Chapter Aii: Loads and Forces

AIMS & OBJECTIVES

- To understand the forces that act in bridges
- To recognise and describe tension and compression
- To show that forces must be balanced for a bridge to stand up

CONTEXT

You cannot see a force, but you can see the effect of a force. When a force is acting on an object, it can change its shape, speed or direction of movement. For a bridge to stay standing and functional, the forces and loads exerted on it and within it must be balanced.

LANGUAGE OF BRIDGES:

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

Dead load: the bridge's own weight which does not change or move.

Live load: mainly the weight of what the bridge is carrying, although wind and snow also have an effect. This moves and changes constantly.

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

Here, we will start thinking about the loads and forces that act on every bridge.

You will need...

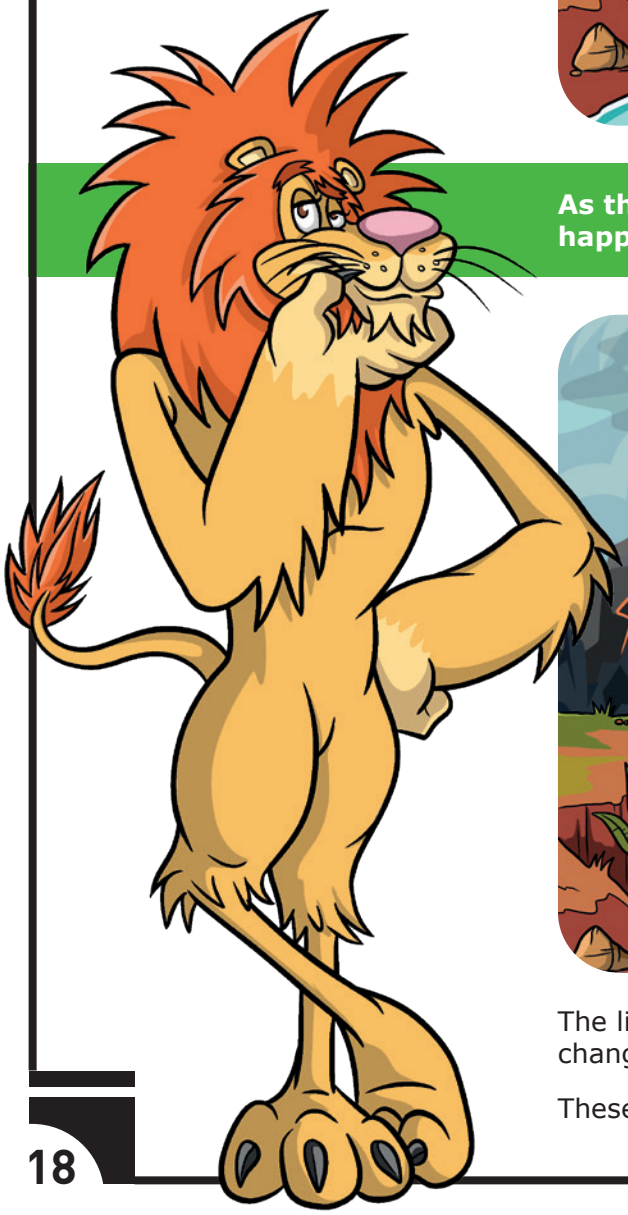
- Slinky spring
- Large sponge (such as used for car cleaning), marked along the side with a marker pen, with vertical lines, approximately 2.5cm apart

Photo by Adam Valstar on Unsplash

- Bridge pier building challenge, per group:
  - Range of every day materials: for example, string, Lego® bricks, uncooked spaghetti, cardboard tubes, bread rolls, cardboard boxes
  - Handout: *Testing everyday objects record sheet*
  - Range of craft building materials, such as household recycling, cardboard boxes and tubes, string
  - Sticky tape
  - Ruler
  - Weights, such as nuts/ washers, thin books

Something to Try:

In the introductory session, we started thinking about why people might need bridges.This picture shows a simple bridge, strong enough to hold up its own weight. The weight of the bridge is called the dead load. This is because once the bridge is built, the dead load stays the same and does not move about.



