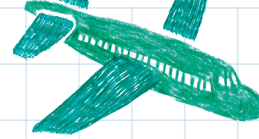
BAE SYSTEMS



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



FAQs



How to Complete this Challenge:

The Clever Cogs - Going Places 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 recommend you spend a minimum of two meetings working on the challenge. Rainbows and Brownies should aim to complete 3-4 activities; Guides and Rangers 5-6.

Leaders

At the end of each activity there is a 'Guidance for leaders' section, giving extra information on how to support delivery of 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, Rangers' planning meeting or just a simple discussion.

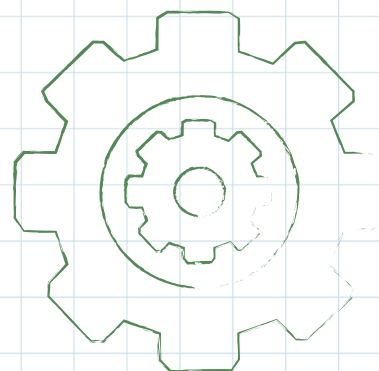
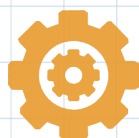
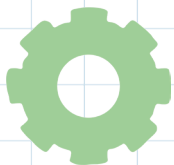
This is a fun badge, not a qualification, and a flexible approach is required. As long as you have taken a full and active part in the challenge, then you should receive the badge.

How to Order your Badges:

Badges are £1 each and can be ordered from the Girlguiding North West England shop. They can be purchased in store or online.

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 double-sided, for optimum paper economy
- Only print the pages and sections you need
- Print the challenge in black and white, to save on ink



Chocolate Bridges

Equipment:

- 13 x chocolate bars of your choice (preferably long and thin)
- Chopping board
- 2L empty milk carton
- Kettle
- Coins
- Weighing scales
- Cup (preferably paper)
- Funnel (Optional)
- Fridge

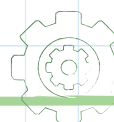
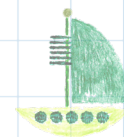
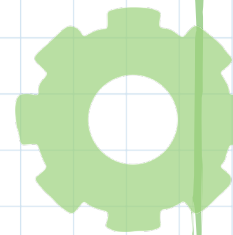
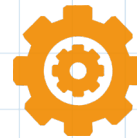
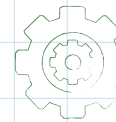
Estimated Time: 60 Minutes

Method:

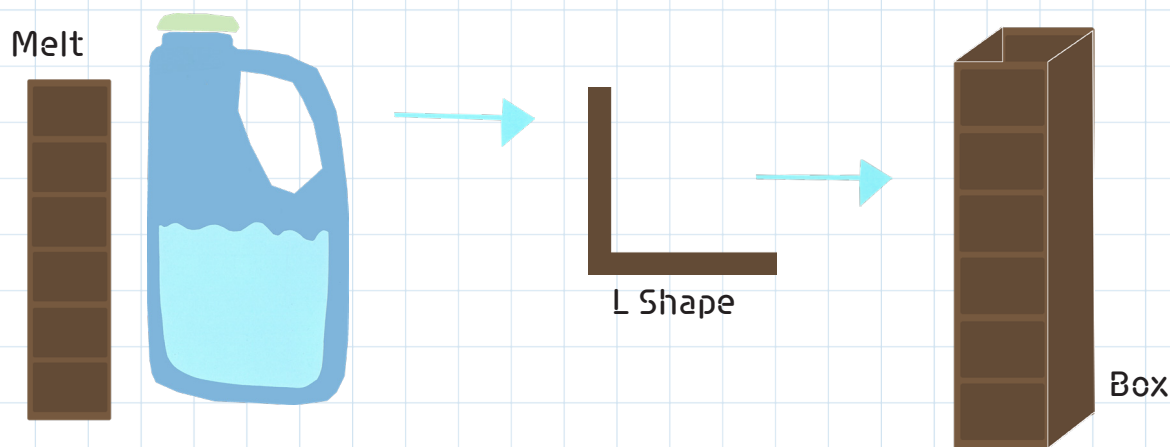
Caution: This activity includes pouring hot water from a kettle into an empty milk carton. For Rainbows and Brownies, this should be done by a leader. For Guides and Rangers, help and supervision should be given, as required.

To make your chocolate bridge you'll need to make 3 boxed structures; two of the boxed structures will form your supports and the third will form the main structure of the bridge.

1. To start making the first of your boxes, first boil the kettle and open up four of the chocolate bars.
2. Once the water is boiled, leave it for 5 minutes to cool. Then, carefully pour the water into the empty, 2L milk carton and screw the lid back on. Make sure the water has cooled slightly otherwise it may deform the milk carton.
3. Take two of your chocolate bars and hold the edges against the milk carton until the edges start to melt a little. Once they've melted, hold the two chocolate bars together at the right angle to form an L shape. The melted chocolate will act as the cement for the structure and will hold the sides of the chocolate together - you could also think of this process as welding with chocolate!
4. Repeat this process by melting the sides of the other two chocolate bars together to form another L shape.
5. As before, hold the free edges of both of the L-shaped structures onto the milk carton, until the edges begin to melt a little, and then hold them together to create the boxed structure. Try to line up the pieces of chocolate perfectly and ensure that the chocolate is welded along each side with no gaps - this will help to make your structure stronger.
6. Place the structure onto the chopping board and place it in the fridge to harden.
7. Repeat this process twice more until you have 3 boxed structures in the fridge.
8. Leave the boxes in the fridge for about 20 minutes.
9. Once the time is up, take the boxes out of the fridge. Place two of the boxes upright on the chopping board and now place a single bar of chocolate across the tops of the two upright structures.
10. You can test the strength of this structure by placing the paper cup on the middle of the bar crossing the two boxed structures and gradually adding coins into the cup. You will notice that the bar will break quite easily.



11. Next, replace the single bar with the third boxed structure and repeat the process; placing your cup in the centre of the third boxed structure and gradually adding coins into the cup. You will notice that the bar is much stronger and takes longer to break.
12. When the bridge collapses, where does it break? Does it break along the joints? Discuss why you think this bridge can take more weight than the single bar?
13. Have a read of the 'How this relates to Engineering' section to understand how this works.
14. Finally, enjoy eating it!



Guides and Rangers

Once your bridge collapses, you can weigh the coins using the scales which will give you the mass. To calculate the weight, you can times the mass by 9.81 (value for the acceleration due to gravity). This weight of the coins gives you the maximum force acting on the bridge when it collapses. If you took part in the activity in groups, you can compare the value with the other groups to see which team built the strongest bridge.

Why not take it further and try to make bridges out of different types of chocolate, to see which type of chocolate can support the greatest force.

How this relates to Engineering:

Bridges are made out of different types of materials and often the simplest ones are beams that span the distance of the bridge. Some bridges are made using a boxed structure, where the beam is a box shape instead of a single beam; this helps to make the beam much stiffer and hold more weight.

Welding is a way of heating pieces of metal using electricity or heat so that they melt and stick together. This makes the structures much stronger and is often used on bridges to weld together large pieces of metal to form the strongest bridge. In this challenge, the process of melting the edges of the chocolate bars and sticking them together is effectively welding with chocolate.

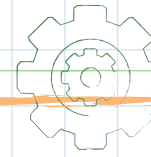
So, why is the box shaped beam stronger than the single bar beam? This is due to the box shaped beam being stiffer than the single beam, so the boxed beam deflects (bends) less under a force being placed upon it. This is like a ruler; it is much easier to bend the longer side of the ruler than it is the short one. The upright parts of the box structure are like bending the ruler on its side, making the whole structure stronger. If a beam deflects too much then it can break quite easily, and a single beam is not as strong so it can break under a smaller amount of force.

The strength of the bridge can also depend on the material used as some materials can be ductile and some can be brittle. Brittle beams will suddenly snap and you'll notice this will probably happen if you use milk or white chocolate. Some softer chocolates will cause the beam to deform slowly and in a ductile manner, so the collapse of the bridge will be much slower.



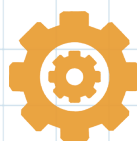
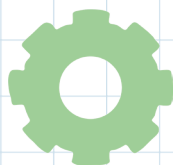
Guidance For Leaders:

This activity involves the pouring of boiling water which, for our Rainbows and Brownies, should only be done by a leader. In addition, before any of the girls (particularly Rainbows and Brownies) press the chocolate against the side of the milk carton. Please ensure that the water has cooled sufficiently so as to not cause burns.

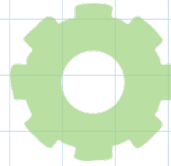


Inspiring Female Engineer: Sarah Guppy

- Sarah Guppy was born in 1770 and was an English engineer who was the first woman to patent a bridge in 1811.
- Sarah was also an inventor and patented a new method of constructing and erecting bridges and railroads without arches; a method using piling for the construction of a suspension bridge.
- Thomas Telford used Sarah's designs for his suspension bridges, including Conwy Suspension Bridge and the Menai Suspension Bridge. The Menai Suspension Bridge was the world's longest bridge at the time. Sarah offered Thomas the design from the license as she believed in knowledge sharing and open innovation.
- Sarah and her family held 10 patents and one of her last patents was for a device that improved the process of caulking ships (sealing the joints on the ships). Through this patent, she earned a contract with the Royal Navy which was worth £40,000 for the invention.
- Sarah went onto inventing a system for exercising whilst still in bed, as well as a breakfast machine that made tea, cooked eggs and, kept the plates warm.



Build-a-Boat



Equipment:

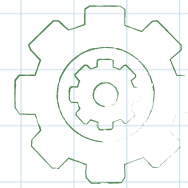
- A large paddling pool or pond, for the boat race
- A selection of materials, depending on which boats you choose to build (See Appendix A)

Estimated Time: 60 Minutes

Method:

In small groups, build a boat using one of the techniques found in Appendix A. Once you have finished building your boats, get together to hold a boat race!

- Which boat travelled furthest?
- Which boat travelled fastest?
- Which boat stayed true (i.e. didn't swerve or change direction)?



How this relates to Engineering:

Each of the boats in Appendix A uses different engineering principles to propel them through the water:

Paddle Boat: This uses energy known as 'elastic potential energy', which is stored in the elastic band when it is stretched and twisted. When the band is released, this energy changes to 'kinetic energy' - movement energy! This causes the band to twist; turning the paddles and propelling the boat.

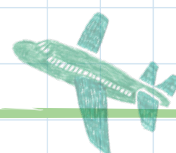
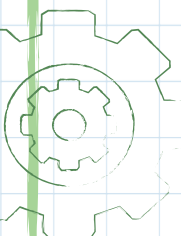
Bicarbonate of Soda and Vinegar Boat: This boat is powered by the chemical reaction between the two ingredients. Bicarbonate of soda contains sodium bicarbonate, and vinegar is an acid. When sodium bicarbonate is mixed with an acid, carbon dioxide gas (the same gas we breathe out!) is released from the sodium bicarbonate. The gas shoots out of the straw and propels the boat.

Balloon-Powered Boat: This boat uses a physics rule known as Newton's 3rd Law, which states that 'every action has an equal and opposite reaction'. When you release the balloon, it forces air through the straw and out into the water - this creates a force. In turn, the water produces an 'equal and opposite reaction' - the water pushes back on the boat causing it to move.

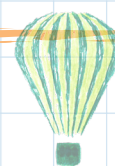
Straw-Powered Boat: When you blow through the straw onto the sail, the air from your straw exerts a force on the sail, pushing the boat forwards.

