TUNNELWORKS
KS4 SCIENCE LESSON 1 (ESSENTIALS)
TEACHERS' NOTES

About this lesson

This lesson challenges students to think about how ultrasound is used to measure the depth of water at different points in the Tunnel. Students first use data to select and 'calibrate' a sensor, exploring its wavelength and frequency. They then use further data to measure water depth before using their understanding to explain other reflections the sensor is detecting in terms of the tunnel's design and dimensions.

Learning outcomes

Students can:
- Work with volume and density to calculate mass
- Calculate the kinetic energy of a moving mass
- Calculate the friction acting on a surface
- Calculate the work done when a force moves and convert this to power.

Curriculum links

KS4 Science (also suitable for GCSE Science, Additional Science and Physics courses)
- How science works 1.1c; 1.3a-c; 1.4a, b
- Breadth of study 2.3d; 2.4a

What you will need

- KS4 Science Lesson 1 presentation
- Lesson 1 worksheet

Students are likely to need calculators for the worksheet challenges.

Preparation

Review the KS4 Science Lesson 1 presentation, presenter's notes and worksheet. Decide on which content youwill include in your teaching, and adjust the timings below to suit your own lesson length, or to spread the content across two lessons.

Think how you can link this activity to other work on transverse and longitudinal waves.

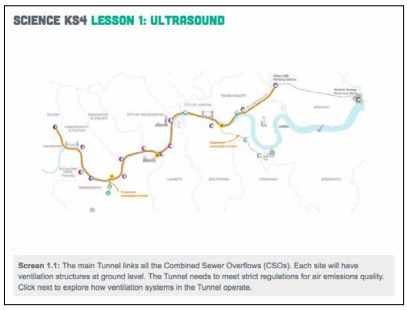
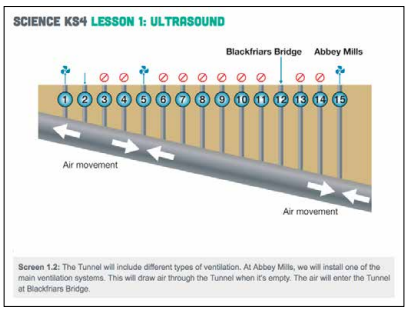
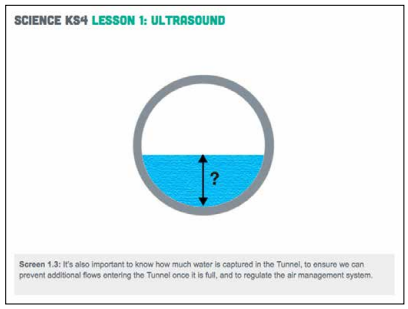
Time (60mins)	Teaching activity	Learning activity	Assessment for learning
5 mins	**Starter:** Ask students to explain how a bat can locate the position of insects flying nearby. Why can't we hear what they're doing? Ask them to relate their ideas to parking sensors work.	Students discuss echo location and ultrasound and share ideas.	Discussion, questioning.
15 mins	**Whole-class:** To begin with, you may wish to show the intro video about the Thames Tideway Tunnel project if the class have not seen it before, otherwise start with screen 1. Explore screens 1.1 to 1.3. Watch the video in screen 2 and find out what students must do. Work through the interactives in screens 3.1 to 3.3 and answer each question (omit the last step if you want).	Discuss reasons why it's important to know the water level in the Tunnel (mainly to manage the rate at which it's pumped out for treatment, so the Tunnel does not over-fill). Students consider wavelength, frequency, speed and relate to distance and time taken.	Discussion, questioning. Discussion, questioning.
5 mins	**Individuals or pairs:** Students complete challenge 1 on the worksheet.	Students choose the sensor with the best range.	Verbal answers.
10 mins	**Individuals or pairs:** Students complete challenge 2.	Students check the sensor works accurately and as specified.	Written work.
20 mins	**Plenary:** Review students' answers. Review challenge 3.	Identify key signal and calculate water depth. Discuss and draw diagrams of reflections in Tunnel; identify second reflection from water (echo) and from bottom of Tunnel, using data to confirm time delays. Contribute to discussion.	Written work. Written work, diagrams, discussion. Discussion, questioning.
5 mins	Watch the answers video on screen 4.		

