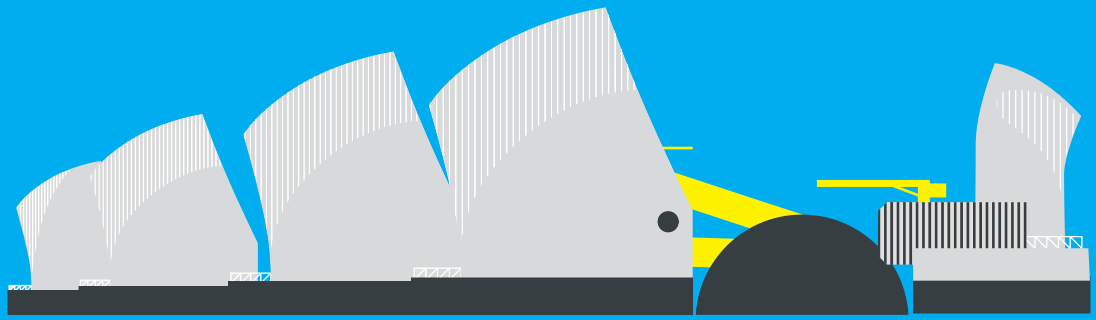
MAYOR OF LONDON

THE LONDON CURRICULUM

PHYSICS KEY STAGE 3

THE FORCE OF THE RIVER



UCL Institute of Education

THE LONDON CURRICULUM

PLACING LONDON AT THE HEART OF LEARNING

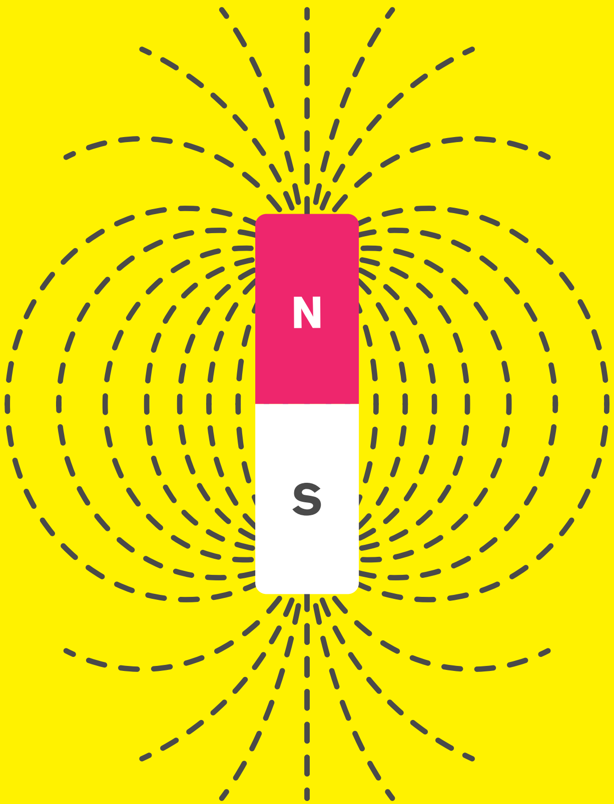
The capital is the home of innovations, events, institutions and great works that have extended the scope of every subject on the school curriculum. London lends itself to learning unlike anywhere else in the world. The London Curriculum aims to bring the national curriculum to life inspired by the city, its people, places and heritage.

To find out about the full range of free resources and events available to London secondary schools at key stage 3 please go to www.london.gov.uk/london-curriculum.

STEM in the London Curriculum

London provides numerous historical and contemporary cutting edge examples of scientists, engineers and mathematicians who have worked in their fields to create innovative solutions to problems throughout the world. Population growth, trade, communication, transport, health, food, water supply and many other aspects of life in London have driven technology-based innovations. London Curriculum science, maths, design & technology teaching resources aim to support teachers in helping their students to:

- **DISCOVER** the application of their subject knowledge to the life of the city.
- **EXPLORE** their neighbourhood and key sites around London, learning outside the classroom to see and understand how STEM subjects have shaped many aspects of the city.
- **CONNECT** their learning inside and outside the classroom, analysing situations and using their subject knowledge to create and present solutions.



CONTENTS

PREREQUISITE INFORMATION

This unit assumes the first part of the national curriculum key stage 3 forces topic has already been covered, in particular forces as pushes and pulls, force arrow diagrams, moments, forces measured in units of Newtons and the difference between mass and weight.

Calculating mass and weight

Mass and weight are introduced in this unit and the usual misconceptions will arise, this website is helpful for guidance on how to approach this with your students:

www.nuffieldfoundation.org/practical-physics/mass-and-weight

For key stage 3 you can assume that weight given as (N) is equal to 10 x mass in (kg). Depending on when you use this unit and the ability of your students you may decide to explain this further to your students or just provide it as a formula to use. This comes from Newton's law $F = ma$ where weight is the force (F) produced by acceleration due to gravity acting on a mass (m). The acceleration due to gravity is $9.81\,m/s^2$ so using an approximation of 10 still gives a reasonably accurate result. When using gravity it is often represented by (g) rather than (a) i.e. *Weight = m x g*.

Risk assessments for practical work and learning outside the classroom in the London Curriculum

It is the responsibility of each institution, delegated to the class teacher, to make risk assessments for a given class and a given location.

Guidance can be found through the membership organisation CLEAPSS for all school science.

www.cleapss.org.uk

A general guide for health and safety guidance and risk assessment of practical work can be found here http://www.nuffieldfoundation.org/standard-health-safety-guidance . If any additional specific guidance is necessary, this will be found within the instructions for each practical.

More general guidance on school trips is available here:

www.atl.org.uk/health-and-safety/off-site-trips/risk-assessment-school-trips.asp

TAMING THE RIVER OVERVIEW

UNIT AIMS AND OBJECTIVES

The Thames is a working river, providing transport, trade and of course water to London but also presenting significant engineering challenges, such as defence of the city from flooding. This unit covers the topics of pressure in liquids and gases and simple machines from the key stage 3 science curriculum and uses a range of real life examples focused on the River Thames and London's other waterways to bring the topics to life. Using this context, students will see how their scientific understanding can be applied through calculation, to tell them about the world. Through the examples and the visits they will see that this is at the core of designing and engineering small-scale structures such as locks and even divers' helmets to large-scale structures such as the Thames Barrier, Tower Bridge, cranes for lifting cargo in London's Docklands and the huge container ships and barges that sail in and out of the city.

A range of potential educational visits are suggested to build on their learning in the classroom, including the Thames Barrier, the London Museum of Water and river walks on the Thames path or on local waterways.

Students' knowledge will be connected by designing a barrier to defend against flood risks predicted for the future.

THAMES BARRIER
Adrian Pingstone © Wikimedia Commons

KEY STAGE 3 NATIONAL CURRICULUM

This unit addresses subject content requirements within the physics part of the key stage 3 national curriculum for science:

Pressure in fluids

- atmospheric pressure, decreases with increase of height as weight of air above decreases with height
- pressure in liquids, increasing with depth; upthrust effects, floating and sinking
- pressure measured by ratio of force over area – acting normal to any surface

Forces

- using force arrows in diagrams, adding forces in one dimension, balanced and unbalanced forces. Energy changes and transfer
- simple machines give bigger force but at the expense of smaller movement (and vice versa): product of force and displacement unchanged

In covering this content, this unit also addresses some of the broader aims of the curriculum in ensuring that students:

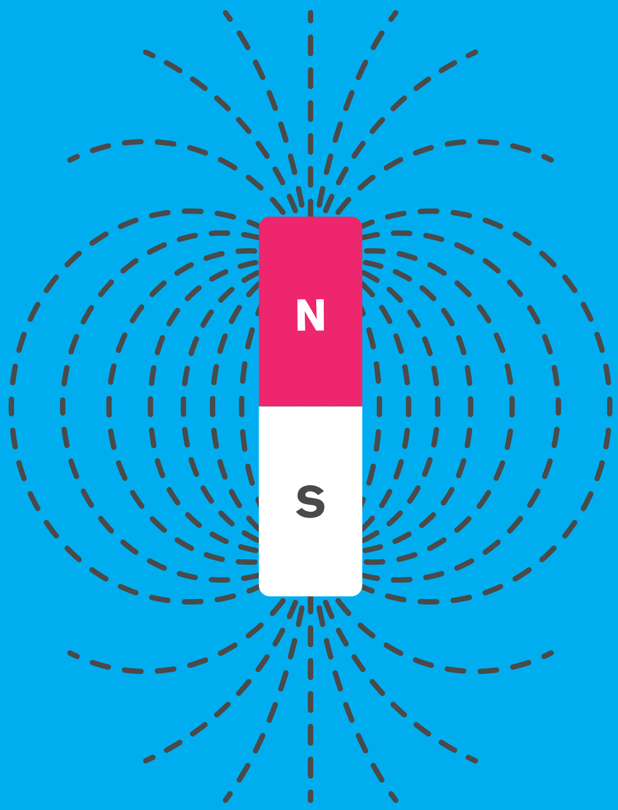
- develop scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics
- develop understanding of the nature, processes and methods of science through different types of science enquiries that help them to answer scientific questions about the world around them
- are equipped with the scientific knowledge required to understand the uses and implications of science, today and for the future.

In order to cover curriculum topics coherently, activities such as some on air pressure may not be directly related to the Thames context. These are provided to complete the relevant aspects of the science topic.

DISCOVER

The Thames is an active waterway, providing transport, trade and of course water to the city. The same river which services London in so many ways also threatens the city with flooding. Students will study pressure in liquids and simple machines from the physics forces topics in the contexts of flood defences, managing water supplies and machines used on the river. This will engage them in a number of practical applications of the science they are studying in real life London contexts. Using the River Thames as an exemplar, students will see how quick scientific calculations can tell them about the world and then use this knowledge to design structures and machines that help us improve life in the city around us and manage the challenges of life by a river.

The Thames is used as a main context, but other examples are given on locks on local waterways. These examples can also be adapted to waterways, structures and machines that may be local to your area.



LESSON 1
TAMING THE RIVER AND THE PRESSING MATTER OF WATER

THE BIG IDEA

Students will look at an event from the history of London floods to set a context for the science knowledge and understanding.

Students will undertake an initial measurement and calculation of the mass of water and how this scales up to appreciate the 'heaviness' of water.

LEARNING OUTCOMES

Could: scale the calculation of mass of water to any volume; perform similar calculations for other fluids and, in particular, for the mass of air.

Should: explain and correctly use the terms mass and weight and corresponding common units with simple examples: scale a measured volume and mass of water to calculate the mass of $1 m^3$ and recognise that water is very 'heavy'.

Must: describe impacts and costs of the River Thames flooding on London and measure and record the volume and corresponding mass of samples of water.

RESOURCES

Resource 1.1: Image pack

Resource 1.2: Flooding 1953 article extract

Resource 1.3: Common volume, mass, force & pressure units

Resource 1.4A: Problem solving framework

Resource 1.4B: Scaffolded solution method

Resource 1.5: Diver working on the Thames Barrier

YOU WILL ALSO NEED

Image of London flood plane, Thames Barrier project pack, page 15
bit.ly/1HQcP6I

LESSON 1
TAMING THE RIVER AND THE PRESSING MATTER OF WATER

MATHEMATICAL SKILLS

- Units – cubic centimetres (cm^3), cubic metres (m^3), litres (l or dm^3), grams, kilograms, tonnes (metric).
- Measurement and calculation of mass and volume. Units of mass and volume.

PRACTICAL WORK

Weighing liquids:
www.nuffieldfoundation.org/practical-physics/weighing-liquids

Weighing air:
www.nuffieldfoundation.org/practical-physics/measuring-density-air-1

EXTERNAL LINKS

Thames Barrier project pack 2015
bit.ly/1HQcP6l

Details on the Thames Barrier:
www.gov.uk/the-thames-barrier

Addressing the issue of mass vs weight:
www.nuffieldfoundation.org/practical-physics/mass-and-weight

KEYWORDS

- Downstream
- Ebb
- Flood
- Flow
- Fluvial
- Force
- Mass
- Navigable
- Tide
- Upstream
- Weight

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

SETTING THE SCENE

London exists because of the River Thames and its power to support transport, water and food, trade and industry. However, the river's power also puts the city at risk from flooding and Londoners have been struggling to tame the river for many centuries. The land close to the River Thames has always been vulnerable to flooding and there have been reports of floods in London as far back as Anglo-Saxon times. Historically this was managed by building higher, stronger river walls and embankments. However, a terrible flood in 1953 led to the loss of 300 lives in the Thames Estuary and along the east coast of England. The scenario of such a flood reaching London provoked a rethink about flood management. In 1966 it was decided that the best solution would be a combination of bank raising and a flood barrier with movable gates. Building work started in 1974 and the Thames Barrier was completed in 1982.

The Thames Barrier is one of the largest movable flood barriers in the world, spanning 520 metres across the River Thames and protecting 125 square kilometres of central London from flooding. It has ten steel gates, each one weighing 3,300 tonnes. The main gates stand as high as a five story building. It is closed under storm surge conditions to protect London from flooding from the sea and also to reduce the risk of river flooding in some parts of West London, including Richmond and Twickenham.

The Thames Barrier is part of a system of flood defences including flood walls and other smaller barriers such as the Barking Barrier, River Darent Flood Barrier, Fobbing Horse Barrier (Canvey Island), King George V Dock flood gate and the Tilbury Dock flood gate.

For further information please refer to pages 10 – 19 of the Thames Barrier project pack 2015:

bit.ly/1HQcP6I

BARKING BARRIER

Thames Barrier Project Pack 2015 © Environment Agency

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

ACTIVITIES

STARTER

This starter introduces the impact of flooding in London recently and in the past. Show and discuss the pictures from Resource 1.1: Image pack (pages 14 – 19). Provide in addition, the image of the London floodplain from the Thames Barrier Project Pack.

In this image Erith is highlighted. Point out other areas of London known to the students on the London floodplain map to demonstrate the possible extent of flooding.

In groups, read Resource 1.2: Flooding 1953 article extract. Provide students internet access to, or of hard copies of, the following Channel 4 article regarding the future of the Thames Barrier.

www.channel4.com/news/floods-crisis-london-underwater

Discuss the following questions:

- What are the advantages and disadvantages of raising river banks (embankment) vs movable barrier flood defence?
- How much would you spend on a London barrier?

Discuss the actual costs: Building costs about £1.7 billion (2014 prices), funded 75% from central government, remainder by local government. Also £9 million a year to maintain and operate and £12 million a year on improvements (2014 prices).

MAIN 1

This activity introduces the idea that the barrier has to resist force as well as height of water. Show *How the Thames Barrier works* video (2 min 40 sec):

www.gov.uk/the-thames-barrier

Highlight the barrier's role in holding back an increased height of water.

- Is the barrier just holding back the increased height of water or does the water exert any force on the barrier?

During or after the discussion explain that there is a push force on the barrier from the water. We need to know how big this is so that we can design and build a barrier strong enough to resist the height of water and the push.

The push force is a combination of two main forces, which are the pressure due to the depth of water and the force from the flowing water due to the tidal nature of the Thames and North Sea storm surges. We can calculate the push from pressure. (The push from the water flow is in fact larger than the force due to pressure at depth when a tidal surge occurs but this is outside the scope of key stage 3 science.) Explain that scientists and engineers would use similar calculations for this force but would need to predict what they think the maximum flow would be and work from that assumption.

MAIN 2

This activity helps students use the terms mass, weight and force consistently and provides opportunity to practice measuring and recording values with corresponding units of measurement.

Ask students to:

- use a balance to weigh some standard masses: 100g, 200g etc. and some classroom objects e.g. pencil case, book and record the results in a table
- use a force meter to weigh the same objects again, add an extra column to the table to record the results
- discuss the terms mass, weight and force in groups
- write a sentence linking the terms mass, weight and force and using one of their measurements as an example

To conclude, provide students with the formula that weight in newtons (N) is approximately 10 x mass in kilograms (kg) and ask them to compare if this matches up with their measurements.

Differentiation

To support students provide a blank table with correct columns and a scaffold for the writing part of the activity

For more able students allow them to produce individual writing.

It is important that you model consistent use of these terms and engage students in discussion of their correct use if they are using them incorrectly or inconsistently.

Explain to students that they will continue to see the terms mass and weight used inconsistently and confusingly in everyday life and in science.

MAIN 3

This activity introduces the idea that water is very heavy.

Ask students to carry out the following practical experiment to measure the mass for a given volume of water and some comparable substances such as sand. Experiment details can be found here:

www.nuffieldfoundation.org/practical-physics/weighing-liquids

From the above experiment students will have a measurement of the weight of water and of the weight of sand for the volume of the container that they used in the experiment.

Before proceeding with the following calculations, give out or display for reference Resource 1.3: Common volume, mass, force and pressure units (pages 21 -22). To visualise volumes it will be useful to have boxes or different containers for the different volumes $1cm^3$, 1l, $1m^3$.

The aim now is for students to scale up their measurement of the mass of water and volume from the experiment to the mass for a volume of $1m^3$. This can be supported by asking them to follow through a worked example of a similar problem first.

Resource 1.4: Problem solving framework (page 23) sets out alternative scaffolding approaches with worked examples that might be used with higher and lower ability students. A similar problem of scaling up the mass of a known volume of sand to a larger volume needed to fill a sand pit is given.

After working through the appropriate approach, students should then complete the scaling of their experimental result for the measured mass and volume of water to the mass for $1m^3$.

Differentiation

Differentiated scaffolding as described in Resource 1.4 Problem solving framework (page 23).

Questions

1. What is the mass of $1m^3$ of water?
2. How heavy is 1000kg, is it more or less heavy than all the students in your class together?
3. How many tonnes of water does the Thames Barrier have to hold back and how heavy is this?

Answers

1. $1m^3$ of water should have a mass of *1000kg = 1t = 1,000,000g* depending on accuracy of measurement.
2. Prompt students by suggesting they should estimate an average mass for each student in the class e.g. *average student mass = 60kg, class of 25 students mass = 1,500kg only* $1m^3$ *of water.* Reiterate water is heavy.
3. Prompt students to estimate the depth and width of the river to get a very approximate answer. The key point is again to notice how large this is.