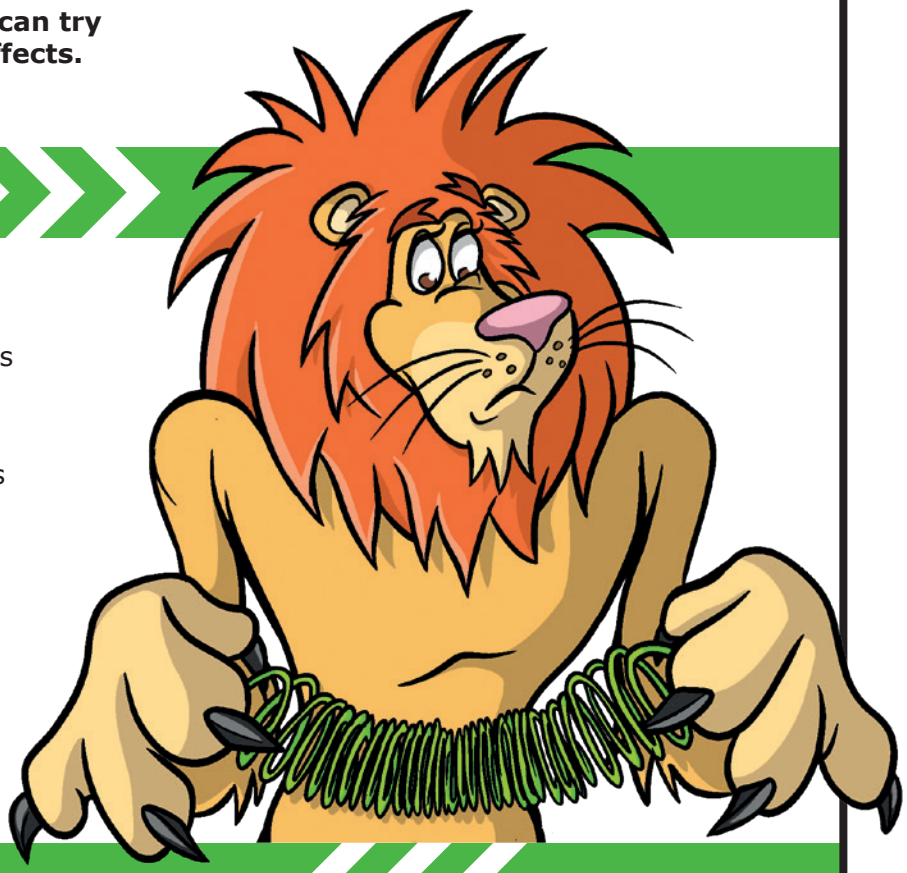
As the person walks across, what do you think happens to the bridge?

The live load, whatever the bridge is carrying, moves and changes constantly.

These loads cause forces inside the bridge.

Here are a series of activities you can try to demonstrate forces and their effects.

TENSION



Using a Slinky spring, pull from each side. This force is tension which always tries to make things longer. Think of it as a stretching force.

