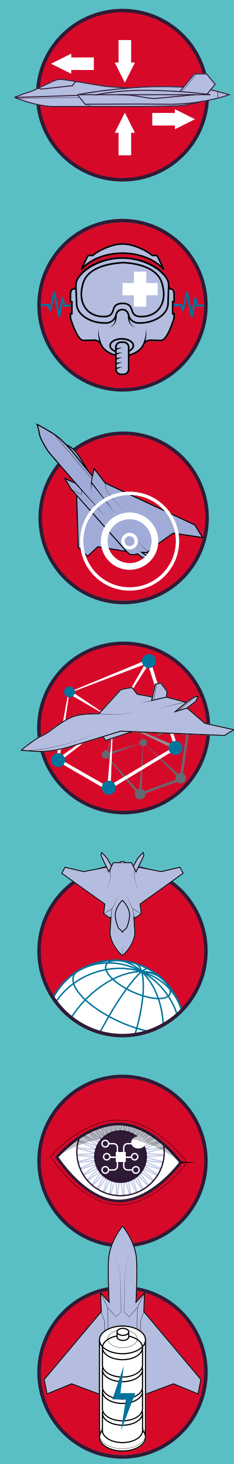
Future of flight:

Teacher guide



Royal Academy of Engineering

THIS IS ENGINEERING

TEAM TEMPEST

About this resource

Tempest is one of the UK's largest ever science and engineering endeavours and will ensure the development of world-first technologies continues to flourish.

It is a beacon to attract the engineers, manufacturers and technologists of the future and a place for young people to build their careers.

The passionate and ingenious employees are embracing new ways of working and mixing the knowledge of highly experienced engineers with a young workforce to break new ground.

The challenges in this STEM resource invite learners to explore innovations within flight technology ranging from AI, machine learning, communication, exploring the forces of flight, investigating material science, and the changes happening that are making flight technology more sustainable.

Through a series of creative and collaborative challenges, students will develop enquiring minds and teamworking skills and are encouraged to find imaginative approaches to problem-solving, understanding the role STEM-based learning plays in real-world engineering scenarios.

We need people to bring the ideas of tomorrow to life:
https://www.baesystems.com/en/product/generation-tempest

Teacher notes

This resource is designed to provide practical and contextualised applications where students and teachers can see the role that STEM-based learning plays in real-world engineering scenarios.

Each of the activities and challenges have links across science, maths and design technology. However, some activities will be more heavily weighted towards one subject.

Don't worry! Experience or subject knowledge about engineering and STEM subjects is not required. The resource has been designed to allow students to learn independently and at their own pace, with your support as a facilitator, not a subject expert.

What do I need for the activities in this resource?

We want to make this resource as inclusive and accessible as possible.

Although we provide some physical hands-on materials, most of the challenges can be adapted to use items that are easy to find around the house or in most classrooms.

Both the student and teacher guide are available online for free: https://stemresources.raeng.org.uk/future-of-flight/

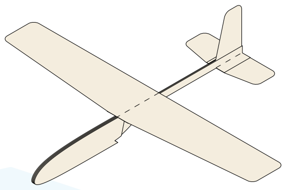
Any teacher who is part of our Connecting STEM Teachers programme will receive hard copies of the resource and the physical materials that are included for free.

Any teachers, anywhere in the UK can join without any cost at any stage.

Find out more about the programme at: https://stemresources.raeng.org.uk/connectingstem-Teachers

What’s in the box

A



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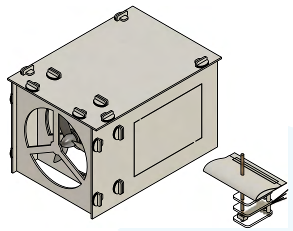

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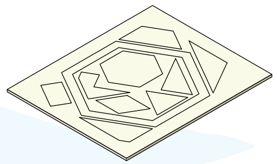

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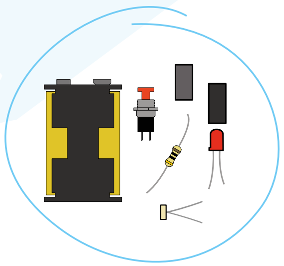

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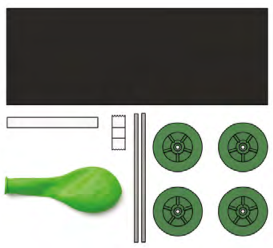

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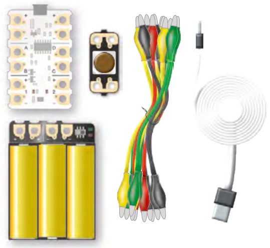

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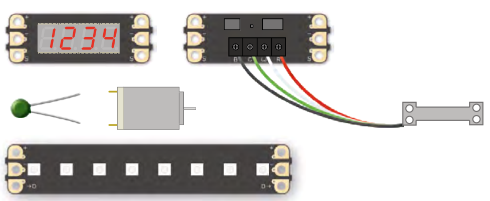


- **A** 10 x Laminated gliders
- **B** 1 x Wind tunnel kit and force sensor jig
- **C** 5 x Hexagon puzzles
- **D** 5 x Fibre optic communications kit
- **E** 10 x Balloon car kit
- **F** 2 x Basic Crumble parts
- **G** 1 x Smart Crumbs: Digits and Force
  1 x Thermistor
  1 x Motor
  2 x Sparkle Baton

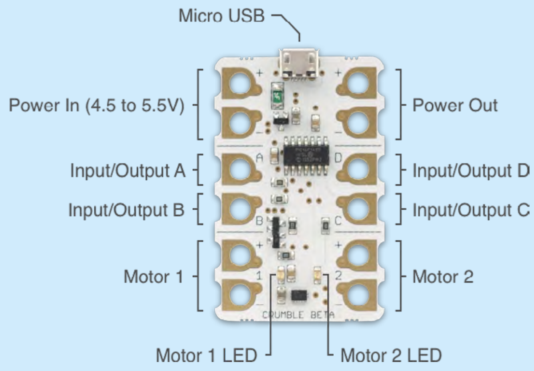
What is the Crumble?

Some of the challenges in this resource use the ‘Crumble’. All the Crumble activities are designed to be used as group activities, so only one group of pupils need to do the actual programming and all pupils can take part in the associated activity.

You will notice a ‘Plugged in’ symbol next to any activity that uses the Crumble.

The Crumble controller by Redfern Electronics

The Crumble is a programmable controller that can be coded to drive outputs such as motors and lights known as Sparkles. It uses crocodile leads for simple connections and once programmed it can be easily embedded into a design or product. A useful output component is the Sparkle Baton consisting of eight LEDs that can be programmed to display interesting light sequences.



https://redfernelectronics.co.uk/crumble/

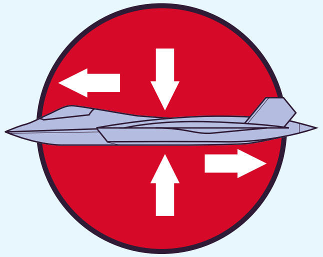
The ‘getting started guide’ available from the Redfern website is an excellent starting point for those that haven’t used Crumble before or need a refresher!