MAIN 4

Conduct the following experiment to introduce the weight of, and later on, the pressure of air. Ask students to consider the similarities and differences between the two. Experiment details for weighing air can be found here:

www.nuffieldfoundation.org/practical-physics/measuring-density-air-1

This method weighs the air content of a balloon and continues to calculate its density.

Clearly state again that $1m^3$ water has a mass of approximately 1 tonne (1000kg) and it is also useful to know that $1cm^3$ of water has a mass of 1g. If density has been covered with your students before then you could introduce the density of water as $1g/cm^3$ which is also equivalent to $1000kg/m^3$.

In contrast $1m^3$ of air has a mass of approximately 1kg. (The actual density is around $1.2kg/m^3$, depending on pressure and temperature.

Plenary

Give each student a copy of Resource 1.5: Diver working on the Thames Barrier (page 25). Explain that the Port of London Authority (PLA) employ a team of divers to carry out maintenance on the flood barrier and other underwater operations.

More information about divers working for the Port of London Authority on the River Thames can be found here:

www.pla.co.uk/About-Us/Diving

You may wish to show the video above (3 minutes) of one of the divers describing their work.

Ask students to imagine that they are the diver gradually swimming deeper into the River Thames. Using the ideas in the lesson, how do they think they would feel as they descend?

The students should be instructed to write their name on the resource and keep it. They do not need to write anything else on the resource this lesson, but it will be used in the assessment questions for lesson 3, at which point students will annotate with mass and pressure calculations and force arrows.

Ask students what they might feel as they dive deeper underwater by thinking of the mass of water above you being pulled down onto you by gravity.

Differentiation

To support students provide a blank table with correct columns and a scaffold for the writing part of the activity.

Assessment questions

Adapt or extend questions based on the activities or use the following examples:

1. State the units for mass and weight and explain the difference between mass and weight.
2. Give examples of how the term weight or weighing is used incorrectly in everyday life.
3. Find some other situations where the heavy weight of water or other liquids is a problem.
4. Calculation examples for volume and mass unit conversions and scaling.

Homework ideas

Ask students to research and present one of the topics below:

- Flood defences around the local area of the school and in other parts of the world for comparison.
- Rate of sea level rise due to climate change.
- Data on air pressure – find the size of and units used for air pressure at sea level. Find out how pressure is measured in air and liquid.

Further reading:

Environment agency web page with upcoming closure times, flood forecasting, how the barrier works (incl video 2 min 40 sec), future, visiting:
www.gov.uk/the-thames-barrier

Port of London Authority youtube channel for a wide range of short films on life and work involved on the Thames:
www.youtube.com/user/portoflondon/videos

Careers link – Blog from an Environment agency flood forecaster working at the barrier:
www.environmentagency.blog.gov.uk/2015/03/27/keeping-london-safe-from-flooding/

Wikipedia page – more information and lots of references for further reading:
en.wikipedia.org/wiki/Thames_Barrier

Units and conversions, common units and many you will never have heard of:
en.wikipedia.org/wiki/Conversion_of_units

Detailed Met Office weather data on Dec 2013 – Jan 2014 storms:
www.metoffice.gov.uk/climate/uk/interesting/2013-decwind

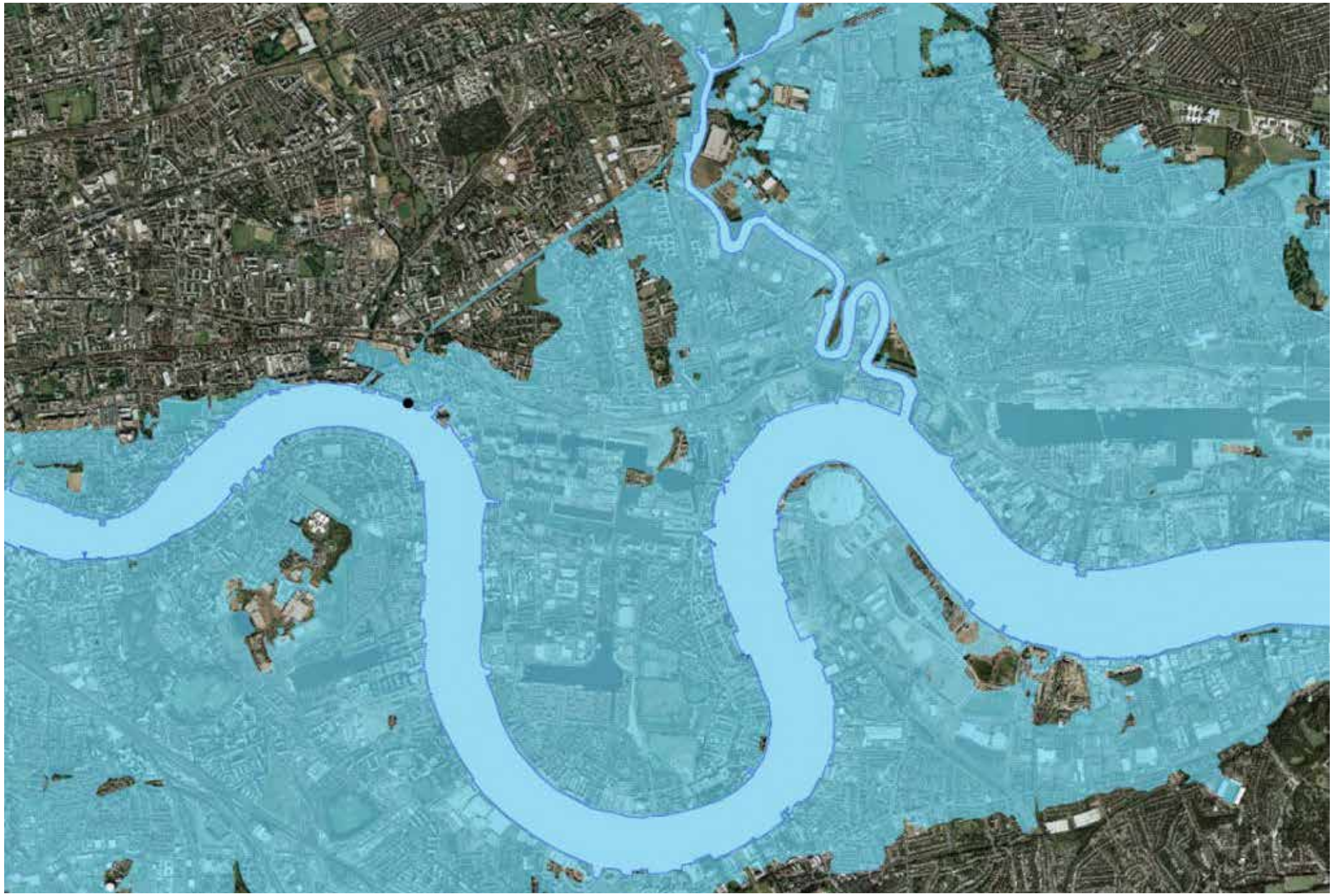
LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.1: IMAGE PACK

A BREACH AT ERITH AFTER THE NORTH SEA FLOOD OF 1953

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.1: IMAGE PACK CONTINUED



LONDON FLOODING WITHOUT THE THAMES BARRIER DEC 2013

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.1: IMAGE PACK CONTINUED

THAMES BARRIER

Thames barrier project pack 2015 © Environment Agency

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.1: IMAGE PACK CONTINUED

YORK WATER GATE AND THE ADELPHI FROM THE RIVER, 1872

John O'Connor © Museum of London

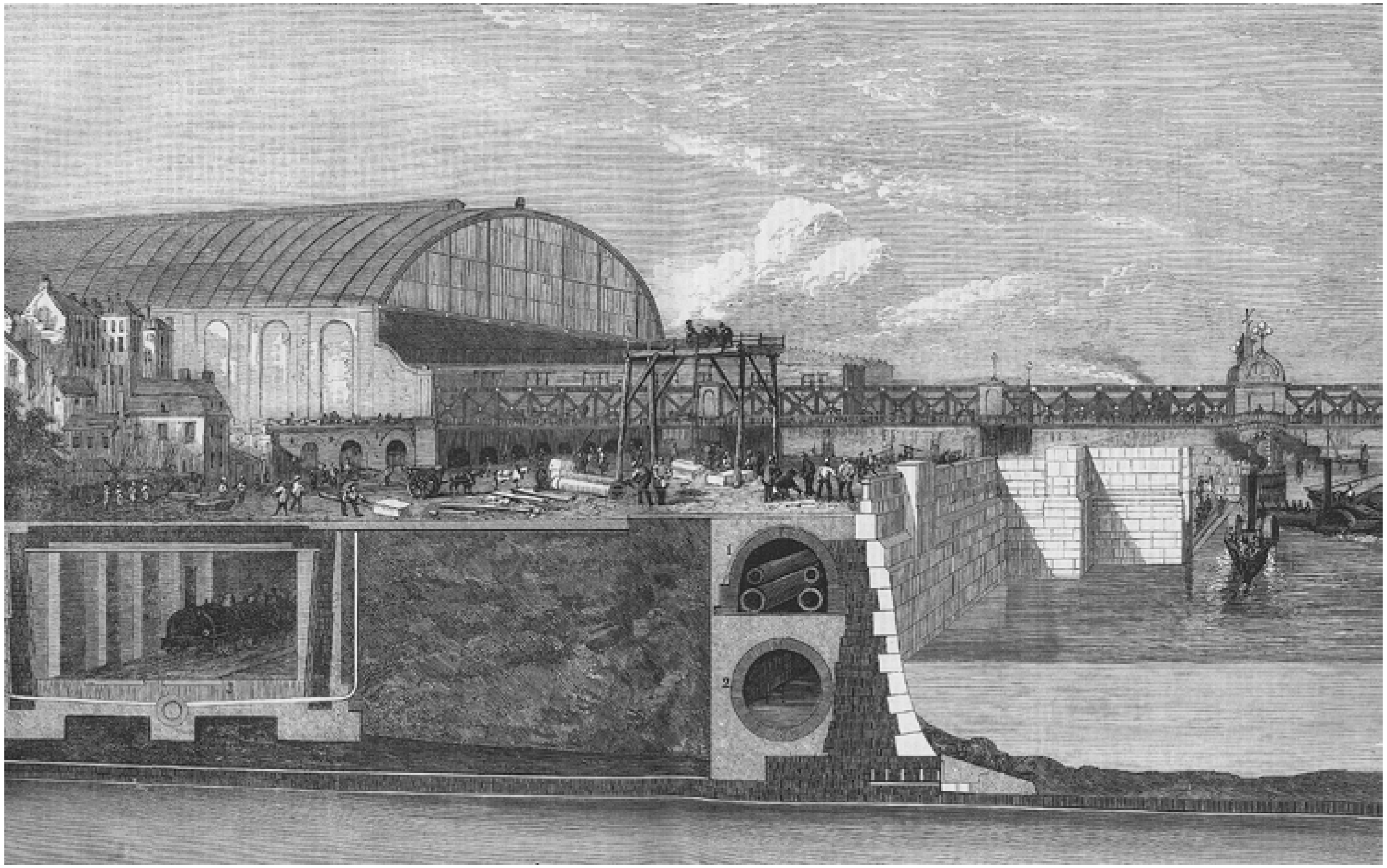
Shown is a view of Strand waterfront before the Embankment construction, looking towards the north east and showing Somerset House and an arch of Waterloo Bridge in the distance.

In the foreground is York Water Gate behind which is the terrace of the York Buildings. To the right are the Adelphi wharves with Royal Terrace towering above.

A Thames waterman in traditional uniform and barges as well as other craft are seen on river.

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.1: IMAGE PACK CONTINUED



VICTORIA EMBANKMENT, 1867
Unknown artist © Museum of London

The Victoria Embankment was completed in 1870. A new river wall was built up to 500 feet out into the Thames, providing 37 acres of new land. This engraving shows a cross-section through the Embankment beneath Charing Cross Station.

It shows an underground conduit carrying water and gas mains, telegraph cables and beneath that is the low-level intercepting sewer. The Metropolitan District Railway occupied a tunnel under the newly laid-out Embankment Gardens.

This engraving was published in *Illustrated London News* dated June, 1867.

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.2: FLOODING 1953 ARTICLE EXTRACT

1953 Flood – Before the Barrier

Article source: **Thames Barrier pack**

In 1953 the Thames Estuary experienced a widespread flood which claimed 307 lives and caused an estimated £50 million damage (£5 billion at today's costs).

This led to a dramatic rethink of the way in which flood defences were built to protect London.

Before the barrier was built, the solution to flooding was to build higher and stronger river walls and embankments – a solution that became popular following the Thames Flood Act of 1879 and remained an accepted measure until midway through into the 20th century.

Following a report in 1966 by Sir Herman Bondi, it was decided that the best solution was bank raising and a flood barrier with movable gates built across the Thames. The Thames Barrier and Flood Protection Act 1972 gave powers to carry out this solution and led to the construction of the barrier.

Extract source: **en.wikipedia.org/wiki/North_Sea_flood_of_1953**

The 1953 North Sea flood (Dutch: Watersnoodramp, literally "flood disaster") was a major flood caused by a heavy storm, that occurred on the night of Saturday, 31 January 1953 and morning of Sunday, 1 February 1953. The floods struck the Netherlands, Belgium, England and Scotland.

A combination of a high spring tide and a severe European windstorm over the North Sea caused a storm tide; the combination of wind, high tide, and low pressure led to a water level of more than 5.6 metres (18.4 ft) above mean sea level in some locations. The flood and waves overwhelmed sea defences and caused extensive flooding. The Netherlands, a country with 20% of its territory below mean sea level and 50% less than 1 metre (3.3 ft) above sea level and which relies heavily on sea defences, was worst affected, recording 1,836 deaths and widespread property damage. Most of the casualties occurred in the southern province of Zeeland.

In England, 307 people were killed in the counties of Lincolnshire, Norfolk, Suffolk and Essex. 19 were killed in Scotland. 28 were killed in West Flanders, Belgium.

Further loss of life, exceeding 230 deaths, occurred on water-craft along Northern European coasts as well as in deeper waters of the North Sea. The ferry MV Princess Victoria was lost at sea in the North Channel east of Belfast with 133 fatalities, and many fishing trawlers sank.

Realising that such infrequent events could recur, the Netherlands particularly, and the United Kingdom carried out major studies on strengthening of coastal defences. The Netherlands developed the Delta Works, an extensive system of dams and storm surge barriers. The UK constructed storm surge barriers on the River Thames below London and on the River Hull where it meets the Humber estuary.

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.3: COMMON VOLUME, MASS, FORCE & PRESSURE UNITS

Common volume units

UNIT	SHORTHAND	DERIVATIVE
Cubic centimetre	**cm^3**	
Cubic decimetre	**dm^3**	$1dm = 10cm \therefore 1dm^3 = 1000cm^3 = 1l$
Cubic metre	**m^3**	$1m = 100cm \therefore 1m^3 = 1{,}000{,}000cm^3 = 1l$
Millilitre	**ml**	$1ml = 1cm^3$
Litre	**l**	$1l = 1000ml = 1000cm^3$

Volume conversion Chart

	Cubic centimetre (cm^3)	**Litre (l)**	**Cubic metre (m^3)**
Cubic centimetre (cm^3)	**1**	1000	1,000,000
Litre (l)	**0.001**	1	1000
Cubic metre (m^3)	**0.000001**	**0.001**	1

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.3: COMMON VOLUME, MASS, FORCE & PRESSURE UNITS CONTINUED

Common mass units

UNIT	SHORTHAND	DERIVATIVE
Gram	g	
Kilogram	kg	1kg = 1000g
Tonne	t	1t = 1000kg = 1,000,000g

Common force and pressure units

UNIT	SHORTHAND	DERIVATIVE
Newton	N	Approximately the weight of an apple!
Pressure	N/m^2	
Pascal	Pa	$1 Pa = 1 N/m^2$
Atmosphere	atm	Atmospheric pressure = 100,000 Pa (approx.)

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.4: SCAFFOLDED MATHEMATICAL CALCULATION IN SCIENCE

Teachers notes

For less able students a worked or scaffolded solution for a similar problem can be used which the students can then rewrite substituting their own values or measurements. This therefore requires a different scaffold for each problem and will help to develop process skills in less able students but will not develop their general problem solving skills.

For more able students, rather than scaffolding the solution method for a specific problem it is useful to scaffold a general problem solving method in order that students practice developing their own solutions. A four step general method is given below. As the students are using this to develop their own method of solution, the same problem solving scaffold can be used for any mathematical problem.

In either case the thinking of the students is usually not visible and this makes diagnosing students misunderstandings or misconceptions in their mathematical process difficult. It is useful to make students solve problems in pairs or small groups where they are required to explain each step of the solution to their peers. This explanation of processes to peers can take place during working on a problem or after the solution, successful or unsuccessful is completed.

More able students might also support less able students on the scaffolded solution method and also by explaining how they developed their own plan for solving a problem.

The examples below give the mass for a particular volume of sand and work through scaling this up to calculate the mass needed for a larger volume of sand to fill a sand pit. The students will be asked to use their experimental result for the mass for a volume of water and scale that up to the mass of 1m3 of water using a similar method.

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.4A: PROBLEM SOLVING FRAMEWORK

Based on *How to Solve It* by G. Polya

1. **Understand the problem** - Identify the unknown quantities, the things to be found and the known quantities, the data.
2. **Devise a plan** – This is the connection between the known data and the unknown. Thinking of similar problems you have done before may help to solve this one.
3. **Carry out the plan** – Write down your calculations step by step and check each step is correct.
4. **Look back** – Can you check the result is correct or if not, does it at least look correct?

Worked example using the problem solving framework

100cm^3 of sand has a mass of 160g. A sandpit is 1m wide by 2m long and 0.2m deep. What is the mass of sand needed to fill the sandpit in kg and in tonnes?

