MAKING WAVES

INCLUDES STEM LEARNING ACTIVITIES

Royal Academy of Engineering

THIS IS ENGINEERING

A STEM learning and teaching resource that shows how engineers have applied their knowledge of waves to make life better.

Curriculum links

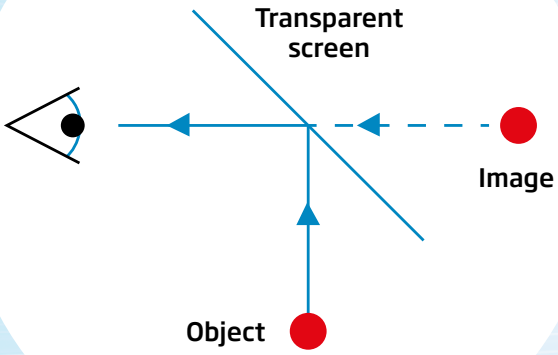
Science: waves, energy changes and transfer, genetics and evolution – adaptations.
Maths: geometry and measure, statistics.

LIGHT WAVES

Light waves reflect (bounce) off surfaces they hit. An image is formed when light reflects off shiny, smooth surfaces.

Head-up display, or HUD, uses reflection to display data without requiring users to look away from their usual viewpoints. Information is projected onto a transparent, angled screen which reflects the light into the user's eyes. The image produced looks like the information is directly in front of the user.

Head-up display was originally used in aircraft to enable the pilots to view information with their heads positioned up and looking forward, instead of angled down looking at lower instruments. This is where the name head-up display comes from.



A diagram that shows how an angled transparent screen reflects light

Image: RAEng

AIRCRAFT HEAD-UP DISPLAY

Some cars are now beginning to use head-up display technology to display data, like speed and hazard information, on the windscreen of the car. This means drivers will no longer have to look down, and can keep their eyes on the road at all times, making driving safer for all road users.

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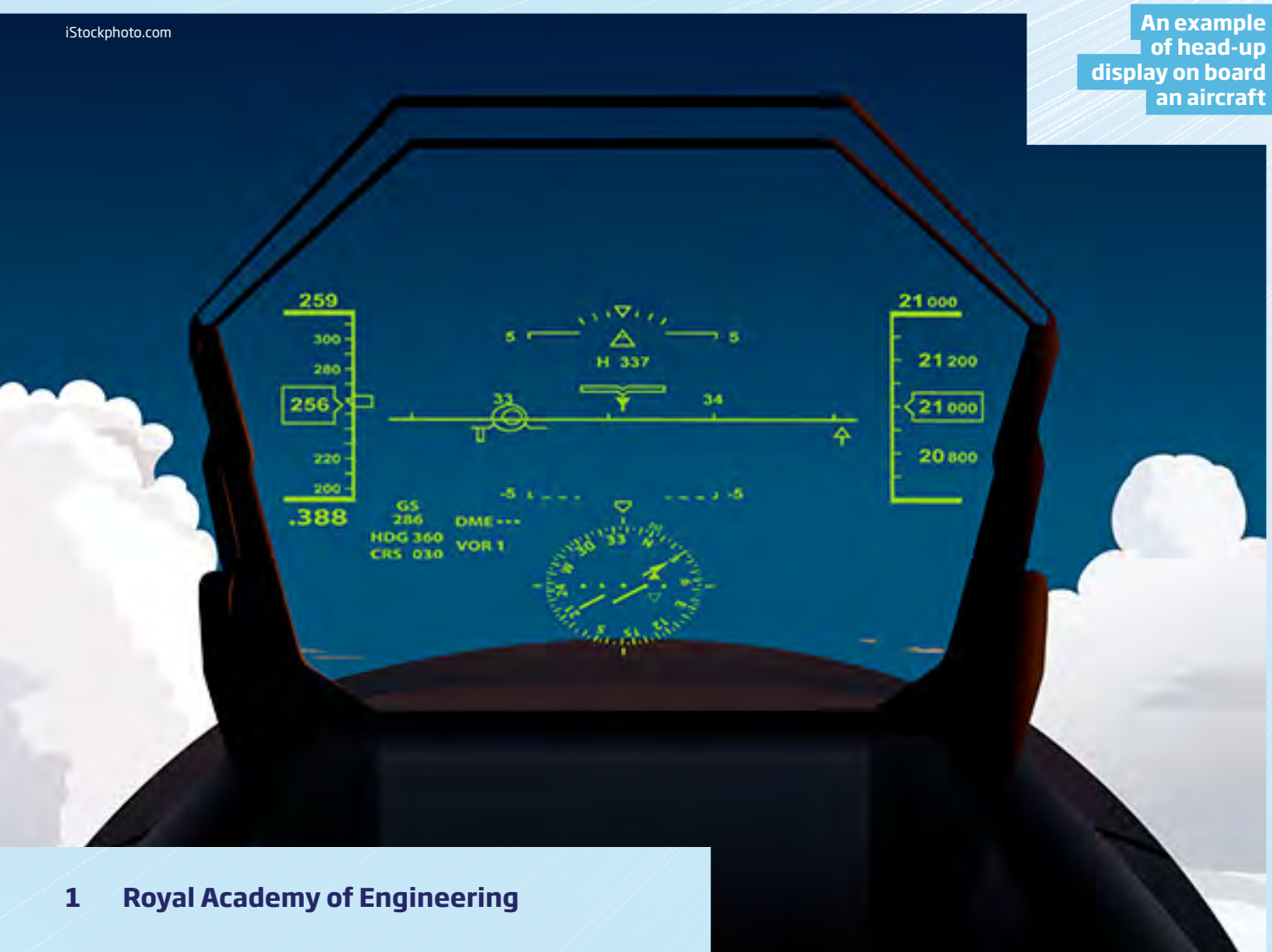