Guidance For Leaders:

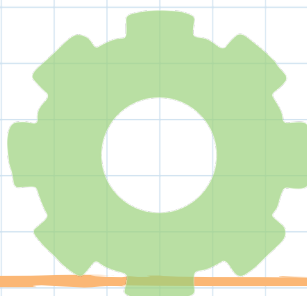
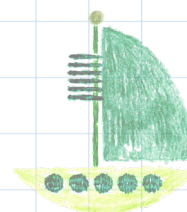
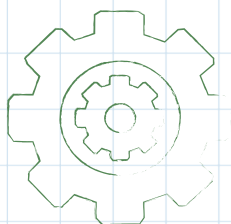
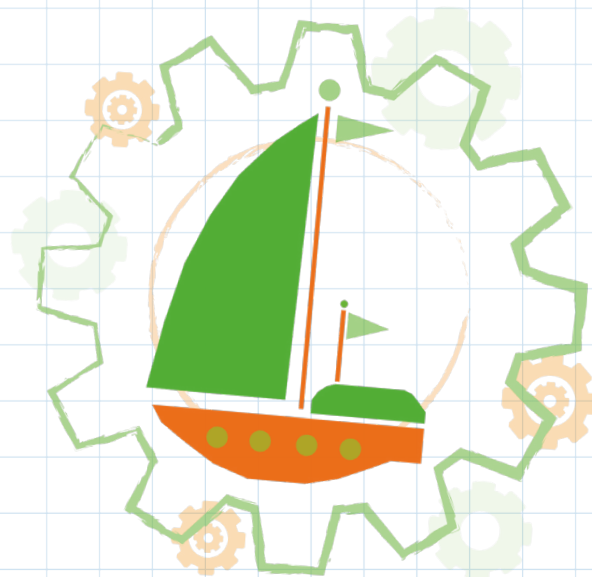
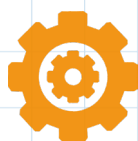
If you would like to make this activity more challenging, why not introduce new criteria for the competition, such as: 'which boat can hold the most weight?'. Use small weights, such as toy building bricks, to add weight to the boats. Which will sink first? You could also try racing the boats again, but with a small amount of weight added to each boat. How does this affect the movement of the boats?



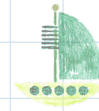
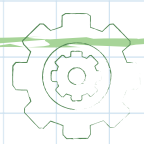
Inspiring Female Explorer: Dame Ellen McArthur



- In 2005, Dame Ellen McArthur broke the World Record, previously held by a man, for the fastest, single-handed circumnavigation of the globe.
- Dame Ellen completed the journey of over 50,600km in 71 days, 14 hours, 18 minutes and 33 seconds.
- Dame Ellen has since set up two charities, including the Ellen MacArthur Cancer Trust.



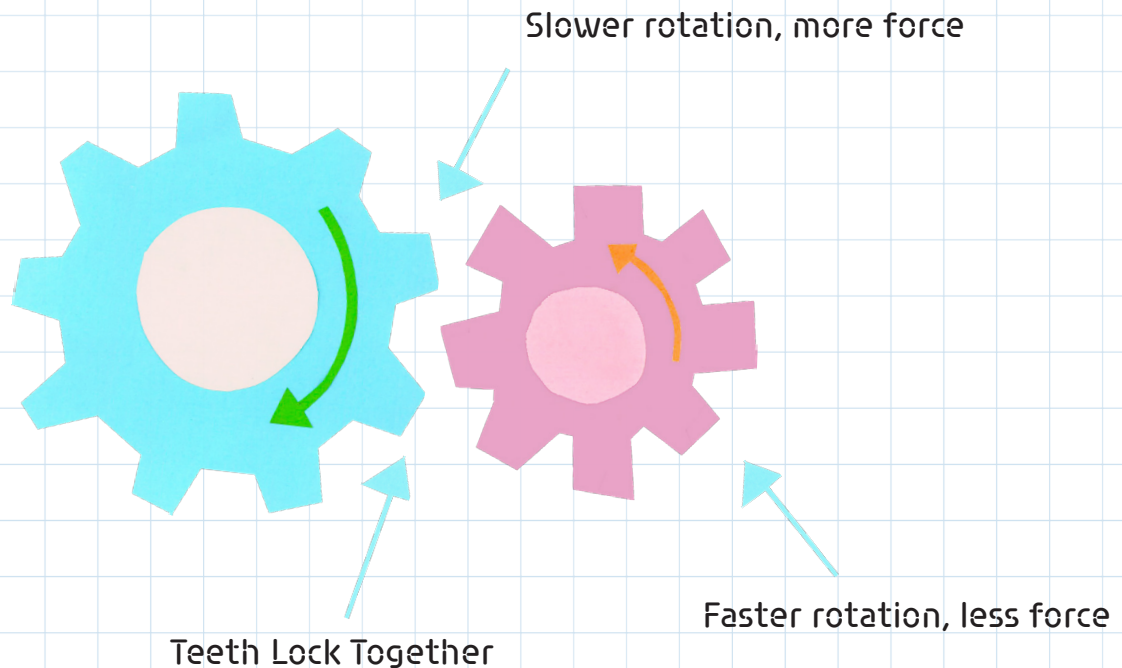
Bottle Cap Cogs



Gears are basically just wheels that have teeth. These teeth are able to slot together with the teeth of another gear. When you turn one gear, the gear next to it will turn as well. If you have different sizes of gears, you can generate more force when you turn them. A small gear will turn quickly, but with less force, and a large gear will turn slowly, but with lots of force. Therefore, you can link different size of gears together to turn small gears quickly and create lots of force by connecting with a large gear. Gears are used in bikes to allow you to pedal up hills more easily, and to go faster when on flat ground.

By the way!

When an object moves (or stops moving) in a circle due to a force being applied to it, this is called torque.



Equipment: (per gearbox)

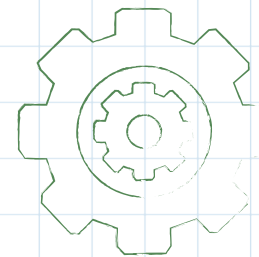
- 1 x cardboard box
- Assortment of sizes of plastic bottle lids
- Lollipop sticks, cut in half
- Scissors
- Low-temperature glue gun or sticky tape

Estimated Time: 45 minutes

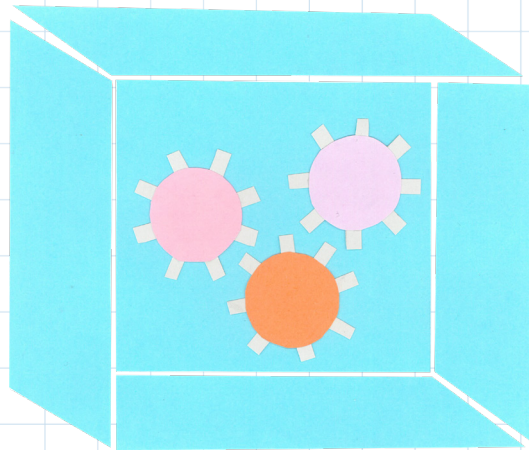
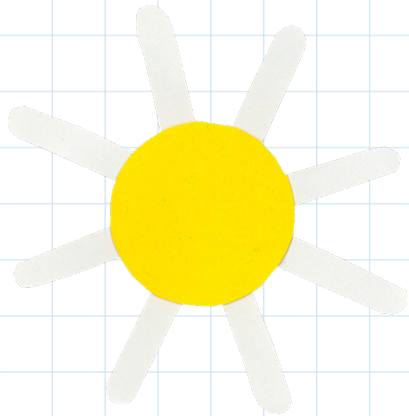
Method:

In your group, build a series of three gears using the materials you've been given.

1. Use the glue gun to glue the flat end of the lollipop sticks around the edges of three of the largest bottle caps. You should glue 8 lollipop sticks all around the outside of the bottle caps, as in the diagram shown below. Rainbows and Brownies, make sure that you ask for leader for help if using a glue gun, as it could get hot.
2. Cut the top half of the cardboard box off, so that you can easily reach the bottom of the box. Rainbows and Brownies, be sure to ask your leader for help with this.



3. Place the three bottle cap gears that you have made into the box and position them so that the lollipop stick spokes overlap with each other about halfway down.
4. Now, mark on the box where you have placed your gears and then remove them. Then, glue smaller bottle caps (ones that your gears can comfortably fit over), onto the positions you've marked on the cardboard box.
5. Next, place your gears on top of the bottle caps that are glued onto the box. They should now be able to spin freely without leaving their positions.
6. Can you think of where gears like this might be used?
7. Finally, see if you can fill in the blanks to label the parts of a bike (Appendix B).



How this relates to Engineering:

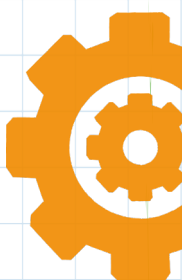
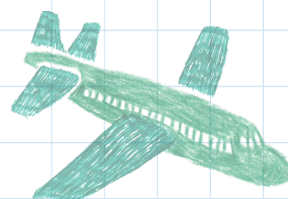
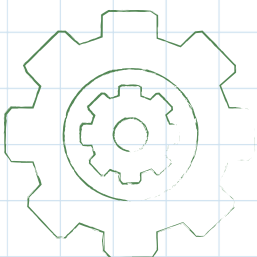
Gears are used in so many things that you will come across in your day-to-day life. They are in cars, bikes, boats, clocks and scales, to name a few!

When gears work together, they are called a transmission, or a gearbox. Transmission mechanics form a part of mechanical engineering, where engineers design and test gears to make things like bikes and cars.

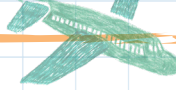
Did you know that Big Ben has huge gears inside of it to make it tick? In a clock, the gears are usually called 'cogs'. Each clock hand is attached to its own cog, so that when one cog turns, it pushes the one next to it to move too. Due to the different sizes of the cogs, the clock hands turn at different speeds. What a Clever Cog!

Guidance For Leaders:

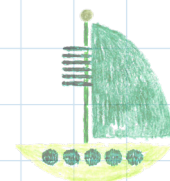
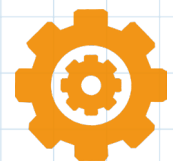
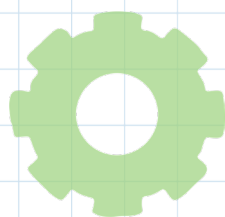
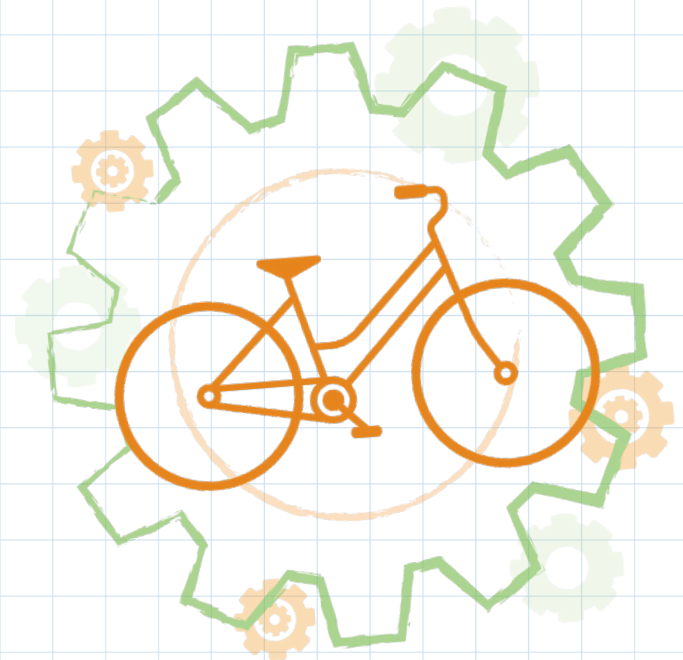
If the girls are finding making the gears too easy, see if they can mount one of the gears onto the inside wall of the box and position it to interact with the gears on the base of the box. They could also cut the 'teeth' (lollipop sticks) to different sizes and see how this affects the way the gears turn and how easy or hard it is to turn them. They could change the number of teeth to see how that affects the way the gears turn too.