1. **Understand the problem**
   a. Unknown – mass of sand to fill the sandpit in kg and in t
   b. Known – length, width and depth of pit and mass for 100cm^3 of sand
2. **Devise a plan**
   Work out the volume of the sandpit and calculate the number of times 100cm3 of sand will fit into this. Multiply this by 160g to give the total mass of sand in g. Convert the mass in g to kg and to t.
3. **Carry out the plan**
   a. *Volume of sandpit = 1 x 2 x 0.2 = 0.4m^3*. Check the units for volume m^3 is ok.
   b. How many times does 100cm^3 fit into 0.4m^3? Check – we cannot calculate with different units convert the 0.4m^3 into cm^3 (you could instead convert the 100cm^3 into m^3)
      1m^3 = 1,000,000cm^3
      0.4m^3 = 0.4 x 100,000cm^3
      = 400,000cm^3
      How many lots of 100cm^3
      = 400,000/100
      = 4000
   c. *Mass of sand = 4000 x 160g*
      = 640,000g
   d. Covert to kg (1kg = 1000g) so mass of sand in kg = *640,000/1000 = 640kg*
      Mass in tonnes (1t = 100kg)
      = 640/1000 = 0.64t
4. **Look back**
   We know that 1m^3 of water has a mass of 1000kg (1t) so 0.4m^3 of water would have a mass of 400kg. Sand is heavier than water so the result looks approximately correct.

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.4B: SCAFFOLDED SOLUTION METHOD

100cm³ of sand has a mass of 160g. A sandpit is 1m wide by 2m long and 0.2m deep. What is the mass of sand needed to fill the sandpit in kg and in tonnes?

Follow the steps below to calculate the answers. Make sure you give the units as well as the values.

1. Calculate the volume of the sandpit. *Volume = length x width x depth*.
2. Convert the volume of the sandpit to cm³.
3. Calculate how many lots of 100cm³ fit into the sandpit volume.
4. Multiply the number of lots by the mass for 100cm³ of sand to find the total mass of sand.
5. Convert the mass to kg and tonnes.

Worked example using the scaffolded solution method

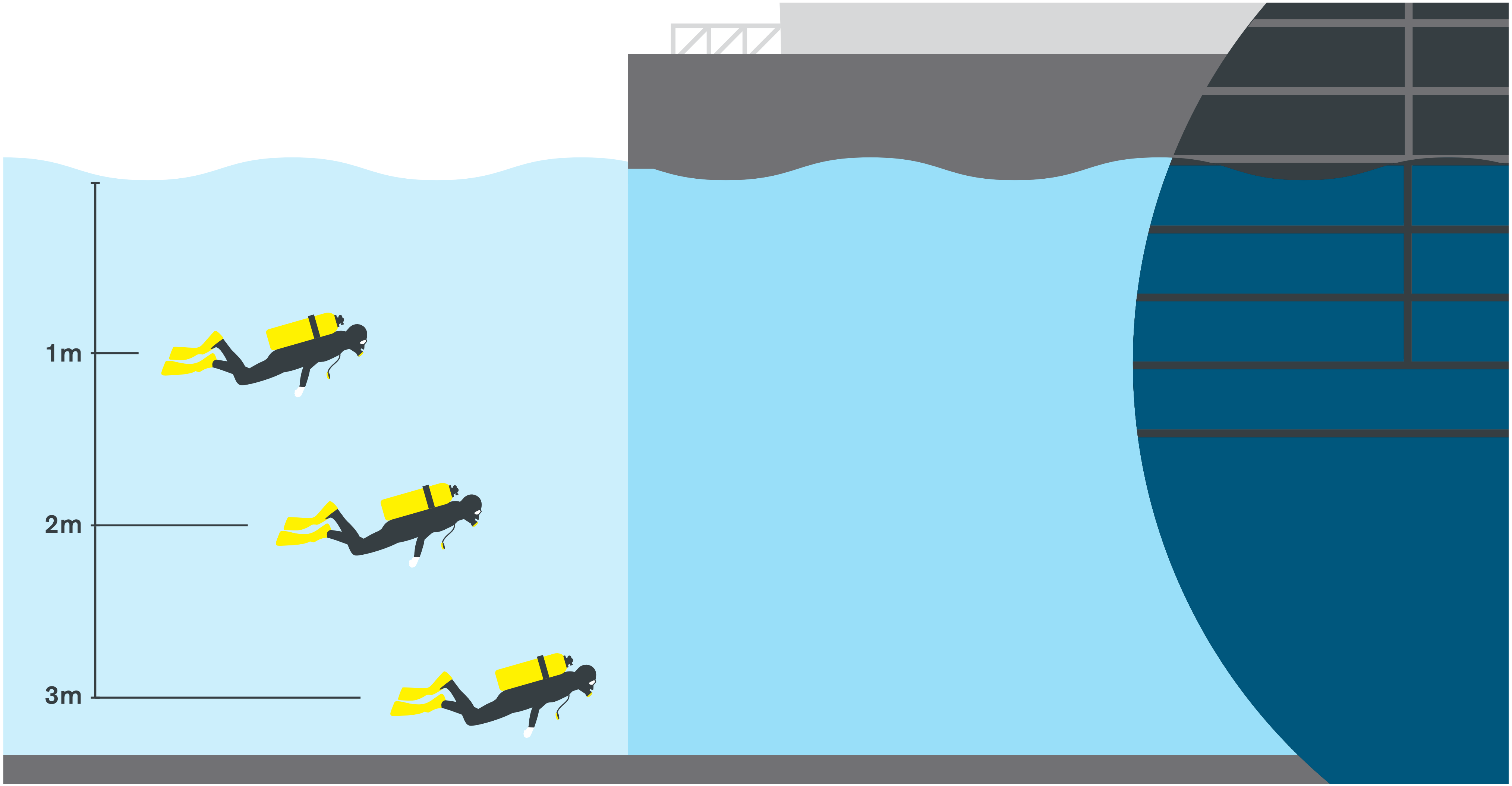
1. Calculate the volume of the sandpit.
   Volume = length x width x depth
   Volume = 1 x 2 x 0.2 = 0.4 m³
2. Convert the volume of the sandpit to cm³. *Volume in cm³ = 1,000,000 x volume in m³ = 0.4 x 1,000,000 = 400 000 cm³*
3. Calculate how many lots of 100cm³ fit into the sandpit volume. *Number of 100cm³ that fit in = 400,000/100 = 4000*
4. Multiply the number of lots by the mass for 100cm³ of sand to find the total mass of sand. *Total mass of sand = 4000 x 160 = 640,000g*
5. Convert the mass to kg and tonnes.

Mass in kg = mass in g/1000
= 640,000/100
= 640kg

Mass in t = mass in kg/1000
= 640/100
= 0.64t

LESSON 1: TAMING THE RIVER AND THE PRESSING MATTER OF WATER

RESOURCE 1.5: DIVER WORKING ON THE THAMES BARRIER



LESSON 2
WATER PRESSURE AT WORK IN LONDON

THE BIG IDEA

Students will look at the related concepts of pressure and force (*pressure = Force/ Area*), units used and measurement and how a large force can result from pressure acting over a given area. They will move from calculating the weight (under gravity) of a column of water or air to the pressure of this as weight over unit area. This will also bring in the idea of density.

LEARNING OUTCOMES

Could: evaluate the result of a simple calculation of height of the atmosphere based on their existing science knowledge and understanding.

Should: relate pressure increases with depth in a fluid to the weight of the fluid above under the action of gravity.

Must: explain that pressure is a measurement or calculation of force acting over a unit area and use the units of N/m^2 correctly.

RESOURCES

Resource 2.1: Kew Bridge standpipe and Shooters Hill water tower

Resource 2.2: Enfield Lock pressure calculation

MATHEMATICAL SKILLS

- Units – Newtons per metre squared (N/m^2), Pascals (Pa, 1 Pa = 1 N/m^2)
- Calculation of pressure

KEY WORDS

- Pressure
- Density
- Fluid (liquid or gas)

LESSON 2
WATER PRESSURE AT WORK IN LONDON

PRACTICAL WORK

Collapsing can under air pressure for example:

www.sciencedemo.org/2014/01/collapsing-can/ – either using a vacuum pump or heating a small amount of water in a can then dipping in cold water or sealing the lid.

Visualising pressure:

1 kg masses, 1 cm sided cubes, 1 m rulers are required.

Introducing pressure:

www.nuffieldfoundation.org/practical-physics/introducing-pressure

Pressure of a water column:

www.nuffieldfoundation.org/practical-physics/investigating-pressure-water-column

Pressure and force:

www.nuffieldfoundation.org/practical-physics/pressure-and-force

LESSON 2: WATER PRESSURE AT WORK IN LONDON

SETTING THE SCENE

STANDPIPE TOWER AT LONDON MUSEUM OF WATER & STEAM

© Wikimedia Commons

As London grew in size and industrial power during the 18th and 19th century, the transport route provided by the River Thames was increasingly supplemented by a number of man-made canals, to manage the transit of materials and produce. At the same time, water supply became increasingly important both to support the industries and the needs of the growing population. Water towers were built to pressurise the water supply system to distribute drinking water. Kew Bridge Works, a pumping station which transferred water from the Thames to supply Ealing and Paddington was built during the 19th century. The building, with its impressive standpipe tower, now houses the London Museum of Water and Steam.

Drawing on practical examples relating to the London's water ways and infrastructure, as well as simple and visual classroom based experiments, this lesson explores the differences between pressure and force and the units used for pressure.

In science liquids and gases are both considered as fluids. They both have similar properties of 'flowing' and not keeping a shape but gases are much less dense than liquids and are compressible. This means gases increase in density, and therefore reduce in volume, with increasing pressure or reduce in density with reducing pressure, resulting in the air getting 'thinner' at altitude. Liquids are incompressible so keep the same density, and volume as pressure increases or decreases.

An example of calculating the pressure at the bottom of a London lock is given based on real data. The common calculation method *pressure = force/area* is given first then an equivalent method based on density is given as an extension. The scientific understanding of increasing density meaning matter being more compressed is useful when learning science concepts, but for calculations the more mathematical understanding of density being simply mass per unit volume leads to a better conception of the working of the calculations. This will be reinforced with calculations on our London diver example.

Finally a simple calculation based on the density of air at sea level is used to estimate the height of the atmosphere by working out the height of air that is needed to provide a weight matching the air pressure at sea level. This gives a very quick simple estimate but is smaller than the true value as it does not account reducing density of air with altitude. The pressure of a liquid at depth can be calculated directly as there is no change in density with depth.

LESSON 2: WATER PRESSURE AT WORK IN LONDON

ACTIVITIES

STARTER

Show the class Resource 2.1: Kew Bridge standpipe and Shooters Hill water tower (page 35). Ask the class whether they recognise them. What were they for? Why would you store water high up in towers rather than in tanks on the ground? Explain that the Kew Bridge standpipe, now part of the London Museum of Water and Steam, is a 61 m high tower which contains vertical pipes through which water was pumped up before going into the mains water supply to Ealing and Paddington. The height of water in the standpipe maintained a high constant pressure of water supply.

Imagine the cross section area of the standpipe is 1 m^2. Ask students to work out or guess the mass of water in the pipe if it is full up to 61 m. Compare answers – the answer will be given in the plenary.

MAIN 1

This activity introduces pressure and contrasts it with force.

Ask students to work in small groups and answer the questions in Introducing Pressure **www.nuffieldfoundation.org/practical-physics/introducing-pressure**.

Share answers with the class. Note 'the items are similar but with a difference' – at the end of the sequence you should bring out the idea that the force is the same (e.g. weight of girl in example A) but the pressure is different.

Discuss the difference between force and pressure. You may wish to draw force arrow diagrams for one of the examples to stress that the force does not change but the pressure decreases with area. For example with flat shoes vs high heeled shoes the force acting through the shoes is equivalent to the weight of the person in both cases, therefore the same size of force arrow, but the pressure is much larger from the high heels which have a very small area.

Differentiation

All students may find it useful to draw diagrams of the situations in their groups. More able students may make an estimate of the different areas in one or more examples and calculate the pressures. Less able students should create their own example statements similar to the introducing pressure example.

MAIN 2

This activity shows that pressure in liquids increases with depth due to the action of gravity and introduces density.

Show Resource 2.1: Kew Bridge standpipe and Shooters Hill water tower (page 35).

Demonstrate pressure of water column increasing with depth – pressure at different depths only.

www.nuffieldfoundation.org/practical-physics/investigating-pressure-water-column

You do not need to do the pressure in different directions or the velocity of water calculations in this example.

Explain that:

- The mass of $1m^3$ of a liquid or gas is called its density. So density is measured in kg/m^3 or sometimes in g/cm^3. So for example water has a density of about $1000kg/m^3$ (this is equivalent to $1g/cm^3$) and air has a density of about $1kg/m^3$.
- Density gives a measure of the difference in mass of the same unit volume for different substances – water is 1000 times 'heavier' than air. Similarly pressure gives a measure of how much force is acting on the same unit area in different situations.
- Pressure is calculated as the force in (N) over $1m^2$ (unit) area and the unit $1N/m^2$ is also known as the Pascal.
- Therefore to calculate pressure over a larger area we usually calculate the total force over the whole area and then divide by the area to find the force on $1m^2$.

MAIN 3

Ask students calculate the pressure at the bottom of a typical London lock. Use the example data given in Resource 2.2: Enfield lock pressure calculation (page 36–37) or similar data for a local lock.

Differentiation

Resource 2.2: Enfield lock pressure calculation (pages 36–37) gives a problem solving framework for higher ability students and scaffolded solution method for lower ability students. You might also talk through the summary method below with lower ability students before they attempt the solution. Worked examples for each scaffold and based on the Enfield lock data may be given to students if data from a local lock is used, or after they have attempted the calculations.

A summary of the method used is as follows:

The force on the bottom of the lock is the total weight of water. This is calculated from the total volume of water multiplied by the density to give the mass in kg, then multiply by 10 to give the weight in N. To get the pressure in N/m^2 divide the force by the area of the lock. You may wish to reinforce this by working through the example lock calculation on the board after students have attempted the calculation.

Extension

Give more able students the ‘calculation based on density and depth only’ example and ask them to read through the calculation and compare to their previous calculation.

Less able students can be given further examples based on the force divided by area calculation, researching the sizes of other local locks or swimming pools themselves.

MAIN 4

This activity visually demonstrates the large forces generated by pressure.

Show the value for atmospheric pressure as approximately *100,000 N/m² = 100,000 Pa* on the board. Explain that this is like a weight of 100,000N resting on a $1m^2$ area, which is equivalent to a mass of 10,000 kg or 10 tonnes (remember weight in N is approximately 10 x mass in kg).

Question

Why aren't we all crushed by this pressure?

Give students a chance to discuss in groups and suggest some answers but before responding yourself carry out the collapsing can demonstration – for example:

sciencedemo.org/2014/01/collapsing-can/

Answer

Air pressure is acting in all directions and is 'inside' us as well as 'outside'. The can experiment removes air from inside the can by heating and when suddenly cooled without allowing more air back inside the air pressure inside drops.

The collapsing can provides a visual demonstration that air pressure can in fact produce large forces. It is actually the difference in pressure on either side of an object that produces an unbalanced force which in this case causes the can to collapse. Pressure differences have many applications, for example planes can fly because they have a wing shape that causes a drop in pressure on the top surface compared to the bottom.
The unbalanced force resulting from this is called the lift.

Further visualise this by using 1kg masses and 1cm sided cubes. Rest a 1kg mass on the 1cm cube on a student's hand and explain air pressure is equivalent to 10N (the weight of 1kg mass) on every square centimetre. The pressure multiplied over the total surface area of the can is large enough to collapse it very quickly.

Use 1m rulers to create a 1m sided square and explain that scaling up from a 1cm sided square, this is the same as having 10,000kg masses (10 tonnes) resting on the $1m^2$ area. This is because $1m^2 = 100cm \times 100cm = 10\,000cm^2$ so there are 10,000 1cm sided squares in a 1m sided square

For further examples students might consider the shape and strength of materials needed in the Port of London Authority diver's helmet shown in the video or the Drebbel submarine and modern submarines. More examples of extreme pressures at depth are given in the further reading.

MAIN 5

This activity demonstrates how to make a rough estimate of a real world quantity using scientific knowledge and calculation.

Before starting on the calculation ask students to guess how high the atmosphere goes. Ask them also to guess the radius of the Earth or state its value if they know. Then ask them to calculate the answer to the following question.

Question

We know that air pressure at sea level is approximately 100,000 N/m^2 and that the density of air is approximately 1 kg/m^3.

From this data, calculate the height of air that must be above us to produce this pressure (this is the height of the atmosphere).

Differentiation

As usual, scaffolding for the less able and problem solving for more able. You might also point them to look at the Enfield Lock Pressure Calculation as a similar problem.

Answer

$1 \times 10 \times H = 100{,}000\ N/m^2$
$H = 10{,}000\ m$
$= 10\ km$

This example shows how by using scientific understanding and simple calculation, scientists can discover things about the world. They can use this knowledge to base future investigations and creations on.

The real answer for the height of the atmosphere is approximately 100km. This may seem much larger than the calculation but it is really of a good comparable size given the simple calculation used. We did not get result of a few metres or of millions of km which would have been poor estimates. The reason the real value is larger is because the pressure reduces with altitude and this causes the air to reduce in density (become thinner) as gases are compressible. This means a greater height of air is needed to produce the pressure.

Mercury barometers use the pressure of column of mercury (density 13,600 kg/m^3) to show the current air pressure as the rising and falling of air pressure is an indicator for weather prediction. The Thames water barometer on Holland Park roundabout uses water as the fluid balancing the air pressure instead of mercury. Note the pressure calculation of *density x acceleration* of *gravity x height* as in our examples shown in:

www.damianosullivan.com/page21/page22/

More able students should consider the density calculation. Less able students should be able to appreciate the height of the water barometer compared to the mercury barometer is due to the difference in density of the fluids.

Plenary

Answer to starter question

Ask students to make up their own 'introducing pressure' type examples and discuss whether they clearly distinguish force from pressure.

Mass of 61m height of water with cross section area $1m^2 = 61m^3 \times 1000kg/m^3 = 61{,}000\ kg = 61\ tonnes$

This then produces a pressure of $61{,}000 \times 10\ N/m^2 = 610{,}000\ N/m^2$ or about 6 times atmospheric pressure.

Assessment questions

Adapt or extend questions based on the activities or use the following examples (please note that for question 3 students will need their copy of Resource 1.5: Diver working in the Thames Barrier, handed out in lesson one):

1. State the units for force and pressure and explain the difference between force and pressure.
2. Using the syringes, drawing pins or other examples explain how a small force can be made into a large pressure or a small pressure can be made into a large force.
3. Calculate the mass of water above the diver at the different depths and annotate the diagram in Resource 1.5: Diver working on the Thames Barrier. Assume that the area of the diver's body is 1m2.
4. Other calculation problems for pressure at given depths of water.

