TUNNELWORKS
KS3 SCIENCE LESSON 3 (ESSENTIALS)
TEACHERS' NOTES

About this lesson

In this lesson students apply their knowledge and understanding of sound to help a marine research team choose the right equipment to survey for harbour porpoises in the Thames Estuary. Students first review their understanding of sound waves and how sound travels. They review how porpoises use echolocation and how this can be used to identify their numbers and position, watching a video that shows the research team at work. Students then choose the equipment that will allow the team to pick up the porpoises' ultrasound clicks. They watch another video to see how the research team interprets the sounds they record and use what they discover to help the team test their equipment by identifying a sound wave that matches the characteristics of one made by a porpoise.

Learning outcomes

Students can:

- Explain that sound is propagated by longitudinal waves that have a wavelength, frequency and amplitude
- Know that echolocation works by reflection
- Know that ultrasound is sound with a frequency above human hearing, more than 20,000 Hz, and that harbour porpoise clicks have a peak frequency of around 130,000 Hz

Curriculum links

KS3 Science

- Frequencies of sound waves, measured in hertz (Hz); echoes, reflection and absorption of sound
- Sound needs a medium to travel, the speed of sound in air, in water, in solids
- Sound produced by vibrations of objects, in loud speakers, detected by their effects on microphone diaphragm and the ear drum; sound waves are longitudinal
- Auditory range of humans and animals.

What you will need

- KS3 Science porpoises lesson 3 presentation
- Lesson 3 worksheets

Preparation

Review the lesson plan below and the KS3 Science porpoises lesson one presentation. Adapt the content to suit your students' ability.

Time (60 mins)	Teaching activity	Learning activity	Assessment for learning
10 mins	**Starter:** Explain that students are going to explore how marine scientists use sound to survey a type of marine mammal. The scientists need students' help to select and test their equipment so they will get accurate, valid results. **Pairs:** Explain that you have amnesia about the topic of sound. Ask students to list all the facts they can recall about sound: how it's produced, how it travels and how it can be detected. Students can use a sketch to help them. **Whole class:** Ask pairs to share how many facts they could list. Ask pairs to swap their lists with another pair. Invite pairs to read out their facts, identifying which are correct and which are incorrect. (Optionally, pairs could mark each other so a winning pair, with the most correct facts, can be found.) List the correct facts on your board (see answers for a selection).	Students work in pairs to list facts about sounds and can sketch and label a sound wave to illustrate their ideas. Students count and list their facts. Students read out their facts and can optionally mark each others' lists.	Written lists, sketches, discussion.
10 mins	**Whole class:** Watch the video on **slide 1**. Students will need to identify and remember important information from this video.	Students watch the video, paying attention to information about harbour porpoises and sounds.	

Time (60 mins)	Teaching activity	Learning activity	Assessment for learning
15 mins	**Pairs or small groups:** Hand out the **lesson one worksheet**. Show **slide 2**. Explain that students need to identify the right equipment for the research team so they will be able to detect the harbour porpoises. The harbour porpoise facts will help them do this. **Whole class**: Share answers, asking students to justify their choices using their understanding of sound waves.	Students read the harbour porpoise facts then complete **Task 1** and select the equipment that will best detect harbour porpoises' ultrasonic clicks. Students verbally share answers.	Students' verbal answers and written work. Students' verbal answers.
10 mins	**Whole class:** Show **slide 3** and watch the second video. Explain that students need to make sure the team's equipment displays the harbour porpoise clicks accurately on its power spectrum (a spectrum displays the amplitudes of sounds at different frequencies). Highlight that when humans or other animals make sounds, these are across a range of different frequencies. Show **slide 4.1** and identify the units for the x- and y-axes (the x axis is frequency in kilohertz, while the y axis is amplitude, for which the unit is decibels. Click to reveal the units, slide 4.2. Ask students to suggest where sounds that a human can detect would show up on the spectrum, thinking back to what they could recall about sound during the starter. Click to show the answer, slide 4.3. Establish where on the graph high and low sounds would appear, and loud and soft sounds.	Students watch the video paying particular attention to how a spectrogram shows the amplitude for different frequencies of sound. Students suggest where human sounds are located on the spectrum.	Students' verbal answers and written work.