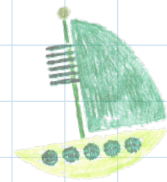
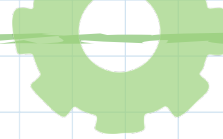
Inspiring Female Explorer: Annie Londonderry



- Annie was born in Latvia, and later married in the US to become Annie Kopchovsky. As a mother of three, athlete, entrepreneur, and explorer, she decided to change her name to Annie Londonderry. Annie was the first woman ever to circle the globe on a bicycle.
- Annie was actually completing a bet when she did this. The bet was that she couldn't circumnavigate the world in under 15 months, while earning \$5000 along the way (this was a lot of money in those days - worth around \$150,000 today!). What seemed like a silly bet became a way for Annie to challenge the concept of female propriety, as well as a chance for her to show everyone that a woman can get on in the world by herself.
- Annie departed from her husband and children on 25th June 1894 and set off from the Massachusetts State House in Boston with more than 500 people watching. On her route, she sold promotional photos of herself and was paid to make appearances. She also leased out advertising space on the clothing she was wearing, and on her bicycle. She completed the ride around the world, and The New York World said her adventure was "the most extraordinary journey ever undertaken by a woman".



Snowy Science

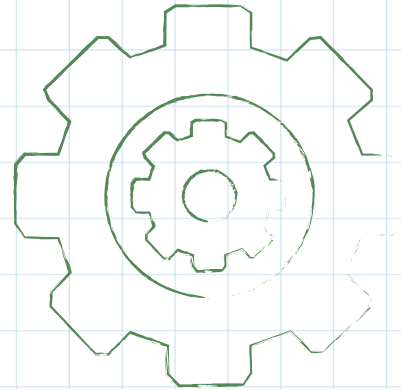


Part One: Friction

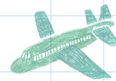
Skiing is made possible because of something called friction. In this activity you'll learn all about friction and how it makes skis slide.

Equipment: (per experiment)

- Rice (enough to fill an empty plastic bottle)
- Pencil
- Funnel
- Empty, dry plastic bottle
- Scoop/spoon
- Cooking bowl



Estimated Time: 15 Minutes



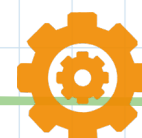
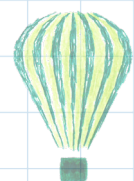
Method:

Do you think you can lift a bottle of rice with a pencil?

1. First, pour the rice into the cooking bowl, so it is half-full.
2. Dip your pencil into the rice and lift it back up. Does anything happen?
3. Place the funnel in the top of the plastic bottle and scoop the rice from the cooking bowl into the funnel. Once the bottle is full, remove the funnel from the bottle.
4. Next, put your pencil into the plastic bottle and wiggle it slowly down into the rice until it is all the way in.
5. Grab the pencil and lift it up. You should be able to lift the whole bottle of rice without the pencil coming out!
6. Why do you think this happens? (See 'How this Relates to Engineering').

Guidance For Leaders:

Make sure that the bottle is completely packed full of rice, and that the pencil is fully inserted into the bottle, if you find that it doesn't lift when tested. You could ask the girls why sometimes the pencil lifts up the bottle and sometimes it doesn't (this will be because the rice isn't settled well enough around the pencil). You could try other materials instead of rice, such as sand or stones. You could also try switching the plastic bottle for something different. Note the differences you see and see if the girls can figure out why some worked and some didn't (see the 'How this Relates to Engineering' section to understand how friction plays a part!).

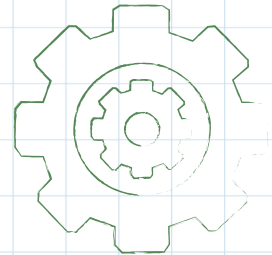


Part 2: Ice Cream in a Bag

Ice cream starts off as a liquid (milk), and transforms into a solid when it is cooled. This is an example of physics, where things can change from one form to another by adding or removing heat.

Equipment: (per bag)

- Lots of ice - either cubes or crushed
- 6 tablespoons of rock salt
- 125ml milk
- ¼ teaspoon of vanilla essence
- 1 tablespoon of sugar
- Large (4 litre) ziplock bag
- Small (500ml) ziplock bag
- Bowl
- Spoon
- Various toppings



Estimated Time: 30 Minutes

Method:

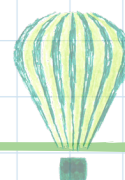
1. Fill the large ziplock bag half full with ice and add the rock salt to the ice.
2. Put the milk, sugar, and vanilla into the small ziplock bag and seal it shut. Make sure it is properly sealed and won't leak!
3. Now, place the small ziplock bag inside the large ziplock bag, together with the ice and seal it shut. Again, make sure it is properly sealed.
4. Shake the large ziplock bag until the mixture inside the small bag freezes and becomes ice cream. This will take about 5 minutes so keep shaking it!
5. Carefully open the large bag (take care not to spill the ice), and then remove the small bag.
6. Open the small bag and pour the ice cream into a bowl.
7. Add some toppings and enjoy!



How this relates to Engineering:

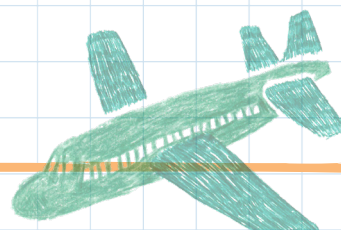
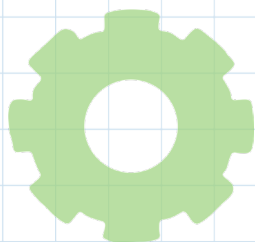
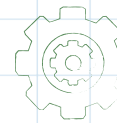
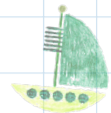
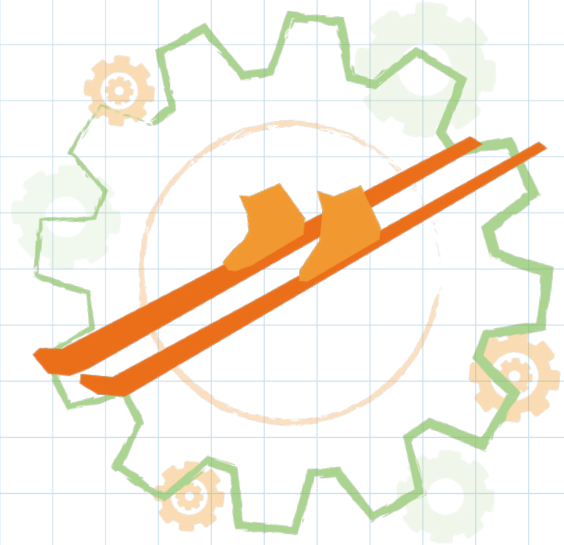
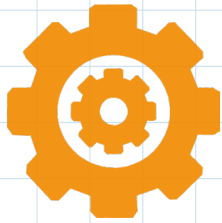
Friction is a force that we can't see. Friction is the resistance of one object rubbing against another object. When you rub your hands together when you're cold, this creates friction, which creates warmth. In the rice activity, when we pushed the pencil into the plastic bottle, the grains of rice moved closer to each other. Normally, air between objects prevents friction and allows objects to slide past one another. However, because the pencil pushed all of the air out of the way, friction caused the grains of rice to push against each other and against the pencil, which made it stay in place.

When a ski puts pressure onto snow, the snow directly underneath the ski melts. This makes a very thin layer of water underneath the ski, which reduces friction between the ski and the snow, and therefore lets the ski slide across the snow very easily.



Inspiring Female Explorers: The Ice Maiden Team

The Ice Maidens are a team of six women from the British Army who are the largest all-female group to ski coast-to-coast across Antarctica. The expedition took place in October 2018 and was 1056 miles long. It was predicted that the team would take between 75 and 90 days to complete the expedition, but the team managed to complete it in just 62 days! Each of the women had to pull an 80kg sledge behind them all of the way, so they all had to train very hard before they left. They faced 60mph winds and temperatures as low as -40°C , and all they had were skis and their own strength to pull the sledges all of the way. The six Ice Maidens were selected out of more than 250 female soldiers who applied to complete the expedition. They trained for almost two years to prepare, and had to do some really gruelling tasks to get ready for the challenge.



Taking Flight

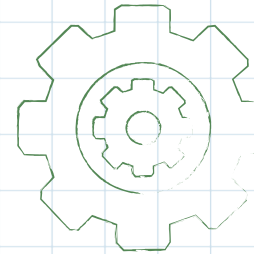
Part One: Aeroplane/Helicopter Making



Rainbows & Brownies

Equipment: (per helicopter)

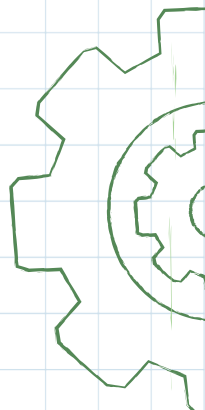
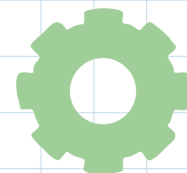
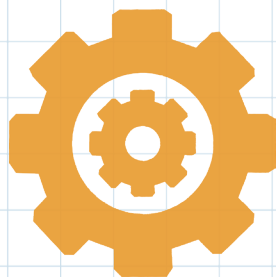
- Paper helicopter template (Appendix C), printed on paper and cut out
- Scissors
- Paper clips
- Sticky tape
- Fans (not essential but makes it more fun!)

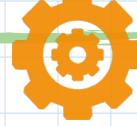


Estimated Time: 20 minutes

Method:

1. Cut along the solid lines of your template (the lines between section D and E, and the top of section A and B). Ask your leader for help with this, if you are unsure.
2. Now, fold along the dotted lines. Fold section A and B inward and fold section C upward. Secure this fold with a paper clip to add weight to the bottom.
3. Fold flap D forward along the dotted line and flap E backward so they are folded in opposite directions
4. Now, stand on a balcony (or a chair with your leaders' supervision), and drop your helicopter from a height.
5. Watch it flutter to the ground!
6. Why do you think it is behaving like that?
7. Discuss this with your leaders.