Homework ideas

Work out what depth of water will give the same pressure as air pressure (100,000 N/m^2)?

Research a London waterway that has a number of locks on it. Find out the number of locks and the fall on the locks to find the total fall of the waterway coming into or out of London. Find out what the waterway was used for in the past and what it is used for now.

Research altitude sickness in mountaineers (reducing air pressure with height) – state heights and pressures.

Further reading

Examples of extreme pressure deep in water:

Natural History Museum ocean pressure on deep sea animals, follow other links on the site to find the depths that some of the animals live at:
www.nhm.ac.uk/nature-online/earth/oceans/deep-ocean-life/challenges/ocean-pressure/index.html

Article on the Drebbel Submarine:
www.nmmc.co.uk/index.php?/collections/archive/the_drebbel_submarine

Thresher Submarine crushing accident, engaging reads for students:
www.nationalgeographic.com/k19/disasters_detail2.html

LESSON 2: WATER PRESSURE AT WORK IN LONDON

RESOURCE 2.1: KEW BRIDGE STANDPIPE AND SHOOTERS HILL WATER TOWER

STANDPIPE TOWER AT LONDON MUSEUM OF WATER & STEAM

Ed Stannard © Wikimedia Commons

SHOOTERS HILL WATER TOWER, GREENWICH

Angus McLellan © Wikimedia Commons

LESSON 2: WATER PRESSURE AT WORK IN LONDON

RESOURCE 2.2: ENFIELD LOCK PRESSURE CALCULATION

Enfield lock is 4.9m wide, 25.6m long and has a fall (depth) of 2.9m. Calculate the pressure at the bottom of Enfield Lock when full of water. If you know the method needed then follow the general problem solving steps to create your own answer or if you are unsure of the method then follow the calculation steps.

1. **Understand the problem**
   What do you want to find out (the unknown) – what quantities do you know (data)?

2. **Devise a plan**
   Describe the steps you will use to convert the known data into the unknown answer.

3. **Carry out the plan**
   Write down your calculations step by step and check each step is correct.

4. **Look back**
   Check the result is correct or at least looks correct in comparison to other things you know.

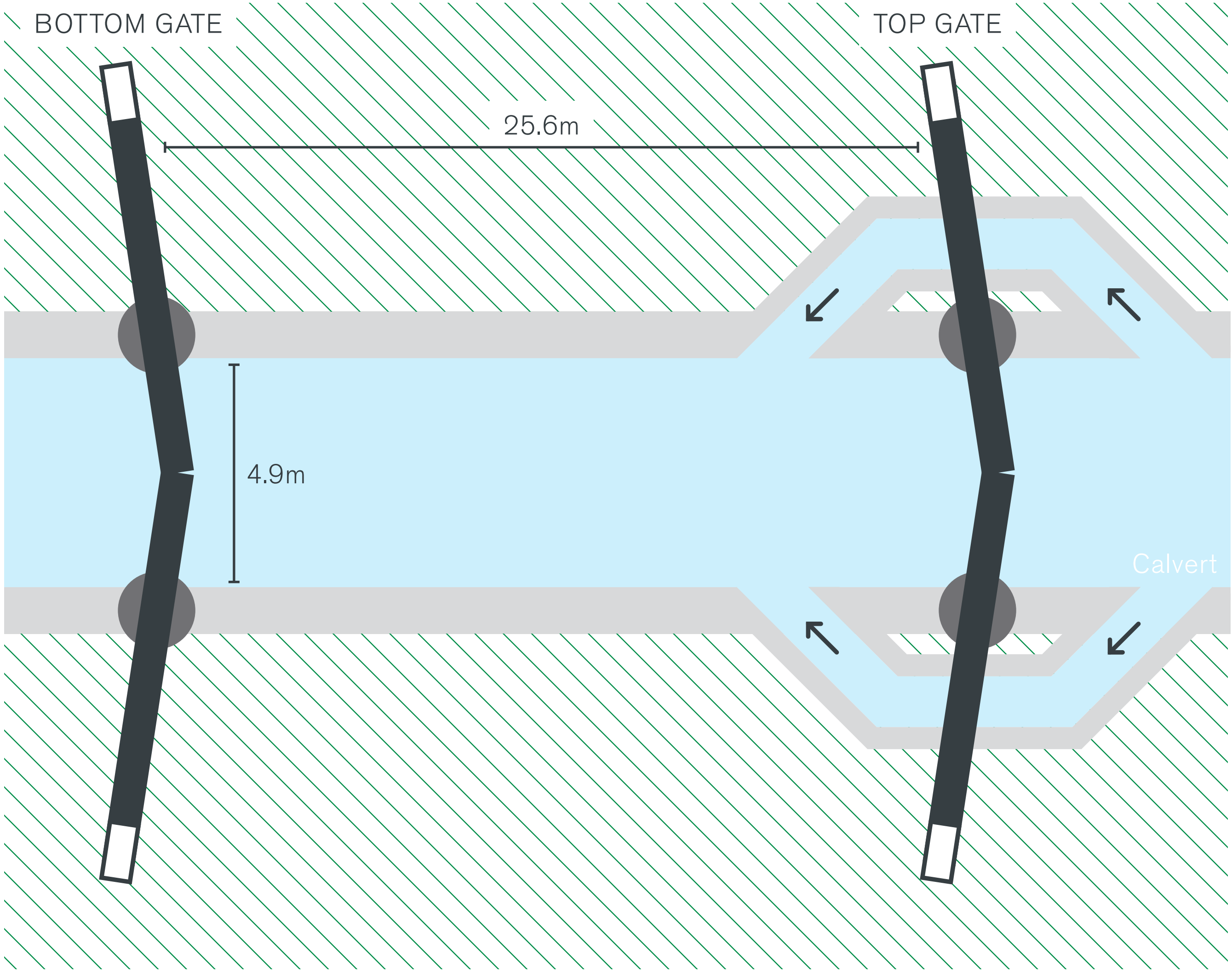
ENFIELD LOCK DETAILS	
Waterway	River Lee Navigation
Constructed	1725
Operation	Manual
Maintained by	British Waterways
Length	25.6m
Width	4.9m
Fall	2.9m
Coordinates	51.667319° N 0.018207° W
Distance to Bow Creek	18.5 km (11.5 miles)
Distance to Hertford Castle Weir	14.8 km (23.8 miles)

ENFIELD LOCK, COTTAGES AND OFFICE
© Wikimedia Commons

LESSON 2: WATER PRESSURE AT WORK IN LONDON

RESOURCE 2.2: ENFIELD LOCK PRESSURE CALCULATION CONTINUED

SCAFFOLDED SOLUTION METHOD	
Volume of lock	= *length x width x depth* =___*m x*___*m x*___*m* =___m^3
Total mass of water	= *volume x density* =___m^3 *x*___*kg*/m^3 =___*kg* (=___*tonnes*)
Total weight of water	= *mass x 10* =___*N*
Area for lock	= *length x width* =___*m x*___*m* =___m^2
Pressure	= *force / area* (the force is the weigh of water) =___*N* / ___m^2 =___*N* / m^2



LESSON 2: WATER PRESSURE AT WORK IN LONDON

RESOURCE 2.2: ENFIELD LOCK PRESSURE CALCULATION CONTINUED

Problem solving framework – worked example

1. **Understand the problem**
   Unknown – pressure per m^2
   known – dimensions of lock:
   Width 4.9m
   Height 25.6m
   Depth (fall) 2.9m and we need to know the density of water 1000kg/m^3

2. **Devise a plan**
   Pressure = Force x Area. The force is the weight of water in the lock so calculate the volume of water and multiply by the density, then x10 to convert kg to N for weight, then divide by the lock area for the pressure.

3. **Carry out the plan**
   Volume of water = 4.9 x 25.6 x 2.9 = 364 m^3
   Mass of water = 364 x 1000 = 364,000 kg (= 364 tonnes)
   Weight of water = 364,000 x 10 = 3,640,000N
   Area of lock = 4.9 x 25.6 = 125 m^2
   Pressure = 3,640,000 / 125 = 29,100 N/m^2

4. **Look back**
   Check the result is correct or at least looks correct in comparison to other things you know.

LESSON 2: WATER PRESSURE AT WORK IN LONDON

RESOURCE 2.2: ENFIELD LOCK PRESSURE CALCULATION CONTINUED

Worked example: Scaffolded solution method

Pressure = Force / Area

For the lock we will need to calculate the total weight of water in the lock and divide by the area of the lock.

Volume of lock = length x width x depth
= 25.6 x 4.9 x2.9
= 363.776 m^3
= 364 m^3 (3 s.f.)

Total mass of water = volume x density
= 364 x 1000
= 364,000 kg (364 tonnes)

Total weight of water = 10 x 364,000
= 3,640,000 N

Area of lock = length x width
= 25.6 x 4.9
= 125 m^2 (3 s.f.)

Pressure = force / area (the force is the weight of water)
= 3,640,000 / 125
= 29,120 N/m^2

LESSON 2: WATER PRESSURE AT WORK IN LONDON

RESOURCE 2.2: ENFIELD LOCK PRESSURE CALCULATION CONTINUED

Extension: Calculation based on density and depth only

1. **Problem**
   To calculate the pressure at the bottom of the lock when it is full of water.

2. **Understanding the problem**
   The unknown is the pressure – the data for the height of water is the fall = 2.9m, the density of water is 1000kg/m^3

3. **Devise the plan**
   Calculate the pressure from the density and height:
   Pressure = density x 10 x height

4. **Carry out the plan**
   Pressure = 1000 x 10 x 2.9
   = 29 000 N/m^2

5. **Look back**
   As before this is a sensible answer in relation to the value for air pressure.

The result is the same as before allowing for the rounding to 3s.f. If you examine the calculation you will see that the length x width calculation for the area cancels out the length x width part of the volume calculation leaving only the depth, so in fact the two calculations are equivalent. This is also equivalent to showing that the pressure is the same as the force per 1m2 of area if you consider the density to be the mass of a 1m cube.

The general calculation for pressure at any depth is *pressure = density x 10 x depth* where 10 represents the approximate value for acceleration due to gravity g used to convert mass to weight.

LESSON 3
IN ALL DIRECTIONS

THE BIG IDEA

This lesson shows that pressure in fluids acts in all directions and therefore pushes in all directions on any object floating or submerged in the fluid.

LEARNING OUTCOMES

Could: explain why pressure with depth variation for water is different from the variation of pressure with height in air.

Should: calculate pressure from the weight of water due to gravity at a given depth and then further calculate the resulting force in all directions.

Must: explain that pressure in fluids acts in all directions, distinct from the force of gravity.

RESOURCES

Resource 3.1: Magic glass experiment

Resource 3.2: Cartesian diver experiment

Resource 3.3: Lock gate pressure depth diagrams

Resource 3.4: Thames Barrier gate cutaway image

KEY WORDS

- Buoyancy
- Buoyant
- Upthrust

LESSON 3
IN ALL DIRECTIONS

PRACTICAL WORK

Institute of Physics IOP Mobile Science Experiments
www.iop.org/activity/outreach/resources/mobilscience/experiments/page_39619.html

Water in inverted cup experiment
www.iop.org/activity/outreach/resources/mobilscience/experiments/page_39619.html

Cartesian diver experiment
www.iop.org/activity/outreach/resources/mobilscience/experiments/page_39619.html

LESSON 3: IN ALL DIRECTIONS

SETTING THE SCENE

The Thames is a significant transport route for shipping bringing goods into the capital.

The shipping industry and docks have had a major impact on the lives of Londoners bringing employment and services into the city.

Students are generally happy with the idea of gravity 'pulling' things down and over the previous lessons and this lesson should become used to calculating pressure from the 'weight of water above' being pulled down by gravity. The particle model provides a simple explanation of how this occurs. The particles in liquids and gases move in all directions and therefore any force is transmitted through the motion of the particles in all directions.

You may need to recap the difference between the movement of particles in solids, liquids and gases and also that forces on a stationary object must be balanced.

Some simple applications of the action of pressure are given to show students that the principles apply in broad contexts and may also give opportunities for cross curricular work.

A particular application of pneumatic pressure being used to raise and lower Tower Bridge is given in lesson 4 of the London Curriculum unit *Bridging the River* and uses different sized syringes to multiply force in the same way as activity 2 in this lesson.

TOWER BRIDGE OPENING
Tony Hisgett © Wikimedia Commons

LESSON 3: IN ALL DIRECTIONS

ACTIVITIES

STARTER

Begin by showing the Port of London Authority Green Motorway video clip:

www.youtube.com/watch?v=bI7qqu0z-VA

Highlight key points in the video: Much larger loads can be carried by boats on the river than by lorries on the roads. The Thames is therefore used to provide a major route to carry heavy loads through London. To replace this with road transport a large number of lorries would be needed to do and this would have a severe negative impact on the already congested roads of London and on pollution. Hence the Thames being described as a 'Green' motorway.

Ask students why much larger loads can be carried by a boat than by lorry. Ask the students to discuss this in groups to produce an explanation which includes pressure of water acting on the boat.

This can be explained by pressure from the liquid water acting upwards on the boat combined with the large hull area of boats such as barges, i.e. it is the combination of a small pressure over a large area that gives a large force to support the weight of the boat (*force = pressure x area*). With a lorry on the road, only the tyres are in contact with the road and therefore if the same weight had to be supported an extremely large pressure, much greater than tyres are capable of holding, would be needed.

Heavy load carrying lorries have many large tyres to deal with this problem but the road contact area is still tiny relative to something like the area of a barge hull in contact with water.

Large ships and canal barges can therefore carry much higher loads than road, rail or air. Historically this has meant that the Thames and other London waterways have made London a centre of trade as well as a route for heavy loads. Today the Port of London Authority with various ports along the Thames, including the new London Gateway Port (completed 2013) handles huge cargo loads. The Port of London youtube channel contains further short videos illustrating this. Also see further reading below.

MAIN 1

This activity uses Resource 3.1: Magic glass experiment (page 51) to show that pressure acts in all directions in liquids and gases. Also have available a model boat or other object floating in water.

Question

Gravity is pulling the water in the cup down to press on the card and gravity is pulling the floating boat down. As the card and boat are not moving there must be a balanced force on each pushing up. What is this balancing force:

- on the cup?
- on the boat?

Answer

- Air pressure is pushing up on the card. Water pressure is pushing up on the boat.

You may discuss the details of each situation if appropriate but the key idea to make clear is that unlike weight which we usually see acting only downwards, pressure in fluids acts equally in all directions.

The boat sinks in the water far enough so the pressure at that depth pushing up on the bottom of the boat is a match for the weight of the boat and the boat floats. If you try and push down on the boat you will feel the force pushing back up increasing, as pressure increases with depth so on releasing the boat will be pushed back up. This could also be demonstrated by pushing a tennis ball or ping pong ball under water to different depths and observing what happens.

You might introduce the terms upthrust and buoyancy and illustrate this with a force arrow diagram. You could ask the students to push down on the boat and explain what they feel, as usual with the correct use of force and pressure.

MAIN 2

This activity is to reinforce the distinction of pressure from force.

www.nuffieldfoundation.org/practical-physics/pressure-and-force

Develop descriptions of pressure and force and try to explain behavior of syringes. Students work in small groups trying out the connected syringes and then writing an explanation of the observed behavior. They must use the words Force, Pressure, Area and Length (or distance) correctly.

Pressure can occur due to the weight of water/air above, but also we can apply pressure ourselves by applying force e.g. pumping a bicycle tyre or the syringes in the example.

Differentiation

Give less able students the hint that the pressure of water is the same everywhere in the syringes (water is incompressible). Share the descriptions at the end.

After completing the writing you should reinforce the fact with all students that the pressure in the water in the syringes, caused by applying a force to one of them, is the same in both syringes and the tube and is transmitted in all directions in both syringes and the tube.

Simple machines are covered in the next lesson, but you should make sure that the students notice that if a force is applied to the smaller syringe then a larger force is caused at the larger syringe but the smaller syringe also has to move a longer distance. Note that the pressure is always the same throughout.

MAIN 3

This activity uses the principle of pressure acting in all directions together with compressibility of gases and buoyancy and relates this to real world applications.

Students in groups use Resource 3.2: Cartesian Diver experiment (page 52) and use it to see that they can control neutral buoyancy.

Try to use some sort of transparent tube such as a clear straw or a test tube for the diver body. Students should be asked to observe the diver closely as they squeeze (increase the pressure) on the bottle. They should notice that the air bubble in the diver reduces in size as they squeeze. The air is compressible but the water is not.

Explain that fish have air in a swim bladder which they can squeeze and relax to achieve the same control of depth. Submarines are built with tanks that can have water and air pumped in and out to achieve the same effect.

MAIN 4

This activity demonstrates how a construction takes account of pressure at depth and pressure acting sideways.

A cross section of a large dam will show the need to build water storage structures that are thicker and stronger as the depth increases to resist the increased water pressure. London does not have any dams but it has many water reservoirs to store water needed by the population. These are generally built surrounded by embankment dams.

A list of London reservoirs can be found here:

en.wikipedia.org/wiki/List_of_dams_and_reservoirs_in_the_United_Kingdom

The images on the linked pages for the Island Barn Reservoir and the Queen Elizabeth II Reservoir show the shape of the reservoir walls. If you have a local reservoir then take similar pictures and use these instead.

Display an image of a reservoir from the above links or your own picture. You might draw a simple diagram indicating the wall is not a vertical wall but is triangular in cross section getting thicker as the water in the reservoir gets deeper.

Question

Why are walls of reservoirs for water built much thicker at the bottom unlike buildings which usually have walls of even thickness?

Answer

Two points are needed for a complete answer, both that the pressure is large at depth so a strong structure is needed to resist the pressure but also that the pressure acts in all directions so the structure must resist this sideways as well as down.

Reinforce by working through a pressure calculation example using data for reservoir depth or just giving an example of a 15m deep reservoir.

