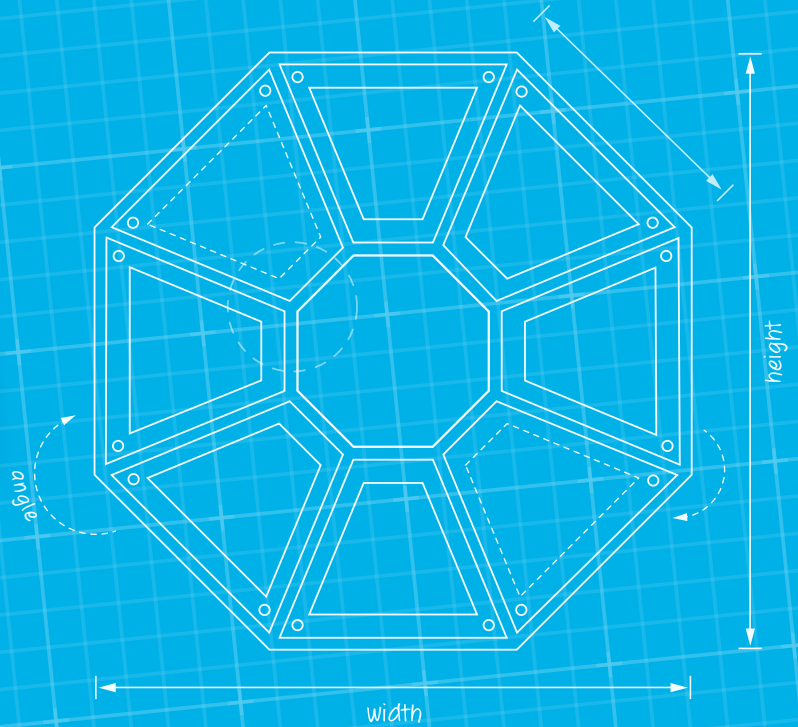




Royal Academy
of Engineering

THIS IS
ENGINEERING



DEPLOYABLE STRUCTURES

Rolling bridges

This resource gives students the chance to analyse the design of a rolling bridge and develop/use their understanding of circles and pi.

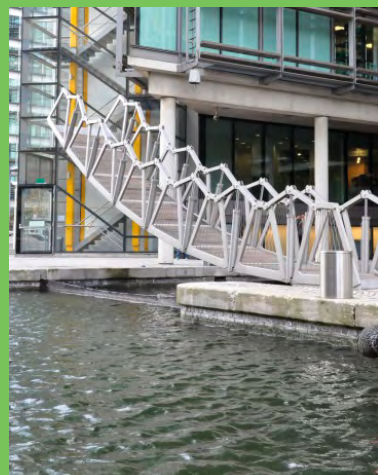
ROLLING BRIDGES

The photographs below show a special bridge designed by Thomas Heatherwick. Thomas is a British designer who created the Cauldron at the London Olympics and the new Routemaster bus in London.

He used a lot of mathematics and engineering to develop all these things. But how did he make the bridge and what mathematics did he use? Follow the activities below to find out how.

Rolling bridge
designed by Thomas
Heatherwick

Search the internet for
a video of the bridge
rolling/unrolling



Rhys Morgan/Royal Academy of Engineering

ACTIVITY 1:

MAKE YOUR OWN ROLLING BRIDGE

Step 1

Take a sheet of A4 card and divide it into five equal strips cut lengthways.

To do this you will need to measure the total width of the paper in centimetres (cm) and divide by 5. What is the width of each strip?

ACTION: Write down your answer.



Photograph 1

Take one strip of paper and measure its length **L**. Give your answer in centimetres (cm) to one decimal place.

ACTION: Write down your answer.

Step 2

Next, divide the length of paper into sections to make a roll up bridge.

Start with a six section bridge.

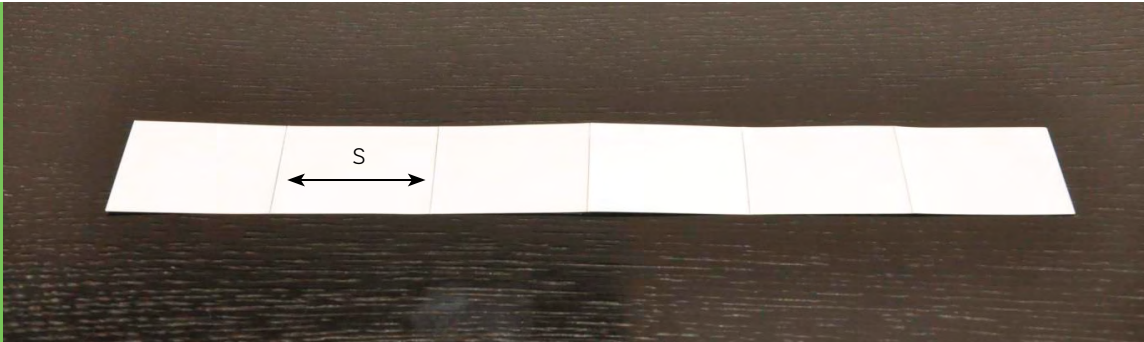
Divide your answer for the length **L** by the number of sections.