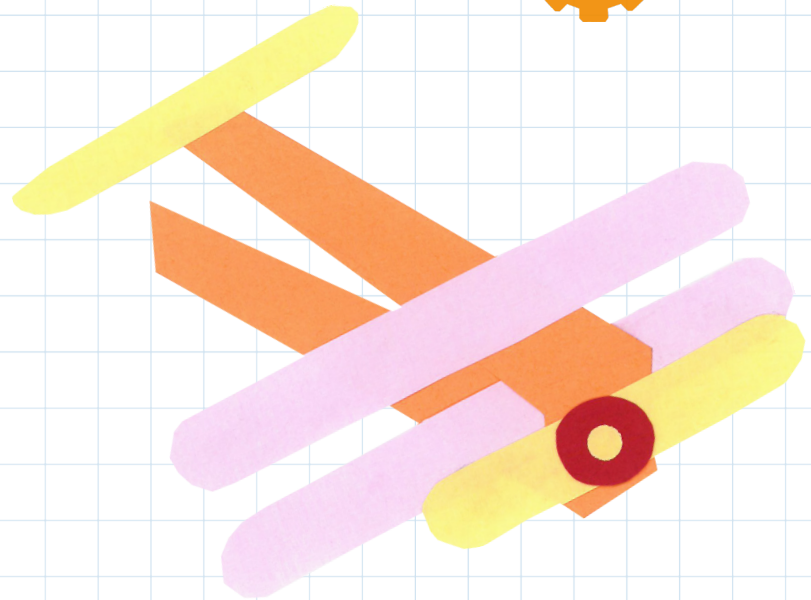




Guides & Rangers

Equipment: (per plane)

- 1 x wooden clothes peg
- 2 x mini lollipop sticks
- 2 x large lollipop sticks
- Scissors
- 1 x craft bead
- Low-temperature glue gun
- Acrylic paint
- Paintbrushes

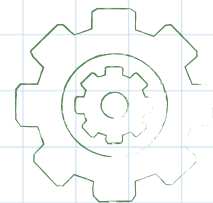
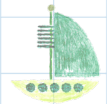


Estimated Time: 30 Minutes

Method:

In your groups, make a small wooden aeroplane that can fly when you throw it, using the materials listed above.

1. First, remove the spring from the clothes peg and leave it to one side (don't throw it away!). Ask your leader to help if you need to.
2. Paint the peg, the lollipop sticks and the craft bead in whatever colours you like.
3. Tip: A wooden skewer is great for holding these still while you paint them!
4. When everything has dried properly, put the spring back into your clothes peg.
5. Use the glue gun to glue the large lollipop sticks to the top and bottom sides of the clothes peg (see the diagram above for help). Younger Guides, be sure to ask your leader for help with this, as the glue gun could get hot.
6. Glue one mini lollipop stick to the top of the peg at the opposite end to the large sticks.
7. Then, glue the other mini lollipop stick to the front of the peg, to act as the propeller.
8. Finally, glue the craft bead in the centre of the mini lollipop stick that you just glued to the front of the peg, to act as the propeller (refer to the diagram for help, if you are unsure).
9. Once the glue has dried properly, try testing your new aeroplane by throwing it (if possible, throw it over a grassy area so that it doesn't break when it lands!).



Part Two: Balloon Propeller

Equipment: (per propeller)

- Round balloon
- Sticky tape
- Straw (preferably paper)
- Pin
- Pencil with rubber on the end

Estimated Time: 20 Minutes

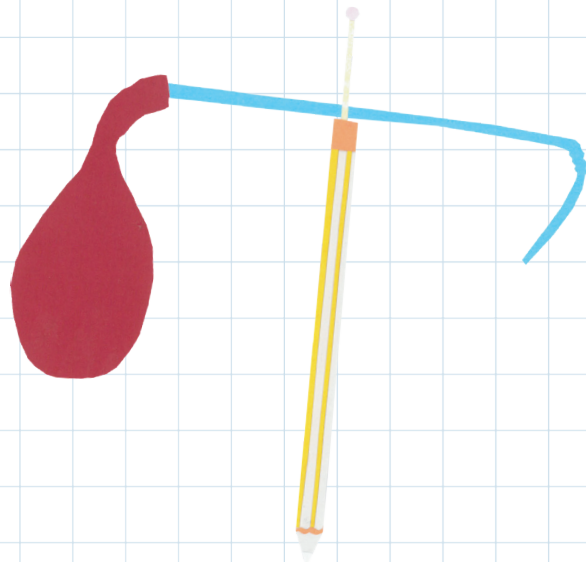
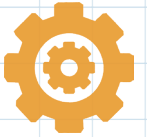
Method:

1. Stretch the balloon by blowing it up and then letting the air out.
2. Place the end of the straw inside the balloon and tape the balloon around it (if using plastic straws, use the opposite end to the bendy part). The seal needs to be air-tight, so ask a leader to help make sure, if you need to.
3. Once the balloon is taped onto the straw, you need to find the balance point. To do this, put the straw on your fingers and move it side-to-side until you find the position where it balances. When you've found the balance point, poke a pin all of the way through that section of the straw (both sides). Rainbows and Brownies, be sure to ask a leader for help with this.
4. Whilst the pin is still through the straw, poke it into the top of the pencil's rubber (as in the diagram above), to attach the straw to the end of the pencil. Again, our younger sections should ask a leader for help with this.
5. Spin the straw around a few times to stretch out the pin-hole you've made in the straw.
6. Now, blow up the balloon (be careful not to pull the pin out!) and keep hold of the end of the balloon once it has been blown up, so that the air doesn't escape.
7. Finally, let go on the balloon and watch it spin around like a propeller.
8. Can you think of where a propeller might be used in real life? Can you think of what purpose it serves?

Guidance For Leaders:

For the aeroplane, you could get the girls to test their planes by throwing them as far as they can, and then asking them what they could do to make them go even further (this could include things like a powered engine, more streamlined wings or a lighter body). You could even try creating them out of different materials to see the difference.

The girls will most likely need some assistance with the paper helicopters, in particular where to fold each section. The diagram should help with this. If the girls finish the task quickly, you could ask them to add more weight (paperclips) and test them out, or try using bigger templates to see how that affects the flight of the helicopter. They could also try using card instead of paper to note the difference this makes.



How this relates to Engineering:

Aerodynamics is the term used to describe how air interacts with solid objects, like aeroplane wings or helicopter rotors. Aerodynamics is part of physics, and applies to anything that flies - even birds! Aeroplanes can fly because of two main reasons; 'push' and 'lift'. 'Push' is generated by the aeroplane engines, which propel them forwards through the air. 'Lift' is generated by the movement of air over the aeroplane's wings and is what keeps the aeroplane up in the air. In physics, 'push' is called thrust.

For birds, both thrust and lift is generated from the flapping motion of their wings. Because aeroplanes can't flap (this would be very difficult to engineer!), aeroplanes have to have engines to create thrust.

Gravity is the force that pulls things to the ground (like the helicopters you have made!). When the helicopter is dropped, air pushes upwards against the wings, which makes them spin around. When they spin around, they create lift which is what helps the helicopter stay in the air for longer.

A propeller has wings too, but these wings move in a circle instead. A propeller creates thrust by rotating and pushing against air or water very quickly.

Isaac Newton was a famous scientist who created some rules in physics. Newton's 3rd Law of Motion is a famous physics law which states that "for every action, there is an equal and opposite reaction". This means that, when the propellers apply a force on the air/water (the action), the propellers are pushed forward by the air/water (reaction).

Inspiring Female Explorer: Bessie Coleman

- Bessie Coleman was the first ever black female pilot in the world.
- After being banned from flying schools in America, Bessie fought against racism and gender discrimination to do what she loved. Since she was banned in America, Bessie taught herself French and then travelled to France to earn her pilot's licence, which she completed in 1921.
- After that, Bessie flew all over America, performing flying tricks and also teaching, to raise money to build an African-American flying school so that others like her could learn to be a pilot in America.



Constellations

Pipe-Cleaner Constellation

Rainbows and Brownies

Equipment: (per constellation)

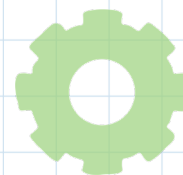
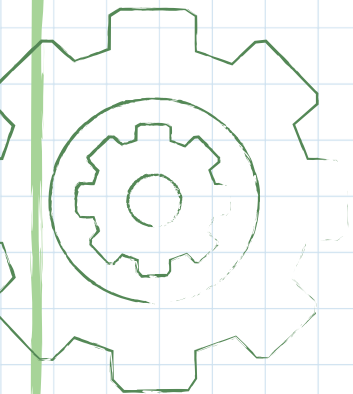
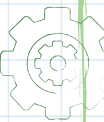
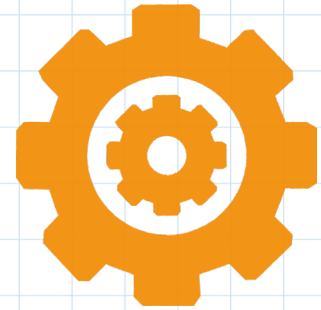
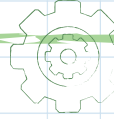
- 1 x pipe cleaner
- Beads (ideally star shaped, but any will work!)
- Scissors
- Constellation cards, printed out (Appendix D)
- Constellation finder (Appendix E)

Estimated Time: 30 Minutes

Method:

1. Take one of the constellation cards that have been printed out from Appendix D.
2. Then, take a pipe cleaner and a few beads - the pipe cleaner will form the 'lines' of the constellation, and the beads will form the stars.
3. Count how many stars are in the constellation that you are planning to make, and thread that number of beads on to your pipe cleaner.
4. Twist the ends of your pipe cleaner to stop the beads falling off!
5. Using the constellation cards as a template, bend the pipe cleaner until it forms the shape of the constellation.
6. If you need to, slide your beads along your pipe cleaner until they are in the right position to form the stars of the constellation.

Once everyone has created a constellation, using the constellation finder sheet (Appendix E), look at all of the other pipe cleaner constellations that have been created and see if you can identify what constellation they have created.



Constellation Jars

Guides and Rangers

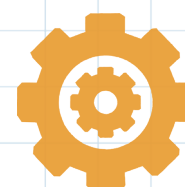
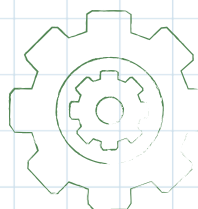
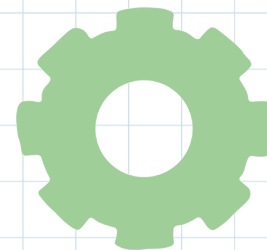
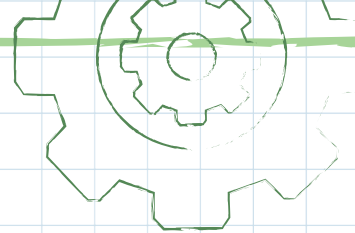
Equipment: (per jar)

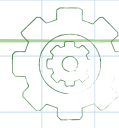
- 1 x empty jam jar or similar
- 1 x Tea light
- Long matches
- Black card
- Small hole punch
- Ruler
- Scissors
- Sticky tape
- Star constellations, printed out (Appendix E)

Estimated Time: 30 Minutes

Method:

1. Cut the black card to size so that it will wrap around the outside of your jam jar.
2. Lay the black card flat on the table and use a pencil to mark the card with some star constellations, copying them from your print out.
3. Where you have marked a star, use the hole punch to punch a small hole in the paper.
4. Where you have marked a constellation (a line joining two stars), use the scissors to cut a line through the paper - be careful not to make this too big.
5. After you have cut all of your constellations into the black paper, wrap it around the outside of the jar and secure it in place with sticky tape.
6. Place the tea-light inside your jar and carefully light it. Turn out the lights and you should be able to see your constellations light up! Place the jar close to a wall and you will be able to see your constellations projected on to the wall.





Guidance For Leaders:

After this activity, you could challenge the girls to go away and see if they can spot any constellations in the night sky!