MAIN 5

Students have seen that pressure increases with depth and calculated its value at a particular depth, for example at the bottom of a 3m deep lock. However many structures such as the Thames Barrier gates and lock gates are vertical in the water and therefore the water pressure is zero at the surface but increases linearly with depth to the bottom. This means calculation of the total force on a gate of this type needs to take account of the changing pressure at different depths.

This activity introduces the idea of pressure varying with depth on a lock gate structure and explains that for calculation of the total force on the gate, an average value of the pressure can be multiplied by the gate area to get the answer. The average pressure is the pressure at half the depth of water.

Show students diagram 1 from Resource 3.3: Lock gate pressure depth (page 53).

Question

A lock is filled with 2m depth of water and is 1.6m in width. Imagine looking onto the gate from inside the lock. How would you calculate the total force of the water on the lock gate?

Answer

Force = pressure x area

Question

But what is the pressure on the gate?

Allow time for discussion and ideas. If no one suggests that pressures are different at different depths then ask students to calculate the pressure and discuss the values they produce. They may just calculate the pressure at the 2m depth which is the pressure at the bottom of the lock but not at any other depth.

Show Resource 3.3: Lock gate pressure depth (pages 53 – 54), and reinforce that the pressure is different at different depths but that we need to have a value that we can multiply by the area to work out the total force on the gate.

Question

Referring to Resource 3.3: Lock gate pressure depth (pages 53 – 54) the total force on the gate is calculated from *pressure x area*

What pressure value should we use?

Answer

The pressure at the middle depth. This is the average pressure so using this pressure multiplied by the area will give the correct value for the total force.

Work through the calculation on the board:

Depth = 2m

Average pressure is at 1m depth

Average pressure = density x 10 x height

= 1000 x 10 x 1

= 10,000 N/m2

Total force = average pressure x area

= 10,000 x 2 x 1.6

= 32,000 N

If there is a lock near your school then you may wish to take pictures and approximate measurements and use these in example calculations.

Plenary

Students have now calculated pressure at depth a number of times. Ask for a quick estimate to see if they are able give a sensible estimated value and use correct units. Ask them to write their estimate on mini whiteboards and hold them up for everyone to see.

Show Resource 3.4: Thames Barrier gate cutaway image (page 55).

Question

The straight back of each gate measures 20m, 4m of which are below the riverbed. Estimate the average pressure on the gate in flood conditions where the height of the river has reached the top of the gate.

Make sure students appreciate how tall 20m is – approximately the height of a 6 storey building. Ask them to compare to their own height or the height of a familiar building such as their school.

Answer

The depth of water, above the river bed, is 16m so average pressure is at 8m depth = 80,000 N/m^2

Assessment questions

Adapt or extend questions based on the activities or use the following examples:

Make up a table for pressure under water at a series of depths 2m, 4m, 6m etc.

Draw a graph of the variation of pressure under water with depth.

Calculate the pressure on the diver at the different depths and annotate the diagram in Resource 3.2: Cartesian diver experiment (page 52). Add force arrows to show in which directions the force from the pressure will act on the diver.

Other calculation examples for pressure at given depths of water.

Homework ideas

The effects on the human body of diving deep and then surfacing can be very dangerous. Research the causes and effects of the 'bends'.

Research how the water supply to your house or schools is stored and how it reaches you. Find out about the pressures required in the system.

Research into load carrying capacities of different types of air, road, sea/river cargo carrying transport. This can be extended to include information.

Further reading

Background reading on London Docks:

en.wikipedia.org/wiki/London_Docks

en.wikipedia.org/wiki/King_George_V_Dock,_London

en.wikipedia.org/wiki/Port_of_Tilbury

Port of London Authority suggested short videos from their Youtube channel:

This is the PLA (short version) – a quick overview of the work and people involved. Also useful to illustrate the range of careers

www.youtube.com/watch?v=E--InuV5INI

The Green Motorway – showing the freight carried through the city on the Thames, equivalent to over 250,000 lorry journeys in 2013

www.youtube.com/watch?v=bI7qqu0z-VA

Docked in 75 seconds – a timelapse of a container ship coming through the Thames Estuary and docking at a port:

www.youtube.com/watch?v=hdB3Y4SsQq8

London Gateway Port

Photos to illustrate the scale of cargo handled

www.londongateway.com/media-page/photos/

Video case studies of engineering careers

www.londongateway.com/careers/case-study-engineers/

LESSON 3: IN ALL DIRECTIONS

RESOURCE 3.1: MAGIC GLASS EXPERIMENT

You will need

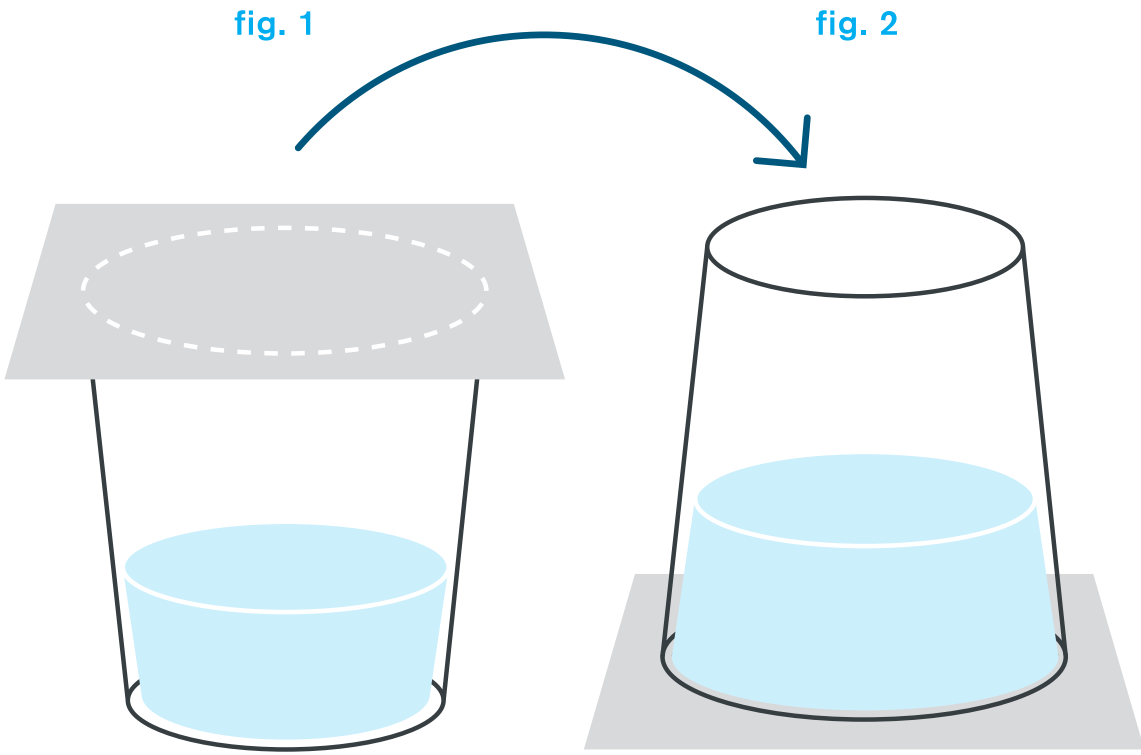
- Cardboard of various thickness
- A glass of water

Place a thin piece of cardboard over a half full glass of water.

With a little care you can turn the glass upside down and the card will keep the water in the glass.

Why doesn't the water just fall out?

1. Try various stiffnesses of card; you should find that the stiffer card won't do the trick, so the secret is in the flexibility of the card.
2. Try varying how full the glass is as well; the trick works better for a stiff card if the glass is fuller.



LESSON 3: IN ALL DIRECTIONS

RESOURCE 3.2: CARTESIAN DIVER EXPERIMENT

You will need

- A drinking straw
- Glue
- Putty or sticky-tack
- A plastic drink bottle
- Water

The idea is to make a small squashable submarine that is neutrally buoyant (neither floats nor sinks).

An example would be a medicine dropper with some water in it. A home-made version is a small length of a drinking straw, sealed at one end with glue and sealed and weighted at the other end with some putty or sticky-tack.

1. Put the submarine in a plastic drink bottle, the sort you can squeeze somewhat, and fill with water and seal.
2. Now squeeze the bottle. You should find that your submarine sinks. Let go of the bottle and it rises again.

fig. 1

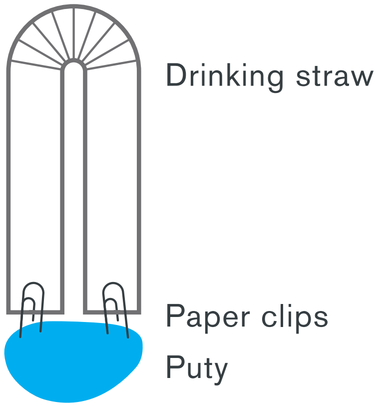


fig. 2

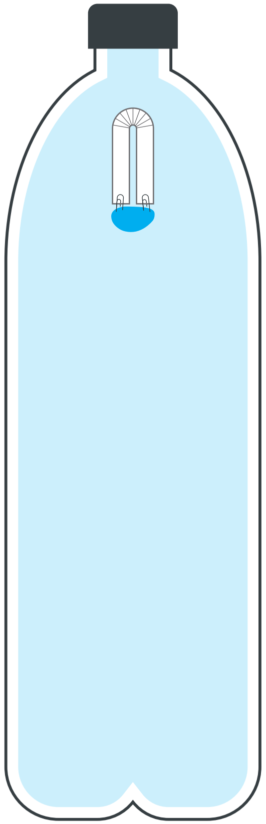
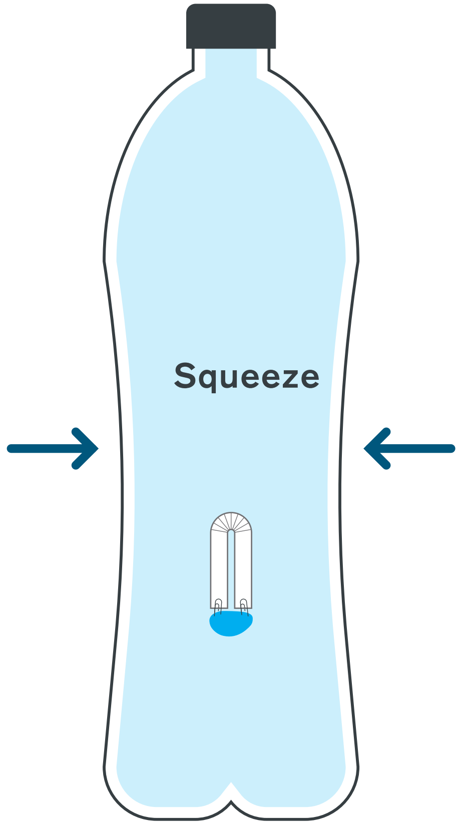


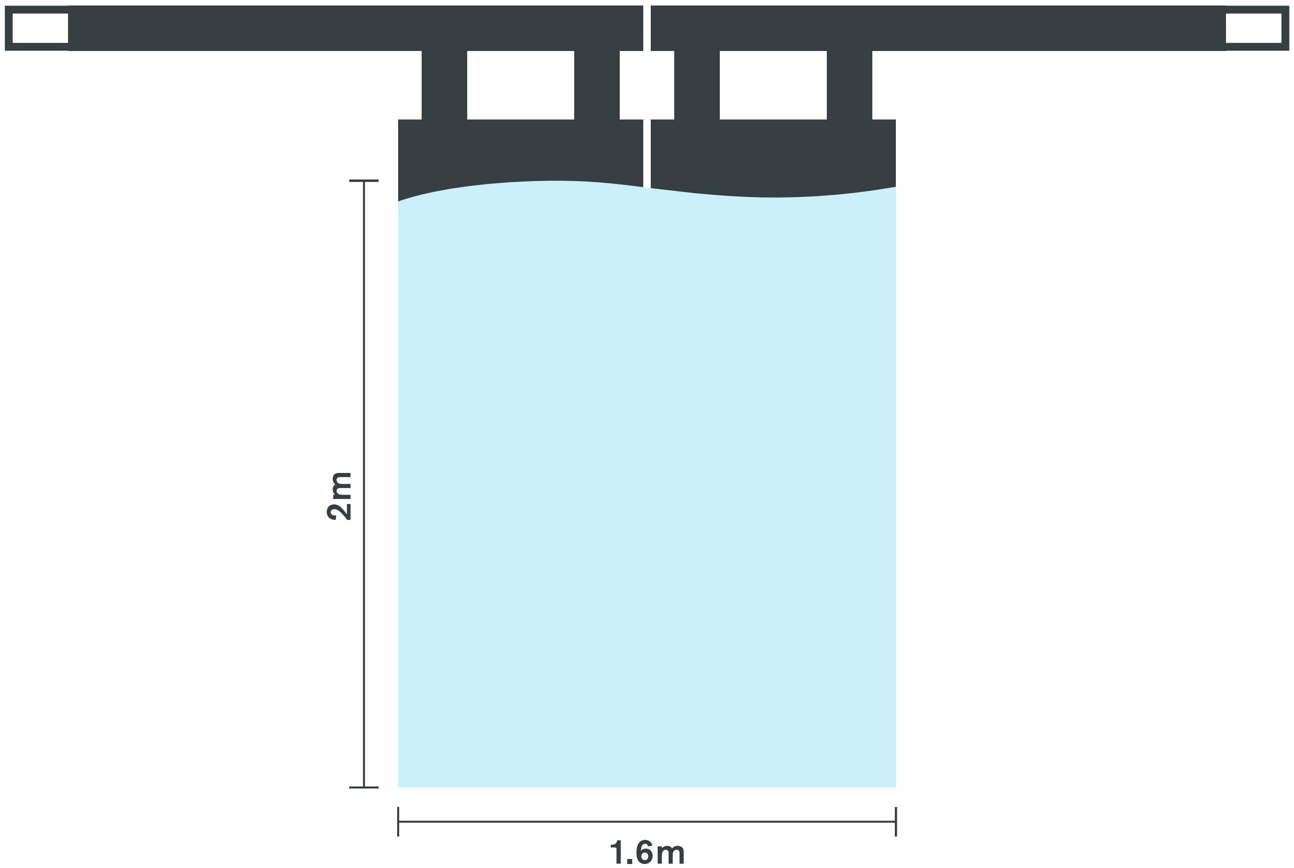
fig. 3



LESSON 3: IN ALL DIRECTIONS

RESOURCE 3.3: LOCK GATE PRESSURE DEPTH DIAGRAM

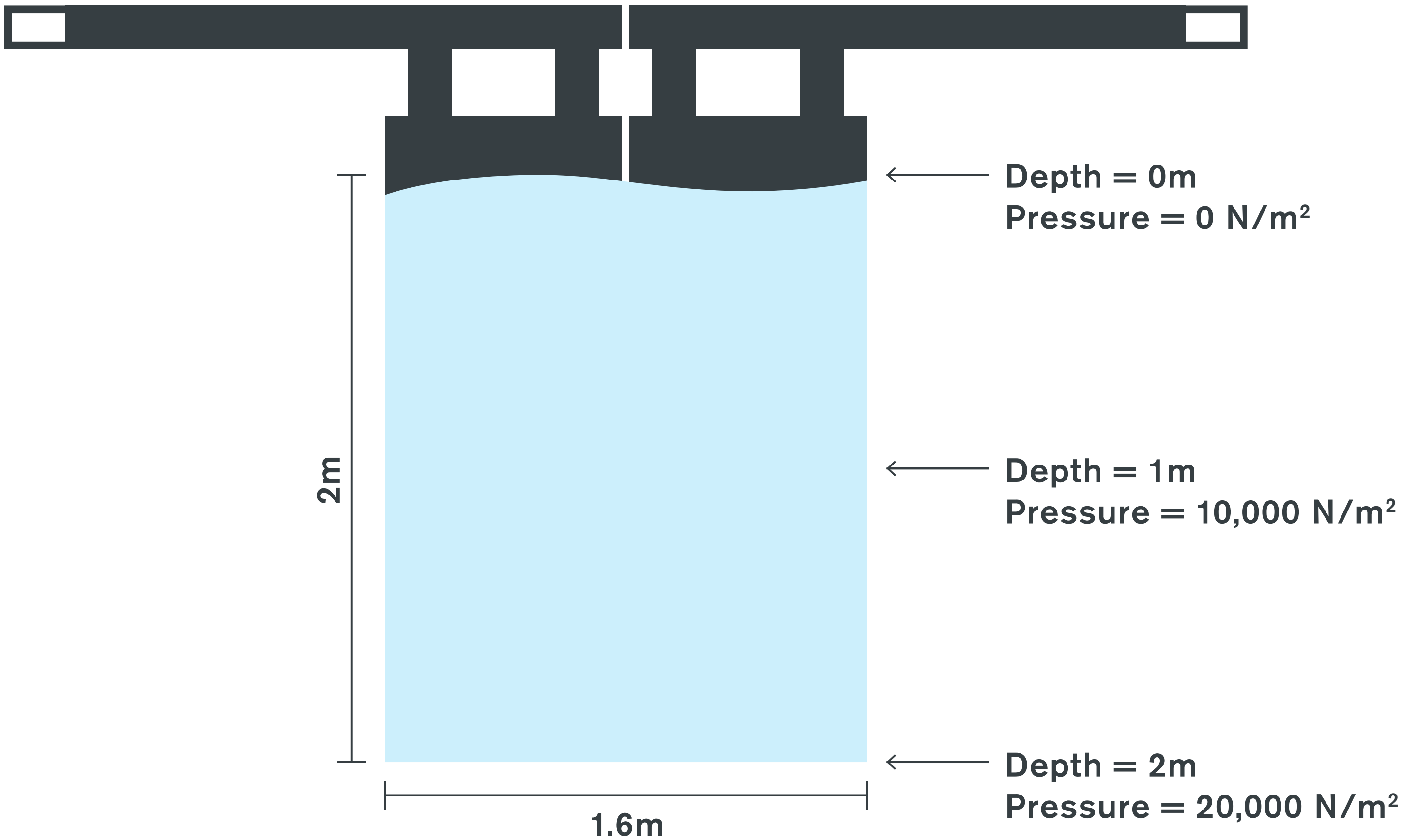
Lock gate pressure depth 1



LESSON 3: IN ALL DIRECTIONS

RESOURCE 3.3: LOCK GATE PRESSURE DEPTH DIAGRAM CONTINUED

Lock gate pressure depth 2



LESSON 3: IN ALL DIRECTIONS

RESOURCE 3.4: THAMES BARRIER GATE CUTAWAY IMAGE

THAMES BARRIER GATE CUTAWAY IMAGE

LESSON 4
THE MACHINES OF THE WORKING RIVER

THE BIG IDEA

If a large force is needed, a simple machine can be used to convert a small force into a large force but requires that the small force move a larger distance and the large force a correspondingly smaller distance. The amount by which the small force is multiplied is known as the mechanical advantage. This principle can be seen in action in many contexts along the banks of the working river.

