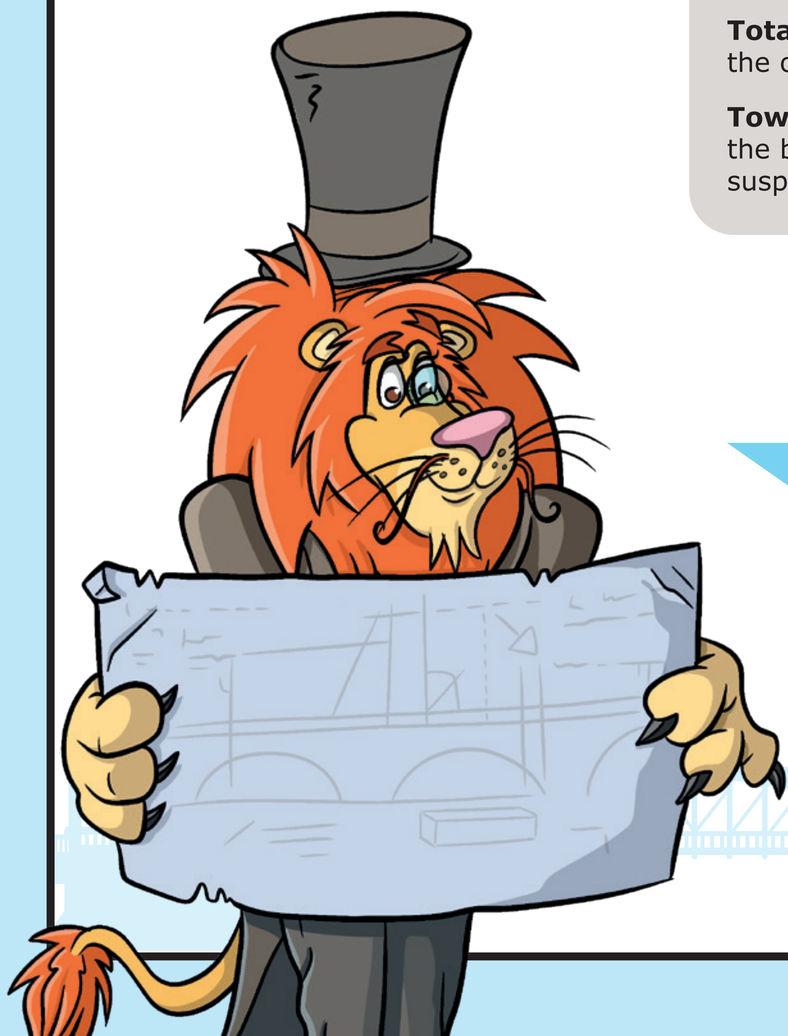
Chapter Ei: Suspension Bridges – Hanging Tough

AIMS & OBJECTIVES

- To show how transferring loads can make a bridge stronger
- To introduce the suspension bridge

CONTEXT

A suspension bridge is a type of bridge in which the deck is hung from main cables on vertical hangers. The suspension bridge was developed by engineers to cross long distances without needing extra piers, such as a beam bridge would require. Although suspension bridges are spectacular and beautiful structures, they are expensive and complex to build.



LANGUAGE OF BRIDGES:

Anchor: acts to secure the bridge to the ground.

Compression: a force that tries to make things shorter or smaller (a squashing, pushing force).

Deck: the main surface of the bridge, the traffic crosses here.

Hanger: the cables that hang the deck from the main cable.

Main cable: the cables that hold up the bridge, anchored at either end and suspended from the towers.

Piers: the upright columns that support the bridge.

Span: the distance between bridge supports.

Tension: a force that tries to make things longer (a stretching, pulling force).

Total span: the full distance, from one side to the other, the bridge covers.

Tower: the main structure that supports the bridge, over which the main cables are suspended, or hanging.

As a budding civil engineer, you will learn all about how suspension bridges transfer forces really well. This means they can span very long distances compared to other types of bridges.

You will need...

