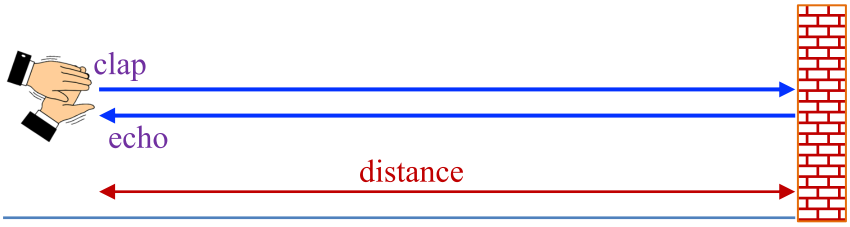
6.3.2 Uses of sound and ultrasound

Echolocation

Sound echoes can be used to determine distances to surfaces that produce echoes. Consider the following situation:

videos



A person claps their hands. A sound wave travels from the hands to the wall and is reflected back. The person hears an 'echo'. There is a delay between the clap and the echo, because sound has to travel to the wall and back, and this takes time. If we measure this time interval, and knowing that sound travels at 330m/s in air, we can work out the distance the sound travels between clap and echo, and hence the distance to the wall.

$$distance\ travelled\ (there\ and\ back) = time\ interval \times speed$$

The distance to the wall is half the total distance travelled by the sound wave.

$$distance\ to\ wall = \frac{distance\ travelled\ (there\ and\ back)}{2}$$
$$= \frac{time\ interval \times speed}{2}$$

(1) A person claps their hands and hears an echo 0.20 seconds later. How far away is the surface reflecting the sound. (Hint: Use the equation, above.)

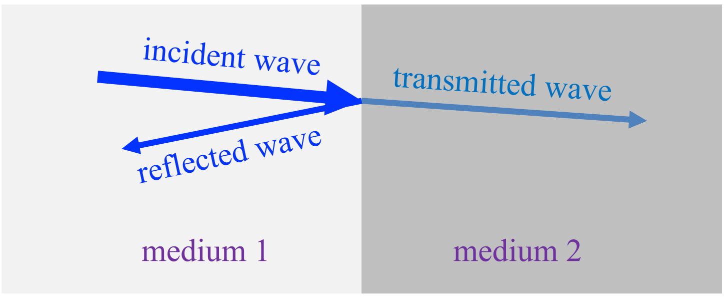
(2) Rearrange the equation ($distance = \frac{time\ interval \times speed}{2}$) to make time interval the subject (i.e. $time\ interval =$ ...).

(3) A person claps their hands and a short time later hears an echo from a wall which is 250m away. What is the time interval between clap and echo? (Hint: Use the rearranged equation from (2).)

(4) ✏ Rearrange the equation distance $= \frac{time\ interval \times speed}{2}$ to make speed the subject (i.e. speed = …).

(5) ✏ A person is 350m away from a wall. They clap their hands and hear an echo 2.06 seconds later. What is the speed of sound in air? (Hint: Use the rearranged equation from (4).)

When sound passes from one medium (material) to another, some of the sound energy will pass on into the second medium (this is called transmission) and some will be reflected back.

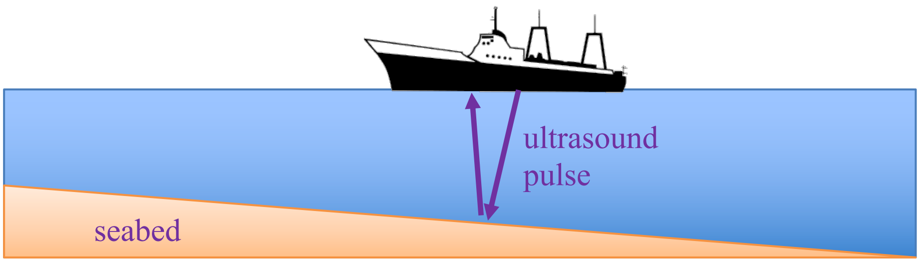


The amount of energy transmitted and reflected depends on the relative speeds of sound, and the relative densities of the two media. Particularly strong echoes are achieved from the brick wall, in the diagram at the top, because there is a high contrast between the speed of sound in air compared to brick and there is a high contrast in densities, too. This means that very little wave energy is transmitted, and most of the wave energy is reflected.

Using sound to locate reflecting surfaces has many applications.

Sonar

Sonar can be used by ships to determine the depth to the seabed.