LEARNING OUTCOMES

Could: give examples of simple machines used in reverse to increase displacement or speed.

Should: relate the input and output forces and displacements together to show that the product of force and displacement are unchanged (conservation of energy).

Must: recognise common uses of different types of simple machines.

RESOURCES

Resource 4.1: Pulley simulation activity

Resource 4.2: Beam balancing

KEY WORDS

- Displacement
- Mechanical advantage
- Machines (in the physics sense)

LESSON 4
THE MACHINES OF THE WORKING RIVER

MATHEMATICAL SKILLS

- Product of force and displacement being constant (equivalent to inverse proportion between force and displacement)
- Mechanical advantage calculation

PRACTICAL WORK

Balancing beam experiment
www.nuffieldfoundation.org/practical-physics/balancing-beam

Lever, pulleys, force and energy experiment
www.nuffieldfoundation.org/practical-physics/levers-and-pulleys-multiply-force-not-energy

LESSON 4: THE MACHINES OF THE WORKING RIVER

SETTING THE SCENE

The River Thames has been a working river since London's very beginning; its potential to carry people and cargo is one of the principle reasons why the Roman's first settled on its banks and founded the city. To support the work on its waters and banks – to load and unload cargo, to transport people across the Thames, to build the warehouses and offices – simple machines have been helping for centuries with the heavy lifting. From the gates of the Thames Barrier protecting the city from flooding, to the Emirates Air Line, the UK's first urban cable car, capable of carrying 2,500 people an hour across the Thames, to the raising of the bascules of Tower Bridge to let the ships pass through, simple machines are in use all the time to convert small forces into large forces to help with the heavy work. The numerous cranes that populate the skyline along the Thames demonstrate the way that a simple machine continues to enable the city's growth and industry.

The six basic types of simple machines are the wedge, lever, ramp, pulley, wheel & axle and screw. Each type can have many variations. Gears can be considered as a type of lever.

Simple machines do not have their own energy source; they do not have engines or batteries, so they can only put out as much work as is put in. The key thing to note is that we cannot get something for nothing. The small force will have to move a longer distance to produce a large force moving only a short distance. This numerical relationship needs to be brought out when looking at simple machine examples.

This is actually the conservation of energy principle as the work done by a force is calculated by multiplying the force by the distance moved (the distance moved may also be known as the displacement). Thus a large force moving a small distance does the same work, or uses the same energy, as a small force moving a large distance.

In real life where there will probably be some friction then some of the effort going in will always be wasted. The idea of efficiency can be discussed here but is not calculated in the examples.

Nowadays we power machines with engines and motors to do heavy work for us, but in the past this was done with human effort through simple machines.

Machines like bicycles are built from a number of simple machines such as levers, gears, wheels and axles.

LESSON 4: THE MACHINES OF THE WORKING RIVER

ACTIVITIES

STARTER

Explain the role of the River Thames as a working river, based on the information in setting the scene, and that when they visit the river they will be looking out for a range of simple machines playing their role alongside more complex technology and helping with the heavy work. Explain that simple machines can be used to convert a small force into a big force.

See the pulley simulation activity resource. The rods with string looped around simulate a block and tackle pulley system. Take turns with groups of students at the front of the class. This is a fun activity for the students. It should become clear very quickly that four students holding the rods cannot resist even a small force from the student pulling the rope.

Remind students of the force activity with the syringes in lesson 3.

Ask students to think about both the forces being experienced and the distances moved (displacements) for the student pulling compared to the students holding the rods.

MAIN 1

This activity shows different types of simple machine and indicates that they all follow the same principle.

Make up a circus of the 6 simple machine types in physics and let students move around and try out each one. The types are lever, ramp, wheel & axle, wedge, pulley and screw (see for example: **hyperphysics.phy-astr.gsu.edu/hbase/mechanics/simmac.html**).

Ask students to think back on the forces and displacements in the pulley simulation starter and ask them to describe how this is common to all the simple machines.

Suggest some example applications then ask students to suggest others for each type of simple machine.

MAIN 2

This activity allows students to explore the general principle of levers and simple machines by balancing a beam.

Students in groups carry out the beam balancing experiment below:

www.nuffieldfoundation.org/practical-physics/balancing-beam

It is important that students create a table of their results to be able to see the pattern and the numerical relationship.

Differentiation

More able students will see the pattern themselves and can be prompted to use it to make predictions of balanced arrangements or to use it for weighing. Less able students will need to have the pattern and its use for prediction explained to them.

Explain that the tower crane with load and counterweight provides another example of the use of simple machines and balancing. Show the class the images of tower cranes in Resource 4.2: Beam Balancing (page 64) and discuss with students the role of the counterweight and why larger and smaller loads might be lifted at different distances along the crane arm or jib.

MAIN 3

This aim of this activity is to reinforce the idea of force multiplication and the constant value for force multiplied by displacement.

Demonstrate the plank and pulley examples in:

www.nuffieldfoundation.org/practical-physics/levers-and-pulleys-multiply-force-not-energy

Work through the force multiplied by displacement calculations on the board. Explain the term mechanical advantage and calculate its value for the examples. Discuss the idea of conservation of energy.

Show an image of a local lock gate or use the lock gate diagrams from lesson 3. Explain how the long arm of the lock gate acts as a lever to move the heavy gate through the water it is in.

The forces involved will become clear if students are able to try a lock gate themselves during the Explore visit. Point out the handle and gear used to raise and lower the sluices in the lock gates and that these are also simple machines.

Finally show Resource 3.2: Thames Barrier gate closed cut away image (page 55) from Lesson 3 and indicate the yellow parts are the machinery used to raise the lock gate. The hydraulic pistons used to raise the lock gate are a simple machine, similar to the syringes practical in Lesson 3, used to generate the large force needed.

Plenary

Ask each student to write on post it notes the thing they learnt about pressure or machines that they found most interesting and the thing they did not understand or would like to know more about. Allow the students to post these up grouped by similar topics.

Keep a record of this if you wish to review the topic at a later time.

Assessment questions

1. Find examples of simple machines and draw a diagram using force arrows to show where the small and large forces are. Two examples you can use are the braking system on a bicycle with the brake lever moving the brake pad or a tin opener with the handles moving the cutting wheel. You will find many more examples in your home and school.

2. For each of your example simple machines, measure the distance moved by the force applied and the resulting force and calculate the mechanical advantage.

Homework ideas

Archimedes made the famous quotation "Give me a lever and a place to stand and I will move the earth".

Find out what the weight of the earth is compared to your own weight and work out how much mechanical advantage a lever would have to provide to move the earth.

LESSON 4: THE MACHINES OF THE WORKING RIVER

RESOURCE 4.1: PULLEY SIMULATION

Figure 1

A block and tackle pulley system can be simulated by looping a rope around two rods that are held in position. One end of the rope is tied onto one of the rods and after looping around both rods the other end is pulled to force the rods together in the same way that pulleys are brought together by pulling their rope.

For this simulation any fairly strong rigid rods can be used. For example a plastic pipe or broom handle.

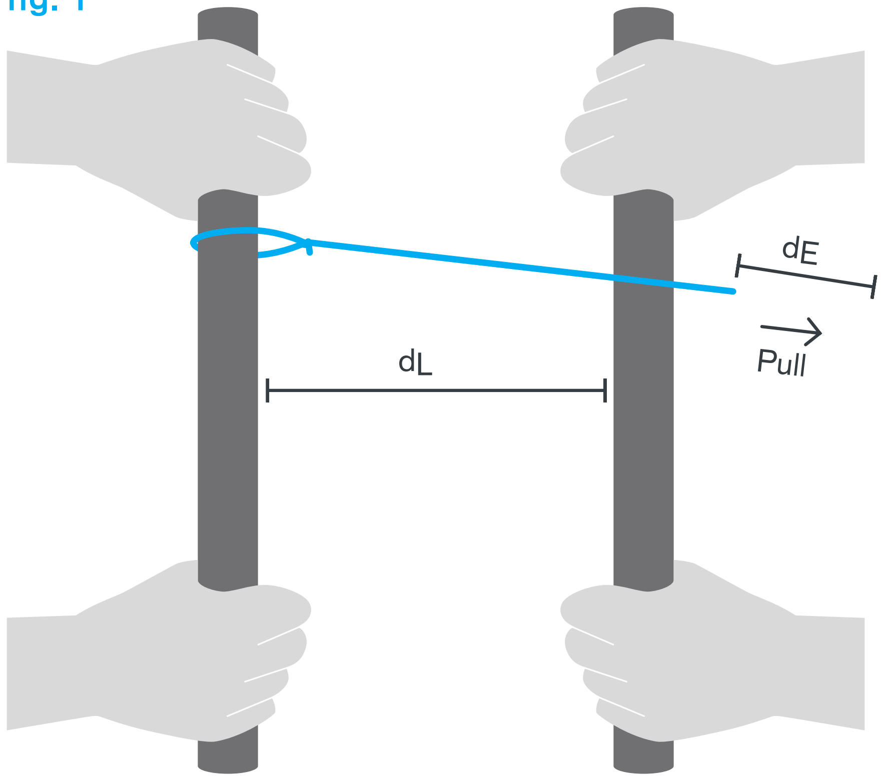
Each rod should be held by one person, with one hand at each end. Hold the two rods parallel to each other, as shown in *fig. 1*. Tie one end of a string or rope around one of the rods and let someone else pull on the other end of the rope.

Before you start looping the rope back around the rods, the people holding the rods should be able to resist the pull from the rope fairly easily.

With a pulley of this type, any load you wish to move would be attached to one of the rods and the effort put in is the pull on the rope.

Compare the distance moved by load (dL) to the distance moved by the effort (dE). This is the mechanical advantage.

fig. 1



LESSON 4: THE MACHINES OF THE WORKING RIVER

RESOURCE 4.1: PULLEY SIMULATION

Figure 2, 3 and 4

Double the string back around the rods as shown in the diagrams and each time see how the force on the people holding the rods is increased by pulling on the free end of the string.

Look at how many times the string is wrapped around the rods and see if you can work out the ratio between the distance moved by the load and the distance moved by the effort each time.

Describe how the mechanical advantage is changing each time you make an extra loop of the rope around the rods.

fig. 2

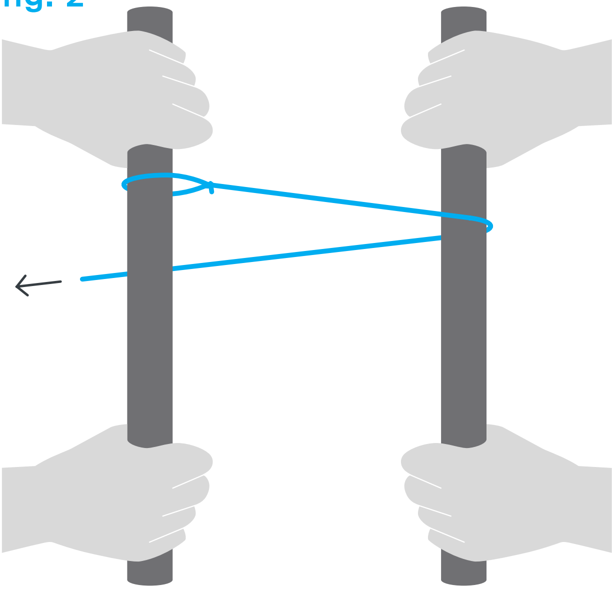


fig. 3

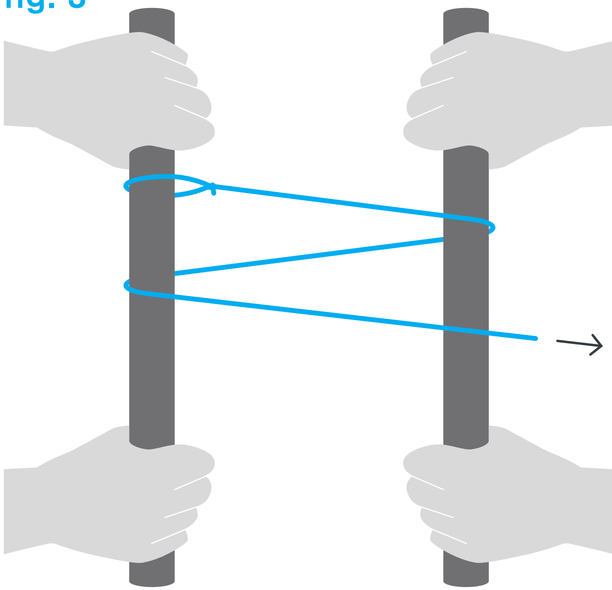
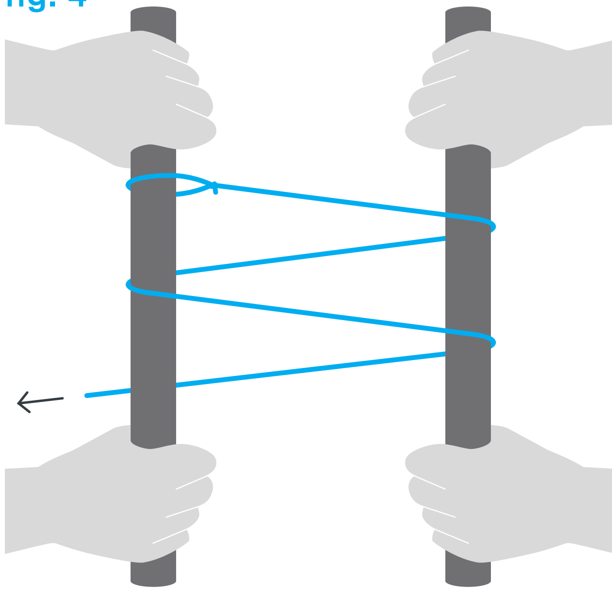


fig. 4



LESSON 4: THE MACHINES OF THE WORKING RIVER

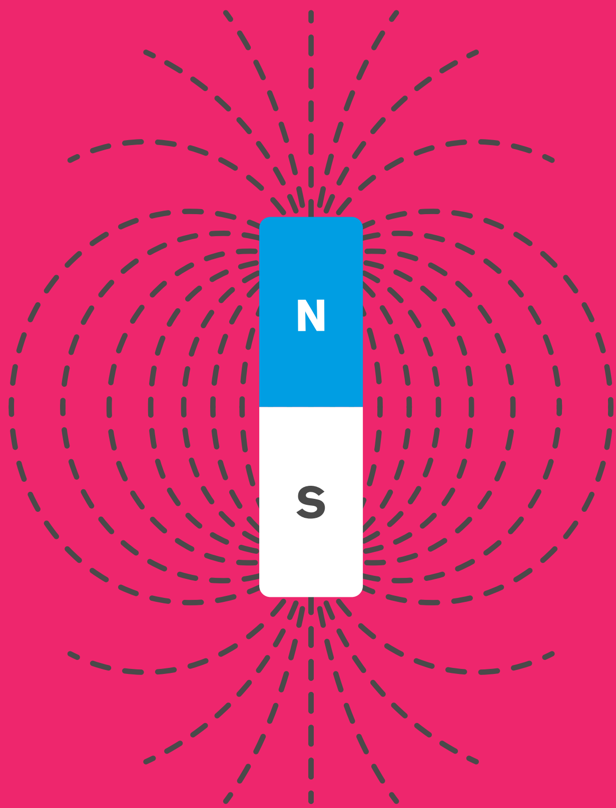
RESOURCE 4.2: BEAM BALANCING

CRANE WORKING ON A THAMES DEVELOPMENT SITE, WOOLWICH

EXPLORE

Students should already appreciate the scale of the forces and pressures involved in working on the river from the Discover lessons. The visits will give students an appreciation of real large scale engineering in London. The Thames Barrier and some of the London docks allow large scale applications to be seen, but visits to other stretches of the Thames and to local waterways will show the application of the same scientific principles but at a smaller scale.

Students are encouraged to take appropriate photographs or videos on their visits but the key aspect is that they should make measurements or observations to collect the data which will allow them to perform the pressure and force calculations for the structure they are visiting.



EXPLORE

THE BIG IDEA

Physics and maths applied to the real world. Students will be able to put their numbers, calculations and scientific principles learned in the Discover lessons into a real context.

LEARNING OBJECTIVES

Could: identify other situations where features of the structures visited might be applied

Should: collect relevant data about the structures they visit

Must: understand that structures and machines used on the river are designed and built to operate for certain forces, that these forces behave according to the scientific principles in their science curriculum and the size of the forces can be calculated using these principles

RESOURCES

Resource 5.1: Thames Barrier worksheet

Resource 5.2: Worksheet with example calculations and comments

Resource 5.3: Lock gate force arrow diagrams

Resource 5.4: Physics terms treasure hunt

YOU WILL ALSO NEED:

- Notebooks
- Cameras
- Maps

EXPLORE

PREPARING FOR YOUR VISIT

A pre-visit to your chosen venue is strongly recommended, as you can then ensure your students' time is focused in the most relevant areas. If there are learning staff based at the site they will be happy to help you get the most of your visit. Owing to the nature of some of the possible sites, a thorough risk assessment should be conducted in line with your school's health and safety policy. More information can be found in the Prerequisite Information section (page 2) of this unit.

The is one of a number of London Curriculum units inspired by the River Thames, other subjects in the series include biology, design and technology, English and art and design. If these resources are also being used at your school it will create the opportunity for a cross curricular visit. Full Curriculum links are outlined on pages 88 – 89.

EXPLORE

POSSIBLE SITES

Thames Barrier Information and Learning Centre

1 Unity Way, SE18 5NJ

020 8305 4188

learningcentre@environment-agency.gov.uk

The Thames Barrier Information and Learning Centre is a small exhibition centre next to the barrier where you can learn how the Thames Barrier was designed and built, and how it works. School visits to the centre will be supported by a guide, to conduct a tour and provide students with detailed information.