Give your answer the letter **S** (for section). What value do you get for **S** in centimetres (cm)?

ACTION: Write down your answer.

X Step 3

Measure from one end of the paper and make a mark with a pencil at each value of S until you get to the end.

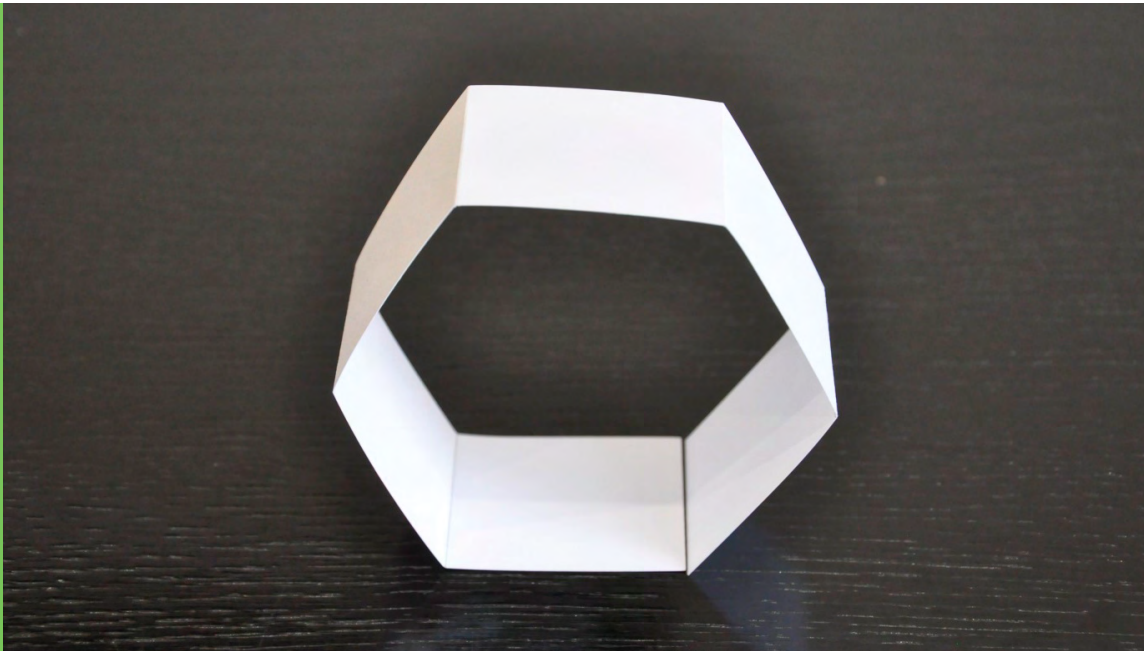


Photograph 2

At each mark, fold the paper. Make sure the paper is folded in the same direction each time so that both ends can be joined together.

X Step 4

Join one end of the paper to the other to make the polygon in the picture below. A polygon is a shape with straight edges.



Photograph 3

What shape is this polygon?

ACTION: Write down your answer.

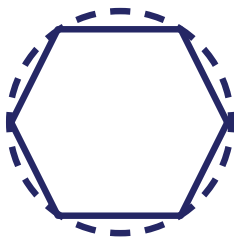
Can you see how your polygon rolls and unrolls like the bridge in the pictures on Page 1?



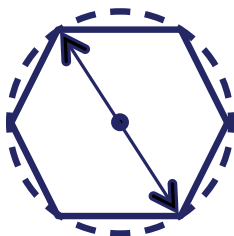
Photograph 4

X Step 5

You can imagine the polygon has a circle around it. We can estimate the **diameter** of the circle that the polygon would fit inside.



The **diameter** is the name for a straight line that goes from one side of a circle to another passing through the centre point.



Estimate the diameter of the circle around your polygon by measuring the distance between two points going through the centre.

It might help to tape the two ends of the polygon together.