The challenges

1. Theory of flight

Flight in nature
Biomimicry and flight technology

Forces of flight
What are the forces of flight?
Investigate forces with gliders
Investigate forces using a wind tunnel



2. Health monitoring

The wearable cockpit
Design a virtual cockpit

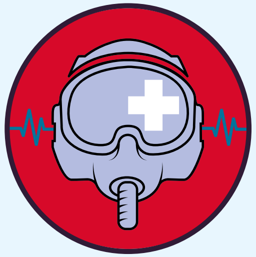
Think like a pilot
Work systematically to move people and medical supplies

Finger on the pulse
Create a program that will test reaction times

Monitoring stress
Create a program that will check stress levels

Temperature check
Create a program that will check the temperature

Pilot training
Put together a pilot training plan based on energy used and consumed



3. Engines

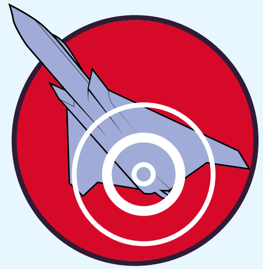
Balloon craft race
Investigate Newton's Third Law by designing, building and racing balloon carts

What is a jet engine and how does it work?
Use the explanation of a jet engine to order the parts of an engine

Build your own 3D Trent Engine
Build your own paper engine

Growing crystals
Create saturated solutions and use them to grow crystals

Faster than the speed of sound
Speed, distance and time calculations



4. Materials

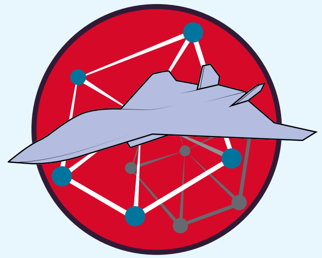
Choosing materials
What materials do you know? How can you group them?

Managing temperatures
What materials could you use to regulate temperature and protect against the cold?

Manufacturing polymers
Make a bouncy ball using a synthetic material

Strength in numbers
Investigate different combinations of composite mixes

Honeycomb structures
Investigate tessellations
Build a honeycomb structure



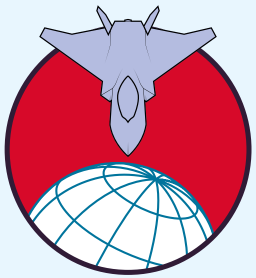
5. Communication

Fibre optic communication
Create a system to send messages using LED signals through fibre optics

Communicating with computers
Looking at binary numbers as a form of communication

Sorting machines – parallel algorithms
Create a sorting machine that can order numbers

Ground control communication
Communicate in teams to build shapes and puzzles



6. Artificial intelligence

Can machines think? What is intelligence?
What do we mean by artificial intelligence?

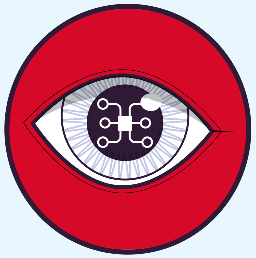
The Turning Test

Where is AI used?

Spotting patterns
Continuing patterns and sequences

Smart data
Design a smart watch that will track and monitor a pilot's health

Drone swarms
Use bearing skills to control drone swarms



7. Environment

What's the damage?
What do we mean by climate change?

What are greenhouse gases?
Match the molecule diagrams to their descriptions.

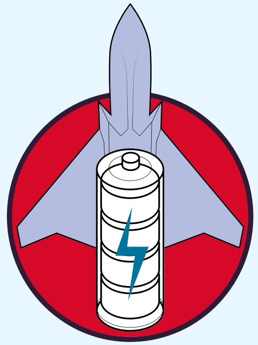
Modelling the greenhouse effect
Investigate rising temperature by setting up mini greenhouses.

Lifecycle of an aircraft
Explore upcycling and the circular economy

Electric travel
What does the future of travel look like?
How do we generate electricity?

Every decision counts
Rolls Royce simulation

Factory of the future
Designing for light
Build a robotic arm



Curriculum links

The activities and challenges bridge several subjects across Science, Technology, Engineering and Mathematics (STEM) curriculum, however for ease of reference, these have been linked to one or two specialisms only.

Age group is given as a guide and activities can be extended or broken down depending on the group.

More information about the National Curriculum in England can be found here.
More information about the Scottish Curriculum for Excellence can be found here.
More information about the Curriculum for Wales can be found here.
More information about the Northern Ireland Curriculum can be found here.

Booklet	Activity	Subject	Age group	Curriculum links
Theory of flight	*Flight in nature*	Science	9 to 14	I can explore different approaches to design such as biomimicry to generate creative ideas.
	Investigating forces	Science	9 to 11	By investigating forces on different objects, I can predict the effect on the motion of the objects.
			11 to 14	I can explain forces measured in Newtons.
Health monitoring	*Think like a pilot*	Maths	9 to 11	I can record solutions using a systematic approach. I can develop rules to describe number sequences.
	Finger on the pulse	Computer science	9 to 14	I can create, develop and evaluate computing solutions in response to a design challenge
Engines	*Balloon craft race*	Design technology	9 to 11	I can design and construct models and explain my solutions.
	Ready steady race	Computer science	9 to 14	I can create, develop and evaluate computing solutions in response to a design challenge
Materials	*Choosing materials*	Design technology	9 to 14	I can recognise basic properties and uses for a variety of materials and can discuss which ones are most suitable for a given task.
	Biomimicry – in materials	Maths	11 to 14	Interior/exterior angles
Communication	*Fibre optic communication*	Maths	9 to 11	I can analyse how lifestyles can impact on the environment and Earth's resources and can make suggestions about how to live in a more sustainable way.
	Sorting machines	Computer science	9 to 14 (depending on numbers used)	I understand that algorithms can be used for processing and sorting information.
Artificial Intelligence	*Spotting patterns*	Maths	11 to 14	I can recognise arithmetic sequences and find the nth term.
	Ordering intelligence /Turing Test	Computer science	9 to 11	I understand how computers process information.
Environment	*What are greenhouse gases?*	Science	11 to 14	I can describe molecules based on the atoms that they are made up from.
	Working with robots	Design technology	9 to 14	I can incorporate control systems, such as mechanical, in products and understand how these can be employed to achieve desired effects.

Engineering habits of mind

The activities presented in this resource are designed to be interactive, open-ended, encourage discussion and promote the engineering habits of mind (EHoM).

The EHoM encourage the use of a pedagogical approach that cultivates problem-solving skills, creativity, making mistakes, reviewing, and planning.

There is no prescriptive teaching method, and it is up to you as a teacher, educator or STEM club leader to decide on which direction you wish to take each activity and where you may wish to spend more time.

Read the full report Thinking like an engineer here.

Engineering habits quiz

In the student booklet, we have called the EHoM 'engineering habits' and have included student statements that aim to bring the EHoM to life for young learners.

Students can take the engineering habits quiz to identify what engineering habits they are using, and perhaps ones they would like to work on.

