# Lock Design

# Lock Design Activity Pack

## Contents of this pack



## 1. Overview

Water pressure is a widely misunderstood scientific concept that students find hard to visualise and understand. Looking at lock design allows a practical investigation into water pressure. It enables students to identify with the concepts of forces and relate them to real-life engineering design examples, focusing on canals.

## 2. National Curriculum links

- Science - Forces (water pressure), conducting a science experiment including formulating a hypothesis and reasoning behind observations, using graphs to present data (in extension task).
- Maths - Substitution of values into a formula, correlation, converting units of measure, averages.
- Design and Technology - Working characteristics of materials and influencers of real-life design.

## 3. Resources and materials

- Lock Design presentation slides.
- Water pressure activity instruction sheet.
- 6 x sports water bottles with a 2cm hole in the base of each bottle.
- 6 x Stopwatches / smartphones.


Developed with support from

Rolls-Royce

## 4. Lesson Plan

### Learning objectives

- ALL pupils will be able to describe what water pressure is.
- MOST pupils will understand one key feature of water pressure.
- SOME pupils will be able to apply the concept of water pressure to the challenges of designing and building a lock.

### Objectives

Explain the objectives of the lesson and the reason for those objectives (see overview of pack).

• **What is water pressure?**

Identify the group's level of knowledge by asking the questions in green - encourage students to try and reach a definition by 'bouncing' ideas around the classroom.

• **Establish that:**

a. Water pressure is the weight of water pressing down per unit area.

b. Water pressure is related to depth because the deeper it is the more water there is pressing down.

c. Water pressure at any depth is the same in all directions [because water is a liquid].

### The experiment

- Ideal group size is 3-4 pupils per group to enable all pupils to actively participate.
- Once the experiment is explained, encourage students to consider what they think the outcome will be, so they can then compare this to the results (hypothesising).
- Remind students to use the results table provided to record what they have found for use later.
- Option to stop class after the first run through the experiment to check they are progressing correctly.
- When students have calculated water pressure, they can plot their results on graph paper. This allows students to see a visual representation of the relationship between the depth of water and water pressure. Using graph paper, students should plot seconds timed on the y-axis against the depth of water on the x – axis.
- This shows the upwards line reducing in angle as the water pressure decreases.

### The results

- Discuss what they have found – encourage pupils to share what they observed and how this differed to expectations prior to the experiment.
- They should have found that the cylinder with greater depth had a greater volume of water escape. Prompt them to link this observation to the concept of water pressure.
- Greater depth = Greater weight of water = Greater water pressure.
- The final slide gives one of the key properties of water pressure: Water has a weight, so as the depth increases, so does the weight.
- The final bubble on the slide gives them one of the key properties of water pressure, which they can link to the previous idea that water has weight.

Additional learning: If the pupils have covered correlation, you could prompt them to understand that this is a positive correlation and they could draw an example of what the graph would look like (upward sloping line-linear relationship).

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### The formula

- Students can then go on to calculate water pressure by using the formula and measuring the water level in the bottle.
- The formula for water pressure is shown below. The formula looks complex, but the pupils should realise that they only need to measure the height of the water levels in each bottle. They are given the values for gravity and water density to use in the formula.
- Water pressure formula:

**Pressure (Pa) =** **Height of water (m)**
**x Density of fluid ($kg/m^3$)**
**x Gravity ($m/s^2$)**

**Gravity = 9.8$m/s^2$**
**Density of water = 1,000 $kg/m^3$**

Additional skills: Get a pupil / group to write up what they have done on the board after they have all had a go - demonstrates communication skills and allows all students to see the correct method and reach the answer.

### Real life examples

- Two examples shown: Bath Deep Lock (5.9m deep) and Wolverley Court Lock (1.82m deep - a very shallow lock).
- To bring to life the depth of these you could relate to how many times taller the lock is than their own height.
- Students can then practice with the formula again by calculating the water pressure at the bottom of each lock. Answers on slide 10.

### What does this mean for engineering?

- Links the theoretical concepts to practical application of designing a lock.
- Encourage pupils to either write a list of features of the lock gate or discuss ideas, e.g. strength of materials chosen to withstand the pressure of the water when the lock is filled.

### Summary

- Suggest reminding pupils of objectives, e.g. what is water pressure and why do we need to be able to calculate it?
- Allow students to reflect on what they have learnt and they could perhaps say what their partner has learnt from the activity to encourage them to share thoughts.
- Additional learning: prompt pupils to think of other examples where water pressure has influenced the design of items relating to canals and rivers, e.g. dams, a boat's hull, bridges with supports in the river.

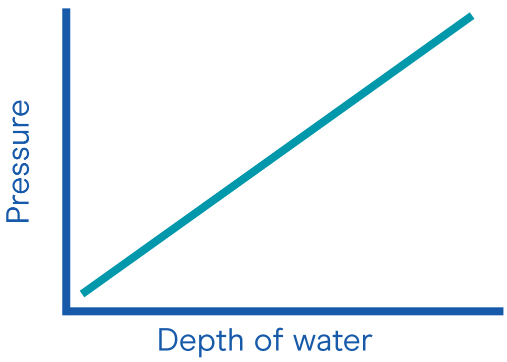
## 5. Activity sheet

See Investigating Water Pressure sheet at the end of the pack.