An example of head-up display on board an aircraft

ROAD VEHICLE HEAD UP DISPLAY

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TIME TO MAKE

1. On a piece of plain paper, construct a circle with a radius of 6cm (Diagram 1).
2. Divide the circle into six equal sectors.
3. Draw a chord at the top of each sector, so that the length of the chord is 6cm. You should have a large hexagon in your circle.
4. Draw a 1cm line at the bottom of each sector. You should now have a smaller hexagon in your circle.

Now you are ready to trace your template using transparency paper or a clear plastic report cover.

Draw the red and blue lines onto the transparency paper (Diagram 2).

Cut along the red lines and fold along the blue lines.

Stick the two sides together with tape so that you have a truncated transparent pyramid.

Place your pyramid upside down in the middle of your smartphone or table and play the firework video **http://tinyurl.com/zfepq8r** for your very own personal firework display. For the most striking results, watch in a dark room.

You could try creating your own videos.

Diagram 1

Diagram: RAEng

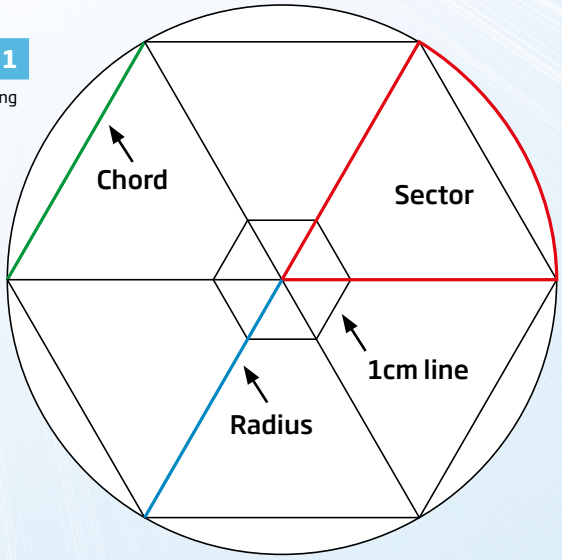
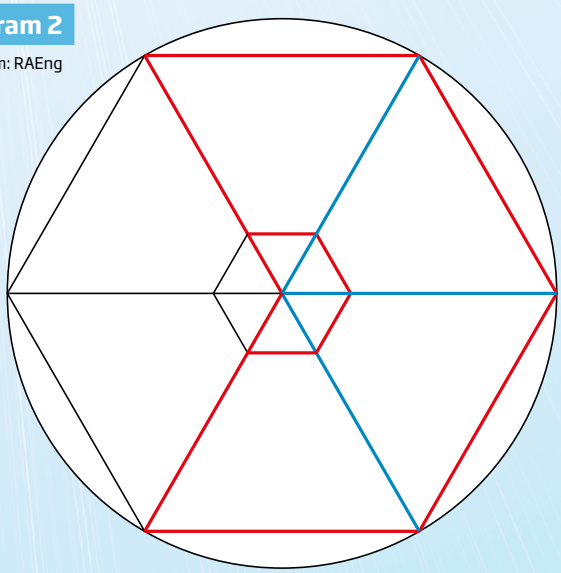