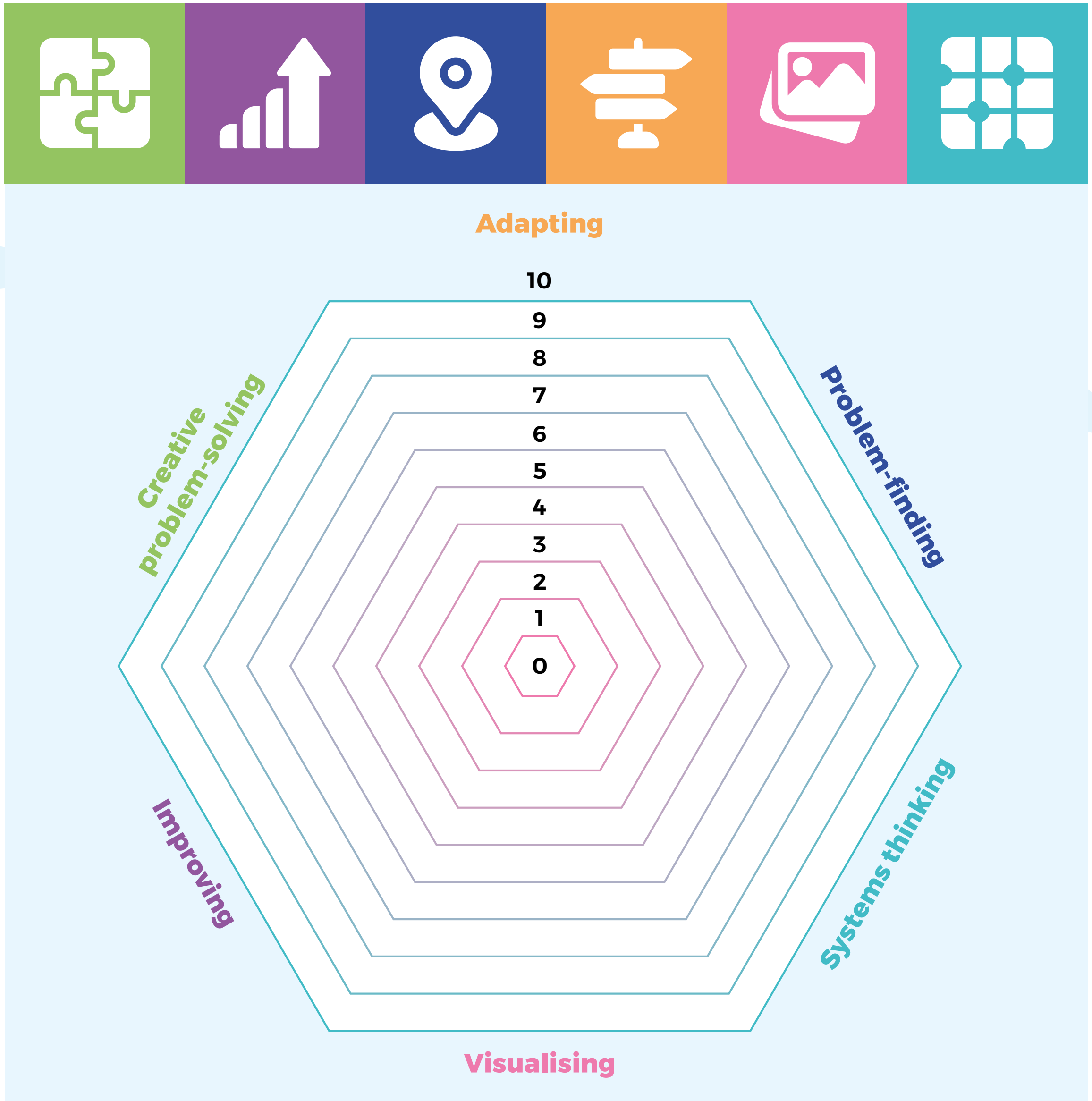
Once students complete the quiz, they can see their results on the EHoM spider diagram and can easily pick out their engineering strengths.

Results are not fixed! We encourage young learners to complete the quiz several times.

They might find that different engineering habits are stronger depending on the type of activity or challenge they are doing.

We have included all the EHoM student statements for both you and young learners for reference and to use in different lessons and activities.

Find the engineering habits quiz on the This is Engineering: Sustainable Futures page **on our resource hub**.



Engineering habits – student statements

I am good at...

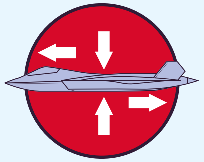
Creative problem-solving	Improving	Problem-finding	Adapting	Visualising	Systems thinking
Coming up with lots of new and good ideas	Making what I have done better	Thinking about the world around me and how it could be better	Deciding how something could be done differently	Thinking out loud when I am being imaginative	Spotting patterns and working out what comes next
Working successfully in a group	Experimenting with things just to see what happens	Finding out why something does not work	Explaining how well I am doing to my teachers or friends.	Making a plan before I start work	Using ideas from one subject in another
Taking on board other people's ideas and using them	Working hard and practising to get better, even when it's tricky	Finding mistakes in mine and other people's work	Evaluating how good something is	Practising something in my head before doing it for real	Putting things together to make something new
Making detailed mind maps	Working out what I need to do to improve	Checking and checking again until I am happy	Behaving appropriately in different settings	Explaining my ideas to other people so they understand	Spotting similarities and differences between things
Thinking first before doing something	Sticking at doing something until it's the best it can be	Asking lots of questions to make sure I understand	Sticking up for what I think when talking with other people	Making models to show my ideas	Working out the possible consequences of something before they happen

The quiz and student statements are based on EHoM research supported by the Royal Academy of Engineering and published in Hanson, J., Hardman, S., Luke, S., Maunders, P. & Lucas, B. (2018) Engineering the future: training today's teachers to develop tomorrow's engineers. London: Royal Academy of Engineering.

STEM Badge Tracker

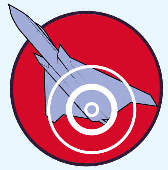
Name:

1. Theory of flight

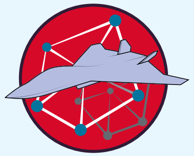


2. Health monitoring

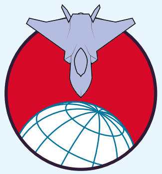
3. Engines



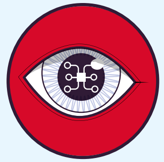
4. Materials



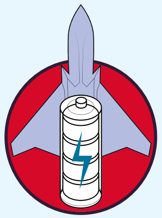
5. Communication



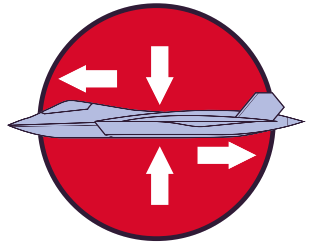
6. Artificial intelligence



7. Environment



Solutions and further investigation



Theory of flight

Theory of flight

Flight in nature

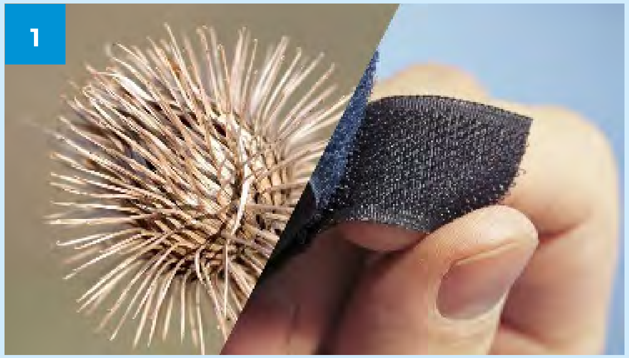
Flight description	Bird	Aircraft
Speed	Peregrine falcon	Tempest aircraft
Gliding	Albatross	Glider
Manoeuvring	Hawk	Spitfire
Endurance	Godwits	Voyager
Hovering	Hummingbird	Helicopter
Soaring	King vulture	Protector

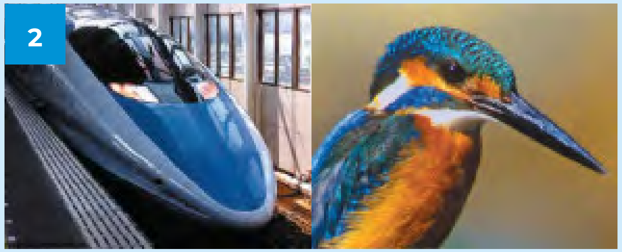
Forces of flight

Build your own glossary

Thrust	is the force that moves an aircraft through the air. It overcomes the drag and weight of an aircraft. Aircraft engines generate this force through the propulsion system (propeller or jet engine).
Weight	is the force generated by the gravitational attraction of the earth on the aircraft. This is the only force not controlled by the aircraft.
Lift	is the force that directly opposes the weight of an aircraft and holds it in the air. It is generated by every part of the aircraft, but mostly through the wings.
Drag	is a form of friction known as air resistance. This is the force that opposes an aircraft's motion through the air. Every part of the aircraft generates this force, even the engines. It acts in the opposite direction to the motion of the aircraft.

