ARE WE CONNECTED?

ROYAL ACADEMY OF **ENGINEERING**

THIS IS ENGINEERING

A STEM teaching and learning resource that explores engineering through the technology we communicate and connect with.

Curriculum links

Science: Electromagnetic spectrum
Maths: loci, collecting and comparing data sets
Computing: algorithms and textual computer programming language

GET CONNECTED

Where would we be without mobile phones? Mobile phones have become a central part of many people's lives and how we use them has changed over the last couple of decades.

TIME TO THINK

- How do you think mobile phones have changed since the first call was made on a mobile phone in 1973?
- What do you think the future of mobile phones will look like?

"YOUR PHONE CAN DO WHAT?!"

Share one big change that you think has already happened and one that you think will happen with mobile technology.

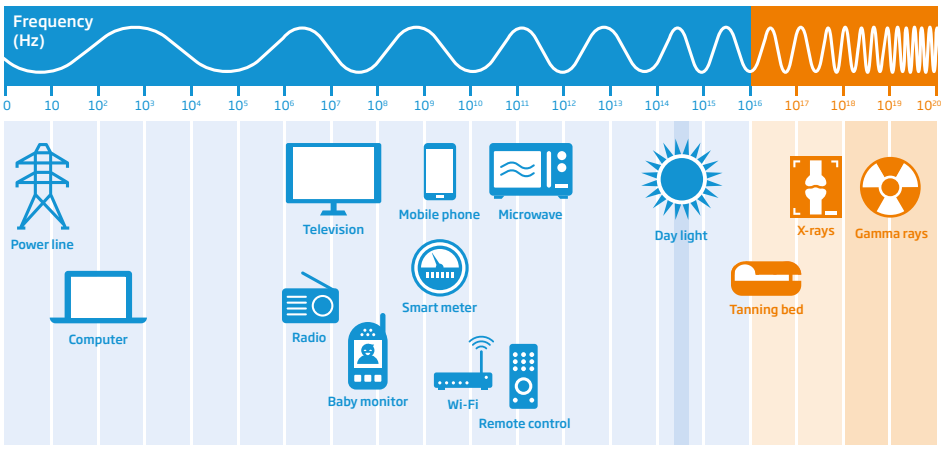
THE EVOLUTION OF THE MOBILE PHONE...

Mobile phones communicate by using low-intensity microwaves.

The microwaves are transmitted from the aerial in our phone to a telephone mast or base station. It is then relayed from mast to mast or station to station until it reaches the mast or station closest to its destination.

Microwaves travel in straight lines and can only be received by a mast or station that is in it's 'line-of-sight'.

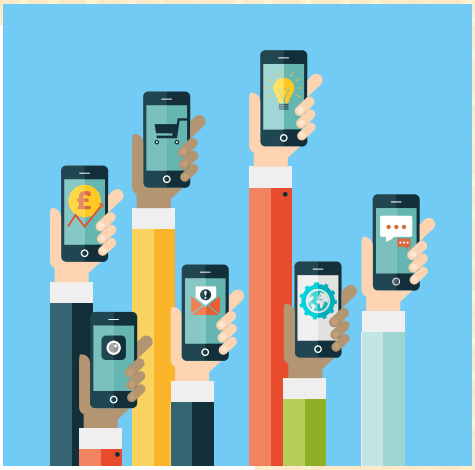
- How do you think this affects signal strength in different areas?



Mobile phone signals are generated by transmitting microwaves

Hertz (Hz) - the number of waves passing a point each second

A diagram showing the electromagnetic spectrum, changes to wavelength and frequency and uses of different electromagnetic waves.



Microwaves are part of the electromagnetic spectrum. All electromagnetic waves form a continuous spectrum of oscillating waves.

In your groups...

- describe oscillations.
- describe how the wave length and frequency change as you move along the electromagnetic spectrum.

Many of you will have used microwave ovens before and will have seen how quickly they can heat up your food. Microwaves penetrate about 1cm into food and are absorbed by water which is what causes food to heat up. Microwave radiation cannot pass through metals so we are protected from their harmful effects as the glass doors are made using a metal mesh and the microwave oven is made using a metal case.

- Are we putting ourselves at risk by using mobile phones every day?

