Measure the speed of sound.

Find out how easy it is to measure the speed of sound. Increase your own knowledge of acoustics, important in the music industry, medicine, engineering, earth science and environmental science.

You can look up the speed of sound on the web but the values you get are all derived from mathematical models. Theory has to explain experimental evidence.

You can calculate the Mach Number for each of BLOODHOUND SSC's test runs. By getting involved with BLOODHOUND you will improve your maths, science and technology skillls at the same time.

BLOODHOUND Super Sonic Car

Stand at the goal line of four football pitches end to end. A friend at the far goal line four football pitches away shouts just as BLOODHOUND SSC at full speed arrives at that far goal line. Less than one heart beat later BLOODHOUND SSC goes past you and then another half a second later you hear your friend's shout! Amazing? No, BLOODHOUND SSC is travelling faster than the speed of sound. But what is the speed of sound and if you know it, how do you check it?

Some history

The French mathematician Marin Mersenne was the first person to measure the speed of sound in 1640. He used the return of an echo and arrived at a figure that was in error (using the modern value) by about 10 percent. Look up Mersenne prime numbers, only 46 are known after nearly 400 years!

After Mersenne, scientists used the sound of cannon-fire to measure the speed of sound and according to the modern value were in error by only one percent.

Then along came Newton. He was the first person to construct a theory to predict the speed of sound and came up with a formula which is essentially correct.

speed of sound = $\sqrt{(\text{Pressure}/\text{Density})}$

Check this using:

Air pressure = 102 000 Pa and Density = 1.3 kg/m^3

You should have got about 280 m/s, which is of course not very close to the speed of sound as it was known then. Newton was pretty angry and invented bogus reasons for the discrepancy. Now that really is amazing, the world's greatest scientist had to cheat! Newton did not know that the pressure waves travelling through the air heated up the tiny compressed regions (in the same way that a bicycle pump gets hot in use) which affected the speed of the pressure waves. (It is harder to compress a cylinder of hot gas than the same cylinder when cold).

The above picture of an F-18 breaking the sound barrier shows a cone of water vapour thought to form when the drop in air pressure behind the shock wave (see below) cools the air so that water droplets form.

What you can do

You live in the twenty first century with a lot of knowledge which you can find in books and on the web. You also have better tools and you can measure the speed of sound yourself using a laptop or PC and a pair of old walkman style headphones. Furthermore you can do much better than a one percent error! Easy to do at home and can be linked to CREST awards on the BSA (formerly BA) website.

<u>How to measure the speed of sound using Audacity software.</u>

Quick instructions

Download Audacity, set preferences to stereo and plug a pair of miniature headphones or microphones into the microphone input. Place phones a metre or more apart and record a sharp pulse of sound (hand clap) as it passes from one speaker to the next. Use the audacity tool bar to measure the time taken for the pulse to travel from one phone to the next and so calculate the speed of sound. (a very few laptops, 5%, will not support true stereo, you can only find out by trial)

Setting up audacity

1 Download audacity. If you Google audacity the first link will be **Audacity**: Free Audio Editor and Recorder . It has the same controls as recorders you are familiar with.

2. Find a pair of old walkman style headphones, ones that can be pulled apart so that the phones are about one metre apart.

3 Plug them into the microphone input of laptop or PC. Yes, headphones will work as microphones, not good ones but your teachers may have told you that speakers and microphones work on the same principle. A message will probably appear saying the system has detected an audio device connection event. Microphone will be highlighted, click on ok.

4. Open Audacity. A tool bar appears, do not be frightened, you will only be using the buttons record and stop, find

them by hovering over the buttons in turn.