What is the relationship between the living thing and the technology?





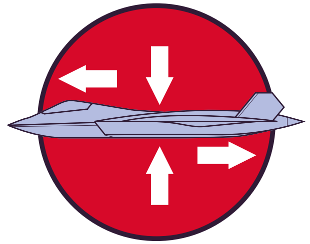
1 Bullet train inspired by the kingfisher. The old design caused a loud boom when it travelled through tunnels disturbing wildlife, passengers and people who lived nearby. It was also slowing the train down. Mimicking the long, narrow and streamlined beak of the kingfisher, engineers were able to overcome this problem.

2 Burdock and Velcro®. Burdock produce seeds are covered in tiny hooks. These tiny hooks catch on the fur of passing animals. This inspired the inventor of Velcro® to create the first hook and loop fastener. This consisted of one surface covered in tin hooks and another with fuzzy loops.

3 Beaver inspired wetsuit. Rubbery hair-lined wetsuits to keep surfers warm.

4 A gecko's foot inspired these Vibram shoes. The manufacturer claims they have a natural feel and their grip aids walking, running and climbing.

Theory of flight



Students can use the Crumble to set up a program that will measure force in Newtons using a wind tunnel. Coding blocks and guidance is given in the student guide to support students in writing a program that will do this.

```
program start
force crumb on C : set to zero
motor 1 FORWARD at 100 %
do forever
    let w = force on C in mN
    digits crumb on C : display w
    wait 250 milliseconds
loop
```

Example program that will display force on the Digits Smart Crumb.

Students can use the wind tunnel to compare the lift of different style aerofoils as well other objects.

They could also use the wind tunnel to investigate drag.

If you do not have access to the box of materials that comes with the Future of Flight resource, then visit the IET 'Engineering Open House Day' for a video by Sophie Harker on how to build your own wind tunnel.

Health monitoring

Think like a pilot

To get started, you could get the pupils to physically demonstrate this problem by sitting four pupils on five chairs, two at each end and asking them to swap places. You could also use different colour counters.

We have just provided solutions for an equal number of medical supplies and civilians, but your students might want to extend this further by investigating different combinations. This task has several different directions where you and your students can take it.

This creates the following quadratic sequence: 3, 8, 15, 25, 35...

	Medical supplies						
People		1	2	3	4	5	?
	1	3					
	2		8				
	3			15			
	4				24		
	5					35	
	?						

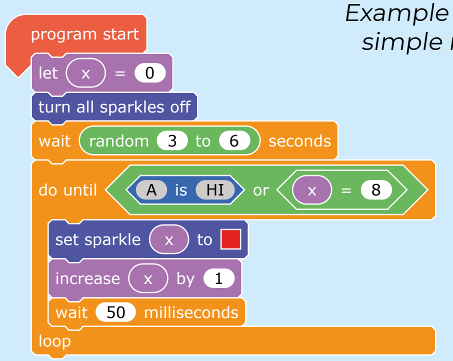
With position to term rule:

$n^2 + 2n$.

Finger on the pulse

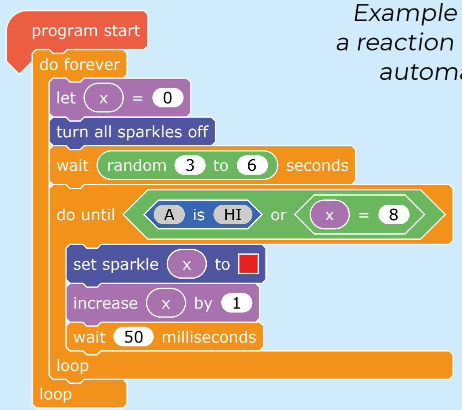
Students can use the Crumble to write a program that will test the groups reaction times. There are opportunities here for whole class data collection and analysis.

Coding blocks and guidance is given in the student guide to support students in writing a program that will do this.



Example program for a simple reaction timer.

Stretch and challenge



Example program with a reaction timer that will automatically restart.

Monitoring stress

Students can use the Crumble to write a program that will test the groups stress levels. There are opportunities here for whole class data collection and analysis.

Coding blocks and guidance is given in the student guide to support students in writing a program that will do this.

Example program for a simple 'stress' test.

```
program start
do forever
  let x = analogue C
  if x > 100 then
    set all sparkles to [red]
  else
    turn all sparkles off
  end if
  wait 1 seconds
loop
```

Stretch and challenge

Example program where sparkles will flash if 'x' goes too high.

```
program start
do forever
  let x = analogue C
  if x > 100 then
    set all sparkles to [red]
    wait 500 milliseconds
    turn all sparkles off
    wait 500 milliseconds
  else
    turn all sparkles off
  end if
loop
```

Temperature check

Using the thermistor and the Digits Smart Crumb, students can write a program to measure temperature. If you have enough equipment, you could encourage students to use the sparkle baton within their system to use a light warning system if the temperature is too hot/too cold.

Coding blocks and guidance is given in the student guide to support students in writing a program that will do this.

Example program to show temperature. Other mathematical arrangements are possible.

```
program start
set A HI
do forever
  let x = analogue B
  let t = ((x - 128) ÷ 3) + 25
  digits crumb on C : display t
  wait 1 seconds
loop
```

Stretch and challenge

Example program to give maximum temperature warning.

```
program start
set A HI
let maximum = 0
do forever
  let x = analogue B
  let t = ((x - 128) + 3) ÷ 25
  if t > maximum then
    let maximum = t
  end if
  digits crumb on C : display maximum
  wait 1 seconds
loop
```

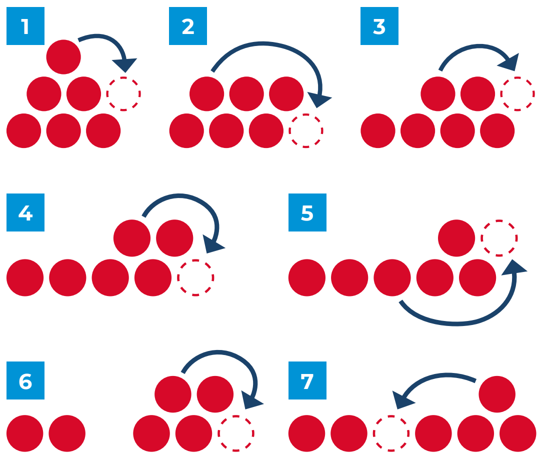
What is the temperature?