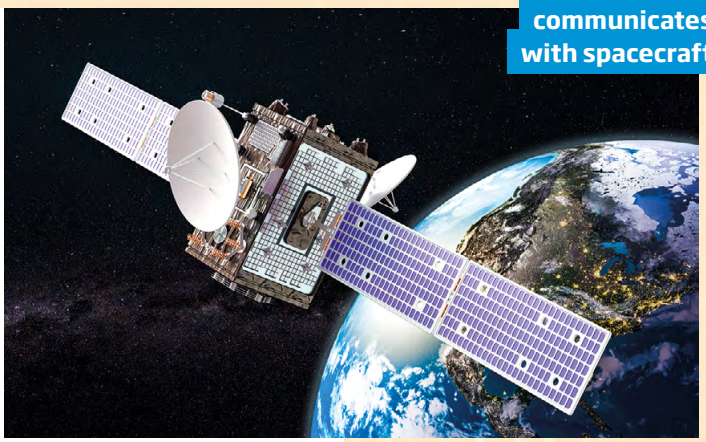
Don't worry, you won't be cooking your insides from using your mobile phone as the intensity of the microwaves are too low to cause any internal damage!

STRETCH AND CHALLENGE

Microwaves are also used to transmit signals between earth and orbiting satellites.

In pairs, use a computer, tablet or smart phone to visit the NASA Space Place and investigate **"How NASA communicates with spacecraft"**. Type this into a search engine to find the web page.

Present three interesting facts to your classmates or another group.



How Nasa communicates with spacecraft

TIME TO CALCULATE

All microwaves travel at the speed of 300,000,000 metres per second (speed of light). The circumference of the Earth around the equator is approximately 40,000,000 metres.

How many times does an electromagnetic wave travel around the earth in 1 second?

STRETCH AND CHALLENGE

Carry out the calculations in standard form.

CAN I GET A SHOUT OUT?

How about 'shouting' a message across the classroom? Across the playground? Across your town?

Sound waves travel at 343 metres per second. How long would it take for a sound wave to travel across the earth? Compare this to the speed microwaves travel.

DROP ME A PIN

Radio waves are used for navigation in systems such as GPS.

GPS stands for **global positioning system**. It is a system that can pinpoint exactly where you are by using satellites that orbit the Earth at an **altitude** of 20,000 kilometres – that's further than the distance between the UK and New Zealand!

GPS works by calculating your distance from at least three satellites (the technical term for this is **trilateration**). It only works if there is nothing obstructing your signal to the satellites.

WHERE IN THE WORLD?

Activity: Your friend has 'shared their location' with you, which first must be detected by satellites. You know that they are 250km from Aberystwyth, 470km from Ipswich and 440km from Edinburgh. Use the map to work out where they could be.

Activity: Your classmate is using the app 'Find my friend' to locate you somewhere in the UK and Ireland.

Give your friend three distances from three different cities across the country. Can they work out where you are?

Discussion: Why do you think you need at least three satellites for GPS to work? What happens if you just have distances from two locations?

ARTIFICIAL INTELLIGENCE: THREAT OR OPPORTUNITY?

AI technology is becoming more advanced and sophisticated.

Some AI machines have been designed to look like humans, 'replacing' people in society with programming that enables the machines to 'learn' from their environment.

Do you think that these advancements in AI are a threat or an opportunity?

TIME TO THINK

- Where do you think AI will be most useful in society?
- How do you think engineering in AI will continue to develop?
- What risks do you think there are with advancements to AI?
- In your groups, come up with three statements for opportunity and three statements for threat.

OPPORTUNITY	THREAT

TIME TO PROGRAM

Robots and computers are **programmed** using **algorithms**, which are a set of instructions that tell you how to solve a problem or complete a task.

Algorithms are not just for computer programs. Every time that we use instructions or follow a certain sequence or pattern, we are following an algorithm.

You can create algorithms for yourself, or follow someone else's algorithm.

Algorithms can be recipes for baking, your morning routine before school or someone giving you directions.

Where do you use algorithms in your life?

UNPLUG ALGORITHMS!

Often (especially in computing) you will need to create algorithms for someone else to follow.

A tangram puzzle is a Chinese logic game where the goal is to rearrange the seven pieces (tans) into an image.

Working in groups of three or four, take it in turns to use tangram puzzle pieces to build algorithms for the rest of your group to follow.