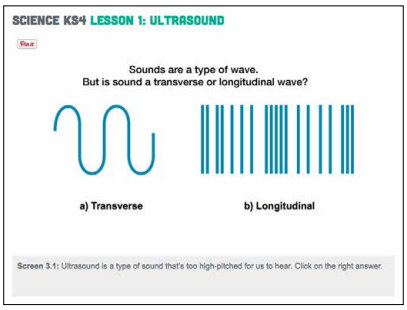
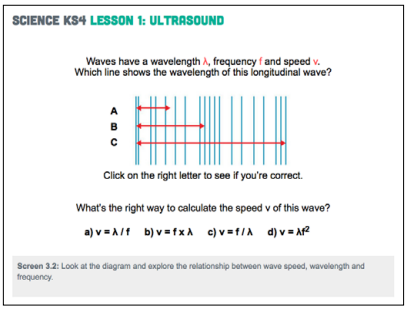
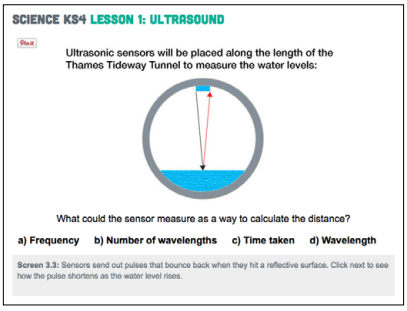
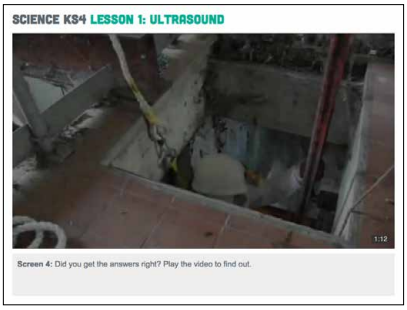
Differentiation

Easier	Harder
Work through a sample depth calculation step by step on the board using 0.0128s for a depth of 5m (eg 2.2m air gap above), drawing a diagram to explain. Just calculate the water depth in challenge 3 using the first pulse.	Challenge students to use the particle theory of matter to explain why sound travels so much faster in water than through air. Would they expect the speed of sound through concrete to be 30m/s or 3000 m/s? (It's 3200 – 3600 m/s).

Presentation Notes
Lesson 1

Screen	Notes
Intro	This short video introduces the Thames Tideway Tunnel. It is just under 3 minutes long. Use the video at the start of KS3 Science Lesson 1 (and Lesson 2 as well is you wish) to set the overall scene for your students. **About the Thames Tideway Tunnel:** 39 million tonnes of untreated sewage overflows into the River Thames each year from London's Victorian sewerage system. The Thames Tideway Tunnel is a major new sewer that will tackle this problem, protect the River Thames from increasing pollution for at least the next 100 years, and enable the UK to meet European environmental standards. Though built to last and in good condition, the existing sewerage network is now too small to transfer all London's sewage to our treatment works for processing (after rainfall). London's sewerage system dates from the 19th Century and was designed as a combined system. This means that a single pipe carries both foul water (from homes and businesses) and rainwater run-off (from streets, roofs and parks) to sewage works for processing before being discharged into the River Thames. Increasingly, when it rains in London there is not enough capacity in the sewerage network to convey all the rainwater as well as foul flows. The system was designed to overflow into the River Thames so that peoples' homes and streets are not flooded with untreated sewage. The system does this through combined sewer overflows (CSOs) on the banks of the River Thames. Thames Water have worked with the Environment Agency to identify the most polluting CSOs – the ones that cause unacceptable environmental impacts because of the frequency or volume of the overflow, or because they discharge into an environmentally sensitive part of the river. The Thames Tideway Tunnel Project will address the overflows from these CSOs, either by directly connecting them to the tunnel, or by making other alterations to the sewerage system which will utilise the existing capacity more effectively. The flows diverted into the Thames Tideway Tunnel will be stored in the tunnel and pumped out for treatment at Beckton Sewage Treatment Works in east London. The CSOs will still be needed after the Thames Tideway Tunnel has been built to direct flows to the River Thames in exceptional circumstances when the new tunnel system is full. This is only expected to occur very occasionally. The Thames Tideway Tunnel will also bring wider social and economic benefits: A cleaner, healthier River Thames is essential for the wellbeing of the city as a whole. There will be less pollution and more dissolved oxygen in the water. The Thames Tideway Tunnel will ensure the country's capital remains a flourishing business centre and tourist destination, protecting the city's reputation around the world. The river is a great, under-used asset for the capital that must be protected.