Diagram 2

Diagram: RAEng



ULTRASOUND

Ultrasound is the name given to sound waves that have frequencies above 20,000Hz, the limit of human hearing.

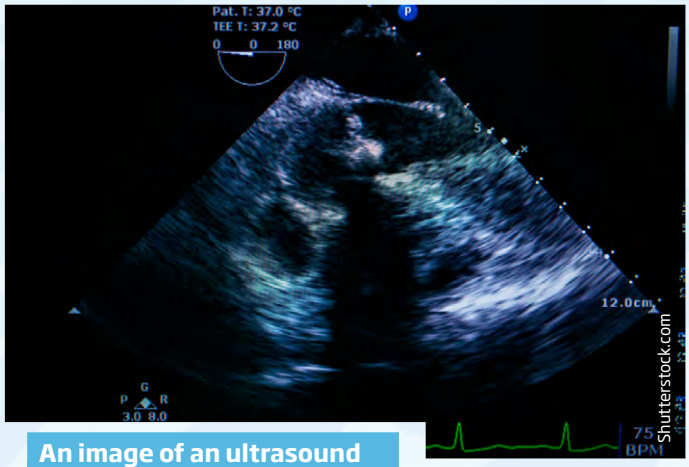
TIME TO OBSERVE

Q How good is your hearing?

To find out, connect a signal generator to a speaker. Set the frequency to 1000Hz and adjust the volume to a comfortable level. Slowly increase the frequency until you can no longer hear the sound. This is the upper limit of your hearing.

Do not turn up the volume if you can no longer hear the sound, as this could cause damage to your hearing.

Q Test your teacher's hearing - who has a bigger hearing range and why?



An image of an ultrasound scan used to diagnose heart problems

ECHOCARDIOGRAM

Ultrasound has many medical uses; from imaging foetuses and organs, to breaking down kidney stones and diagnosing sports injuries.

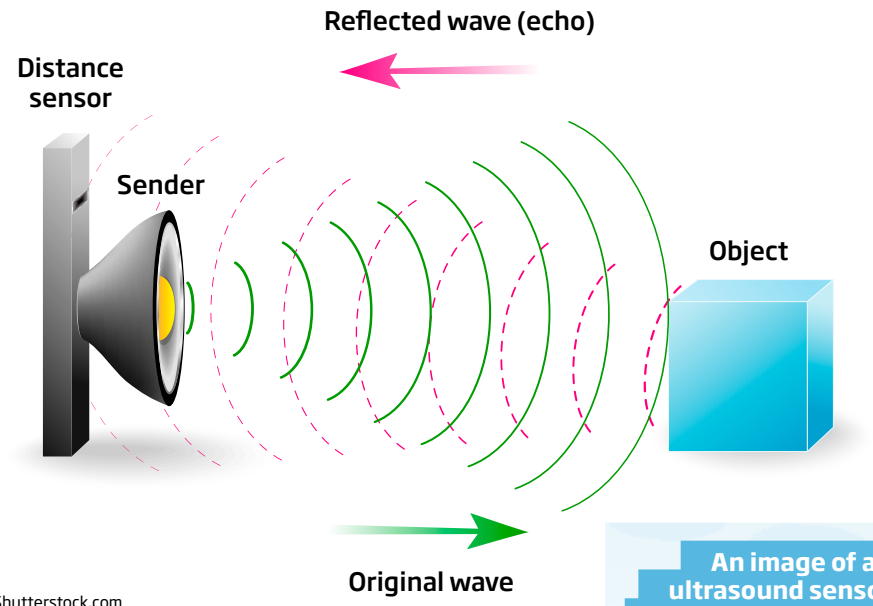
A gel has to be applied to the patient's body before an ultrasound test because the gel allows the ultrasound to transmit through the skin. Without the gel, the ultrasound would be reflected by the skin of the patient.