°C	Analogue
50°C	**203**
-10°C	**23**
9°C	80
0°C	53

The **minimum temperature** is approximately -18°C. The **maximum temperature** is approximately 67°C.

Putting your stress to the test

Challenge two – changing formation



Pilot training

This challenge asks pupils to find the relevant information on the cards provided to answer the questions given.

We suggest that the students split the cards equally between them. Each person in the group is then in charge of their cards and for sharing that information when they think it is relevant. Not all the cards need to be used. And some of the cards will hopefully be points for discussion.

There is no correct way to do this, but see the diagram with the nutrition cards below for an example of how students might work through this challenge.

Time to train

They are preparing for a short training ride.

- How much energy will they use during this ride?

A typical short training ride is two hours long

→ On average, a pilot will cycle at 9 mph on rides that take less than one day

→ A pilot uses 100 kJ of energy to cycle 1 km (in addition to normal energy use)

→ In two hours they will have travelled 28 miles.

38 miles ≈ 61 km

61km x 100kJ ≈ 6100 kJ

What on the road snacks will they need to take to minimise the amount of calories they lose?

We know that in a short training ride the pilot uses 6100 kJ.

→ 1 kcal ≈ 4 kJ

1 mile ≈ 1.6 km

→ 6100 kJ / 4 = 1525 kcal

→ Pilots like to eat a big meal before a short training ride. The energy is released during the ride

→ A big meal contains about 800 kcal

→ 1525 kcal – 800 kcal = 725 kcal.

The pilot needs to make up 725 kcal on a short ride.

→ A pack of energy gel contains 110 kcal and weighs 42 g

→ An energy bar contains 220 kcal and weighs 65 g

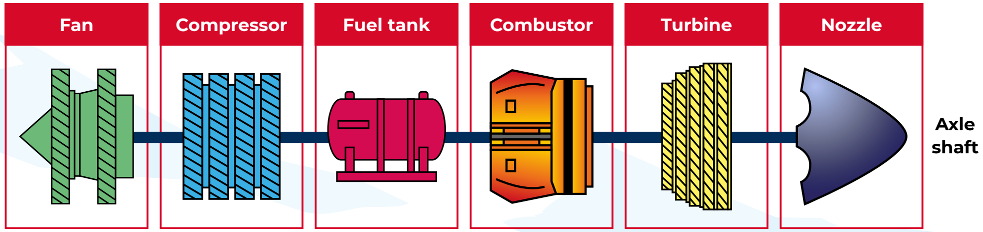
Engines

The **Rolls Royce website** has some fantastic resources. We have linked to the ones we feel are most relevant to the resource in the student guide.

You can also download a poster for your classroom which shows how a jet engine works.

What is a jet engine and how does it work?

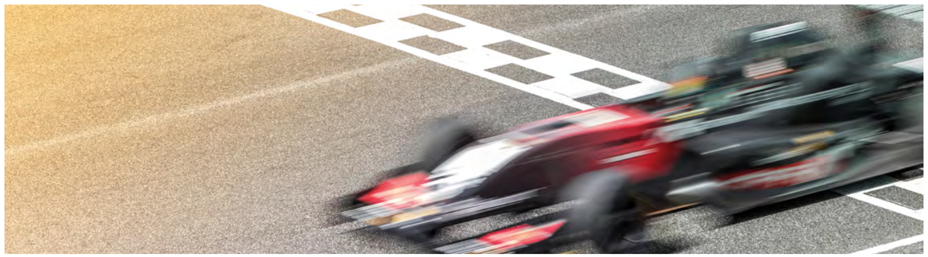
Using the information provided, students can place the parts of the engine in the correct order.



Balloon craft race

Students can use the materials provided in the box, as well as another materials they want to use to build their balloon craft car. There is a hand pump in each kit to make it easier and consistent when blowing up the balloons for the race.

There are a couple of group Crumble activities which can be carried out alongside the 'Balloon craft race'. These are:



Ready, steady, race

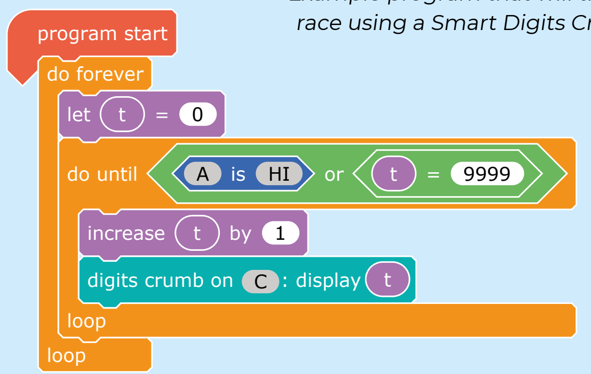
Write a program that creates a flashing light sequence activated by a switch to countdown to the start of a race.

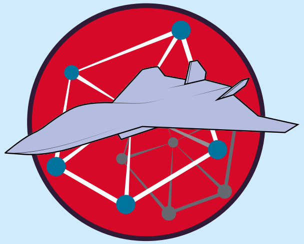
Example program to create a countdown timer using a Sparkle Baton.

And the winner is...

Write a program that will time a race.

Example program that will time a race using a Smart Digits Crumb.





Faster than the speed of the sound

Students can use the materials provided in the box, as well as another materials they want to use to build their balloon craft car. There is a hand pump in each kit to make it easier and consistent when blowing up the balloons for the race.

Time to calculate

Sound waves travel at approximately 340 metres per second in air.

- How fast did the Concorde travel?
  2,179 km/h
- What is the average speed of a passenger aircraft?
  Approx. 900 km/h

When will you hear the One O'Clock Gun?

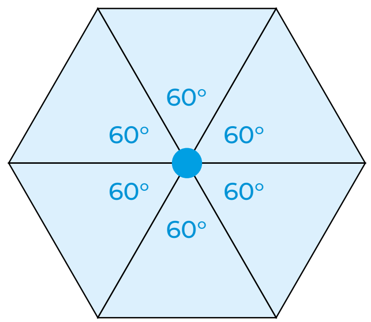
Use the map to calculate:

- The distance between Arthur's Seat and Edinburgh Castle
  Distance = speed × time = 340m/s × 6s = 2040 m
- The distance between Port of Leith and Edinburgh Castle
  Distance = speed × time = 340m/s × 11s = 14960 m

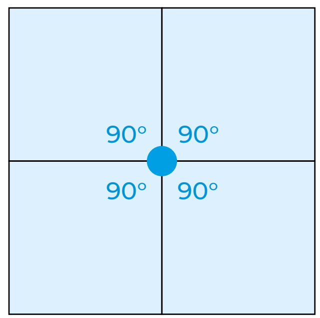
Materials

Biomimicry – in materials

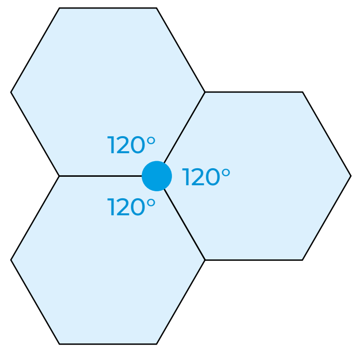
Regular polygon	Size of each exterior angle	Size of each interior angle	Divide by 360°	Does this polygon tessellate?
Triangle	$\frac{360}{3} = 120°$	180 - 120 = 60°	$\frac{360}{60} = 6$	Yes
Square	$\frac{360}{4} = 90°$	180 - 90 = 90°	$\frac{360}{90} = 4$	Yes
Pentagon	$\frac{360}{5} = 72°$	180 - 72 = 108°	$\frac{360}{108} = 3.33$	No
Hexagon	$\frac{360}{6} = 60°$	180 - 60 = 120°	$\frac{360}{120} = 3$	Yes
Octagon	$\frac{360}{8} = 45°$	180 - 45 = 135°	$\frac{360}{135} = 2.67$	No



4 × 90° = 360°



6 × 60° = 360°



3 × 120° = 360°

Communication

Fibre optic communication

This challenge asks students to create a code using a LED light, a switch, a fibre optic cable.