How this relates to Engineering:

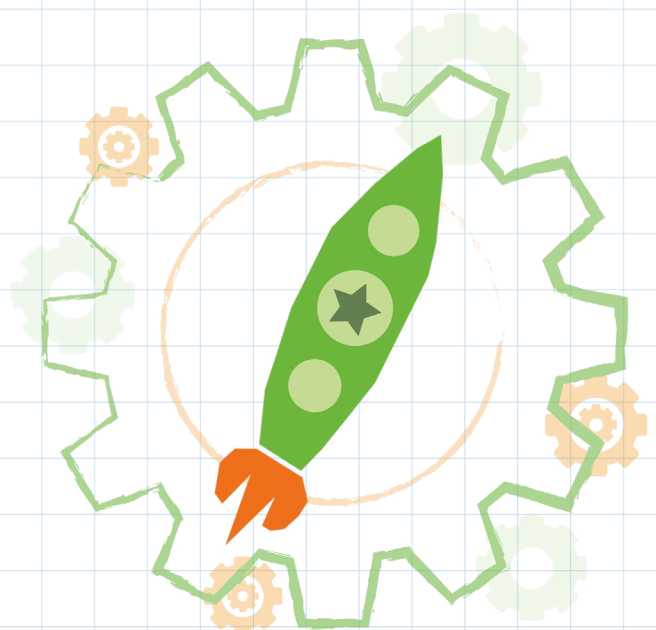
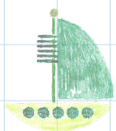
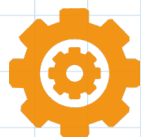
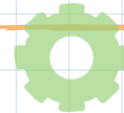
Space is an incredibly challenging environment, and in order to explore it, Space Engineers have to think of new methods to overcome these challenges. At the moment, the furthest that a human has travelled in space is the far side of the moon - approximately 250,000 miles from the Earth. To put this into perspective, the nearest star (the sun) is 93 million miles away from the Earth. The closest star besides the sun is known as 'Alpha Centuri'.

There is huge potential for exploration in space, and many scientists believe that there is life elsewhere in the universe. Each of the stars which you have looked at in your constellation could be like our sun, and have planets orbiting it - some of those planets might even be like Earth! However, before we can explore space further, we need engineers and scientists to develop new technology.

Inspiring Female Engineer:

Mae Jemison

- Mae Jemison is an engineer and physician who worked for NASA as an astronaut. In 1992, Mae became the first black woman to travel to space. Mae took part in the STS-47 space mission and conducted experiments on the effects of weightlessness on crew members. In 1993, Mae resigned from NASA and set up her own technology company.
- Mae Jemison is also on the advisory committee for a project known as 'Project Breakthrough Starshot', which is attempting to use nano-technology to send a probe to the Alpha Centuri. The idea of the project is to create tiny 'nano-crafts', which are miniature space probes powered by light, which can travel at speeds of up to 100 million miles per hour. Even at that speed, it is estimated that it would take 20 years for the 'nano-craft' to reach the Alpha Centuri.



Fuel-Free Car

Equipment: (per car)

- 1 x plastic bottle
- 4 x bottle caps
- 2 x wooden skewers
- Blu Tack
- 1 x elastic band
- Scissors
- Plasticine
- Pen

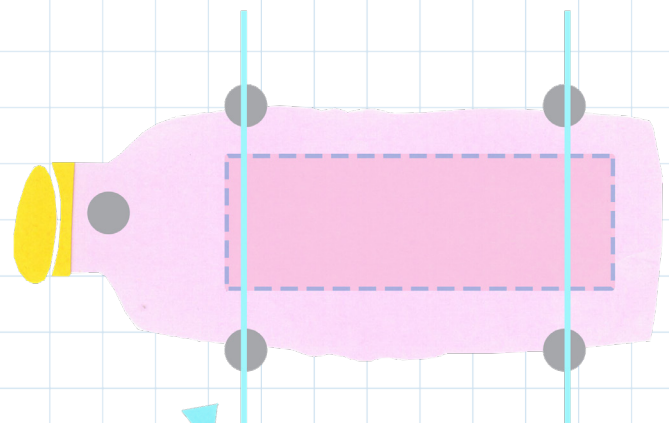
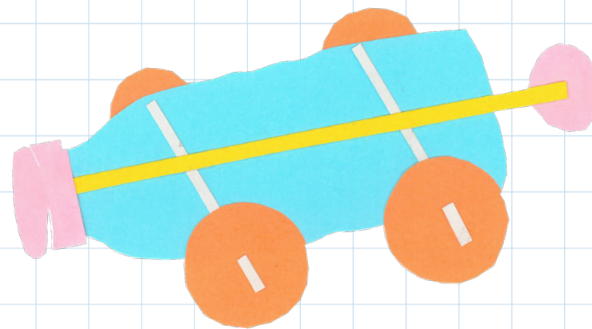
Optional Equipment:

- Materials for a ramp (e.g. books and cardboard box)
- Stopwatch
- Brightly coloured tape
- Tape measure

Estimated Time: 45 Minutes

Method:

1. Remove the lid from the plastic bottle and lay the bottle on its side.
2. Use the scissors to pierce a small hole in the side of the bottle, then cut that hole in to a large rectangle; this will be the top of your car. Our younger sections should ask a leader for help with this.
3. Pierce another small hole, using the scissors, on the top side, just under the rim of the bottle.
4. Pierce the bottle using the skewers through the under-side (the skewers should sit low down to allow the bottle to sit off the ground once the bottle tops are attached), one skewer should go through towards the neck, and the other near the base. These will form the 'axles' of your car. Initially, you may wish to use something sharper to puncture the holes, after which you can easily push the skewers through.
5. Make a small hole, using the pen in the centre of each bottle top and slide one bottle top to each end of the skewers. Use the Blu Tack to secure the tops in place and place some on the end of the skewers, to round the points; making sure the bottle tops are evenly spaced.
6. Take the elastic band and cut the loop to make a single string. Tie one end of the elastic band through the hole at the rim and around the rim itself. Feed the elastic band through the bottle to the back axle and tie it around the axle, making sure that it is tight.
7. Trim the excess elastic band.
8. The car is now complete. When the car is pulled back, the elastic band will wrap around the rear axle and be propelled forward when the car is let go.



Pierce hole here
and insert skewer

(Birds eye view)

Guides and Rangers



Why not try using ramps at different angles and think about why it is more, or less, difficult to do so. Or, try using elastic bands of different lengths to see which ones are more powerful. Why do you think this is?

You could also use the tape to mark out a start and a finish line at a set distance apart and use the equation 'speed = distance / time' (calculating the time taken to get from one line to the other on the stopwatch), to find out which one of your designs is the fastest.

How Does This Work?

Elastic bands store energy, known as 'Elastic Potential Energy'. As you pull the car back, and wind the band up, you are converting the 'Kinetic' (Movement) Energy of your hand to the elastic band, where it is stored. When you let go, the elastic band releases its potential energy and converts it back in to Kinetic Energy.



Guidance For Leaders:

Some of the girls may require some help for this activity as it involves using scissors to pierce holes in the plastic bottle caps and the water bottles themselves. Once the girls have completed the activity, they may want to try out the method suggested above for Guides and Rangers, testing their cars on ramps to calculate the speed of their cars at different angles.

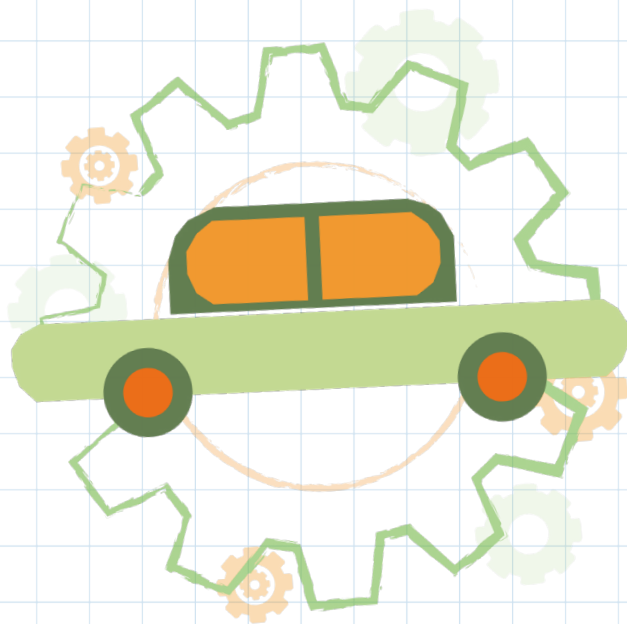


How this relates to Engineering:

Transferring energy from one state to another is used in nearly all aspects of engineering. Car engines, much like the elastic band car, keep energy stored; although this is as Chemical Energy (in the fuel), rather than potential energy. This energy is then released in the engine to turn the axles.

Inspiring Female Engineer: Dr. Justyna Zander

- Justyna Zander is a Senior Automotive Product Manager at NVIDIA in the USA, one of the main companies building the technology for self-driving cars.
- Justyna has been working on self-driving cars for more than a decade and is an expert in artificial intelligence and machine learning.
- She holds a PhD, MSc, and two BSc degrees in Computer Science and Electrical Engineering.
- Justyna spent three years as a Postdoctoral Research Scientist at Harvard University and seven years as a Senior Scientist at the Fraunhofer Institute in Germany, where she worked on self-driving cars and their safety features. In 2016, she worked as a Software Architect and Technology Lead in autonomous driving at Intel.
- Justyna also holds 7 patents and 12 patent applications at USPTO, has co-authored over 40 publications, including 3 books, and has won multiple awards. In 2018, she was listed in Business Insider's annual list of the Most Powerful Women Engineers.



Rainbow Fuel

Equipment: (per group)

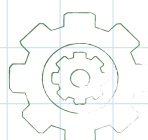
- Food colouring (4 different colours)
- Sugar
- Warm water
- 4 x cups for mixing
- 1 x jam jar, or similar
- Spoon for mixing
- Plastic syringe

Estimated Time: 45 Minutes

Cup	Amount of sugar
Cup One	No Sugar
Cup Two	Two teaspoons
Cup Three	Three teaspoons
Cup Four	Five teaspoons

Method:

1. Add 100ml of warm water to each cup, and then add one or two drops of food colouring so that each cup of water is a different colour.
2. Add sugar to the cups according to the table above.
3. Stir the water in the cups well, until all of the sugar has dissolved into the liquid.
4. Use the syringe to draw up some of the liquid from cup four, and empty this into the bottom of the jam jar. Repeat this until you have a layer approximately 2cm in height (you might need to do this two or three times, depending on the size of your syringe and your jam jar).
5. Next, use the syringe to draw up some of the liquid from cup three and gently syringe this onto the top of the liquid in the jar, being careful not to disturb the layer too much. Again, do this until you have another layer of approximately 2cm in height.
6. Repeat this process with the liquid from cup two, and then cup one, until you have four layers in your jar.
7. Now try repeating the experiment, but don't add any sugar to any of the cups of water. What happens? How does this look different to the jar that contained water with sugar in?



Guidance For Leaders:

If you are doing this activity with Rainbows, it might be easier to make a large batch of each mixture, and then split the girls into small groups and allow one girl from each group at a time to come and use their syringe to draw up some of the coloured liquid.

The girls should find that, in the sugary-water jar, the coloured layers stay separate, and there isn't much mixing of the colours. This is because liquids separate according to their density - liquids with more sugar are denser, and therefore sink to the bottom of the jar. In the jar with water, but no sugar, all of the coloured waters are the same density, therefore they don't separate.

How this relates to Engineering:

Most people know that lots of vehicles use petrol or diesel to power them, but did you know that petrol and diesel actually come from a substance known as petroleum, which is found deep beneath the sea? Petroleum is formed over millions of years, and is removed from under the sea by drilling very long holes down into the earth, and then extracting the petroleum with a pump. Since petroleum takes so long to form, it is a non-renewable energy source, and will eventually run out. Approximately 95 million barrels of petroleum are used around the World every day.