Time (60 mins)	Teaching activity	Learning activity	Assessment for learning
10 mins	**Individuals or pairs:** Ask students to use the information on the lesson one worksheet to identify the spectrum that most accurately displays the harbour porpoise's click. **Whole class:** Share answers, identifying that the correct spectrum shows that the harbour porpoise's click contains sounds between 110 and 130,000 Hz (130 kHz).	Students complete **Task 2**, reading the information and examining each spectrum to identify the one that correctly shows the harbour porpoise click.	Questioning; students' verbal answers and written work.
7 mins	**Plenary:** Explain that the class needs to help the researchers look for a different kind of cetacean, whales, which communicate using both infrasound (sounds below the limit of human hearing) and sounds audible to humans. Ask students to select the right hydrophones for this new task, explaining their choice. Ask students to sketch and label a spectrum that shows the range of sounds these whales might produce, using what they know about the range of frequencies humans can hear. Highlight that surveys like these are an important way to help understand the distributions of important and often rare marine mammal species, and how these distributions might change as a result of human activity. This can help protect animals that may be affected by large-scale human activities.	Students consider which hydrophone will best detect infrasound and sounds audible to humans, and can sketch a spectrum showing infrasound and audible sound.	

Differentiation

Easier	Harder
Convert the starter sound facts below into some true / false statements for students to sort. Draw a simple sound wave sketch yourself and use a discussion to help annotate it with wavelength etc. Help students identify that sounds need a medium because they are pressure waves that cause the molecules in what they are travelling through to move. Without a medium there can be no sound.	Discuss how different media might cause the sound waves to drop off at different rates (attenuate). (Attenuation is the opposite of amplification.) Ask students to think about how they might test for the effectiveness of different liquids at transmitting sounds with little attenuation, or how sounds at different frequencies attenuate at different rates (this is how we can hear the bass frequencies in music from far away, but not the higher frequencies like cymbals).

Answers

Starter sound facts

Sound is a longitudinal wave – the vibrations are in the same direction as the direction of travel.
Sound vibrations are variations in pressure.
Sounds are produced by vibrating objects, like vocal chords or a guitar string.
Sound waves need a medium through which to travel – a material like air, water, oil or metal.
Sound waves have a:
Frequency – how many waves per second, measured in Hertz (Hz) (the pitch)
Wavelength – the distance from one wave's peak to the next
Amplitude – the height of the wave from trough to peak (the strength or volume)
Humans can hear from about 20 Hz to 20,000Hz.
Sound with a frequency below 20 Hz is infrasound.
Sound with a frequency above 20,000 Hz is ultrasound.

How marine mammals use sound

Large marine mammals like whales have large sound-making organs and can create infrasound. Infrasound can travel for hundreds of kilometres through water. This allows whales to communicate with one another over vast distances.
Smaller marine mammals like porpoises have much smaller sound-making organs and are able to create ultrasound. Ultrasound doesn't travel very far through water (a porpoise's clicks can travel about 300m). However, they can be easily distinguished from the lower-frequency noises that can be heard all the time, like crashing waves or man-made sounds like passing vessels' engines. Ultrasound also has a high 'resolution'. That is, porpoises are able to detect very small differences in the objects from which their ultrasound clicks reflect. This makes ultrasound an excellent tool to help porpoises locate fish to eat.

Worksheet 1 answers

Task 1: Hydrophone D and Liquid C. Hydrophone D will detect the full range of click frequencies, from about 110,000 to 150,000 Hz, while not detecting too many sounds with higher or lower frequency ranges. The team use oil in the tube because it is a very good medium for sound (the fact about porpoises' oil-filled 'melons' is a hint) and will not electrically harm the hydrophones, as mentioned in video 1.

Task 2: Spectrum C. This is the best match to the 110 – 150 kHz range scientists think porpoises use for finding food.

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SOUNDS

- Research the frequencies of different cetaceans' (whales, dolphins and porpoises) sounds and what is known about how each species uses sounds to communicate or locate food. Students can present their findings as a table or report and could sketch spectra of the frequency range of each species.

- Investigate or research the speed of sound through different media, such as air, water, oil and metals like steel. Discuss why sounds might appear to travel better through water than air (faint sounds can be easier to hear, for example) – this is because it is denser than air and so acts as a more efficient medium for the sound waves to travel.

- Model sound waves using a slinky toy, to explore how the pressure vibrations move longitudinally through the medium.

- Use an oscilloscope, tone generator and microphone (you may also need a preamplifier) to explore and measure the wavelength and frequency of different pitches and instruments and to see how the different sounds at the same pitch (for example by comparing the tone generator with different instruments and the human voice) display different mixtures of frequencies, which create the unique tone of each source.

- Harbour porpoises' clicks tend to be in a range from 110 – 150 kHz. Can older and more able students use the wave equation to calculate the wavelength of these sounds in water? (Take the speed of sound in salt water to be 1,500 m/s.)

- Download and use a spectrogram app for iPad (search the iTunes store for 'spectrogram') to see a visual display of students' voices and other sounds.

- Bats also use ultrasound to detect insects while flying. Bat detectors reduce the frequency of bats' ultrasonic pulses so they are audible to the human ear. Explore how bat detectors work and search YouTube for videos of them being used.