- Slinky spring
- Large sponge (such as used for car cleaning), marked along the side with a marker pen, with vertical lines, approximately 2.5cm apart)

Photo by Adam Valstar on Unsplash

- For the long K'Nex bridge demonstration, per group:
  - K'Nex® Education Introduction to Structures – Bridges set
  - Two 70cm lengths of string
  - Safety glasses
  - Heavy books/supports/desks, to act as abutments (at least 10cm tall, 40cm gap)
  - Small masses/washers/coins, to act as the load on the bridge
- Handout: *Suspension bridge terminology*
- For the simple suspension bridge demonstration, per group:
  - Two large, heavy books
  - Ball of string
  - Two drawing pins
  - Handout: *Forces in a suspension bridge*
- For the human suspension bridge:
  - Two ropes, each 4m long (or one 6m long rope)
  - Four towels/cushions/rolled up jumpers or similar cushioning material for the shoulders of the four 'towers'
- For the rope bridge activity, per group:
  - Two clamp stands, clamps and bosses (if you do not have these in school, or in sufficient quantities, it may be possible to borrow these from a local secondary school science department)
  - String – at least 12m ball, to be cut into 26 lengths of at least 45cm.
  - Range of small objects to test the bridge
- For the friendship bracelet (per bracelet):
  - At least three different colours of embroidery thread (these can be bought from a local craft supply shop)
  - Scissors
- Handout: *Card wheel method for making friendship bracelets*
- Handout: *Famous suspension bridges*
- Local area map

Something to Try:

Links to *Learning About Bridges Chapter Aii – Loads and Forces*

In the earlier section of this book, the chapter on Loads and Forces includes a series of activities you can use to demonstrate forces and their effects. You can re-visit these to remind learners of loads and forces on the bridge.

When an engineer is designing a bridge, they must first understand how different loads will put forces on the bridge. Then they must find a way to balance them. Where the load is likely to exceed the strength, the bridge will fail.

An example would be when an engineer needs to build a bridge across an estuary which is more than 1km wide. The water is very deep and is used by large boats to reach a port upstream.

What are the different options for the bridge?

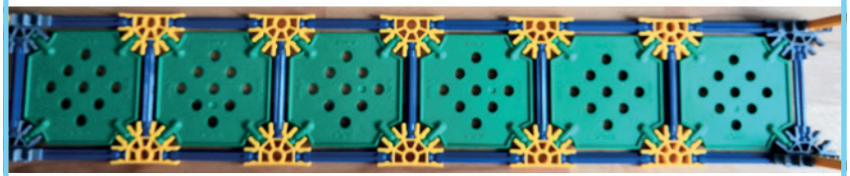
The length of each span in a beam bridge is limited to about 300m – the addition of extra spans requires more piers. These would be challenging to build and obstruct the shipping lanes.

An arch bridge has a maximum span of about 500m – the same issue as a beam bridge then arises, with the need for more piers etc.

In the truss bridge section of this book, learners explored how making a beam bridge longer weakened the bridge. Ask learners what they think happens when bridges become even longer. If we want a very long bridge, we need to find a way to transfer the load away from the middle of the bridge.

Links to Learning About Bridges Chapter C: Truss Bridges – What is a Truss?

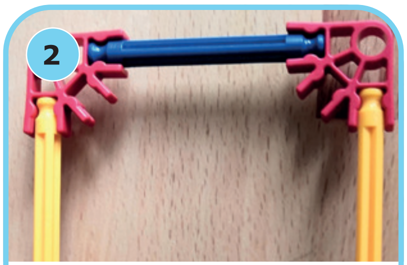
1 Create a K'Nex bridge span using the full six deck plates:



This isn't in the instruction book, so it needs to be created using:

- 6 green deck plates,
- 10 yellow half cog pieces
- 19 blue rods
- 8 grey half cogs fitted together at right angles

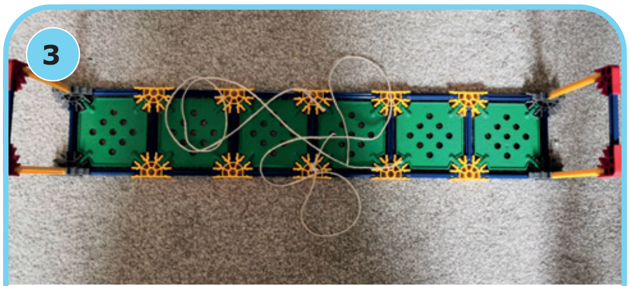
2



Then add two upright sections, one at each end

- 4 yellow rods
- 4 red right angled cogs
- 2 blue rods

3



Tie two 70cm lengths of string on each side of the middle of the bridge.