Once petroleum has been removed from under the sea, it goes through a refinement process, to extract useful substances such as petrol and diesel. This takes place through a process known as fractional distillation. The petroleum is placed in a long tower, and heated up. The different substances within the petroleum rise to different heights in the tower depending on their density and their boiling point, hence separating the petroleum into useful materials. This is similar to the way that your coloured water separated into different layers!

Engineers are involved in fractional distillation - in particular chemical engineers, which you might know a little about from the exploding volcanoes activity in the original Clever Cogs challenge pack! Engineers are also exploring ways that we can become less reliant on non-renewable energy sources such as petroleum, and instead develop renewable energy sources like wind turbines, solar energy, and tidal energy!

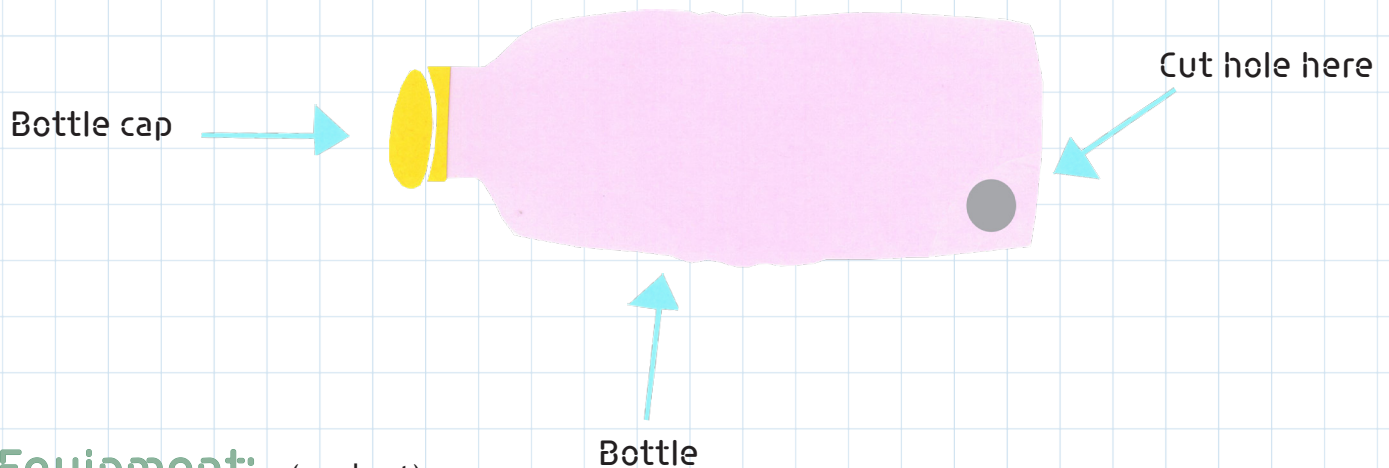
Inspiring Female Engineer: Jennifer Pluckhahn

- Jennifer Plückhahn is a Formula 1 Fuels Co-ordinator for Shell, working to research, analyse and test the fuel which is used in the Ferrari racing cars.
- Jennifer started working for Shell as an Apprentice in 2010, and now works both on the track- side at Formula One races, and at the Shell Technology Center in Hamburg. Her job involves sampling and testing fuel which has come directly from the engines of Formula One racers to check that the cars are operating correctly.

Appendix A

Boat Building Instructions

Bicarbonate of Soda and Vinegar-Powered Boat



Equipment: (per boat)

- Bicarbonate of Soda
- Vinegar
- Tissue or kitchen roll
- 1 x plastic bottle and cap
- Duct tape
- Scissors
- 1 x straw (preferably paper)
- Plasticine

Method:

1. Use the scissors to cut a small hole in the bottom of the bottle (see diagram above). Push the straw into this hole, until about 4cm of the straw is inside the bottle.
2. Use the duct tape and the plasticine to secure the straw in place and block any holes around the edge of the straw, so that no air can escape.
3. Lay two sheets of kitchen roll on top of one another, flat on the table, and put two tablespoons of bicarbonate of soda onto the kitchen roll.
4. Remove the bottle lid, scrunch the kitchen roll up (being careful not to spill out the bicarbonate of soda) and push it into the bottle.
5. When you are ready for your boat race, pour approximately 50ml of vinegar into the bottle. Hold the bottle with the hole facing upwards, so the vinegar doesn't pour out the straw! Screw the cap on tightly and give the bottle a shake.
6. Quickly place your boat in the water, ensuring the straw is submerged. Let go of the boat and watch it sail!

Paddle Boat

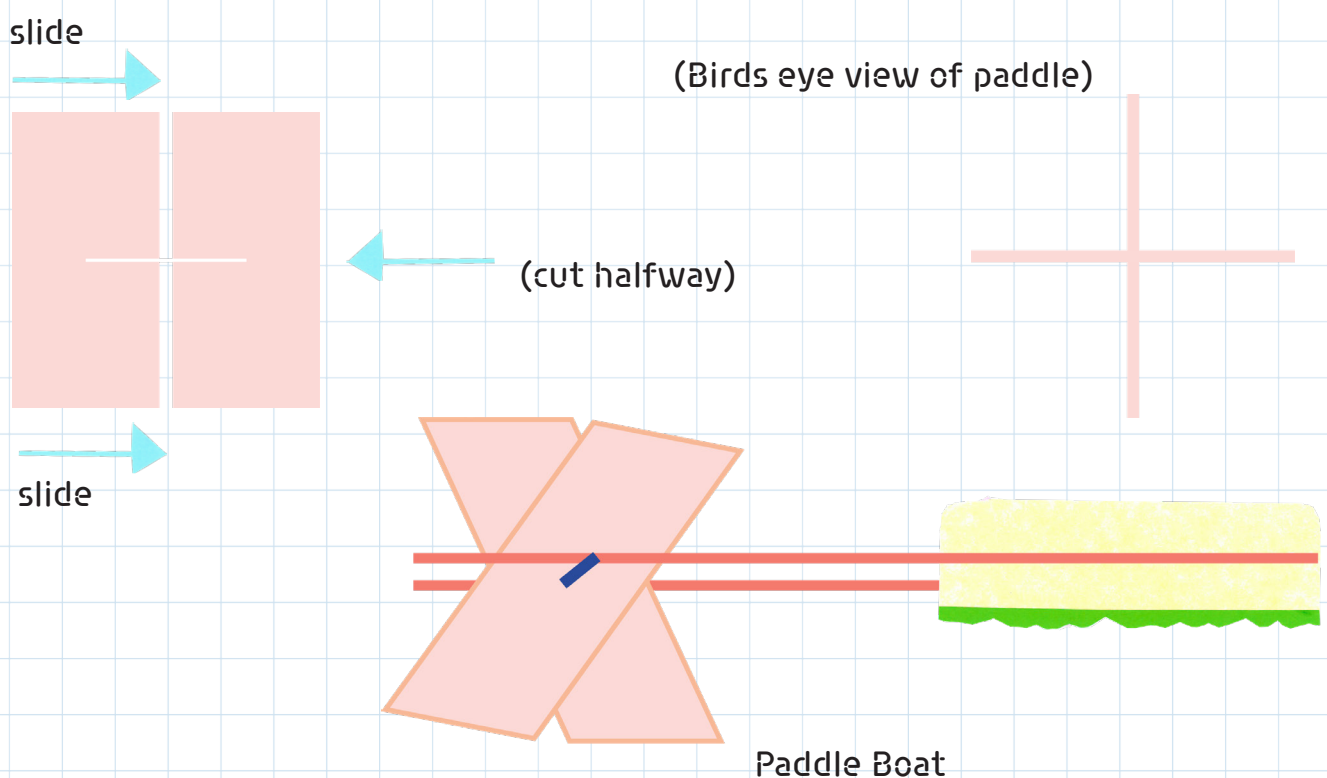
Guides and Rangers

Equipment: (per boat)

- 1 x household sponge or scourer
- 2 x wooden chopsticks
- Duct tape
- Scissors
- Large elastic band
- Scrap piece of easily cut plastic e.g. milk carton
- Tool to cut plastic

Method:

1. Place the sponge on a flat surface and lay the two wooden chopsticks on either side of the sponge. Use the duct tape to secure the two chopsticks to either side of the sponge.
2. Cut two rectangular pieces of plastic, approximately 8cm by 10cm in size.
3. Cut a slit in the middle of each of the rectangular pieces, stopping halfway (see diagram below)
4. Slot these pieces together to form the 'paddle' (shape shown in the diagram below).
5. Stretch the elastic band around the two chopsticks. The elastic band should be quite tight - if it is loose, you should either swap it for a smaller elastic band or loop it around the chopsticks twice.
6. Loop two of edges of the paddle through the elastic band, so that the middle of your paddle is held in place by the elastic band.
7. Wind the paddle up so that the elastic band is twisted. Keep going until the elastic band is twisted as tight as possible - but be careful not to snap it!
8. Place your boat in the water and release the paddle, allowing it to turn in the water. The paddle should propel your boat forwards.



Balloon-Powered Boat

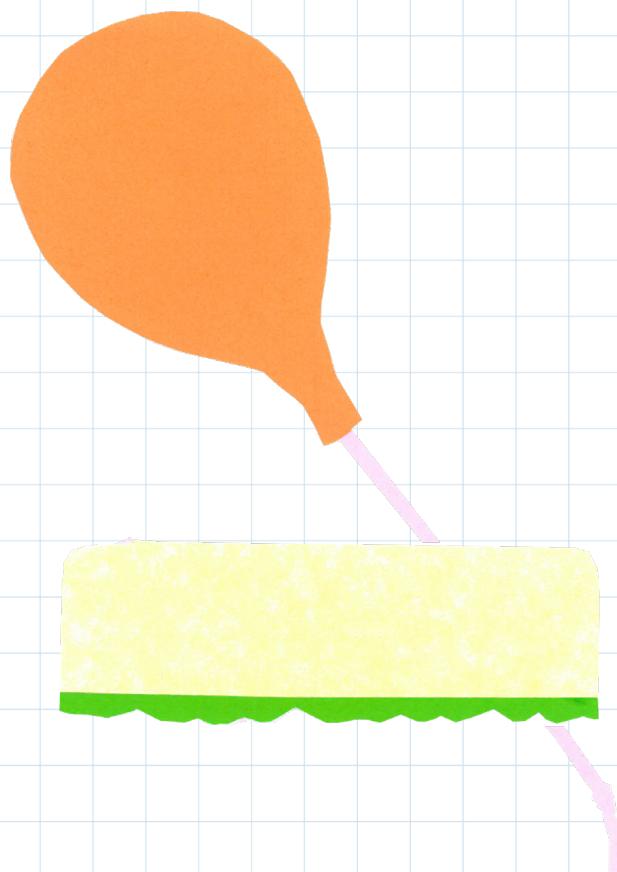
Rainbows and Brownies

Equipment: (per boat)

- 1 x household sponge or scourer
- 1 x balloon
- 1 x straw (preferably paper)
- Duct tape
- Scissors

Method:

1. Use the scissors to cut a small hole from the top of the sponge to the bottom of the sponge. Try to cut this hole on an angle so that your straw will poke out behind the boat (see diagram below). Be sure to ask your leader for help with this.
2. Poke the straw through the hole so that about 5cm pokes out of the bottom of the sponge. Use the duct tape to secure the straw in place.
3. Blow up the balloon and then carefully push the straw through the opening in the balloon, being careful not to release any air from the balloon.
4. Use duct tape to secure the opening of the balloon around the straw, still being careful not to release any air from the balloon.
5. Once you're ready for the race, place your boat in the water with the balloon side on top, making sure that the straw is fully submerged in the water. When you're ready to race, release the balloon and let the air shoot out of the straw!