5 Click on edit. Then click on preferences. A menu appears, Audacity Preferences. Click on the *audio I/O* tab. Look in the box *recording* and click on the channels drop down menu. Select *2(stereo)*, click on ok.

making a recording

1 Click on the record button. Two channels will appear one for each headphone.

2 Click on stop.

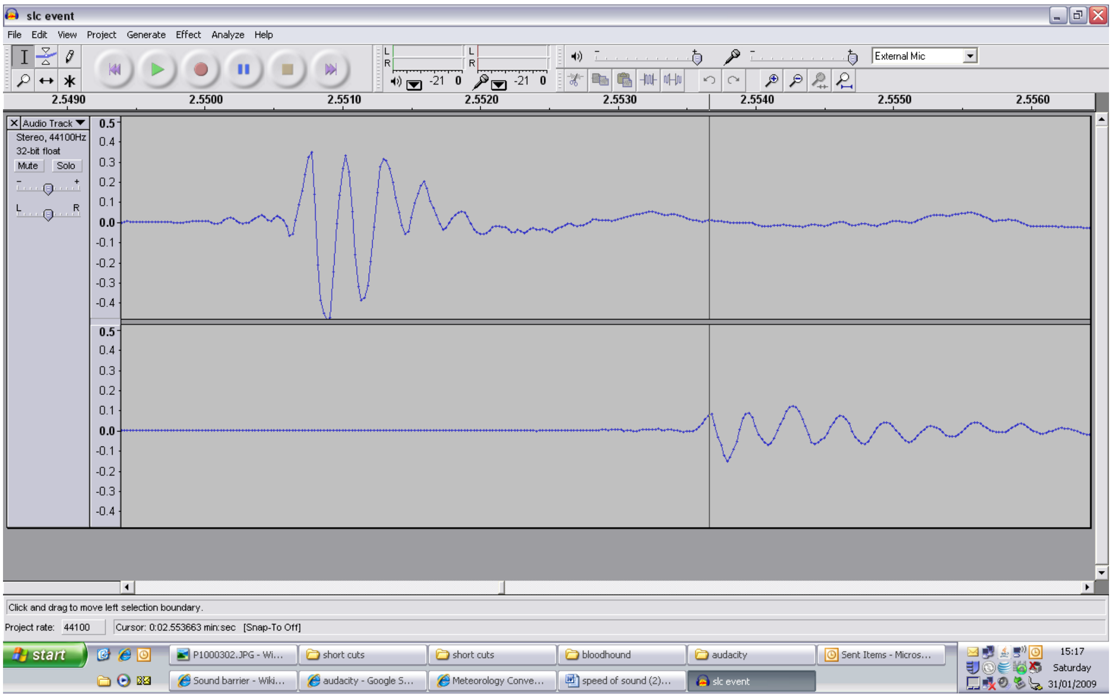
3 Click on new and you will be ready for another recording. The previous one is automatically kept and you will have to delete or save your recordings at the end of your session. Easy as that!

Measuring the speed of sound

1 Stick your headphones to a metre ruler or to something else a metre apart. Make sure there are no reflecting surfaces nearby so that the sound recorded has come directly from the handclap and not from reflections nearby. That is you will need about 2 metres of clear space all around the apparatus.

2. Stand at one end of the ruler. Start a recording and clap your hands. Stop the recording

3 Identify the point where sound was detected. Highlight the region where the handclap was detected. Then click on view and select *zoom to selection.* A magnified piece of the recording is shown. You can zoom in again to identify the individual vibrations.



4. Notice that the pulse was received at the near headphone before the other. The pulse took a little time to travel from one headphone to the next. You will now measure that tiny time interval. Drag the bottom edge of the recording frame down to increase the amplitude a little.

5 Identify a peak or a trough which corresponds in each channel, usually the first peak or the first trough. If you left click in the channel area a little hand appears pointing to a line which marks the time. You can look at the time channel above the recording or you can use

the time noted at the bottom of the page marked *cursor.*

6 Write down the two times and subtract them. Easier to put them straight into a calculator or to simply highlight the interval between your two chosen points and the time interval will appear in the cursor area. You should have a four significant figure number, something like 0.002875. The timer is sensitive to one millionth of a second! Not bad for free software!

7 Measure the distance between the headphones as carefully as you can, certainly to one millimetre. The distance will then be accurate to four figures if you have at least a one metre separation of your phones.

8 Speed is distance/time; your calculation can be given to four figures. Why is your measurement of the speed correct to four figures? What do you think is the uncertainty in your measurement?