We have given them some guidance in the student guide and expanded on the grid system here in the teacher guide. Students are encouraged to not only come up with different systems, but strategies for when they make mistakes.

Check out our resource, Are we connected?, for more ideas for encryption activities.

	1	2	3	4	5	6
1	1-1 A	2-1 B	3-1 C	4-1 D	5-1 E	6-1 F
2	G	H	I	J	K	L
3	M	N	O	P	Q	R
4	S	T	U	V	W	X
5	Y	Z	Yes	No	Repeat	Help

Grid reference: *2-1 = 2 flashes – pause – 1 flash*

Using a grid is one way that students could create a more streamlined system to communicate using the fibre optics.

This grid is just an idea to get you started.

There are many ways they could make it more efficient. For example, rearranging the grid so letters/words that are more common are easier to send as signals.

Communicating with computers

Table 1 – Base 10

10^4	10^3	10^2	10^1	10^0	
10^4 = **10,000**	10^3 = **1,000**	10^2 = **100**	$10^1 = 10$	$10^0 = 1$	
		2 × 10^2 = **200**	**3** × 10^1 = **30**	**7** × 10^0 = **7**	200 + 30 + 7 = 237
		5	**7**	**4**	500 + **70** +4 = 574
	3	**0**	**3**	**6**	3000 + 0 + 30 + 6 = **3036**
7	**2**	**4**	**0**	**1**	**70000 + 1000 + 100 + 10 + 1** = 72401

Table 2 – Binary numbers (base 2)

2^4	2^3	2^2	2^1	2^0	Base 2	Base 10
2^4 = **16**	2^3 = **8**	2^2 = **4**	$2^1 = 2$	$2^0 = 1$		
				1 × 2^0 = **1**	1	1
			1 × 2^1 = **2**	0 × 2^0 = **0**	10	2
			1 × 2^1 = **2**	1 × 2^0 = **1**	**11**	3
			1	**0**	**10**	4
		1 × 2^2 = 4	**1 × 2^1 = 2**	**1 × 2^1 = 1**	111	**7**
1 × 2^4 = 16	**0 × 2^3 = 0**	**1 × 2^2 = 4**	**1 × 2^1 = 2**	**0 × 2^1 = 0**	10110	22
1 × 2^4 = 16	**1 × 2^3 = 8**	**1 × 2^2 = 4**	**0 × 2^1 = 2**	**1 × 2^1 = 1**	11101	29

Decode these facts

Ada Lovelace was born on the **10** December 1815. She was a British mathematician and computer engineer whose work is considered to be the first written algorithm.

Mary Jackson became NASA's first female black engineer in 1958. She analysed data from wind tunnels experiments.

The **16** square foot, **60** thousand horsepower wind tunnel used to study forces on model by generating winds twice the speed of sound.

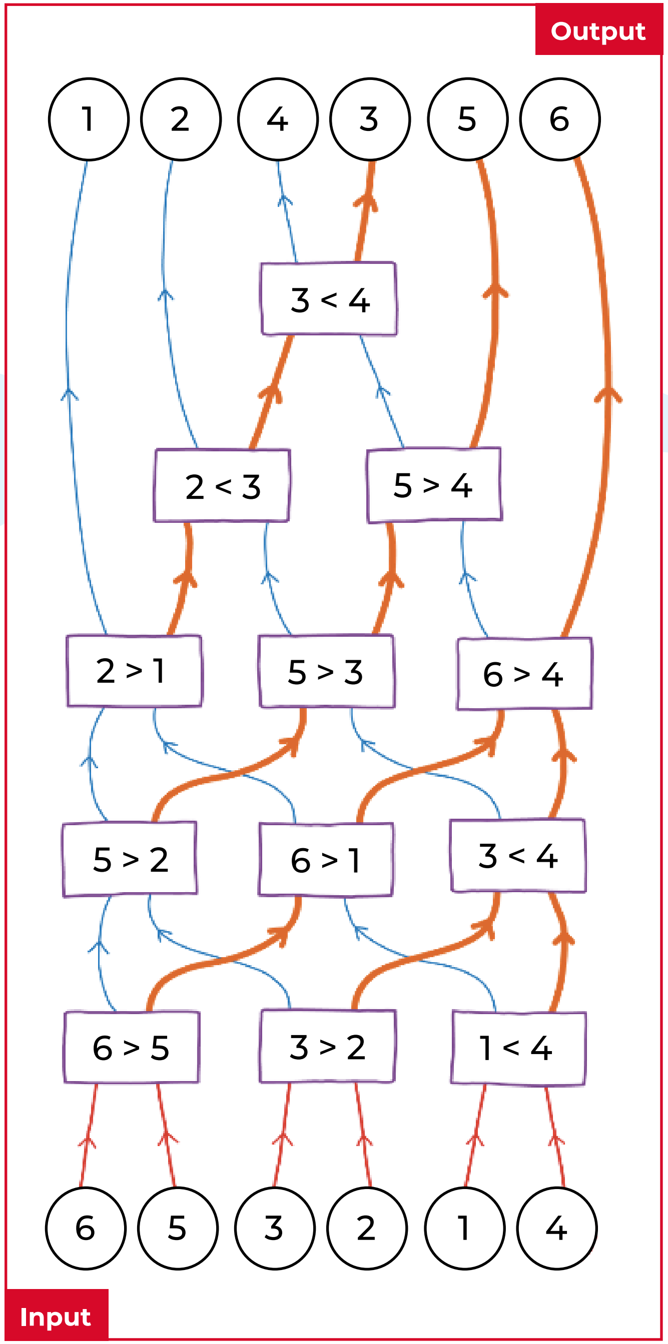
By 2025, it is predicted that global aircraft passenger traffic will increase by **4%**.

The temperature outside an aircraft is **-51°C**.

The average cruising speed for an aircraft is **900 km/h**.

Communicating with computers

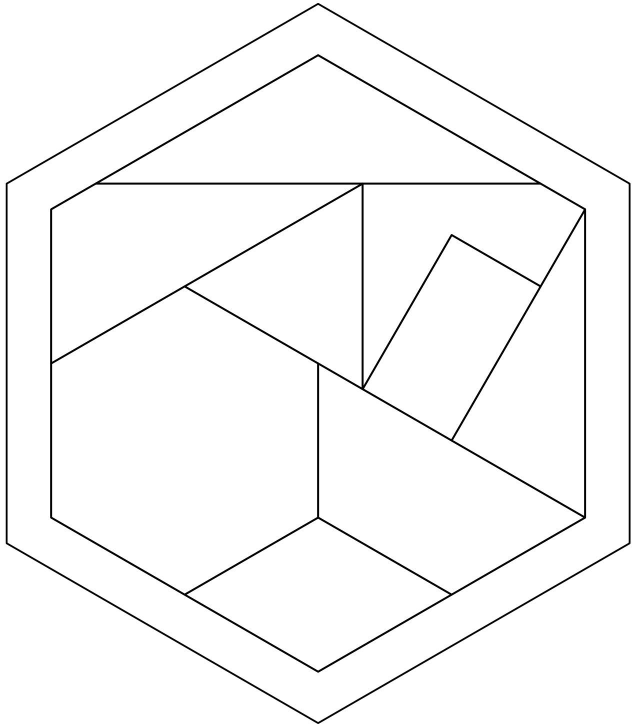
Activity adapted from [Sorting Networks, CS Unplugged]



Ground control cards

The ground control cards will fit together to create a hexagon.