Straw-Powered Sailing Boat

Rainbows and Brownies

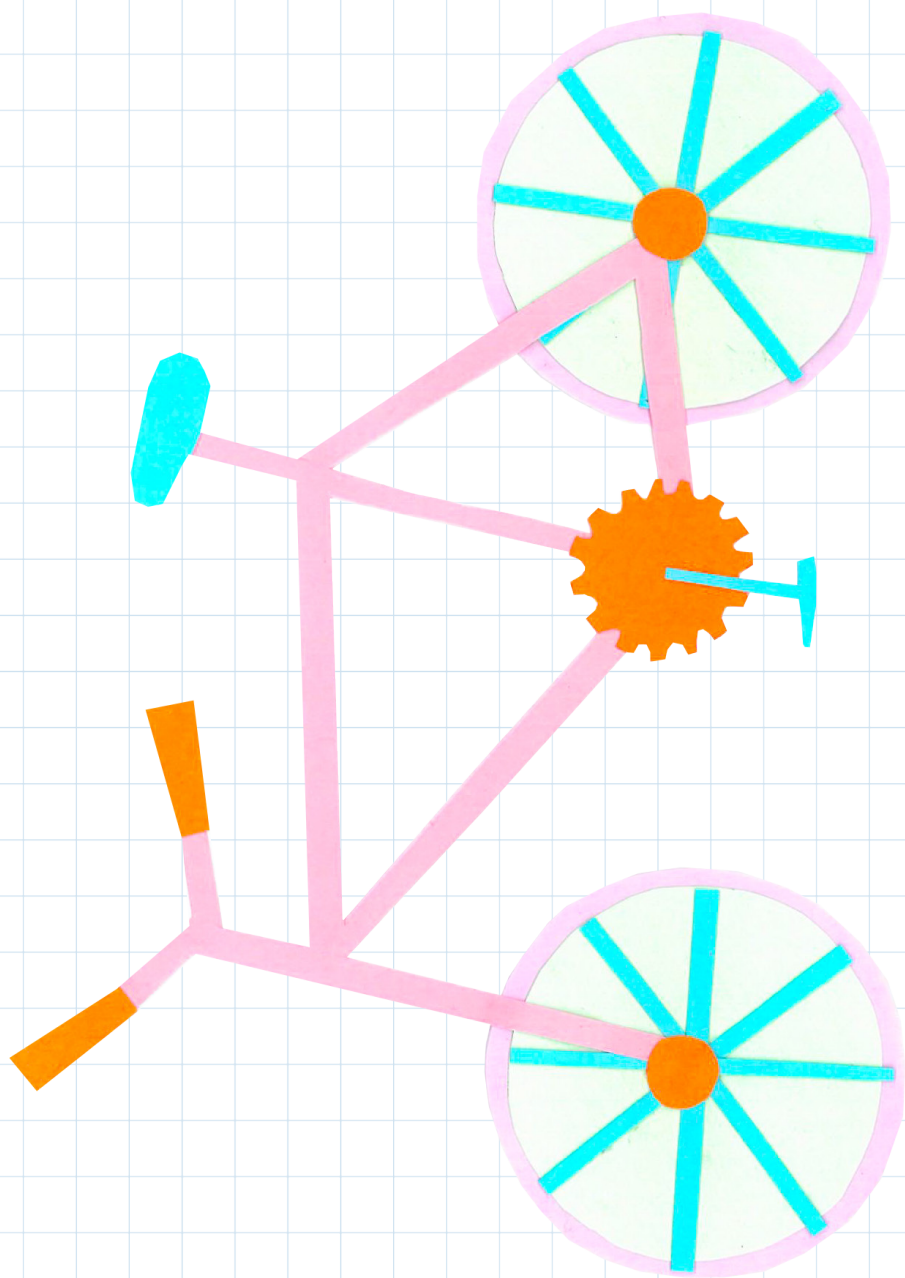
Equipment: (per boat)

- Straws (preferably paper)
- A selection of scrap materials to build your boat (e.g. margarine tubs, household sponges/scourers, milk cartons, plastic bottles, empty juice cartons)
- A selection of scrap materials to build the sail (e.g. paper straws, cocktail sticks, plasticine, paper, card, tissue paper, felt)
- Scissors
- Tape

Method:

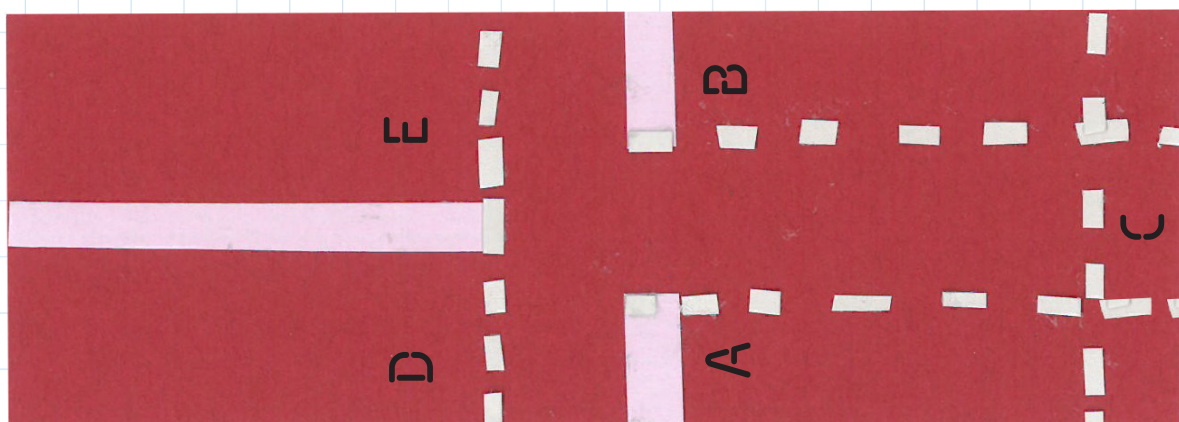
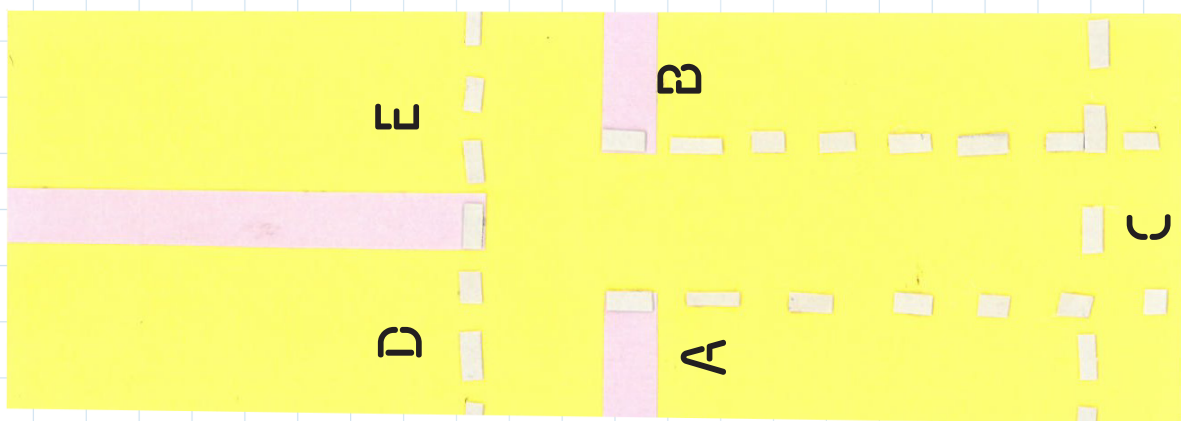
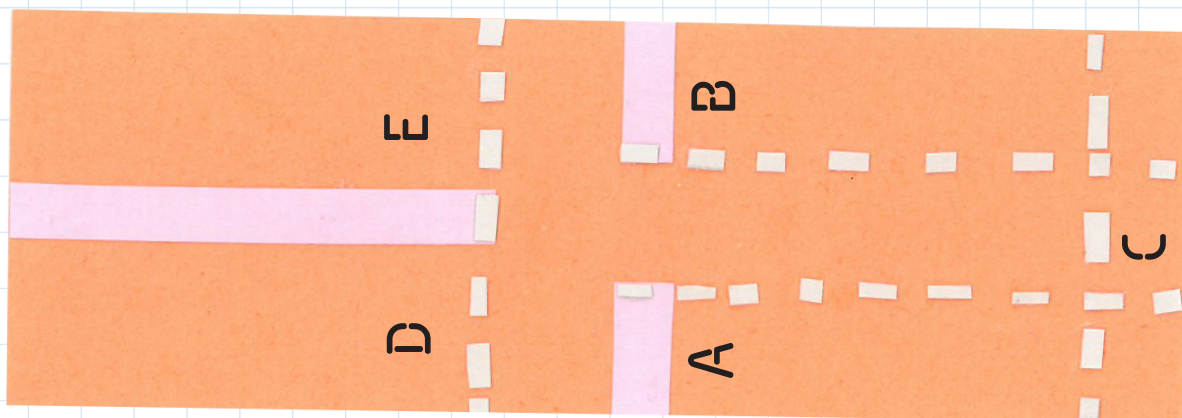
1. Select an item to act as the body of your boat e.g. a margarine tub or plastic bottle.
2. Attach a mast to your boat - this could be a straw, cocktail stick or something else! You could use tape or plasticine to secure it in place.
3. Build a sail and attach it to the mast. This can be any size or shape you would like it to be - experiment!
4. Decorate your boat with anything you choose - could you create a person out of plasticine and see if they fit on your boat?
5. When it's time to race your boats, place them in the water and use a straw to blow into the sail!