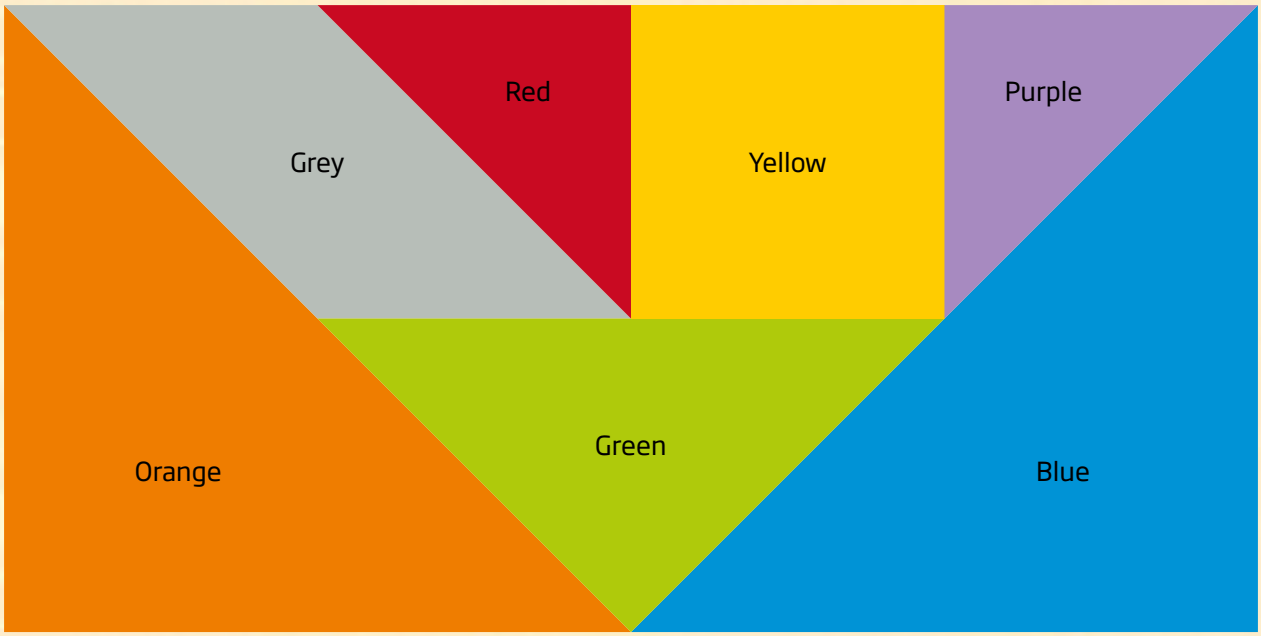
1. Cut out the tangram pieces below. Each person in the group needs a set.
2. Select one person to be the programmer. They will take an algorithm card (your teacher will give each person in the group at least one).
3. Without the rest of the group seeing, the programmer gives everyone clear instructions (an algorithm) so that they can build the shape on the programmer's algorithm card.
4. Once the programmer has finished explaining their algorithm, everyone in the group can reveal their final shape.

- Does it look like the shape on the algorithm card? Does everyone's shape look the same?

Programmers often find mistakes with their algorithms and go through a process to identify and remove errors. This is called **debugging**.

- How could the programmer improve and **debug** their algorithm?

Search for **Unplugged - Tangram Algorithms** on YouTube to hear Tanya, an engineer from code.org talk about building algorithms.



TEACHER NOTE:

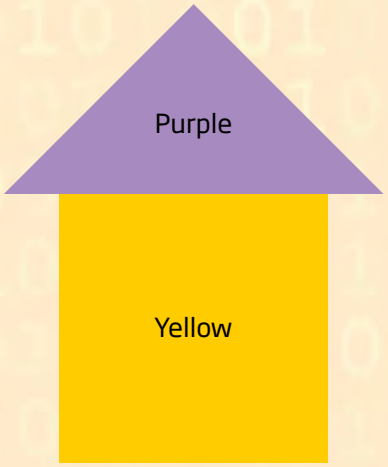
Depending on your group and their experience with tangrams, this task is open for you to create many more 'algorithm cards' with tangram puzzle pieces. More information about tangrams and a selection of new puzzles can be found here – www.tangram-channel.com

ALGORITHM CARDS

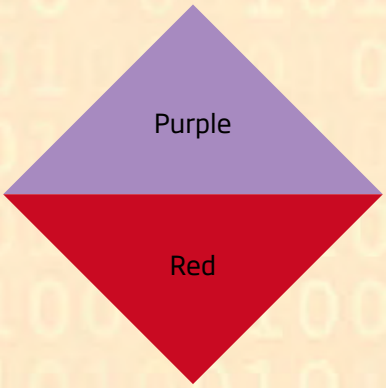
TEACHER NOTE:

Hand out at least one of these to each member of a group so that only they can see what is on the card.