Part of the challenge asks the students to work together to recreate this.



Artificial intelligence

The Turing test

Ideally, the 'Computer' and the 'Human' should receive each question at the same time, and must answer at the same time. Only the person acting as the 'Computer' should see the answers on the computer sheet.

You will find an A5 sheet with both questions as a support sheet on the 'Future of flight' page on our resource hub.

Drone swarms

Background information

A misconception that students may have is that autonomous and unmanned can be used interchangeably to mean the same thing.

A fully autonomous vehicle is any vehicle that is capable of driving completely unaided for the entire journey without any human interaction. An unmanned vehicle, however, refers to any vehicle without a body inside driving it. This could, for example, be a vehicle driven by a remote pilot via radio communication.

There are also levels of autonomy, for example, parking assistance or cruise control. For a vehicle to be truly autonomous, it would have to be able to think for itself. You may like to discuss artificial intelligence with your students.

The word drone tends to refer to unmanned aviation vehicles (UAV); however there are a number of other unmanned vehicles that can travel in or on almost any medium.

For ideas around the use of drones to support society, visit 'How AI Based Drone Works: Artificial Intelligence Drone Use Cases'

Drone swarms

Time to reflect – where do we use drone swarms?

Some ideas to get your group started as to where drone swarms are used:

- Emergency services
  - Swarms of drones are used to look for survivors after a flood
  - During a fire, swarms of drones can be used to survey the area so firefighters know where best to use their resources
- Space exploration
- Cleaning oil or chemical spills
- Monitor crop

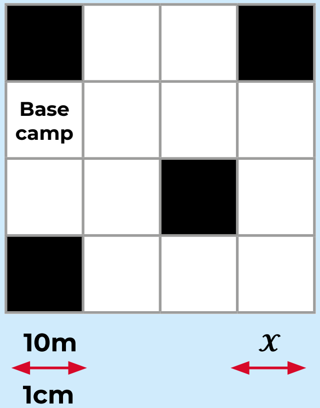
Task two – drone relay

Time to program

There are many different options that students could take.

One way that they could write their program is distance followed by the bearing:

- One step / 10m – Drop aid
- Turn to 090° – Three steps /30m – Drop aid
- Turn to 180° – Two steps / 20m – Drop aid
- Turn to 270° – One step / 10m – Drop aid
- Turn to 180° – One step / 10m – Drop aid
- Turn to 270° – Two steps /20m – Drop aid
- Turn to 000° – Two steps /20m



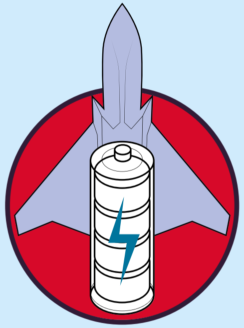
■ **Time to relay**

This activity requires some teacher input to set-up.

- Divide students into groups of 3–5.
- Have each group queue up relay-style.
- Place an identical 'Drone relay card' at the other side of the room and a blank piece of paper at the other side of the room.
- Have the first student in line dash over to the image, review it, run to the blank piece of paper and write down the first line of the program.
- The student then runs back and tags the next person in line, then goes to the back of the queue.
- The next person in line dashes to the image, and repeats this process until the group have a complete program.
- First group to finish is the winner!
- Each group swaps their program with another group and tests it out. Can they recreate the grid map?

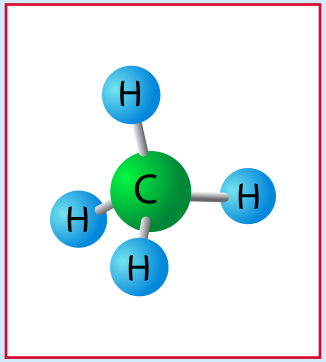
You will find the 'Drone relay cards' as a support sheet on the 'Future of flight' page on our resource hub.

Environment



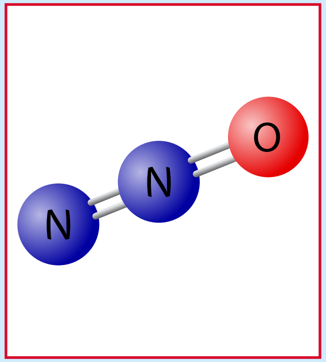
What are greenhouse gases?

Match the molecule diagrams with the description. Can you work out which element each part of the molecule diagram represents?



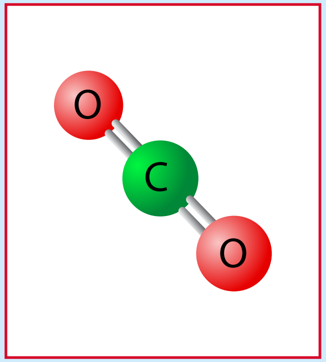
Methane (CH_4)

The main component of natural gas, methane is released from landfills, petroleum industries and agriculture. It does not stay in the atmosphere as long as a molecule of carbon dioxide – about 12 years – but it is at least 84 times more potent over a decade. It accounts for about 16% of greenhouse gas emissions.



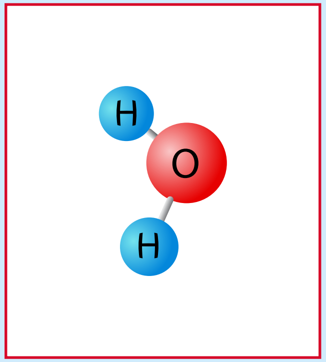
Nitrous Oxide (N_2O)

A powerful greenhouse gas – 264 times more powerful than carbon dioxide over 20 years – produced by soil cultivation practises, especially use of fertilisation, fossil fuel combustion and biomass burning. It accounts for about 6% of global greenhouse gas emissions.



Carbon Dioxide (CO_2)

It is responsible for about threequarters of emissions. It can linger in the atmosphere for thousands of years. It is released through respiration, volcanic activity, deforestation, burning fossil fuels, etc.



Water Vapour (H_2O)

Most abundant greenhouse gas. Water vapour also increases in the atmosphere as the Earth warms. Water vapour only remains in the atmosphere for a few days.

Environment

Modelling the greenhouse effect

Investigation one – vinegar and baking soda

CO_2 is released in the reaction. This models an increase in greenhouse gas. While the jars heat up at about the same rate, the one with CO_2 cools down much more slowly.

Investigation two – hot water

This models how CO_2 and water vapor in the atmosphere affect the rate at which the Earth loses heat (the cling film acts as the CO_2 and water vapor during the experiment).

Investigation three – cold water

This is similar to Investigation #2. This models how CO_2 and water vapor in the atmosphere affect the rate at which the Earth gains and loses heat (the cling film acts as the CO_2 and water vapor during the experiment).