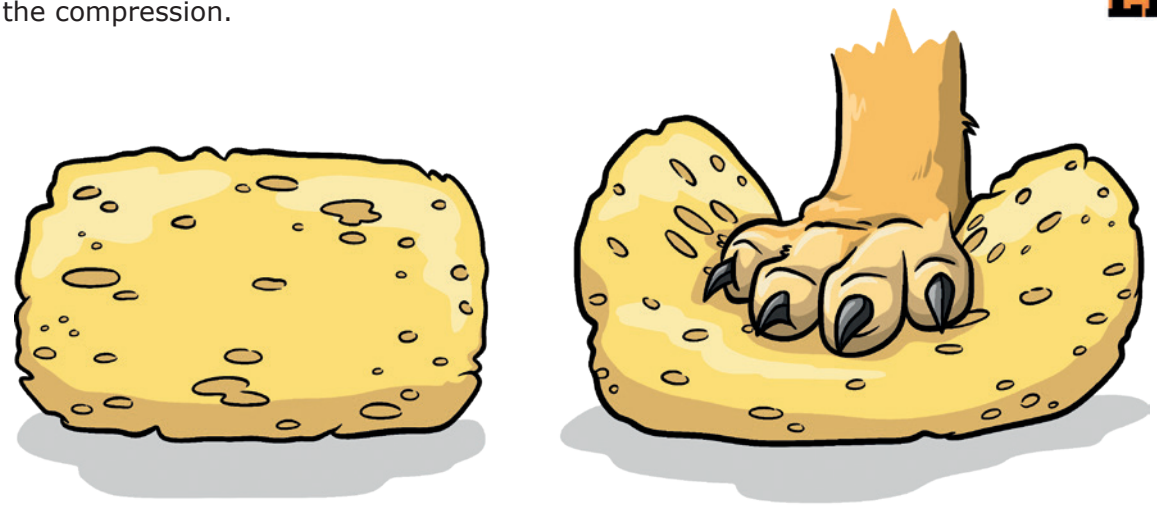
Ask the learners to hold hands in pairs and pull. Feel the tension.

COMPRESSION

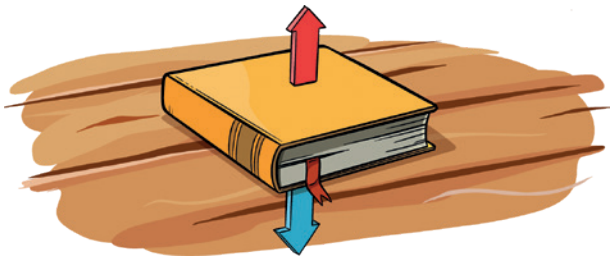
Using the marked-up sponge, push down hard. This force is compression, which always tries to make things shorter or smaller. Think of it as a squashing force. The lines on the sponge help demonstrate the effect of the force: you should notice that as the force is applied, the lines get closer together, at the top of the sponge particularly. If the sponge is firm and large enough, you might notice the lines spread out a little along the bottom, although get closer together along the top edge. This demonstrates the behaviour of a beam bridge as covered in *Chapter Bi Beam Bridges, Simple but Strong*.

LINK

Ask the learners, in pairs, to put palms of hands together and push. Feel the compression.



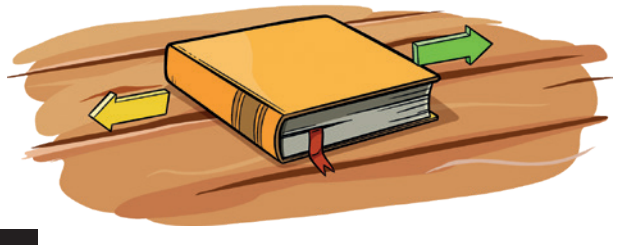
Place a large book on the desk. It is at rest because the gravitational force – the force that pulls objects towards the centre of the Earth – pulls down on it as much as the table pushes up on it. The forces are balanced.



Push the book horizontally across the table. The book moves across the table. It is no longer at rest because the forces are not in balance any more.

How do we get the forces balanced again? Either push with an equal force in the opposite direction; or

apply a pulling force in the opposite direction to the push (taking care not to allow the book to rotate).