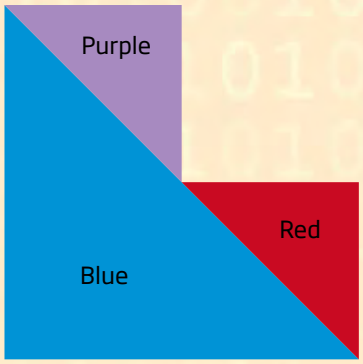
Algorithm card 1



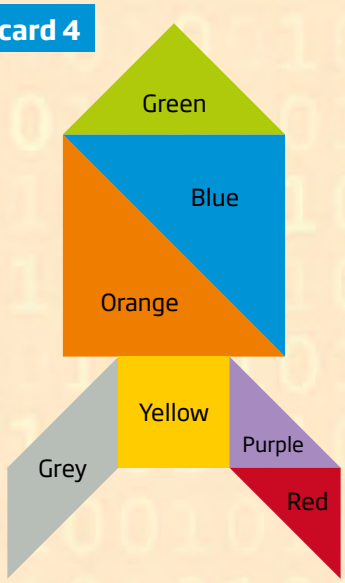
Algorithm card 2



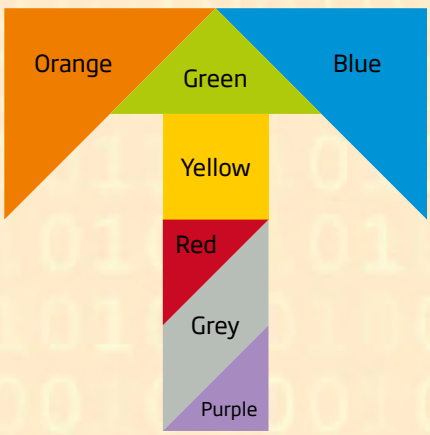
Algorithm card 3



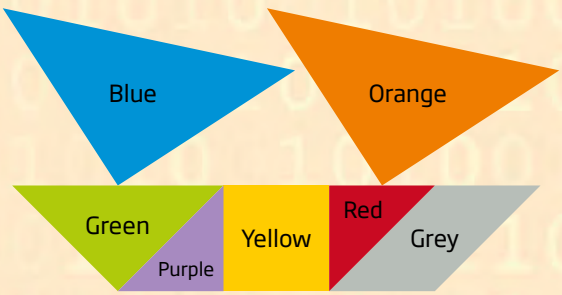
Algorithm card 4



Algorithm card 5



Algorithm card 6



TIME TO CODE

This is a computer, tablet or smartphone based activity where you can show off your Sphero programming skills.

A Sphero robot is a spherical robot that can be controlled by a smartphone or tablet. It is similar to the BB-8 robot from *Star Wars*.

Using the free **Tynker** coding platform, create a **script** using code blocks for your virtual Sphero robot to follow.

You will find the programming page by following the steps listed below.

1. Visit the **Tynker** website (if using a smartphone or tablet, search 'Tynker Hour of Code')
2. Select 'Hour of code', under the drop down menu 'Play'
3. Scroll to 'Coding projects'
4. Select 'Build anything you can imagine!'
5. Select 'Robotics', from the left hand list
6. Select 'Sphero' (you will need to scroll down to find this on a smartphone or tablet)