4

Place this K'Nex bridge across the 40cm gap created by the books/desks.

While wearing safety glasses, add the small masses until the bridge collapses. This demonstrates the maximum load the bridge can support.

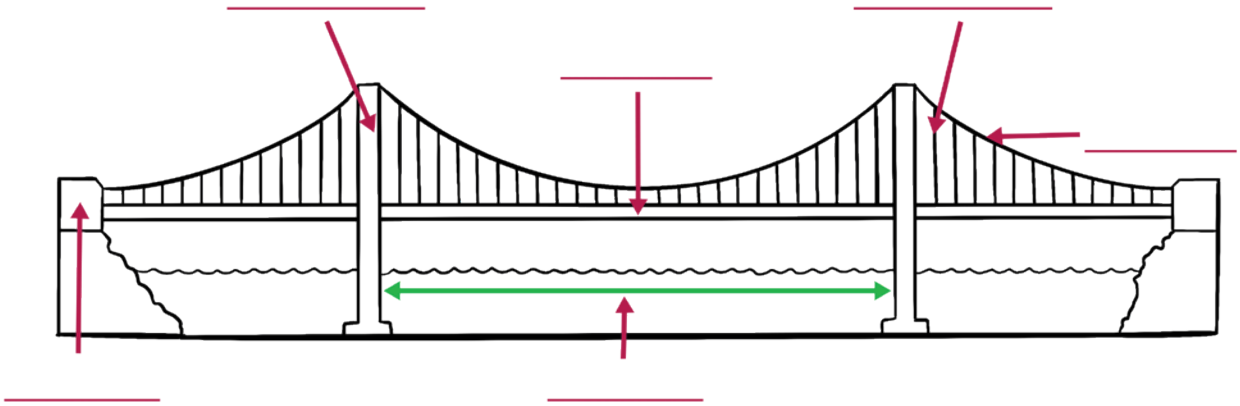
5

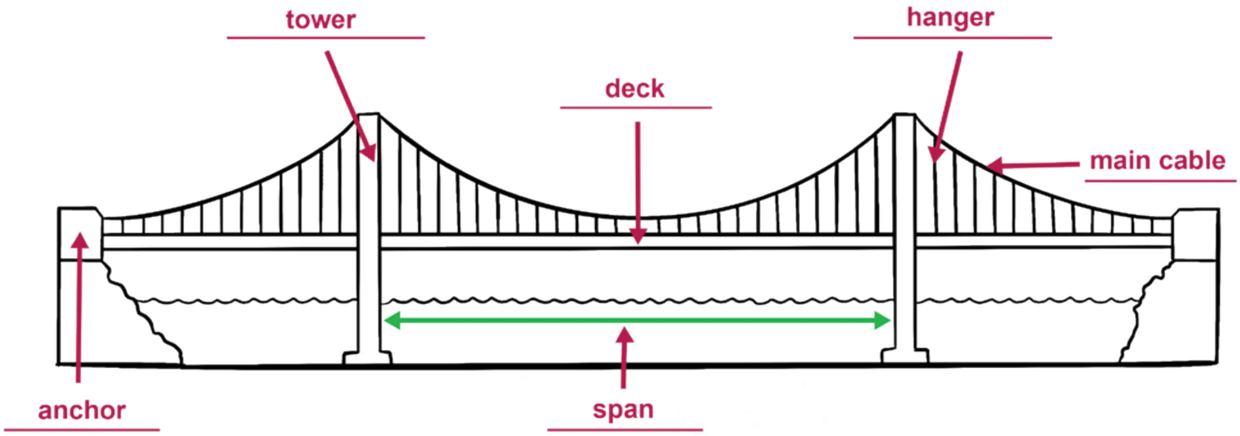
Remove the maximum load from the bridge. Bring one length of string over the upright on the right side of the bridge, and bring the other length over the upright on the left. Using some more of the small masses, weigh down the strings on either end of the bridge. Now return the original maximum load to the centre of the bridge. What do you notice?