As they complete the guided tour of the Information Centre and Barrier and students should complete the data and calculations on the Thames Barrier worksheet resource, Resource E1 . A completed worksheet with answers and sample calculations for the questions is included.

Having collected the data and calculated answers for pressure and force on the barrier gates students should label the force arrow diagrams for the single gate.

Higher ability students can be asked to complete the full river width diagram showing all gates and forces

Students should also find out about the future of the barrier and the Thames Estuary 2100 plans.

Thames Barrier Information Centre visit information, pricing and contact details can be found at the bottom of the page: **www.gov.uk/the-thames-barrier**

Schools following this London Curriculum unit will be given reduced price entry to the centre.

Schools may also wish to send their posters created in the Connect lesson to the Centre for display.

EXPLORE

POSSIBLE SITES

Science Museum

Exhibition Rd, SW7 2DD
0870 870 4868

The London Science Museum has an interactive exhibit made up from five of the simple machines: **www.sciencemuseum.org.uk/objects/interactives/launchpad/big_machine.aspx**

London Museum of Water and Steam

Green Dragon Lane, TW8 0EN
020 8568 4757

The Waterworks gallery tells the story of London's water supply and different types and sizes of steam engines used to pump the water can be seen in operation. The museum has an education team offering school visits: **www.waterandsteam.org.uk/learning/schools**

Lock or other London waterway location

Local stretches of the River Thames, locks or other waterways could also be the location for a research visit.

A similar worksheet to the Thames Barrier worksheet that requires students to capture data about the sizes and depths should be prepared to allow students to complete similar diagrams and calculations from the visit. Simple force arrow diagrams for locks with single and double gates are in the Lock gate force arrow diagrams resource.

The London docks and many other stretches of the river will have cranes to load and unload cargo from ships and canal barges which will allow students to see and make measurements and calculations on simple machines.

Information about London's waterways can be found on the sites listed here.

TFL walk London site: **www.tfl.gov.uk/modes/walking/thames-path**

The link above provides information about the Thames Path walk but the site also links to other London walks such as the Lea Valley, Jubilee Walkway etc. **www.thames-path.org.uk/**

This site looks at the Thames path from Greenwich, 180 miles upstream to the source of the Thames near Cirencester. The walk is broken into sections many of which are around 10 miles in length. You will need to pick shorter sections of the path and check for transport links at each end of your chosen section.

A list of London reservoirs can be found on this page: **en.wikipedia.org/wiki/List_of_dams_and_reservoirs_in_the_United_Kingdom**

A list of locks and weirs on the River Thames can be found on this page: **en.wikipedia.org/wiki/Locks_and_weirs_on_the_River_Thames**

Physics treasure hunt

The Physics treasure hunt Resource 5.4 (page 77) challenges students to find a list physics forces in action and can be used on any of the visits detailed in this section. Students can do this individually or in pairs. Students will record the terms they spot during the visit, taking a picture or sketch and writing a description for each one that they find.

Prizes could be given for the most terms spotted or for finding a term that no one else has found.

Differentiation

For barrier or other location data collection and calculation, pair less able students with more able or give less able students a worked example with similar values and more able students the problem solving framework.

For the treasure hunt, less able students might give a verbal rather than written description. More able students might provide an estimate of the size of force or pressure in each example and state another example from experience where the principle is used.

EXPLORE

RESOURCE 5.1: THAMES BARRIER WORKSHEET

QUESTION	ANSWER
Width of river	
Width of barrier gates (there is more than one)	
Number of gates (of each width)	
Height of barrier gates	
Maximum water depth during barrier closure	
Average pressure caused by maximum depth of water (Calculation – use the above maximum depth value)	
Total force on the widest gate (Calculation – use the width of the widest gate, the depth and average water pressure)	
Force that the widest gate is designed to resist during surge tide	
Mass of barrier gates	
Maximum thrust force possible from gate closing machinery (hydraulic rams)	

Complete the data opposite. Make sure you enter the units as well as the values.

The data will be found in the Information Centre during your visit except for two of the values for pressure and force which you will need to calculate from the other data.

Charles Draper designed the barrier and got the idea for 'rising sector gates' from a piece of equipment that you can see in your science laboratory.

What was this equipment?

EXPLORE

RESOURCE 5.1: THAMES BARRIER WORKSHEET ANSWERS

QUESTION	ANSWER		
Width of river	520m		
Width of barrier gates (there is more than one)	There are three types of gate: 61m rising sector	31.5m rising sector	31.5 falling sector.
Number of gates (of each width)	4 x 61m rising sector	4 x 31.5 rising sector	2 x 31.5m falling sector
Height of barrier gates	20.1m		
Maximum water depth during barrier closure	The river by the Barrier is on average approximately 7 metres in depth at low tide and 15 metres at high tide, however this changes seasonally. Storm surges can raise this value by over 2m but these surges normally occur at mid-tide levels – more details at **en.wikipedia.org/wiki/Thames_Barrier**		
Average pressure caused by maximum depth of water (Calculation – use the above maximum depth value)	Using the high tide value of 15m depth the average pressure is the pressure at half the depth *Pressure = density x 10 x depth* *= 1000 x 10 x 7.5* *= 75 000 N/m2*		
Total force on the widest gate (Calculation – use the width of the widest gate, the depth and average water pressure)	*Force on widest gate = gate area submerged x average pressure* *= Gate width x water depth x average pressure* *= 61 x 15 x 75 00* *= 68,625,000 N* (equivalent to about 6800 tonnes; The concrete foundations of the piers are buried over 20m into the bottom of the river to be able to resist this force.)		
Force that the widest gate is designed to resist during surge tide	9000 tonnes (equivalent to 90,000,000 N)		
Mass of barrier gates	The 61m gates have a mass of 3,300 tonnes		
Maximum thrust force possible from gate closing machinery (hydraulic rams)	The gate machinery is capable of producing a total of 8,000 tonnes of thrust to move the gates, but the gates can be moves using a little as 340 tonnes thrust.		

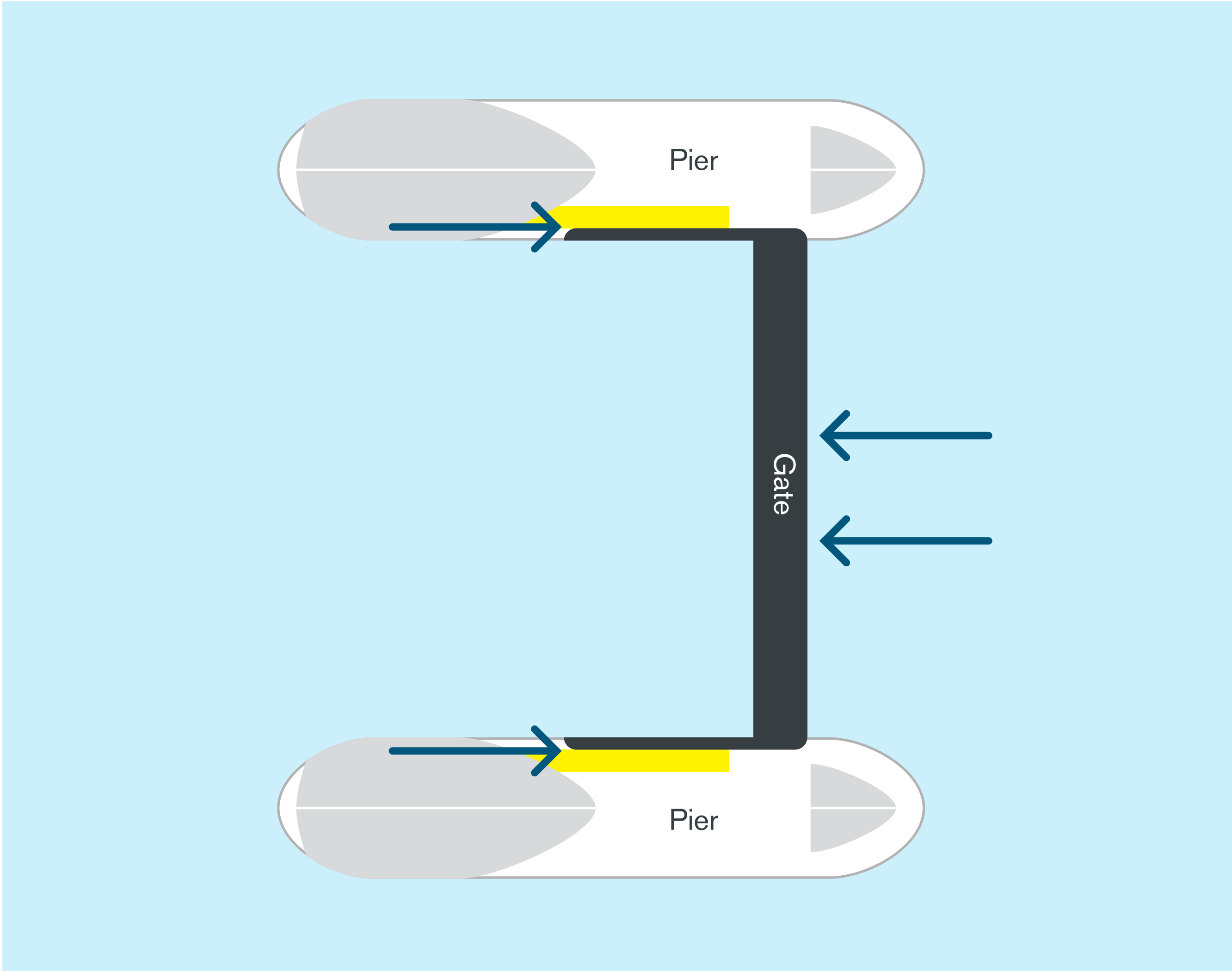
EXPLORE

RESOURCE 5.1: THAMES BARRIER WORKSHEET CONTINUED

Single Barrier gate force arrow diagram

The diagram here shows the top view of a single barrier gate and the piers to which it is attached. There are two arrows for the force on the gate due to pressure and the force on the gate due to tidal flow. There are two arrows for the balancing reaction force on the gate from the piers.

Label the arrows and add the values for each of the forces. Make sure they balance.



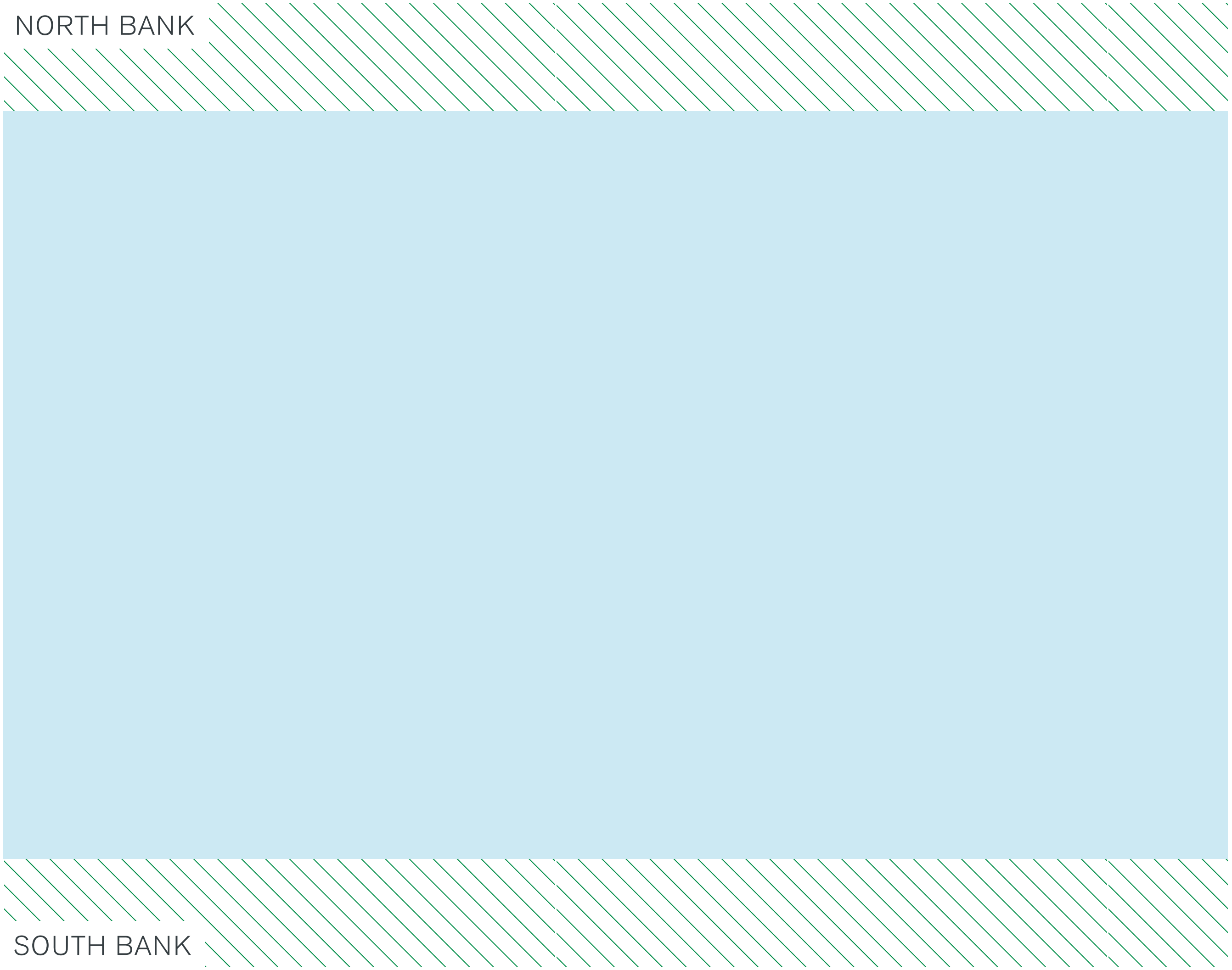
EXPLORE

RESOURCE 5.1: THAMES BARRIER WORKSHEET CONTINUED

Full barrier gate force arrow diagram

Sketch a diagram of the top view of all the piers and gates that make up the whole barrier across the width of the river and add force arrows for the forces on each gate and pier similar to the previous example for the single gate.

The river width is 520m. You should try and sketch the piers and different widths of gate identified in the first part of the worksheet, to span the full width of the river.



EXPLORE

RESOURCE 5.2: EXAMPLE CALCULATIONS AND COMMENTS

QUESTION	ANSWER	NOTES
Average pressure caused by the maximum depth of water. (Calculation – use the above maximum depth value.)	For maximum depth 8m, the average pressure is the pressure at 4m depth. *Average pressure = 1000 x 10 x 4* *= 14,400,000N*	
Total force widest gate (Calculation – use the width of the widest gate, the depth and the average pressure value.)	For gate height 12m and width 30m *Total force = 40,000 x 12 x 30* *= 14,400,000N*	This is the force on one side of the barrier. There is also a lower depth of water on the other side of the barrier and a force due to this in the opposite direction. In order to keep calculation simple, this is not considered but it may arise in discussion and more able students may want to calculate and include this in their force diagrams.
Force that the widest gate is designed to resist during surge tide.	This data will be found from the barrier visit. The data is likely to be given as a load in tonnes rather than a force in newtons. As usual force in everyday life is often interchanged with mass (load). For example for a gate designed for a maximum load of 3000 tonnes. First calculate the equivalent load force (remember 1t = 1000kg) *Maximum load force = 3000 x 1000 x 10* *= 30,000,000N*	No further calculation is necessary but you may wish to discuss the following example with students. The Force on the barrier gate is a combination of the force due to pressure and the force due tidal flow. Therefore we can work out what allowance has been made for the tidal flow force. *Maximum load force = Force from pressure + Force from tidal flow Force from tidal flow =* *Maximum load force – Force from pressure = 30,000,000 – 14,400,000 = 15,600,00N* This is equivalent to a load of 1,560,00kg or 1560 tonnes

EXPLORE

RESOURCE 5.3: LOCK GATE FORCE ARROW DIAGRAMS

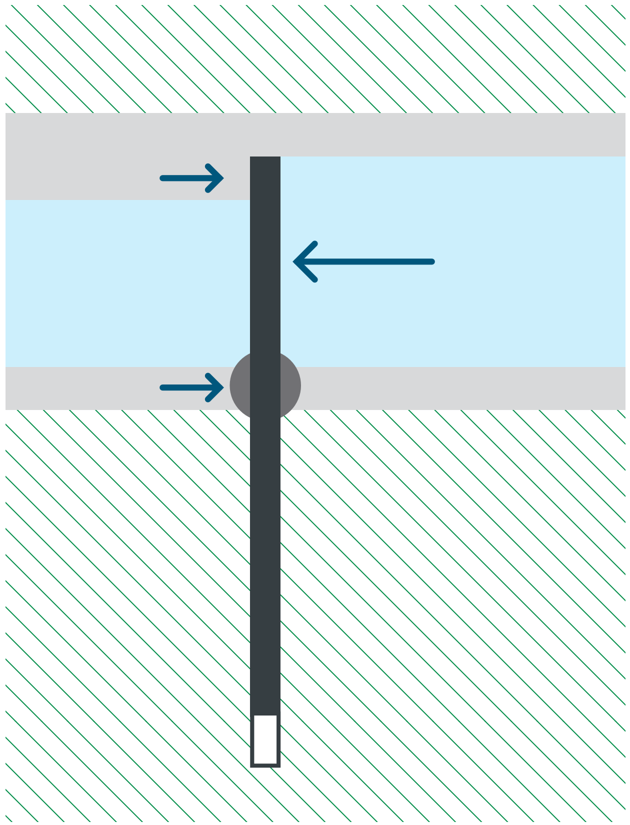
Find out or estimate the width and depth when full of water for the lock you are visiting and write the values above the appropriate diagram.

Now calculate the total force on the lock gate from the water and the equivalent of this in tonnes.