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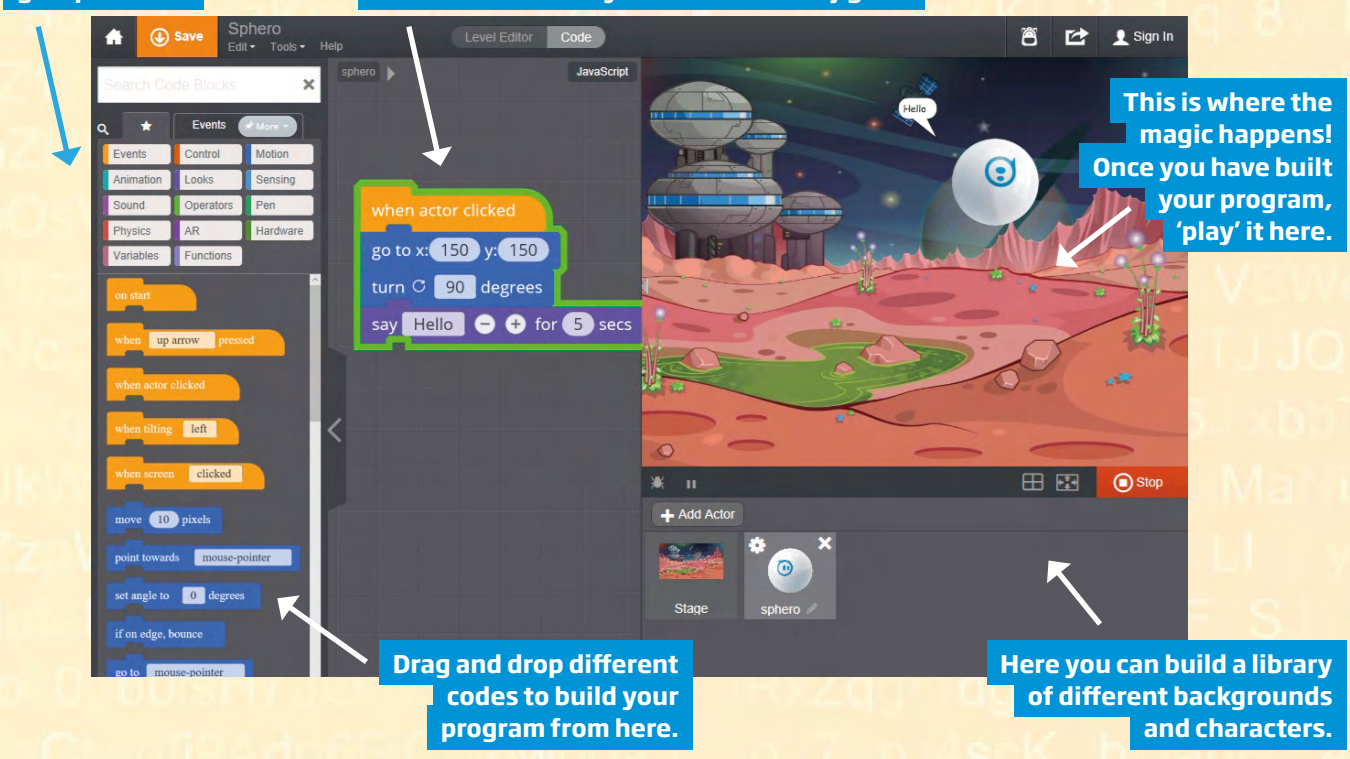


STRETCH AND CHALLENGE

Use the 'Level editor' (top of the page) to create your own backgrounds and new levels.

Most importantly, this is a time for you to 'tinker' with computer programming. Experiment with different handlers. Can you make your robot spin? Can you add sound or animation to your program? Try using different actors and backgrounds.

SECRET CIPHERS

In order to increase security, our online activity is encrypted. This means that all our online data has been converted into a code or a cipher.

Data can be encrypted to make it difficult for anyone else to access unless they have the secret key to unlock the information.

One way of encrypting data is to create a **substitution cipher**. This means we will swap one letter for another in our text. For example, **A** becomes **S** and **S** becomes **A**.

In all languages, some letters appear more often than others.

Which letters do you think are most common in the English language?

THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG.

What is special about the sentence above?

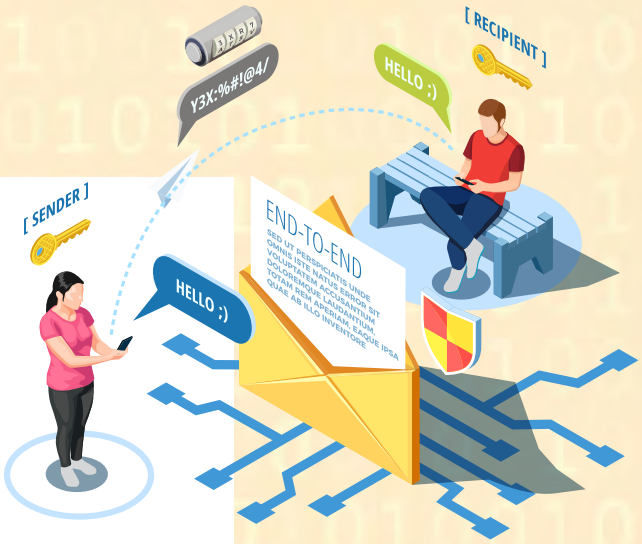
Working in groups of four, select a text from your classroom and perform a **frequency analysis** for the letters – how many times does each letter appear?