Can you add extra load to the centre of the bridge to see how much greater the load now needs to be to collapse the bridge? Why does this happen?

INTRODUCING THE SUSPENSION BRIDGE

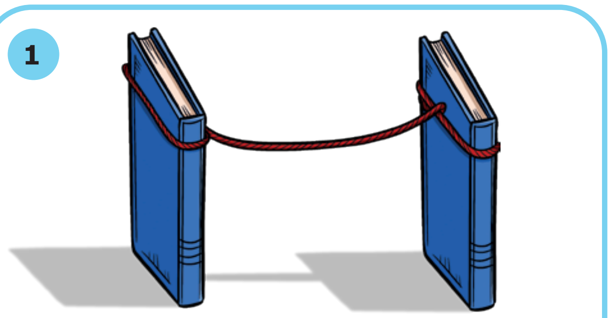
Using the *suspension bridge terminology* handout, learners can identify the different parts of the suspension bridge. Ensure learners understand the meaning of suspend, to hang something, which then explains the suspension bridge: the deck hangs from hangers which are joined to a long main cable strung between towers and anchored into the ground.





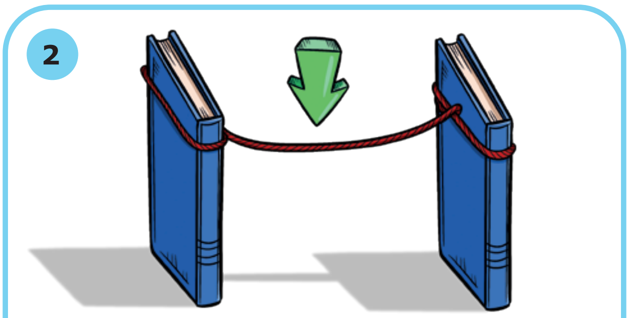
To give a simple demonstration explaining why the towers on a suspension bridge need to be anchored, you need two large books, some string and drawing pins.

1



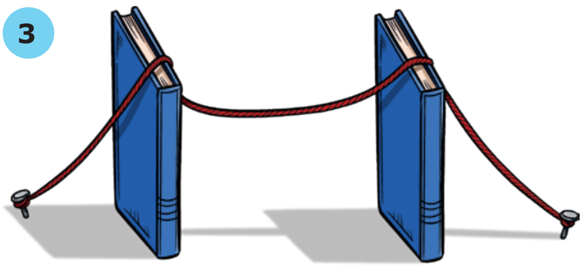
Tie string around two large books, so a 20cm (minimum) length of string acts as a bridge between the books when they are stood on end:

2



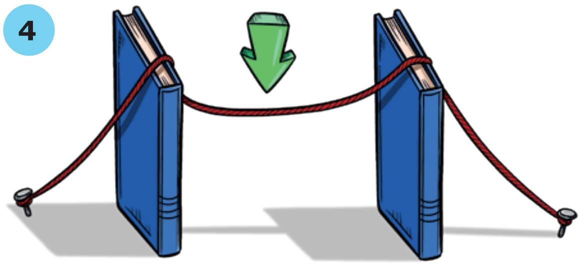
Push down gently on to the middle of the string. What do you notice?

3



Instead of tying the string around the books, fasten the ends of the string using the drawing pins, and rest the string on the top of the books:

4

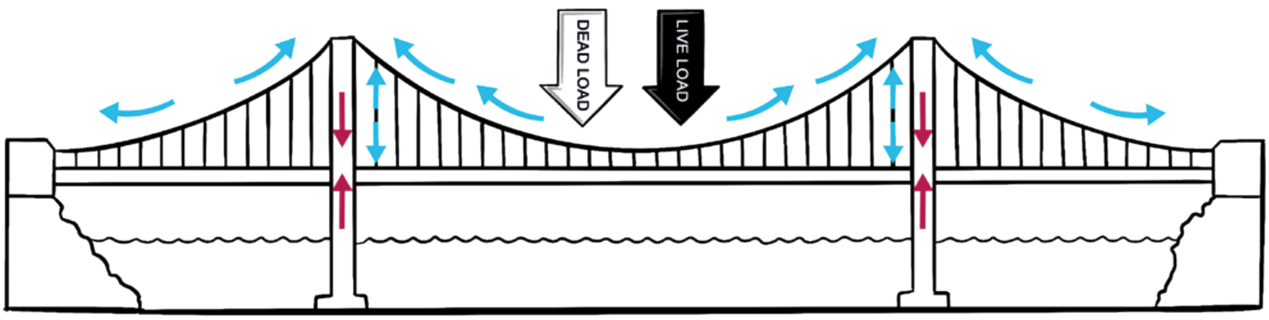


Again, push down on the centre of the string. What do you notice?