Screen	Notes
1.1  **Screen 1.1:** The main Tunnel links all the Combined Sewer Overflows (CSOs). Each site will have ventilation structures at ground level. The Tunnel needs to meet strict regulations for air emissions quality. Click next to explore how ventilation systems in the Tunnel operate.	Use this slide to set the scene for KS4 Science Lessons 1 and 2. At key sites, fans will operate 24 hours a day to draw air through the tunnel, keeping it fresh and ensuring pressure does not build up inside. The fans need to replace all the air in the tunnel once every 24 hours. That's a lot of air!
1.2  **Screen 1.2:** The Tunnel will include different types of ventilation. At Abbey Mills, we will install one of the main ventilation systems. This will draw air through the Tunnel when it's empty. The air will enter the Tunnel at Blackfriars Bridge.	Some sites will have passive ventilation systems. These will have vents that reach the surface and which clean the air to remove smells. The main sites, like Abbey Mills, will have active ventilation provided by large fans. It's important to get the specification right so the ventilation system performs as specified, and the tunnel meets environmental regulations for odours when in operation.
1.3  **Screen 1.3:** It's also important to know how much water is captured in the Tunnel, to ensure we can prevent additional flows entering the Tunnel once it is full, and to regulate the air management system.	It's also vital to know how much water and sewage is in the tunnel at any one time. This is so that the rate at which sewage is pumped out for treatment at Beckton Sewage Treatment Plant is fast enough to stop the tunnel filling up, apart from in exceptional circumstances. It also provides vital information for controlling the ventilation fans: as the tunnel fills the contents push air in and out and the volume of air reduces. This means the fan strength must be regulated
2  **Screen 2:** Meet Matt at the Hammersmith pumping station and hear him discuss the importance of ultrasonic sensors in measuring depth and volume.	Use this video clip to introduce the challenge in KS4 Science Lesson 1.

Screen	Notes
3.1  **3.2**  **3.3**  	Ultrasound is a type of sound that's too high-pitched for us to hear. But is sound a transverse or longitudinal wave? Use this diagram of a longitudinal wave to review and explore the relationship between wave speed, wavelength and frequency. It's worth reading the equation as words to emphasise this: the number of waves per second (frequency) x the length of one wave = total distance travelled in one second = speed. Draw the triangle on your board to show how students can transpose this equation to find v, f or λ. Click the arrow to reveal the answer Ultrasound is generally regarded as being sounds with frequencies above 20kHz. You could discuss: - How ultrasound can be heard by dogs and bats but not humans - How the upper limit of our hearing diminishes with age and there is a product for deterring teenagers from congregating called the 'Mosquito', which emits a sound that can be heard by young people (and is annoying) but not older adults. What do students think about that? Note: students can use trigonometry to calculate water volume in the 'Dig Deeper' extensions to KS4 Maths. Sensors measure the time delay between when a pulse is sent out and when it is received. Use the arrows on this screen to help students with challenge 3. What other reflections can they include for when the sensor sends out a stronger pulse? You could choose to omit this screen for more able students and challenge them to create their own diagrams form scratch and locate the sensor in the right position, explaining their decision.
4  	Use this to provide feedback and answers for KS4 Science Lesson 1.