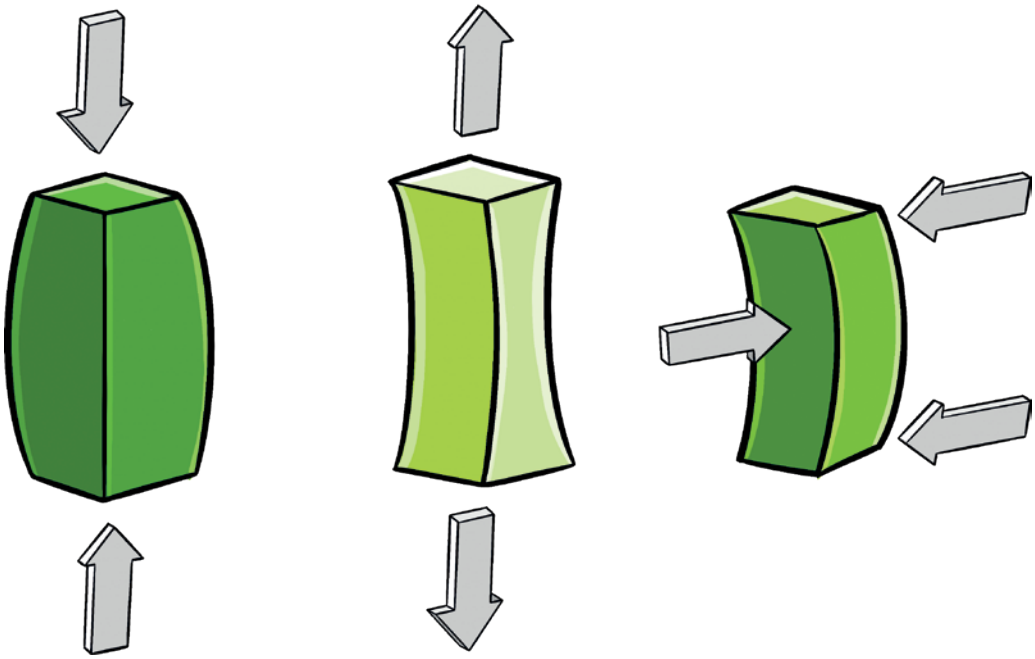
Ask the learners to stand up in pairs facing each other with palms together to form a human bridge. Ask them to feel how much they need to push to make their bridge balanced, strong and steady.

COMPRESSION

Ask them to try this standing back-to-back and leaning their weight against each other. If they can balance their forces, their bridge will stand still and not move. If the forces are NOT in balance, their bridge – and indeed any bridge – will fail!

Ask the learners to hold hands and lean out until they achieve balance. Encourage them to feel the tension in their arms.

TENSION



COMPRESSION **TENSION** **BENDING**

Challenge Time!

Divide the learners into groups and ask them to examine a series of everyday objects. Are they stronger under tension, compression or both?

Try string, elastic bands, a small tower made of Lego® bricks, uncooked spaghetti, bread rolls, building blocks, stickle bricks and cardboard tubes, for example, alongside some general recycling, such as cardboard boxes. Use the *Testing everyday objects record sheet* handout to record the outcome.

Using some of the same sorts of everyday materials as those tested to construct a bridge pier, or simple tower, encourage learners to think about the forces the structure will have to resist, and choose the materials that will have the correct properties to withstand these forces. The aim is to build the strongest pier, able to hold up the most weight. The pier should be 40cm tall, and no wider than 15cm^2 at the base. To increase the challenge in the task, you could limit the quantity or type of materials and/or sticky tape each group can use.

There is no one right solution to this challenge, instead the outcome is to identify the forces applied to the structure and consider the appropriate materials and their properties for construction of the pier.

HOT TOPICS!