When the string is fastened, or anchored, the load in the centre of the bridge is re-distributed to the anchors.

Search the internet for “PBS learning media Clifton Suspension Bridge” for a short video explaining how the forces in a suspension bridge work.

You could use the *forces in a suspension bridge* handout to help visualise the forces.



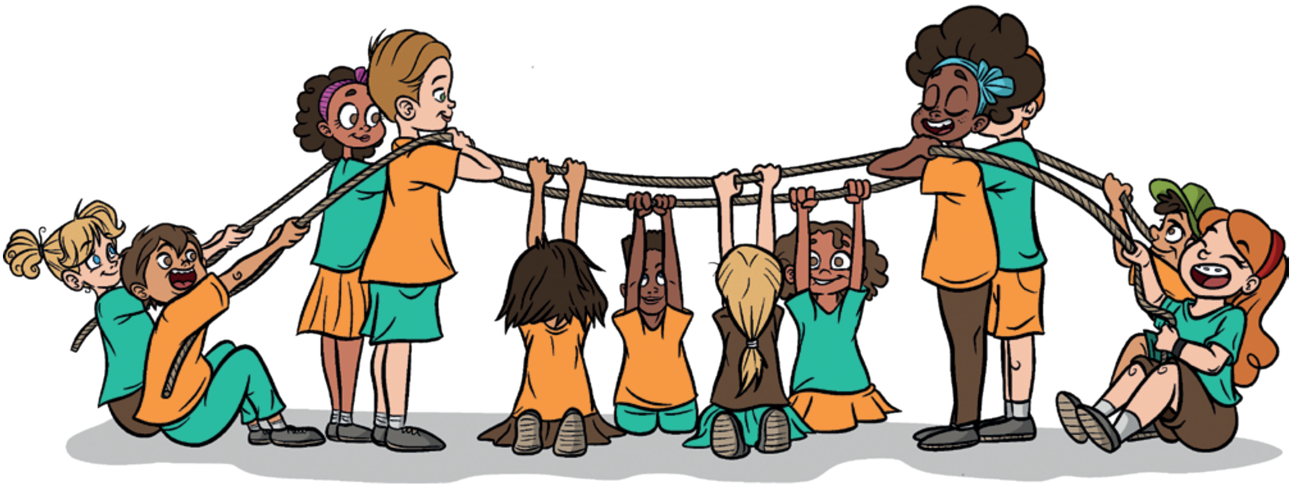
HUMAN SUSPENSION BRIDGE

This activity requires 12 children.

It is important that no-one pulls too hard on the ropes, as this could hurt the children acting as towers or could pull someone over.

1. Select four of the taller children and get one pair to stand facing the other, they should be roughly 2m apart. These children represent the two towers of the suspension bridge.
2. Place the rope across the shoulders of each pair (using the cushioning material underneath) – this represents the main cable.
3. Select four more children to act as anchors, getting each one to sit on the floor facing the back of each tower. They should each hold the end of the main cable. Remind them not to pull on the rope!
4. Select four more children to act as the hangers. They should kneel or sit on the floor, facing each other and holding on to the main cable. They represent the parts holding on to the deck of the bridge (the floor).
5. The four hangers can now pull gently on the main cable. They should feel the tension pulling on their arms. The towers should feel the compression pushing down on their shoulders, and the anchors should feel the tension in the main cable pulling against their arms.
6. Ask the learners to notice that all the parts have to balance the forces for the bridge to stay up and be stable (even without pulling hard).
7. You could invite the children to consider what would happen if there were no anchors, or to consider what might happen if the hangers failed? They might appreciate that a suspension bridge has lots more parts than most other types of bridge. This makes them complicated and expensive to build.