9 Ask your teacher to make sure that the class measurement (four figure accuracy) is uploaded to the BLOODHOUND SSC site, along with the temperature in °Kelvin (easy, just add 273.15 to °C), humidity %, air pressure (Pa), and height above sea level (m). If you have the instruments use them for humidity and air pressure or go to http://uk.weather.com/local . The humidity will be external humidity and the pressure will be in mb (millibars), simply multiply by 100 to convert to Pa (pascals).

Why?

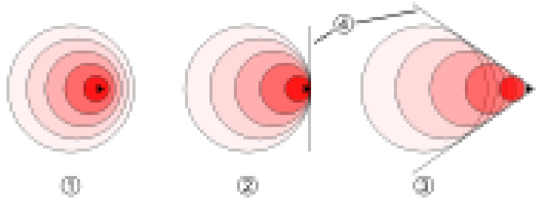
Most scientists simply assume that the speed of sound is affected by the temperature alone. However this is only true for what is called an *ideal gas* (ask your teacher). In a real gas such as the air, the speed of sound is affected by the humidity and just a little by the pressure. You can help the BLOODHOUND engineers by helping to build a large database of measurements so that when the test runs are made, you the students, can calculate the Mach number of the BLOODHOUND SSC test run.

You will also develop your computer skills, have fun with Audacity and improve your maths and science.

What is the Mach Number?

It is simply the ratio of the speed of the object to the speed of sound at that point. Since the speed of sound depends on various factors (notably the temperature) an object can be travelling at different speeds for the same Mach number. For example a plane at sea level will be travelling at 340.3 m/s at Mach 1 whereas higher up (11 km) where the speed of sound is lower, the plane will be travelling at 295 m/s at Mach 1.

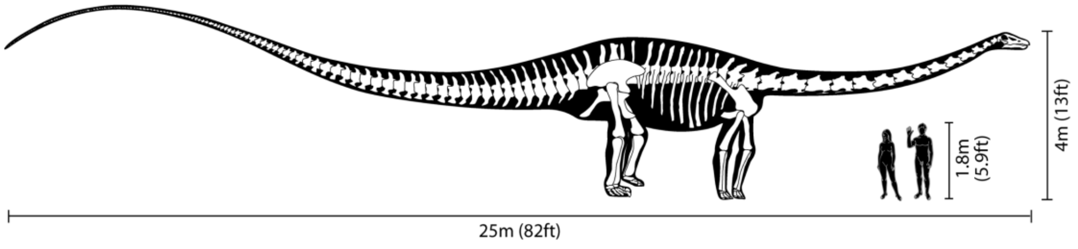
When Thrust SSC (see www.thrustssc.com or http://www.youtube.com/watch?v=LKQ-xj5C2m8) broke the sound barrier in 1997 it became the first (and to date the only) car to break the sound barrier, but only just, at 341 m/s. The proof of course was the sonic boom, see if you can hear the boom of the first plane to break the sound barrier in the news-reel (http://en.wikipedia.org/wiki/Sound_barrier) in Wikipedia.



1. Subsonic 2. Mach 1 3. Supersonic 4. Shock wave

Once a sound wave leaves the source it forgets the source and travels at the speed of sound, not the speed of the source. There was a time when some scientists thought that as a vehicle approached the speed of sound and all the sound waves began to pile up in front of the source the energy would destroy the vehicle. Many early aircraft were destroyed as they approached the speed of sound because control became more and more difficult. This is why it came to be known as the sound barrier. Compare diagram 3, supersonic, to the picture of the American F-18 and the cone shaped vapour cloud behind it.

The tip of a bull whip breaks the speed of sound and causes the characteristic crack. Many weapons fire bullets and missiles in excess of the speed of sound. A (very small) number of paleontologists believe that some long tailed dinosaurs could flick their tails like a bull whip and so create a frightening sonic boom.



[Note; NPL has a speed of sound calculator - http://resource.npl.co.uk/acoustics/techguides/speedair/]

You can use this if you want to see what the mathematical model comes up with. But we are much more interested in your experimental result.