**Hint: divide the text between the members of your group (a sentence each) and combine your results at the end.*

- What letter do you think will appear the most?
- How can you record your results *(hint – the table below could be useful)*? Were the results as you expected?

A frequency analysis was carried out for a sample of 40,000 words! See if your results match their frequency table. Search for **"Pi Cornell frequency analysis"**

A		N	
B		O	
C		P	
D		Q	
E		R	
F		S	
G		T	
H		U	
I		V	
J		W	
K		X	
L		Y	
M		Z	



TIME TO DECRYPT

In the coded BBC Newsround article below, every letter in the original message has been switched with another letter.

Starting with the title of this news article, carry out another frequency analysis and use your results from the previous task to help you crack the coded message.

jtmh pq htx rmdz qprx, yd nmd qprx, yn htx ayyf?

Do you have enough information to decrypt the message? What other clues will help you (think about common one, two and three letter words and use the website address to help too)?

**Hint: do this task in your group again and divide the text between you so you have a sentence each and combine your results at the end.*

Continue the frequency analysis for the rest of the article, keeping an eye out for useful information that will help you along the way.

vtpfm tmq umlfvtxr htx npdqh apqqpyf hy umfr m dygyhpv vdmnh yf htx nmd qprx yn htx ayyf, vtpfxqx axrpm qmo.

fy qimvx idygx tmq xcxd dxmvtxr htmh imdh yn htx ayyf'q qldnmvx gxvmlqx yn vyaalfpvmhpyf rpnnpvluhpxq.

glh pf amo 2018 vtpfm umlfvtxr m qmhxuuphx vmuuxr slxspmy, yd ambipx gdprbx, hy hdo mfr qyucx htpq idyguxa.

htx qmhxuuphx jpuu dxumo qpbfmuq ndya htx qimvx idygx yf htx nmd qprx yn htx ayyf gmvz hy qvpxfhpqhq yf xmdht.

jjj.ggv.vy.lz/fxjqdylfr/44194356

A	B	C	D	E	F	G	H	I	J	K	L	M
N	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**	**X**	**Y**	**Z**

STRETCH AND CHALLENGE

Encrypting messages using pen and paper is a useful skill to have, but it takes a long time, even once we have the encryption key. Try using the Cipher Challenge Toolkit created by NRich maths. You can quickly carry out frequency analysis, create your own encryption key and encrypt and decrypt messages. If you are feeling really adventurous, use formulae on Excel to try to create your own decryption toolkit or explore other ciphers on the toolkit.

Search online for **NRich, substitution cipher toolkit to download the Excel spreadsheet**.

SOLUTIONS

SPEED OF ELECTROMAGNETIC WAVES

An electromagnetic wave will travel around the Earth's circumference 7½ times (300,000,000 / 40,000,000).

A sound wave would take 116,618 seconds (to the nearest second) to travel across the Earth's circumference.

SUBSTITUTION CIPHER

THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG.

The sentence above uses every letter of the English language.

Students can use the table provided to tally their results from the frequency analysis and to create their cipher.

Encryption key for article

A	B	C	D	E	F	G	H	I	J	K	L	M
m	g	v	r	x	n	b	t	p	w	z	u	a
N	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**	**X**	**Y**	**Z**
f	y	i	s	d	q	h	l	c	j	e	o	k

What is the dark side, or far side, of the moon?

China has launched the first mission to land a robotic craft on the far side of the Moon, Chinese media say.

No space probe has ever reached that part of the moon's surface because of communication difficulties.

But in May 2018 China launched a satellite called Queqiao, or Magpie Bridge, to try and solve this problem.

The satellite will relay signals from the space probe on the far side of the moon back to scientists on Earth.

www.bbc.co.uk/newsround/44194356

ROYAL ACADEMY OF ENGINEERING

ARE WE CONNECTED?

Royal Academy of Engineering

As the UK's national academy for engineering and technology, we bring together the most successful and talented engineers from academia and business – our Fellows – to advance and promote excellence in engineering for the benefit of society.

We harness their experience and expertise to provide independent advice to government, to deliver programmes that help exceptional engineering researchers and innovators realise their potential, to engage the public with engineering and to provide leadership for the profession.

We have three strategic priorities:

- Make the UK the leading nation for engineering innovation and businesses
- Address the engineering skills and diversity challenge
- Position engineering at the heart of society

We bring together engineers, policy makers, entrepreneurs, business leaders, academics, educators and the public in pursuit of these goals.

Engineering is a global profession, so we work with partners across the world to advance engineering's contribution to society on an international, as well as a national scale.

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