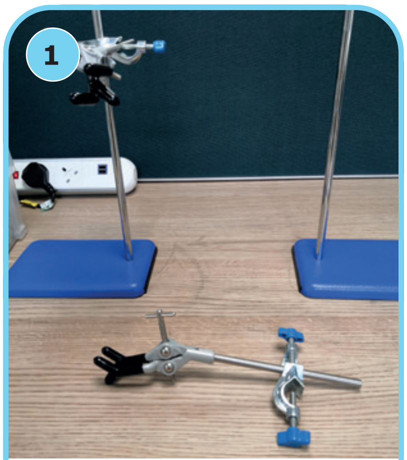
If there are additional participants in the group, ask them to act as cars and move through the centre of the suspension bridge (carefully!), between the two lines of children, remaining on the floor/deck of the bridge. Ask the learners to imagine how the forces in their parts of the bridge would change as this live load travels across.



Challenge Time!

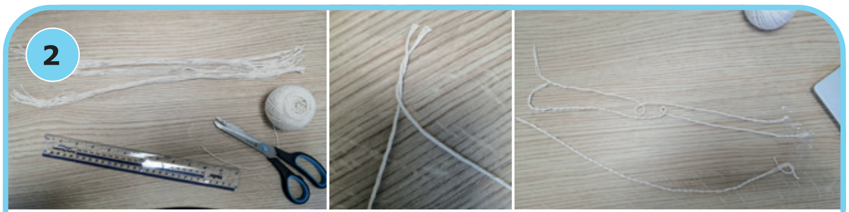
TRY MAKING A ROPE BRIDGE

1



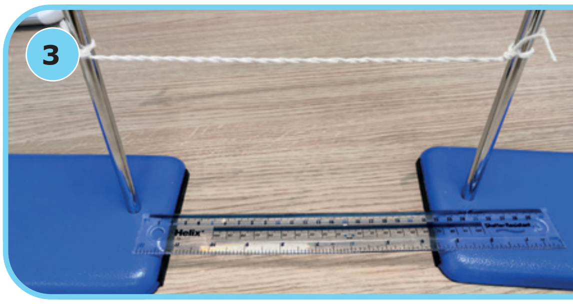
Using two clamp stands, clamps and bosses, fix the clamps at right angles to the clamp stand upright pole. Ensure both are at the same height. Set the stands 20-25cm apart.

2



Cut the string into 26 pieces of at least 45cm length. Weave two pieces together to form one strip, by twisting them around each other. Do this three times, so you end up with three double-thickness lengths.

3



Take one double-thickness piece and tie it a third of the way up the uprights of the clamp stands. Make sure this string is tight.

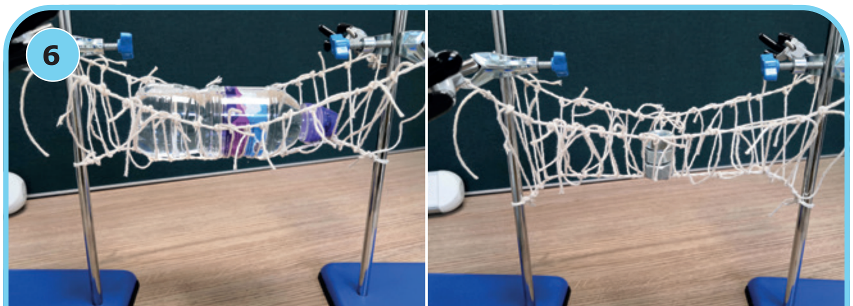
4

Take the other two double-thickness lengths and tie them between clamps so they’re horizontal and parallel to the first piece. Again, make sure they are tight.

5

Take a string and tie it to one of top double strings. Tie the middle of it to the bottom one and then tie the other end to the opposite top string. Repeat this for all the strings. The challenge here is to ensure all the strings remain as tight as possible. There is an excess of string in the lengths to help make it easier to tie them – the extra string can be cut off when the length is knotted in position.

6



Test the bridge with your objects.

Rope doesn’t seem like a strong material, and it isn’t rigid so it will move when in use, but it is lightweight, easy to make and transport, and easily replaced if needed. How could the rope bridge be improved?

Weaving friendship bracelets: although the process of spinning the suspension bridge cables is slightly different, weaving your own friendship bracelet using embroidery thread or yarn is still fun!

