Canal & River Trust STEM

Boat Lift Activity Pack

Contents of this pack

1. Overview

Engineers have used simple, yet effective scientific principles to raise or lower boats when we need to move them through big level changes (e.g. up a hill).
This activity demonstrates how Pascal's Principle works by using a syringe model as a hydraulic system. Students are able to see scientific theory applied to real engineering solutions developed on canal networks, such as the Anderton Boatlift and canal cranes.

This activity can follow on from the water pressure pack for more advanced students to understand the concept of hydraulics and its application.

2. National Curriculum links

- **Science** - forces: hydraulic force, Pascal's Principle, incompressible liquids, pressure in liquids, forces being needed to cause objects to start moving.
- **Maths** - rearranging equations, substitution of values into a formula.
- **Design and Technology** - solving real-life problems.

3. Resources and materials

- Boat Lift presentation.
- Boat Lift activity instruction sheet.
- Closed hydraulic system model, including small and large syringe and tubing.
- Hydraulic crane kit.
- Laminated copy of experiment sheet.
- Laminated photos.

Developed with support from

Rolls-Royce

Boat Lift

4. Lesson Plan

- Describe what hydraulics are.
- Understand how Pascal's Principle works.
- Apply the concept of Pascal's Principle to the design of a boat lift.

Additional teacher information and discussion points on each slide to help you:

Objectives

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

Strength test

- Challenge students to see whether they can squash the bottle at all, when it is completely filled with water.
- Get them thinking about how they find it compared to, say, an empty bottle (you can use one as a direct visual comparison). By feeling the bottle, they will realise that water is incompressible.

Properties of liquids

- Introduce the students (or remind them if they have previously covered this) that liquids are incompressible.
- Explain to students that water is made up of molecules that are so packed together they can't get any closer together. This means the volume of the liquid is fixed.

What are hydraulics?

- Explain the definition of hydraulics, building on the principle that a liquid is incompressible.
- Pascal's Principle is the fundamental principle behind how hydraulic systems work. It explains that in a body of liquid the force within the liquid is constant throughout.

Transferring pressure

- It is possible to transmit a force through liquid by applying pressure on one side.
- The pressure remains constant throughout the liquid so the pressure is equally dispersed on all the sides of the tank.

Forces

- Acts as a reminder that pressure is the force exerted over the area.
- Ask students whether situation A or B exerts more pressure on the ground.
- 'Situation A' does - although the force is smaller (person weighs less than the elephant) the area that force is exerted on is considerably smaller.

Hydraulics - Pascal's Principle & Force

- The diagram shows how a force on one side of the hydraulic system will lift the other side. The pressure in the body of water is constant due to Pascal's Law, so you can write P1=P2.
- Using the pressure formula, talk the students through what P1 and P2 must equal from the formula on the slide. Then ask them what this must mean about the value of the force in each case as A1<A2. They should be able to at least talk through the steps on the board as you write up the equations.
- Use the closed hydraulic system model to demonstrate this principle and relate back to the boat lift.

The experiment

- Using the crane demonstration model, ask some volunteers to show how putting a small weight on the side of the narrow syringe will lift the much greater weight on the wider syringe. Ask them to switch the weights over to show how this only works with the smaller weight on the narrower syringe.

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What did we see?

- Encourage the students to discuss what they have found, to see what was observed & how this differed to any expectations prior to the experiment.
- They should have found that light pressure on the smaller syringe is able to lift the big syringe with a heavy weight. This is why hydraulics have been applied widely in engineering.

An engineering problem

- At Anderton, the canal is much higher than the river. Ask the pupils how you can get boats between the two bodies of water. Give feedback on the relevant positives and negatives associated with any suggestions.
- You could build locks - The height difference is so great that this would require many locks. This requires a lot of space, which isn't available as there are factories and houses around the site. Locks also only allow one boat to travel up or down at a time. As there may be a lot of boats waiting to use the locks, this could cause delays.

The Anderton Boat Lift

- The Anderton Boat Lift uses a hydraulic system to lift boats from the river to the canal on higher ground.
- Hydraulics mean we can use a small force to move a significantly larger object by magnifying the force.
- The Anderton Boat Lift is an example of very clever engineering to solve a problem in the most efficient way possible.
- Hydraulic rams were built into the ground onto which two containers (called caissons) were placed. Liken this to the syringe with the cylinders being the body of the syringe and the piston attached to the caisson being the plunger that moves.
- Ask pupils to name one feature of the water in the cylinders - they should remember that water is incompressible and that the pressure will be constant throughout.
- As a boat enters the lift at the bottom, the caisson is sealed and some water is pumped out. Meanwhile a boat loads into the caisson at the top of the boat lift and some water is pumped in. Which caisson is heavier? The top caisson is heavier so it exerts a greater force than the bottom caisson.
- This causes the positions of the two caissons to switch positions (much like two buckets tied to a pulley system - they must always be at opposite positions).
- The boat lift allows the boats to move between the canal and the river without using too much energy, by using hydraulics to transmit the force.