## 6. Extension activities

### Extension task 1 - Plotting your results

- This allows the students to see a visual representation of the relationship between the depth of water and water pressure. Using graph paper, students should plot the water pressure they have calculated on the y-axis against the height of each colour marker on the x-axis.
- This will visually show a positive correlation between the two variables as we previously found. See below an example of positive correlation displayed graphically.




This shows perfect positive correlation (i.e. a straight line), but any upwards sloping line shows positive correlation because one variable increasing means the other one increases.

Extension task 1 could be used as a starter in the class's next lesson to recap learning from the water pressure pack.

### Extension task 2 - Drainage time

- This task conducts a new experiment, this time looking at drainage time instead of the amount of water leakage in a specified time interval.
- Students will fill the water to the top line and then time how long it takes for the water to drain to the other lines, recording the results on the results table provided.
- They should repeat this experiment three times, to improve accuracy of results and then calculate the average drainage time between each set of lines. When calculating the average ensure students show workings.
- They can also plot these results on a second graph to compare to their previous experiment with the given interval depths on the x-axis and the drainage time on the y-axis.
- They will find as the depth of water decreases, the drainage time increases.
- This is because the water pressure is lower as the depth decreases, so the water escapes more slowly. You can link this to the lock design as shown in the slide pack.
- They can relate this to familiar examples they know, such as how long a bath takes to drain- depth reduces quickly at first but the last bit of water takes much longer to drain away.

### Activity Sheets

See Calculating Water Pressure Instruction Sheet on the back page.

## 7. Background Information

### Design of Lock Gates

- Lock Gates are the watertight doors used to seal off the chamber of the lock from the upper and lower pounds. The end of each chamber has a gate, or pair of halfgates, made of oak or elm (or now sometimes steel).
- The most commonly used gates are Miter gates, which were invented by Leonardo da Vinci, in the late 1400s. When closed, the two gates meet at an angle like a chevron pointing upstream, and only a very small difference in water level is necessary to squeeze the closed gates securely together. This is because any change in pressure between the sides of the gate will enact a force on the gate, holding it shut. This reduces any leaks from between them and prevents their being opened until water levels have equalised.
- If the chamber is not full, the top gate is secure; and if the chamber is not completely empty, the bottom gate is secure (so in normal operation the chamber can't be open at both ends).
- A lower gate is taller than an upper gate, because the upper gate only has to be

tall enough to close off the upper pound, while the lower gate has to be able to seal off a full chamber. This means the upper gate is as tall as the canal is deep, plus a little more for the balance beam; the lower gate's height equals the upper gate plus the lock's rise.

### Why do some locks use a single gate?

Single gates are often used on narrow canals (locks approx. 7 feet (2.1m) wide). The upper end of the chamber is closed by a single gate the full width of the lock. This was cheaper to construct and is quicker to operate with a small crew, as only one gate needs to be opened.

Some narrow locks (e.g. on Birmingham Canal Navigations) go even further. They also have single gates at the lower end. This speeds up passage, even though single lower gates are heavy (heavier than a single upper gate, because the lower gate is taller - see above explanation) and the lock has to be longer (a lower gate opens INTO the lock, it has to pass the bow or stern of an enclosed boat, and a single gate has a wider arc than two half-gates).

A few narrow locks imitate wide locks in having paired gates at both ends, for example the Bosley Lock Flight on the Macclesfield Canal.

### Possible follow up work

- Hydraulics Activity Pack - builds on concept of water pressure and brings in hydraulics, relating to the engineering example of the Anderton Boat Lift
- A field trip to see the design of a lock and other water features in real life to facilitate discussion of how water pressure affects the engineering of these features

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## Activity Sheet

### Experiment 1: Investigating Water Pressure

**Instructions:**

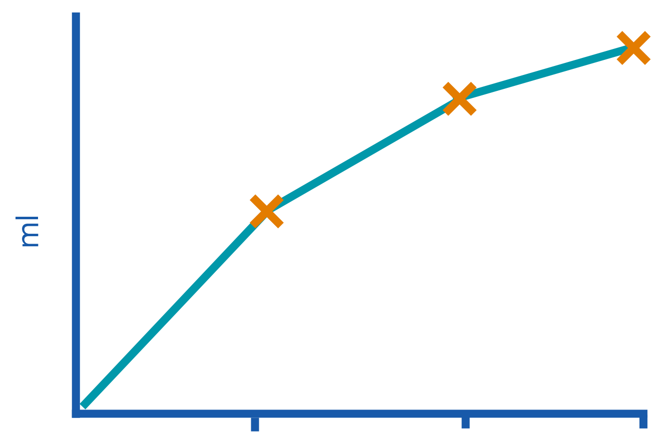
1. Fill the bottle with water to the green line.
2. One person uses a stopwatch to time 10 seconds.
3. Position the bottle over a sink or jug, allowing easy access to the cap to uncover and recover the hole.
4. When you start the timer, open the cap to see how much water escapes. After 10 seconds remove the jug and replace the cap.
5. The remaining team member records the volume of water that escaped on the results table below.
6. Repeat the experiment 3 times, measuring how much water has escaped each time.

Remember to include units with your results.

| | 10 seconds | 20 seconds | 30 seconds |
|---|---|---|---|
| Result 1 / ml | | | |
| Result 2 / ml | | | |
| Result 3 / ml | | | |
| Average Result | | | |

7. Now plot your results on graph paper.

**Your graph should look like this:**



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