Here is a simple way of making a friendship bracelet, and just like a suspension bridge, the strands have to be anchored at the starting end.

1

Choose the colours you want to use for the friendship bracelet. You will need a minimum of three different colours, but you can use as many as you want.

2

Cut each thread to at least 75cm long; 1m should be sufficient for most wrist sizes.

3

Gather all the threads together and then fold them in half. Knot together all of the strands in the middle.

Anchor this knot – you can use a pin on a cushion or a branch on a tree for example.

4

Choose one strand of embroidery thread hanging from the knot. Take this in your dominant hand. Cross it over to your other hand to create a 4 shape, then loop the loose end around the remaining embroidery threads in your non-dominant hand. Then pull the knot you have just created up to the top by the main knot with your dominant hand.

5

Repeat this knotting process with the same strand of thread a few times.

Choose another colour strand and repeat steps 4 and 5.

6

When the bracelet is long enough, knot all of the strands together as you did at the start.

You can explore using more coloured threads, or changing how many knots you tie with each strand. You could also try a completely different method, described here: *Card wheel method for making friendship bracelets* handout.

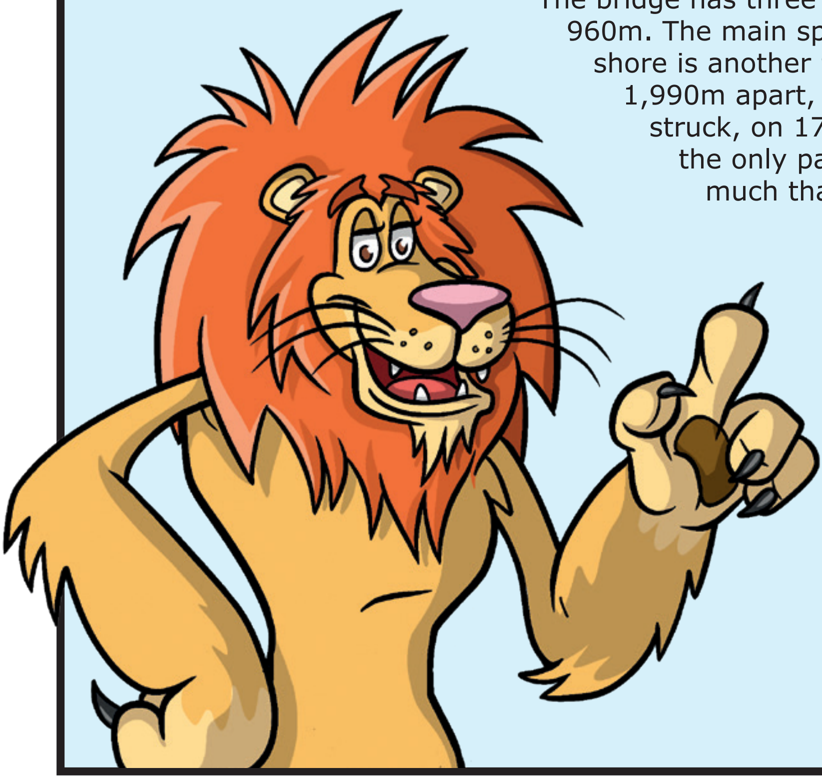
HOT TOPICS!

Take a look at the *Famous suspension bridges* handout. Can you discover where these bridges are in the world, and why they might have needed to be built?

The Akashi Kaikyo Bridge, also known as the Pearl Bridge, has the longest main span of any bridge in the world. It was finished in 1998. It links the city of Kobe on the mainland of Japan to Awaji Island.

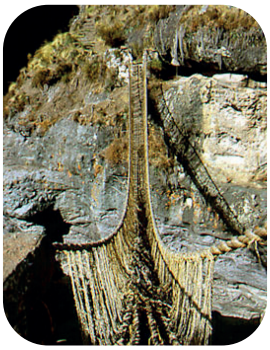
Before the Pearl Bridge was built, ferries carried passengers across the Akashi Strait in Japan. This dangerous waterway often experienced severe storms and, in 1955, two ferries sank in the strait during a storm, killing 168 people, most of them children. The resulting shock and public outrage convinced the Japanese government to develop plans for a suspension bridge to cross the strait.