Appendix B



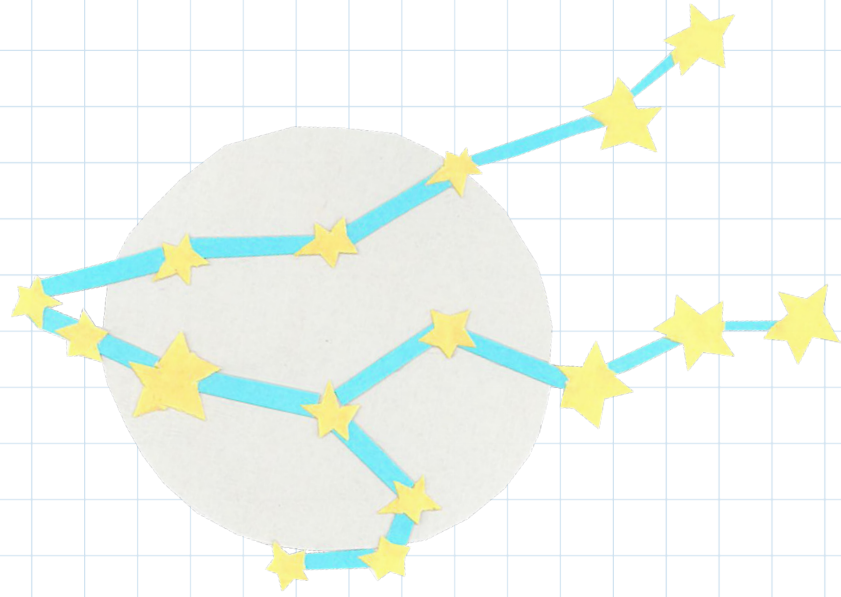
Saddle, Seat post, Top Tube, tyre, Cassette, Stem, Headset,
Rear Derailleur, Cables, Brake Calliper, Chain, Crankset, Fork,
Front Derailleur, Rim, Crank, Spoke, Hub, Pedal

Appendix C

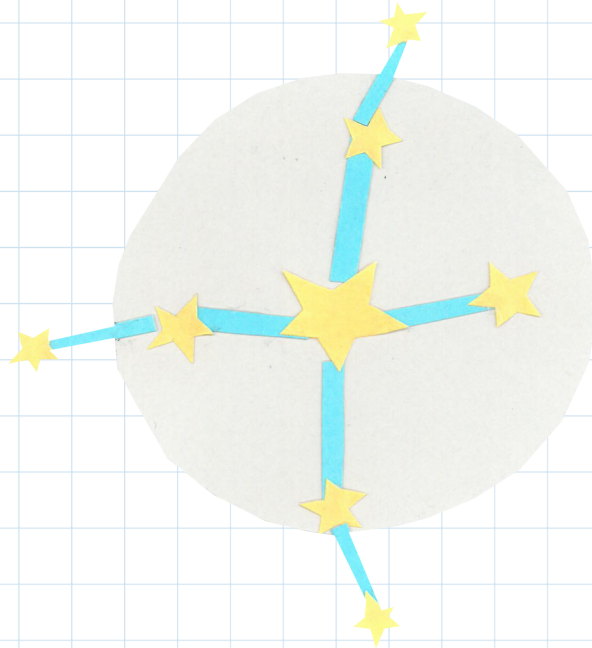


Appendix D

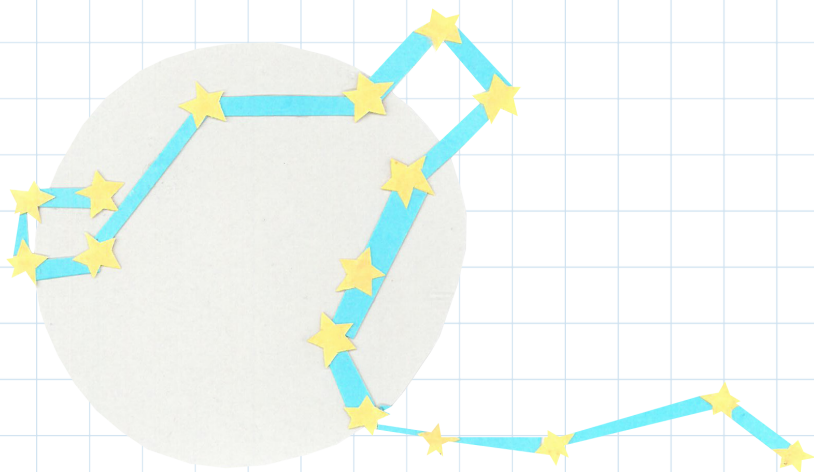
Perseus



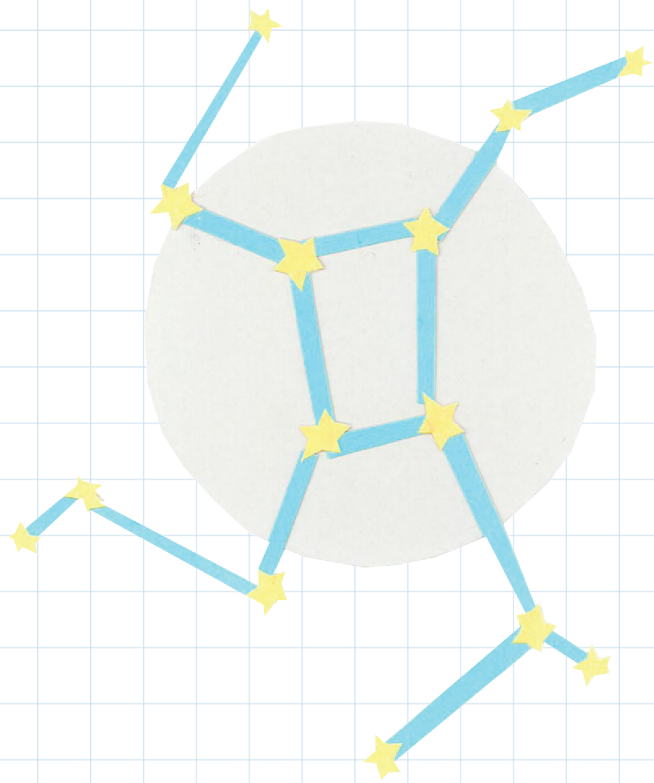
Cygnus



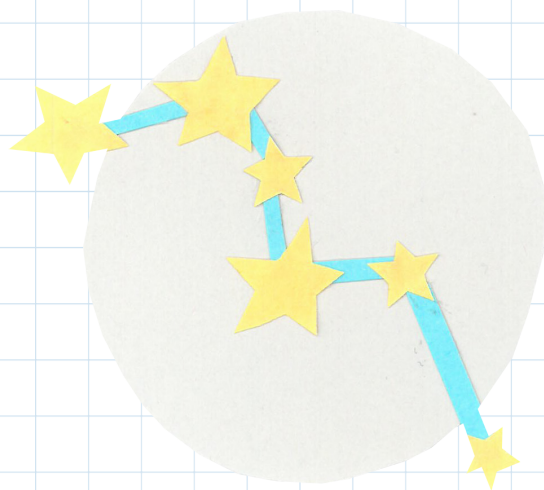
Draco



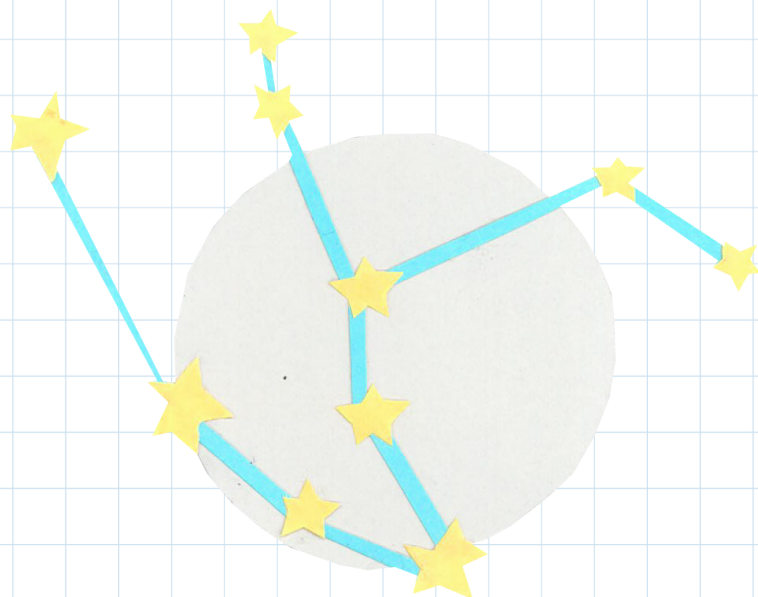
Hercules



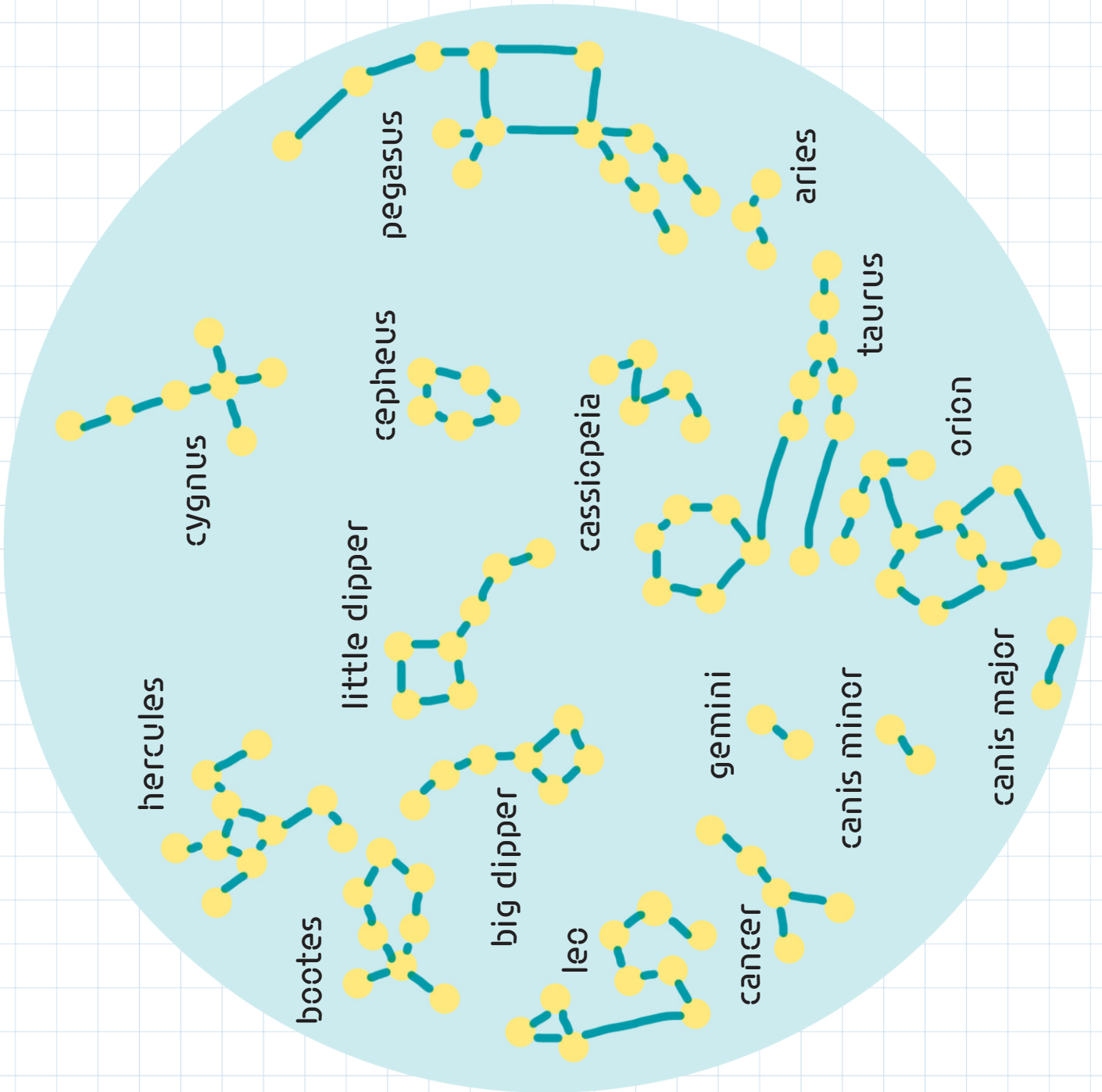
Cassiopeia



Andromeda



Appendix E





WE DISCOVER, WE GROW

Girlguiding

North West England



We hope you enjoyed this challenge pack.

Badges will be available from Monday 5 August 2019. Please visit our online shop to purchase:

<https://shop.girlguidingnwe.org.uk/>.

Or alternatively, visit our store:

Girlguiding NWE, Guiding Road, Preston, PR2 5PD.

We value your feedback so that we can continue to improve our challenge packs. Please spare a few minutes to complete the short survey upon completing the challenge.

<https://www.surveymonkey.co.uk/r/ccgoingplaces>