Photograph 5

We will give the diameter the letter D. What is your measurement for the diameter D in centimetres (cm)?

ACTION: Write down your answer.

X Step 6

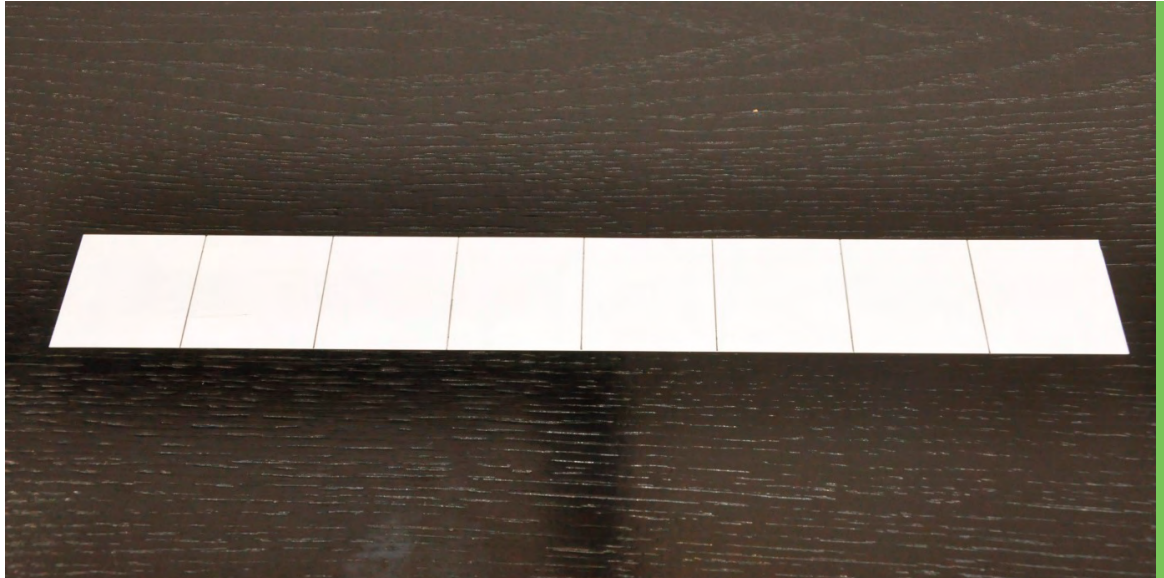
Using a calculator, divide the length L (from step 1) by the diameter D.

ACTION: Write down your answer.

LET'S BUILD ANOTHER ROLL-UP BRIDGE

Take a new strip of paper and repeat steps 1-6 for an **eight**-sided polygon, like the one in the pictures below.

Make sure you write down your answers and show your workings.



Photograph 6

If you have time, repeat steps 1-6 again for a ten-sided polygon.



Photograph 7

TIME FOR SOME PICE!



You should now have answers for step 6 for a six-sided, eight-sided and possibly ten-sided polygon.

ACTION:

Do you notice anything about your answers?
Write down what you notice.

If you did this carefully for a circle rather than a polygon, you would get an answer around 3.1 on your calculator. If you tried lots and lots of circles of different sizes you would find that the answer is always around 3.1 which seems strange. But what you have discovered is that if you divide the length around the edge of any circle (the circumference of the circle) by the diameter then you always get the same number. This number has so many decimal places that your calculator screen could not show them all. In fact, it has infinite decimal places. The number also has a special symbol (a Greek letter) so that we don't need to write lots of decimal places. The symbol is written like this π .

ACTION: Copy this Greek letter into your workbook.

The number π to six decimal places is 3.141592 but most people just remember pi to two decimal places.

ACTION: What is pi to two decimal places? Write down your answer.

π FUN FACT

This is a fun way of remembering π to 6 decimal places

3

.

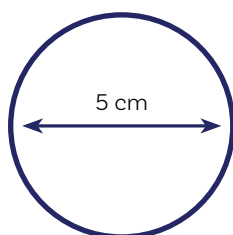
1	I	(1 letter)
4	wish	(4 letters)
1	I	(1 letter)
5	could	(5 letters)
9	remember	(9 letters)
2	pi	(2 letters)

USING PI

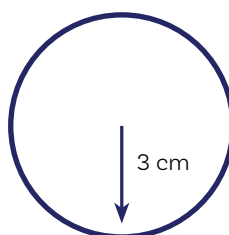
You have just seen that with any circle you can calculate pi by dividing the circumference, C, by the diameter, D. So if you knew the diameter but not the circumference, you could work out the circumference by multiplying the diameter and π together. This can be written as a formula.

$$C = \pi d$$

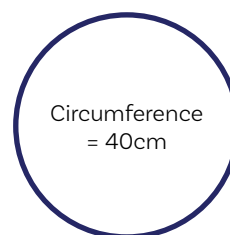
ACTION: Work out the circumference of circles A and B. Write down your answers. Then see if you can work out the diameter of circle C. Approximate π as 3.14.