The ultrasound waves are reflected at boundaries between tissues or organs. The ultrasound scanner takes two measurements from the received echo to build up an ultrasound image:

1 How long it took the ultrasound to be reflected back, which tells us the depth of the tissue.

2 How strong the echo was, the stronger the echo the brighter the images, which doctors use to detect abnormalities in tissue.

A variety of animals also use ultrasound as a way to "see" what is around them. Bats and whales, for example, make ultrasound clicks or pulses with their mouths and detect the echo to build up a picture of what is around them, such as a cave wall the bat is trying to avoid or a shoal of fish the whale is hunting. The bats and whales can use the echo of the ultrasound pulse.



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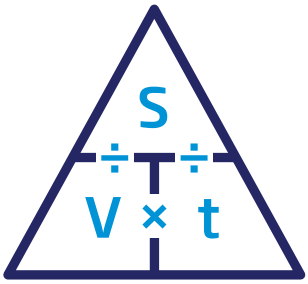
An image of an ultrasound sensor detecting an object

The speed triangle



s = distance
v = speed
t = time

TIME TO CALCULATE

To calculate how far away something is using sound, the speed of sound and the time taken for a sound to be reflected is needed.

With this information, the speed triangle can be used to work out the distance travelled.

Remember, the total distance travelled by the sound is double the distance to the object, because the sound is reflected.

The speed of sound in air is 343m/s
The speed of sound in seawater is 1500m/s

1. A bat sends out an ultrasound pulse, and hears the echo from a cave wall after two seconds. How far away is the cave wall?
2. A shoal of fish is 3000m away from a whale. How long will it take for the whale to hear an echo?

This technique can also be used to detect cracks or structural faults in ships and aircraft.

A pulse of ultrasound is sent through the metal, if there is a crack, the ultrasound will be reflected at the boundary and an echo will be detected.

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An ultrasound sensor being used to test for cracks in a steel pipe

SURVIVAL ON THE WAVES

People wearing survival suits awaiting rescue

If a sailor or offshore worker should find themselves in the sea, they will suffer from hypothermia if they are not rescued quickly.

Hypothermia is caused by a fall in the body's core temperature, which is 37°C for humans. Hypothermia is triggered at 35°C and people start to lose consciousness at approximately 32°C. During the winter, the seas surrounding the UK can fall to 6°C, and in these temperatures people are only expected to survive for a maximum of 45 minutes without the correct safety equipment. However, survival suits can help to prevent hypothermia by stopping the body from losing heat to the surrounding waters.

Survival suits need to perform the following main functions:

1. Prevent the wearer's body heat from escaping for as long as possible
2. Make sure the suit's wearer floats

TIME TO THINK

Q **What other functions do you think survival suits should perform?**

THE HARP SEAL: ULTIMATE SURVIVOR

Harp seals live near pack ice in the waters of the Northern Atlantic and the Arctic Oceans. They spend most of their time in the water and can survive sea temperatures that are just above freezing (approximately −1.7 °C for sea water).