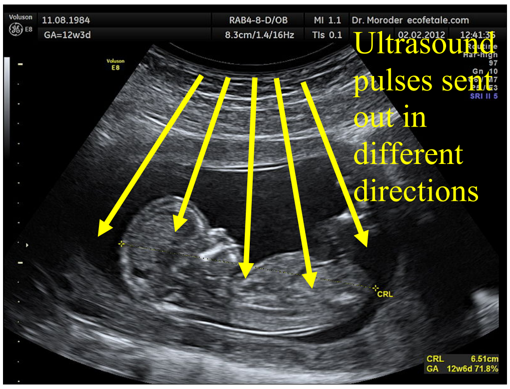
A short pulse of ultrasound is sent into the water and the echo detected. The depth can be calculated from the time interval between sending the pulse and receiving the echo (just like for clap-echo).

(6) ✏A ship sends an ultrasound pulse into the water and receives an echo from the seabed 0.40 seconds later. How deep is it to the seabed? Note: The speed of sound (ultrasound) in water = 1500m/s.

(7) ✏If a school of fish swam between the boat and the seabed, how would this affect the time interval between the ultrasound pulse and its echo?

(8) ✏How could fishermen use sonar to detect a school of fish?

Ultrasound scan



An ultrasound scan can be used to look inside the body. Pulses of ultrasound waves are sent into the body using a device called a transducer. Surfaces inside the body reflect these pulses back. The time intervals between sending out pulses and recording the echoes can be used to calculate distances to surfaces and build up a picture of the inside the body. The ultrasound scanner for unborn babies (see image) sends out multiple pulses in different directions so that a 2D image can be constructed.

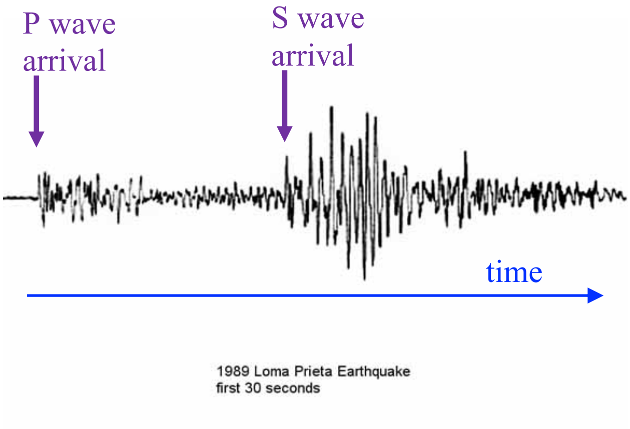
(9) ✏In the image, the skull of the baby produces quite a strong echo. Why might this be? (Hint: Think about the media that the ultrasound is travelling through.)

Ultrasound is used, rather than longer audible wavelengths, because the pulses can be made very short.
(10) ✏Why is it important to use short pulses?

Seismic waves

Sound waves that pass through the Earth are known as seismic waves. They can occur due to earthquakes. Seismic waves that are longitudinal are called P (primary) waves, and those that are transverse are called S (secondary) waves. P waves travel faster than S waves and so are detected first.

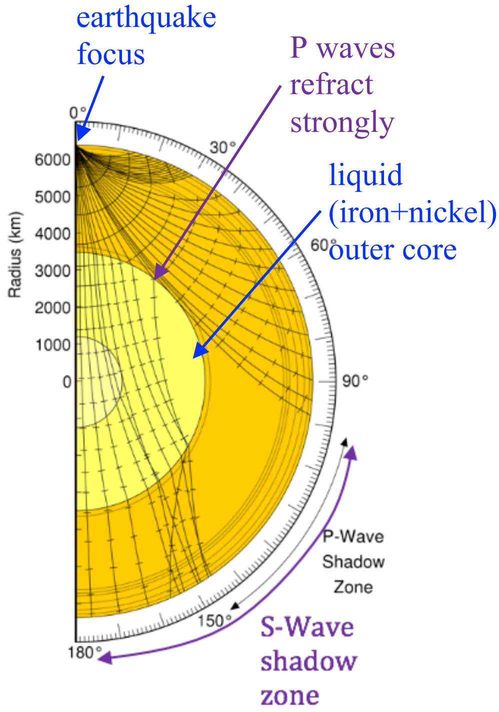
Consider the trace from a seismometer (device for detecting seismic waves) which has detected an earth tremor caused by a distant earthquake:



The P waves arrive first, because they travel faster than the S waves. From the time interval between the P waves and the S waves arriving, the distance to an earthquake can be calculated.

(11) ✏ How many seismometer stations (in different locations) would be needed to locate an earthquake occurring in the Earth's crust?

Seismic S waves cannot pass through liquids, whereas P waves can. When seismic waves pass though the centre of the Earth, the S waves cannot pass though the liquid outer core. An S-wave 'shadow zone' results where no direct S waves are detected.



P waves are refracted strongly as they pass from the mantle into the outer core.

(12) ✏ Why would the P waves refract strongly at this boundary?

When the P waves leave the outer core, they are refracted again. A P-wave 'shadow zone' results where no waves are detected.

(13) ✏ Why do you think the seismic waves follow curved paths as they pass through the mantle?