A



B



C

ACTIVITY 2:

ENGINEERING CHALLENGE

Emergency! After the heavy rains, there has been a flood in Cumbria in Northern England. The overflowing river has torn down one of the bridges in the town of Keswick in the Lake District.



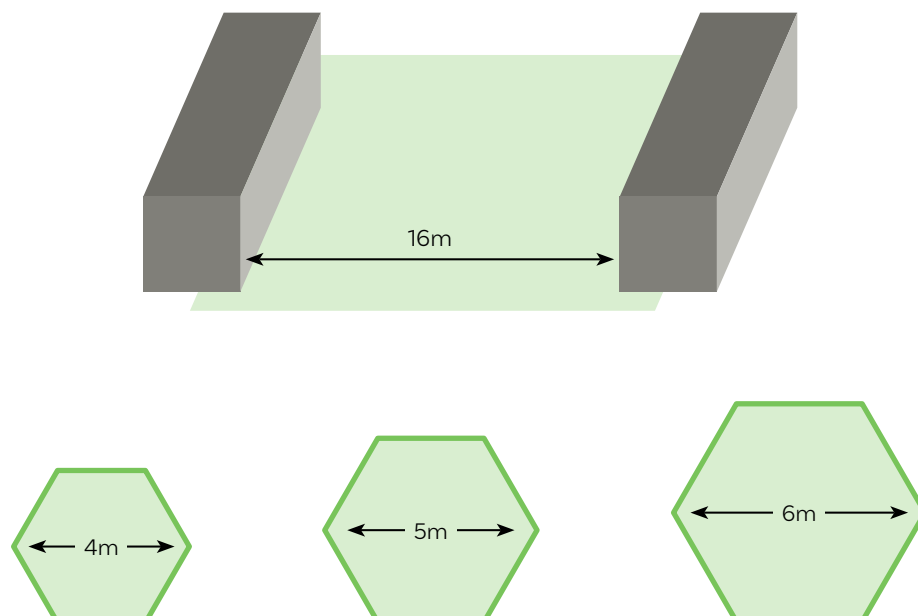
Damage caused to a bridge by heavy rain and flooding

Your company makes roll-up bridges that can be used after emergencies to create temporary river crossings.

Your challenge is to work out which roll-up bridge below would be most suitable for the emergency crossing in Keswick.

Use your knowledge of the circumference and diameter of circles and π to calculate the answer.

ACTION: Write down your answer.

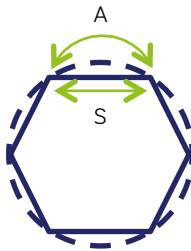


ACTIVITY 3:

EXTENSION ACTIVITY

The bridges you made are not circles. They are polygons.

This means that each segment length S is not quite as long as the length A shown in this picture below. We call this length of a part of a circle's circumference, the arc length A .



How can we calculate the difference between A and S ?

X Step 1

Start with the **six-sided** polygon.

You calculated the value of S for the **six-sided** polygon earlier in Activity 1 (Step 2).

What is the length of S for the six-sided polygon?

ACTION: Write down your answer.

X Step 2

Calculate the circumference of the circle using the diameter and π . You estimated the diameter earlier in Activity 1 (Step 5).

ACTION: Write down your answer.

How do you find the arc length A for one segment?

ACTION: Write down your answer.

X Step 3

How much bigger is the arc than the segment?

ACTION: Write down your answer.

X Step 4

Repeat the steps above for the **eight-sided** polygon.

ACTION: Write down your answers.

ACTIVITY 4:

OTHER TYPES OF BRIDGES

The rolling bridge is an interesting but unusual type of bridge.

There are many other types of bridge. For example, one of the most famous bridges in the world is the Golden Gate Bridge in San Francisco. This is a suspension bridge.



The Golden Gate Bridge in San Francisco

X Step 1

Can you think of any other famous bridges?

ACTION: Write down their names or where you know them from.

X Step 2

The Golden Gate Bridge is a suspension bridge, but there are many other types of bridge. Research the different types and draw a sketch of each type.

Find some real examples of these types of bridge and write down their names.



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.