The bridge has three spans. From the shore, the first span is 960m. The main span is 1,991m and the final span back to shore is another 960m. The two towers were originally 1,990m apart, but when the Great Hanshin earthquake struck, on 17th January 1995, the towers, which were the only parts constructed at the time, moved so much that the span had to be increased by a metre!



Look at a local area map. Measure how far the main span of the Pearl Bridge would carry you from your home or school.

The cables used in suspension bridges are made up of many, many smaller strands that have been spun together. The cables in the Pearl Bridge have 300,000km of wire – enough to go around the Earth almost eight times! When you are out and about, see if you notice any other materials that are like this – made up of lots of smaller parts to become a much larger, stronger object.



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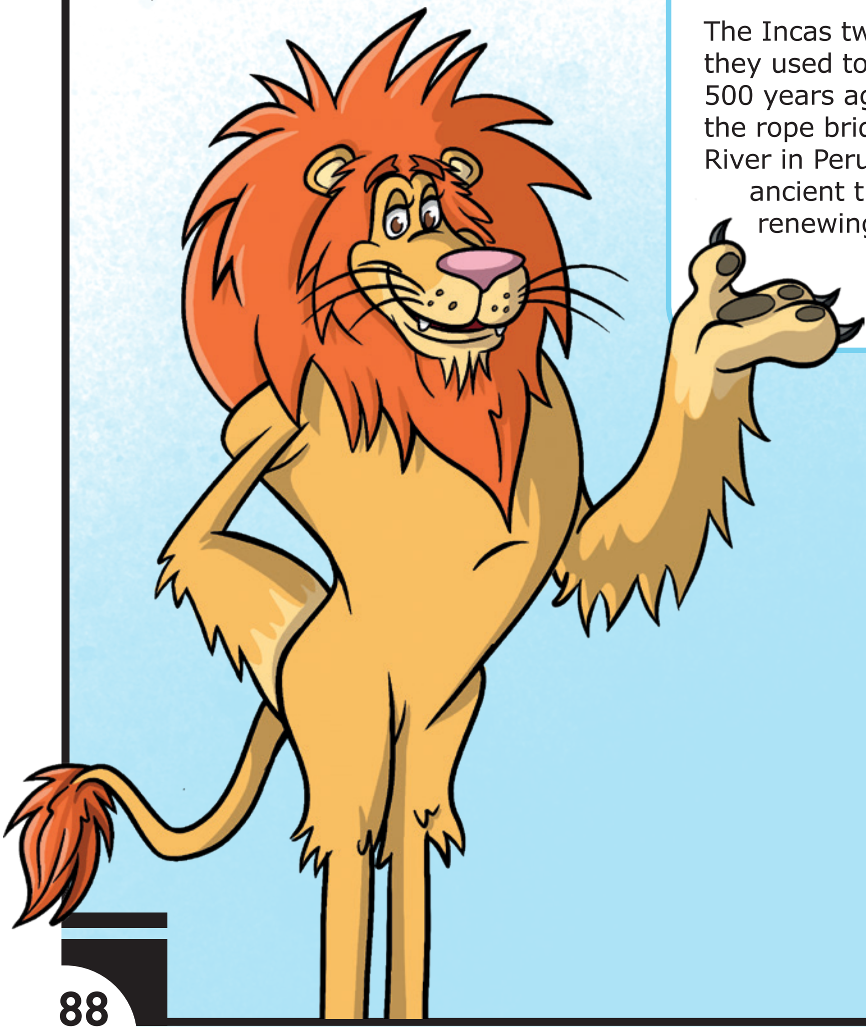
DID YOU KNOW?

The Incas twisted grass to create ropes, which they used to build suspension type-bridges around 500 years ago. One still remains: Q'iswa Chaka, the rope bridge spanning over the Apurimac River in Peru. The locals keep this ancient tradition and skill alive by renewing the bridge every June, even though there is a modern bridge nearby.

GEOGRAPHY



Langdon presents:

- *Language of suspension bridges* handout
- *Suspension bridge terminology* handout
- *Famous suspension bridges* handout
- *Card wheel method for making friendship bracelets* handout

Handouts can be found at www.rochesterbridgetrust.org.uk