Plan view of a lock with a single gate across the width of the lock

Lock width _____ (m)

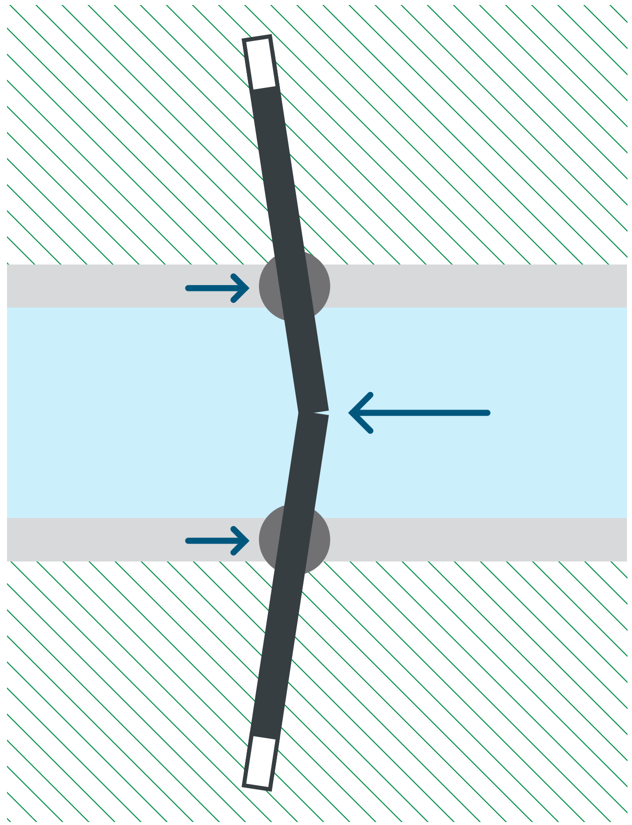
Water depth when full _____ (m)



Plan view of a lock with double gates across the width of the lock

Lock width _____ (m)

Water depth when full _____ (m)



EXPLORE

RESOURCE 5.4: PHYSICS TREASURE HUNT

The words listed below are terms from the Physics, forces part of your KS3 Science curriculum.

During the visit if you see anything that a term from the list applies to, for example any object, machine or action, then make a note of the term, take a picture or draw a sketch and write a very short description using the term.

You may also use other terms from physics that are not on the list, provided you can record an application of their use.

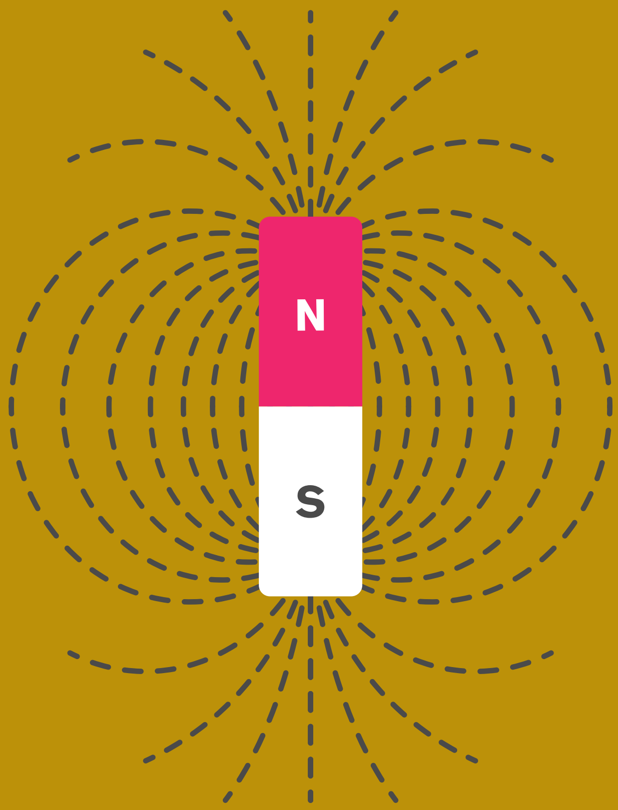
Make your notes in your notebook or on separate sheets and on this sheet tick the terms you have found and also list your own terms that you have found that are not in the list.

FORCES TERMS (TICK OFF THE ONES YOU'VE FOUND)	YOUR OWN PHYSICS TERMS
Force	
Pressure	
Buoyancy	
Push	
Pull	
Friction	
Non-contact force	
Balanced force	
Unbalanced force	
Moment	
Stretch	
Compress	

CONNECT

Rising sea levels and climate change means that the pressure on the Thames Barrier is increasing.

Students will present a report for a new barrier further downstream the Thames at Long Reach. The report will estimate sizes of the barrier gates needed to protect the river at Long Reach. The height needed to protect from the flood risk to the end of the century and show their calculations for the forces on the barrier gates.



LESSON 6
ENGINEERING THE FUTURE OF THE BARRIER

BIG IDEA

Students will apply their physics and maths knowledge to a real situation and produce an Engineering 'specification' based on application of their science and mathematics knowledge and understanding. This will be put into the context of risks to London from flooding and the need for improved flood defences due to increased risk of higher floods due to rising sea levels from climate change.

LEARNING OBJECTIVES

Could: evaluate posters, presentations and reports.

Should: carry out further research on a chosen aspect of the Barrier – climate change, barrier design, London risks.

Must: create a poster, presentation or report for a new Thames Barrier.

RESOURCES

Resource 6.1: Thames flooding over time

Resource 6.2: Thames barrier closures

EXTERNAL LINKS

Thames Estuary 2100 plan:
Climate change – chapter 4, pages 25–28
London risk team – chapter 2, pages 14–19
Barrier design team – chapter 9, pages 57–58, 62

www.gov.uk/government/publications/thames-estuary-2100-te2100

STEMNET Ambassador career case studies including mathematics in action downloaded from: **www.stemnet.org.uk/educators/case-studies/**

Futuremorph case studies from:
www.futuremorph.org/11-13/case-studies/

LESSON 6: ENGINEERING THE FUTURE OF THE BARRIER

SETTING THE SCENE

The Environment agency Thames Estuary 2100 plan looks at managing the increasing flood risk along the River Thames to the end of the century and beyond. The plan suggest what should be done in the short term (next 25 years), in the medium term (15 years after) and in the long term up to the end of the century.

The plan itself is very wide reaching so for this exercise. Students are directed to a particular option – a new barrier at Long Reach and will create their reports based on this. Extracted pages from the plan are to be used to provide the base information for the students working on their barrier reports. The information in these sections will still be complex for lower ability students. You should provide the opportunity to do some research from other sources, possibly provide summaries of key information and select groups and roles to allow the students to best work together.

The session closes with students looking at some case studies from the STEM Ambassadors website where the use of mathematics within their work is highlighted. This revisits the theme that the scientific principles learned in school are applied in the real world through the use of mathematics.

THAMES BARRIER
Thames barrier project pack 2015 © Environment Agency

LESSON 6: ENGINEERING THE FUTURE OF THE BARRIER

ACTIVITIES

STARTER: SETTING THE TASK

Show the images from Thames Flooding over time. Explain that the flooding risk to London is increasing due to increasing sea levels and plans have already been made to improve London flood defences with a range of measures up to the end of the century. Your school has been asked to produce a report proposing a new flood defence barrier on the Thames.

MAIN 1: EXPERT TEAMS RESEARCH

Create three expert groups, one for each of the following aspects.

Divide students into teams so that within each team there are one or more members looking at the following aspects. Give each expert team the corresponding sections of the Thames Estuary 2100 report.

- Climate change and sea level rise over the next century
- Risks to London from flooding
- Design of a new barrier at Long Reach

Direct students that they will be given information on each of these aspects and should then carry out further research to produce summaries, descriptions and calculations, working until they are confident in explaining the relevant issues.

The barrier design aspect will involve mathematical calculation similar to that done in the Discover lessons but students will have to find the width of the river at Long Reach and decide the width, height and number of gates to be used. Students should also include their pressure calculation to indicate the force that each barrier gate must be built to withstand.

MAIN 2

Ask students to research and produce a team poster, presentation or report.

Divide the expert teams into multidisciplinary teams each team with at least one expert, preferably more, for each of the aspects. The team will combine the information they have researched into a complete a poster, presentation or report covering all aspects.

MAIN 3

Distribute career case studies downloaded from the STEM Ambassadors and Futuremorph websites given under External Links (page 79) or use other relevant STEM careers case studies and materials.

Ask students to read a case study in pairs and describe to another pair what the person does, something they did not know before and how the person uses mathematics.

Plenary

If time allows in the lesson students may present their results or this may be done in a later lesson or as a special event.

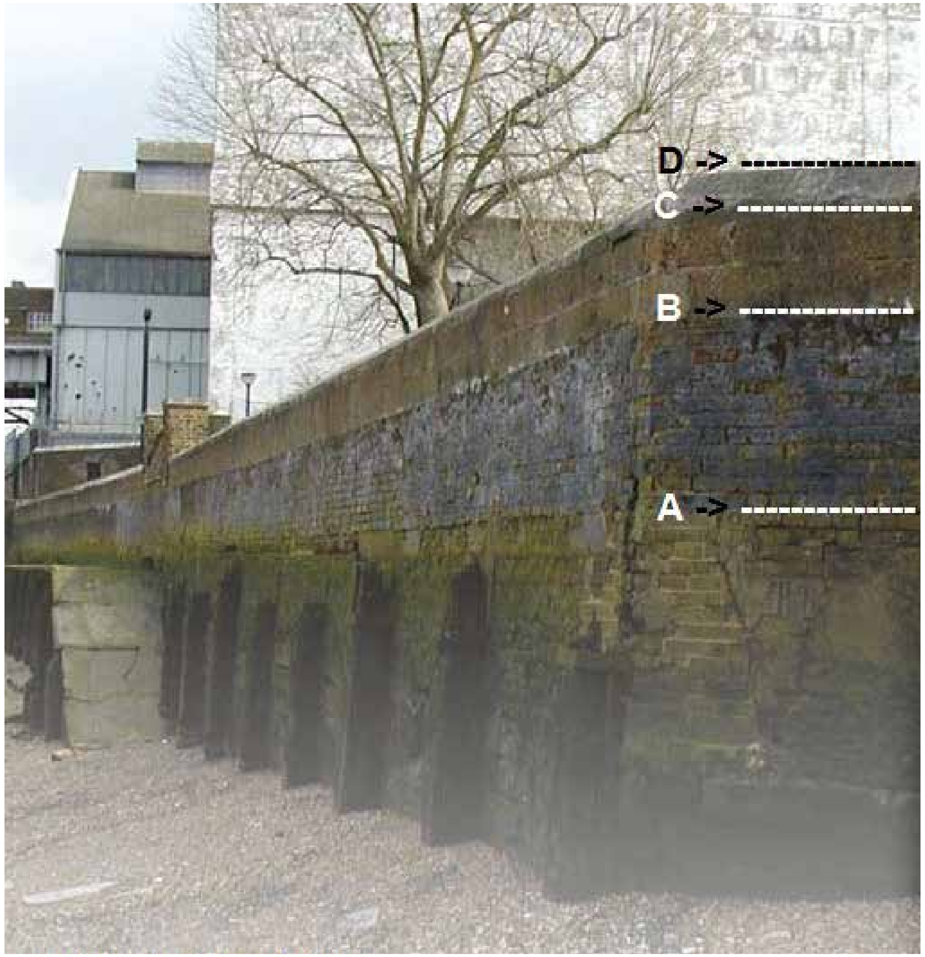
LESSON 6: ENGINEERING THE FUTURE OF THE BARRIER

TAKING THINGS FURTHER

STEMNET STEM Ambassadors are working Engineers and Scientists who are trained and DBS checked to work with schools. They can be booked to talk about their careers and the work they do or to run or assist with activities in their area of expertise. STEM Ambassadors are free to schools. More information and how to book at: **www.stemnet.org.uk/ambassadors**

LESSON 6: ENGINEERING THE FUTURE OF THE BARRIER

RESOURCE 6.1: THAMES FLOODING OVER TIME



D: 1970's Interim defences during the construction for the Thames Barrier

C: 1928 Flood and subsequent 1930 Flood Act

B: Late 19th century update to Flood Act

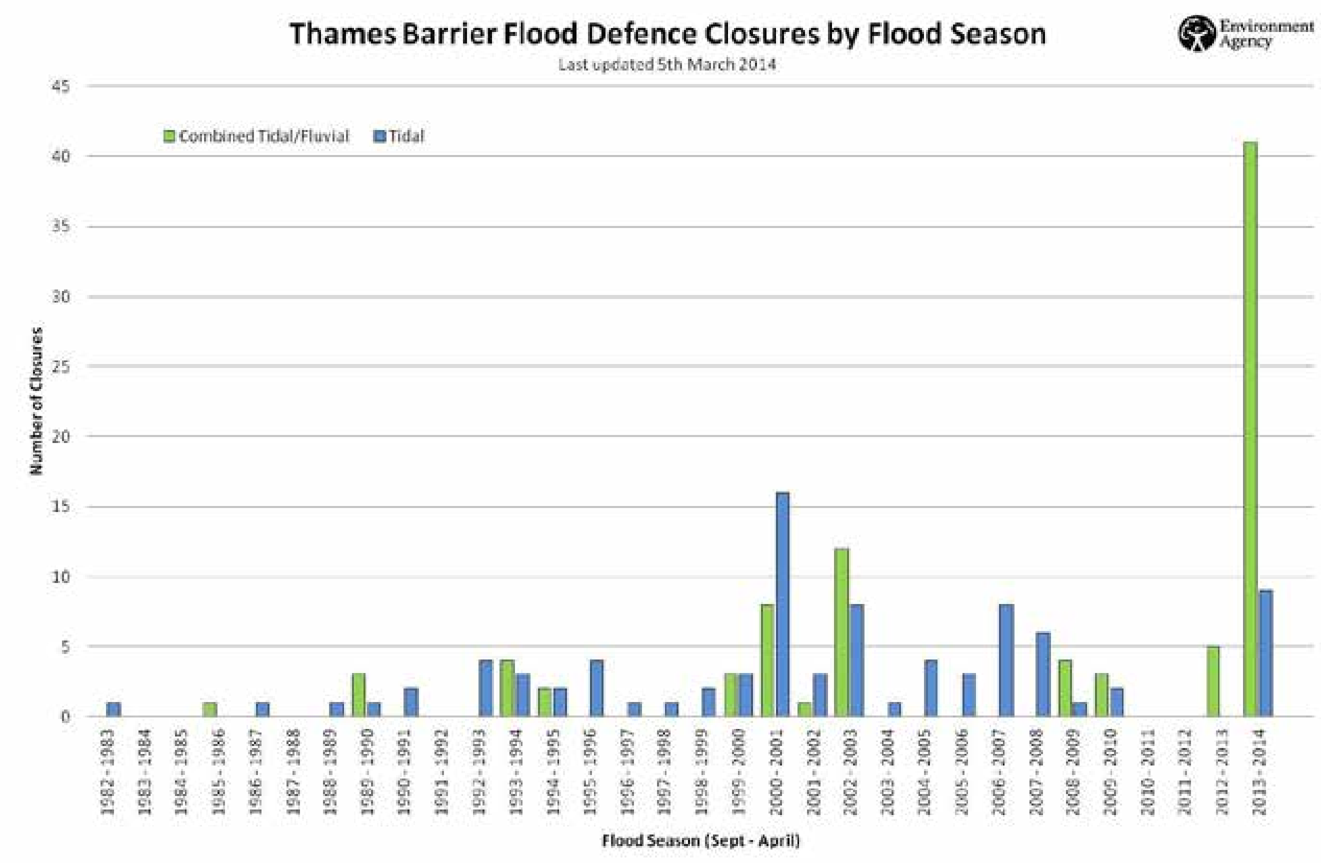
A: 1879 Flood Act

LESSON 6: ENGINEERING THE FUTURE OF THE BARRIER

RESOURCE 6.2: THAMES BARRIER CLOSURES

Barrier closures each season since opening – from Thames Barrier Project Pack 2015

The Environment agency have suggested in the past that the Barrier should not be closed more than 50 times in a year.



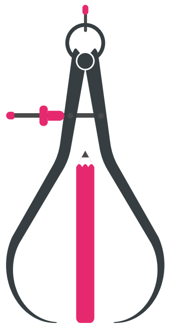
LINKS TO OTHER LONDON CURRICULUM SUBJECTS

The River Thames STEM theme

This unit is part of a set of three exploring the technology and science of the River Thames.

SCIENCE – BIOLOGY

The Living River explores the Thames' changing ecosystems.

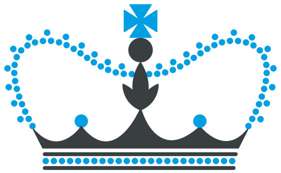


DESIGN & TECHNOLOGY

Bridging the river explores the design and technology of some of the most iconic bridges in the world.

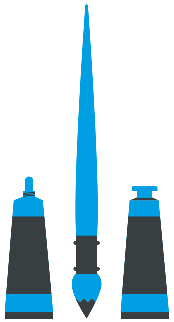
LINKS TO OTHER LONDON CURRICULUM SUBJECTS

The River Thames features in a number of other London Curriculum subjects, creating the possibility of a cross curricular visit.



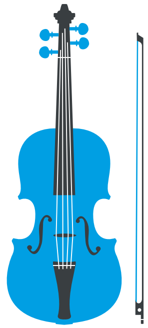
ENGLISH

Tales of the River explores the Thames in writing, as a metaphor for writers' hopes and fears and the city itself.



ART & DESIGN

Riverscape features the dynamic life of the River Thames captured in art



MUSIC

Global City explores the musical impact of London's global and maritime history.

CREDITS

The GLA would like to thank the following organisations for their contribution:

Our collaborators on the London Curriculum

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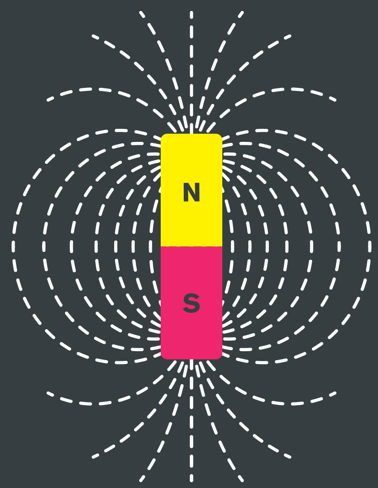

‘The idea of using London as a teaching resource has never been explored much before, so both students and teachers are excited about it’

Key stage 3 teacher

‘It makes me feel proud to be a Londoner’

Key stage 3 student