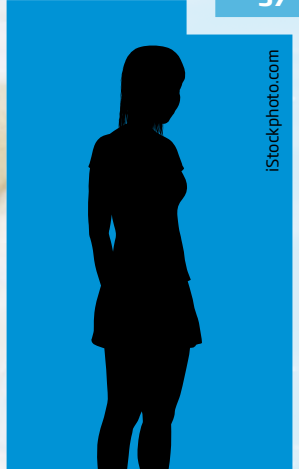
They can survive in this extremely harsh environment mainly because of a 5cm layer of blubber (fat) under their skin, which performs a number of important jobs:

1. Preventing heat from escaping from the seal's core
2. Helping the seal to float
3. Storing energy for the seal

37 °C	Core body temperature
35 °C	Hypothermia triggered
32 °C	Loss of consciousness
20 °C	Max average UK sea temperature
6 °C	Min average UK sea temperature
−1.7 °C	Sea starts to freeze

Harp seal core temperature: 36.5 °C - 37.5 °C

Human core temperature: 37 °C



TIME TO THINK

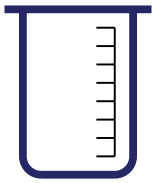
Q **Which materials do you think survival suits use instead of blubber to protect their wearers in extreme conditions?**

THERMAL RESISTANCE:
INVESTIGATING INSULATORS FOR SURVIVAL SUITS

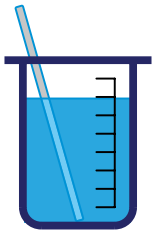
In this investigation you are going to see which materials are good at stopping heat from escaping.

For this investigation you will need:

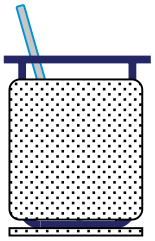
- A beaker
- A thermometer
- A supply of hot water
- An A4 sheet of felt
- An A4 sheet of corrugated card
- An A4 sheet of aluminium foil
- An A4 sheet of flexible foam, such as neoprene or Plastazote
- other suitable materials



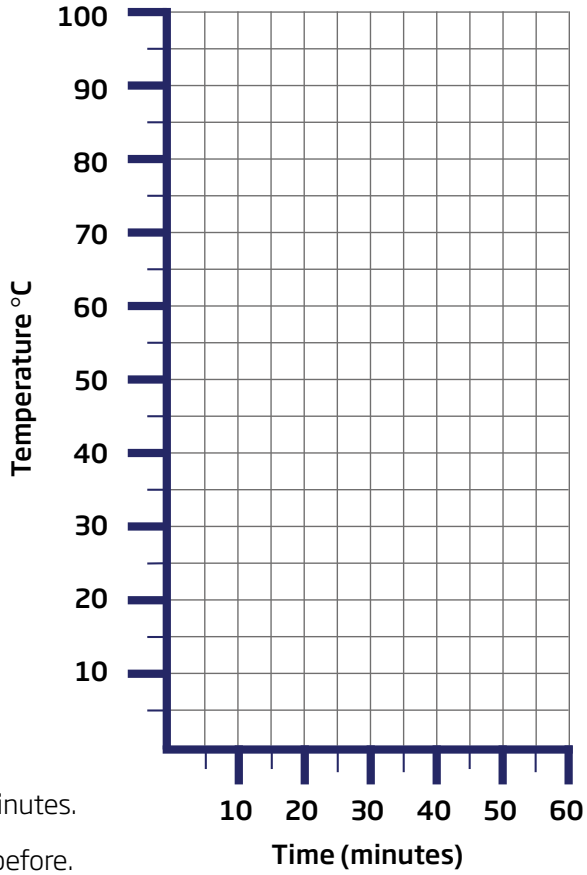
1. Collect a glass beaker.



2. Fill the beaker with hot water and record the water's temperature every five minutes.
3. Plot the temperature of the water on a graph.



4. Empty the beaker.
5. Wrap one of the materials listed above around the beaker. Stand the beaker on a piece of the material too.
6. Fill the beaker with hot water.
7. Record the water's temperature every five minutes.
8. Plot the temperature on the same graph as before.
9. Repeat this process for the other materials



a. Which are the best materials for preventing heat from escaping?

b. What effect does combining some of the materials from the list above have?

c. Which material, or combinations of materials, would you use to make a survival suit?

d. Give reasons for your choice.

For more Royal Academy of Engineering learning resources that investigate thermal insulation, visit **www.raeng.org.uk/publications/other/keeping-it-cool**

Royal Academy of Engineering

The Royal Academy of Engineering is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

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