Investigation four – soil

This models how the temperature of the actual Earth changes (as opposed to water in investigations #2 and #3). The cling film acts as the greenhouse gases.

This challenge has been adapted from [Greenhouse effect models: Hot stuff by Teach Engineering]. Check out the resource for more challenges which model the greenhouse effect.

Design for light

There are many different solutions to this problem, however the main thing to consider was creating 'spikes' around a central space such as the examples shown.

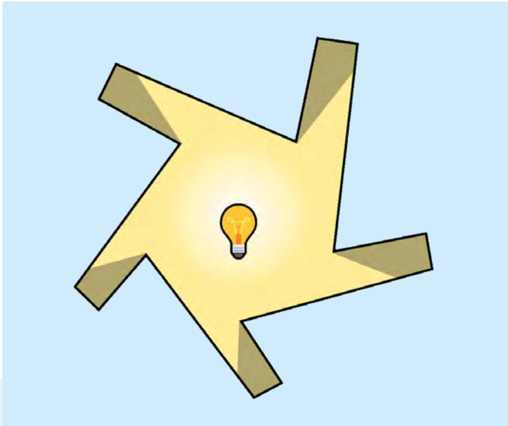
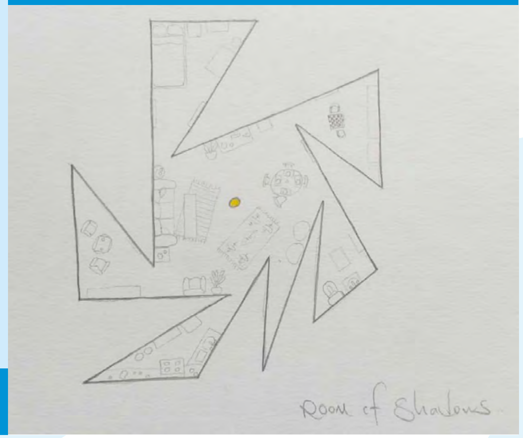


Illustration by Andrew White

Illustration by Liam Roberts



Both images taken from: https://www.theguardian.com/science/2016/feb/01/did-you-solve-it-the-shady-puzzle-that-will-keep-you-in-the-dark

Working with robots

Each team should produce a 2D model of a robot arm from the provided resources.

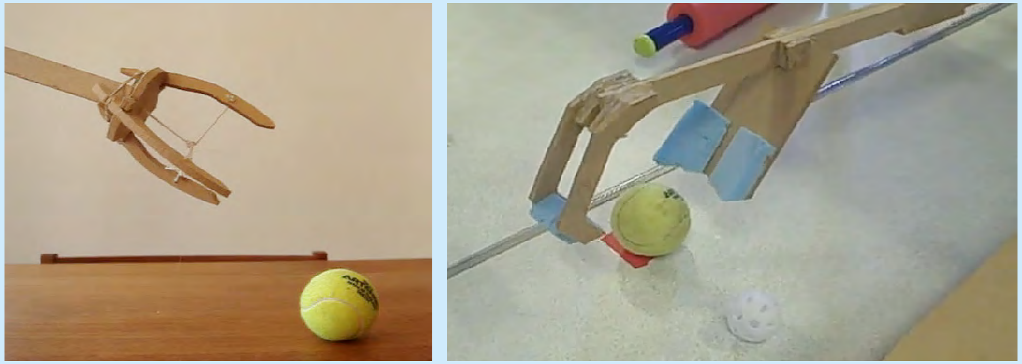
To do this they will need to sketch the shapes of the parts they need onto the card and cut them out.

These will need to be mounted on a backing board for stability.

Fixed pivots can be created using thumb tacks. Moving pivots can be produced using brass fasteners.

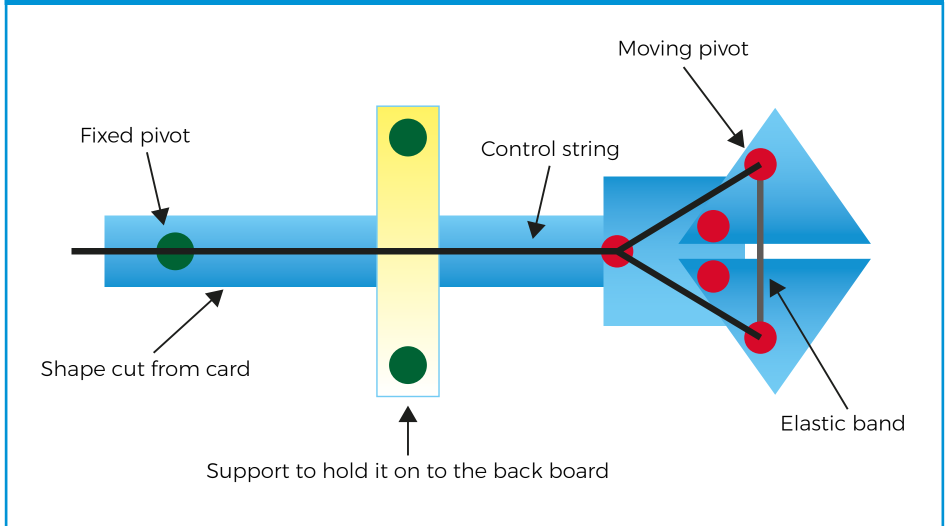
String, fishing line or elastic bands could be used for the control lines to transfer force.

Example gripper designs:



2D card model and gripper designs taken from [IET DIY Faraday Challenges]

Example of a 2D card model



Thank you

This STEM teaching and learning resource has been developed by the Royal Academy of Engineering for the Royal Air Force to mark the launch of Tempest. Tempest is the RAF's next generation aircraft, coming into service from 2035 to replace the Typhoon.

The resource has been developed with the support of a creative writing group made up of industry representatives from Team Tempest, including BAE Systems, Rolls Royce, Leonardo and MBDA.

The Royal Academy of Engineering is grateful to the RAF for their support in allowing physical copies of this resource, and associated kit and equipment, to be disseminated through its schools programmes.

The schools programmes are a support network for teachers across all STEM subjects, ensuring they have the knowledge and confidence to engage a greater number and wider spectrum of school students with STEM.

The RAF Youth STEM programme is designed to engage and inspire young people by building their interest in engineering and technical career pathways. From cyber specialists to aerospace, aviation, electronics, and mechanical disciplines, the RAF is committed to widening participation in STEM, extending opportunities to all, and encouraging greater diversity in this critical area of national skills shortages.

ROYAL AIR FORCE Youth STEM

Royal Academy of Engineering

The Royal Academy of Engineering is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public.

Together we're working to tackle the greatest challenges of our age.

What we do

Talent & diversity

We're growing talent by training, supporting, mentoring and funding the most talented and creative researchers, innovators and leaders from across the engineering profession.

We're developing skills for the future by identifying the challenges of an ever-changing world and developing the skills and approaches we need to build a resilient and diverse engineering profession.

Innovation

We're driving innovation by investing in some of the country's most creative and exciting engineering ideas and businesses.

We're building global partnerships that bring the world's best engineers from industry, entrepreneurship and academia together to collaborate on creative innovations that address the greatest global challenges of our age.

Policy & engagement

We're influencing policy through the National Engineering Policy Centre – providing independent expert support to policymakers on issues of importance.

We're engaging the public by opening their eyes to the wonders of engineering and inspiring young people to become the next generation of engineers.

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