Another engineering problem

- Discuss why the canals were used in this country - to transport a whole range of goods during the industrial revolution. They were often travelling vast distances with heavy loads.
- Ask the students whether they think this could cause any problems. Prompt them to mention that as the goods are heavy, they would need a way of lifting goods on and off boats. You can then ask them if they can think of how hydraulics were helpful in this situation - show them the answer - a hydraulic canal crane.

Other examples of hydraulics

- Explain to the students that hydraulics have improved our lives in many ways since their invention.
- Examples include cranes to dredge rivers or lift boats in and out of rivers.

Build your own hydraulic system

- In groups of up to 8 pupils collect a mini-hydraulic system kit and work together to connect up the system.
- Now push water along the pipe between the large and small syringes. Ask the students to explain what they think this demonstrates. (Note: they may need to 'bleed the system' to get air out of it, to make it work efficiently).
- Ask students to look again at the hydraulic crane. They should be thinking about which way around will be best - they want to arrange the smaller syringe for applying force and the larger syringe to the crane arm to transmit the greatest force.
- As you check on students' progress, ask them why they are constructing it as they are and ask them what would happen if it were the other way around. They can always try both ways and see which feels easier to lift the weights.

Hydraulics Experiment

- A single group can be selected to look at the hydraulic crane model, weighing several items and checking their weight.
- They need to think about which way round the syringes should be and why.

Other examples of hydraulics

- Get students to write down (perhaps on whiteboards so they can hold up answers after) one experience they can think of where hydraulics have been used in real life situations.

Examples shown are:
- Hydraulic paddle gear
- Road crane
- Tower Bridge - a lift bridge

What did you find out?

- Guide a review of findings to confirm:
  - It is possible to 'transmit' a force through liquid by applying pressure.
  - Hydraulic systems use an incompressible fluid, such as oil or water, to transmit force from one location to another within the fluid. Pascal's Law.

5. Activity Sheet

See Hydraulics Experiments at the end of the pack.

6. Extension Activities

Homework

Can you find 5 practical examples where hydraulics have been used to solve an engineering problem in real life?

7. Background information

History of the Anderton Boat Lift

- The Anderton Boat Lift was originally built by Edwin Clark in 1875 to lift cargo boats the 50 feet from the River Weaver to the Trent & Mersey Canal.
- The original design was flawed as it failed to take into account the
- corrosive nature of the river water that was used in the hydraulic system.
- In the 19th century the River Weaver was used to transport salt. Wrought iron was used to build the structure, but salt water was used in the system and
- it corroded the pipes.
- The lift could carry up to four boats (two up and two down) at any one time. It operated successfully for five years unti, in 1882, a hydraulic cylinder burst causing a caisson to descend rapidly. It was found

that the pistons were being corroded by the salty river water.
- Despite repair efforts, including using pure distilled water, the lift had to be closed more and more frequently.
- The original counter-balanced system was replaced in 1908 by electric operation, but was restored to a new hydraulic system in 2002. The new system uses oil in the huge rams instead of water.

Uses of hydraulics

- Hydraulic paddle gear.
- Hydraulic road crane.
- Hydraulic lift bridge.
- One use of hydraulics is the platforms put in place so that passengers can get onto aeroplanes. Large hydraulic platforms are used to lift some luggage into the hold of the plane. Hydraulics are also used to service the aircraft, lifting large items such as the engines, which need to be checked over and repaired if necessary.
- The wing flaps on a plane and some rudders on boats are operated by hydraulic systems
- Aeroplane landing gears are lowered and raised using hydraulics.
- A hydraulic system powers the brakes in cars
- Hydraulics are also used for equipment used in building work and landscaping in the garden, which means we can lift much larger weights and take less time to complete tasks.
- Hydraulic grapples are used at scrap heaps to lift old cars and other large scrap items.

Possible follow up work

- Visit Anderton Boat Lift to help students to relate what they have learned in classroom to a real life engineering example
- Visit a local canal with hydraulic gearing on locks
- Visit a lock stoppage (the Canal & River Trust publish a list of winter works on the website, so you may be able to see examples of hydraulic cranes at a lock stoppage when a lock gate is being lowered into place).

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Activity Sheet

Experiment 1: Hydraulics

Build a simple hydraulic system

- Collect your kit
- Connect up the large and small syringes to the plastic tubing
- Add water and bleed the system to expel air – why do this?

Test the system!

- Take a series of measurements to test the effectiveness of the system
- Which action is easiest?

Experiment 2: Hydraulics

- Collect a crane – what do you notice about the syringes?
- Connect the syringes acting as the hydraulic system so that you can use your crane to lift items.
- Add water and bleed the system. Why are the syringes this way round?
- Weigh several items.
- Measure the distance travelled for each item.
- Draw a graph to show your results. (Weight on the x axis / distance travelled on the y axis).

Test the system!

- Test the effectiveness of the system by moving the small syringe about 4ml. How far did you move the larger syringe?
- Now try moving it 10ml. How far does the larger syringe move? What does this show?