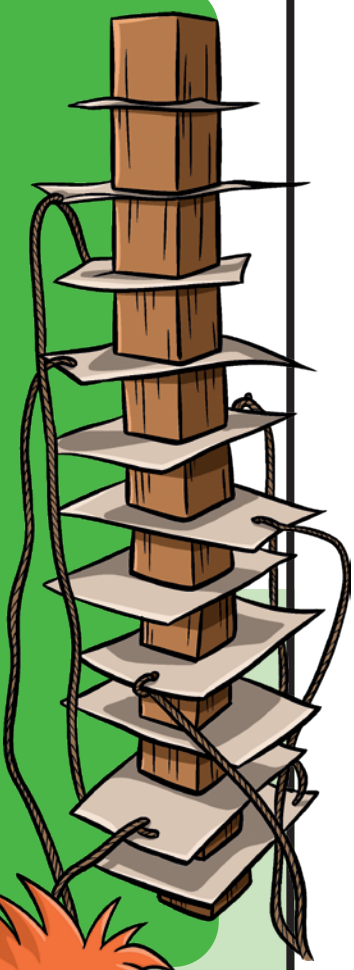
Research Sir Isaac Newton and find out more about how he came up with his Laws of Motion. You could use this to draw a timeline of his life, highlighting his key scientific discoveries. To help you complete your research, you could use the *Standing on the shoulders of giants* resource.

OUT & ABOUT

As you go about your daily activities, start thinking about times when you notice the forces that are acting on you or objects around you, and the effects they have. Can you identify when forces are acting and what forces they are?

Just 4 Fun

You can explore one of Newton's Laws of Motion (a series of laws that explain why objects move, or don't move, the way they do). Newton's first law of motion describes something called inertia – the tendency of objects to stay at rest until a force acts upon them. This is easily tested using Inertia Towers: wooden blocks or plastic cups and notecards attached to strings. Stack the blocks in a tower, placing a notecard between each block. Once you have a tower of a number of blocks, test the Newton's law by pulling on the string on the note card. If you pull it fast enough, the tendency of the block is to resist movement and stay where it is.



DID YOU KNOW?

The Goltzschtalbrucke Viaduct in Saxony, Germany, is the largest bridge in the world made of bricks.

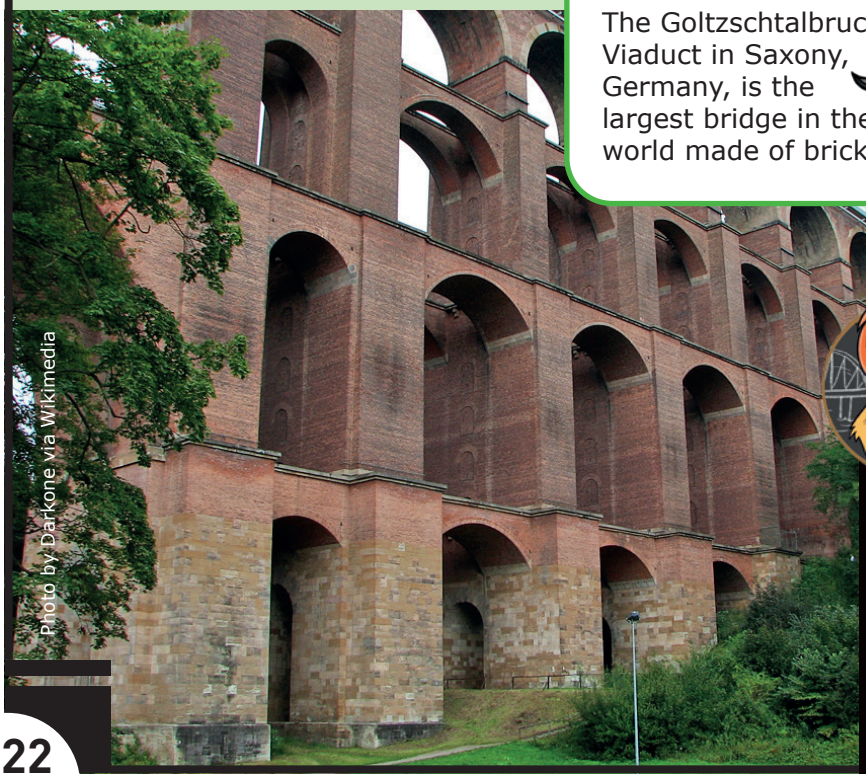


Photo by Darkone via Wikimedia

Langdon presents:

- *Testing everyday objects record sheet* handout
- *Standing on the shoulders of giants* handout

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