PUPIL RESEARCHER INITIATIVE

Sound Judgement

Setting the Scene

You are going to find out if the classrooms in your school have good acoustics. You will learn how the ear works, carry out several investigations similar to those done by real researchers ,and make recommendations about how to make improvements.

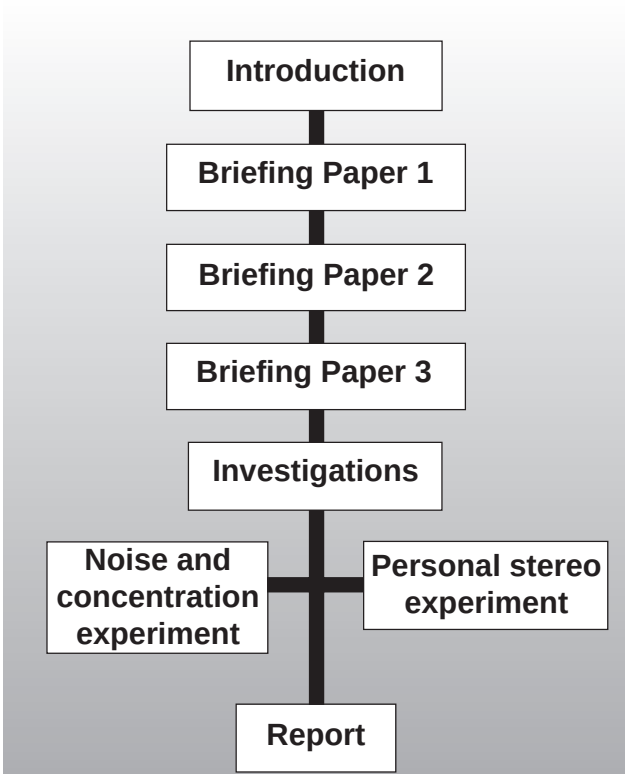
Pupil Research Brief

Study Guide

Syllabus Targets *Science you will learn about in this Brief*

- ❑ sounds are produced when objects vibrate
- ❑ the greater the size of vibration (amplitude) the louder the sound
- ❑ the number of complete vibrations each second is called the frequency (hertz, Hz)
- ❑ you should know how to compare amplitudes and frequencies as they would appear on an oscilloscope trace
- ❑ sounds bounce back (reflect) from hard surfaces (echoes are sound reflections)
- ❑ sound travels through solids, liquids and gases as longitudinal waves

Route through the Brief



Outcome Checklist

You will carry out several investigations into room acoustics and produce a report outlining your findings and make recommendations about how the room acoustics can be improved. You should make sure you produce the following items as you work through the Brief.

Briefing Paper 1

- ❑ brief notes summarising the information in the paper

Briefing Paper 2

- ❑ brief notes summarising the information in the paper

Briefing Paper 3

- ❑ plan for investigating the acoustics of your classroom
- ❑ investigation report
- ❑ recommendations for improving the acoustics of your classroom

Optional

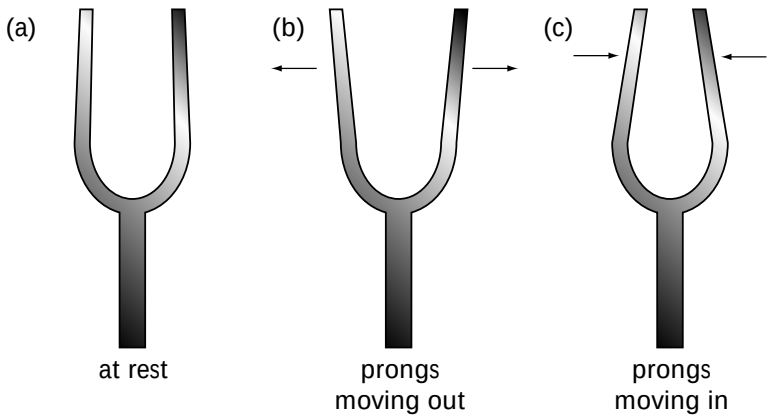
- ❑ report on the personal stereo investigation
- ❑ report on the noise and concentration experiment

Sound Judgement

Briefing paper 1

Making sounds

Sounds are caused by things that vibrate. Think of a tuning fork. When we strike a tuning fork its prongs move in and out, usually too fast for us to see clearly. **Figure 1** shows the prongs vibrating.



The prongs push against the air molecules, causing very tiny changes in air pressure. These are sound waves. If the size of the vibration is big, the pressure changes are large and the sound is loud. The number of times the tuning fork vibrates in a second is called the **frequency** or pitch, and it is measured in a unit called the **hertz** (Hz).

FIgure 1. How a tuning fork vibrates

Hearing sounds

When a sound reaches our ear it travels down a tube called the **ear canal**. There is a small piece of skin stretched over the end of the canal. This is the **eardrum**. The sound waves make the eardrum vibrate. The other side of the eardrum is connected to a bone called the **hammer**. This is connected to another bone called the **anvil**. The anvil is connected to a third bone called the **stirrup**. You can see these 3 bones in Figures 2 and 3. They are the smallest bones in the body, and move like levers in a machine. They pass the vibrations from the eardrum to something that looks like a tiny snail. This is the **cochlea** (cochlea means "snail" in Latin). The cochlea is filled with a liquid and it is lined with very small hairs. The sound vibrations make the liquid move and cause the hairs to bend. These hairs make tiny electrical signals when they bend, which go along a **nerve** to the **brain**. The brain makes sense of these signals and tells us what sounds we have heard.

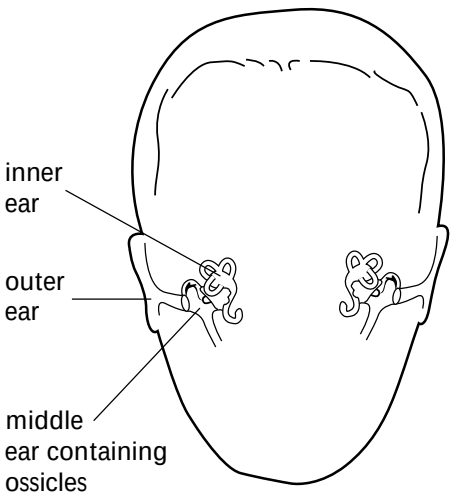


Figure 2. The position of the ears in the head

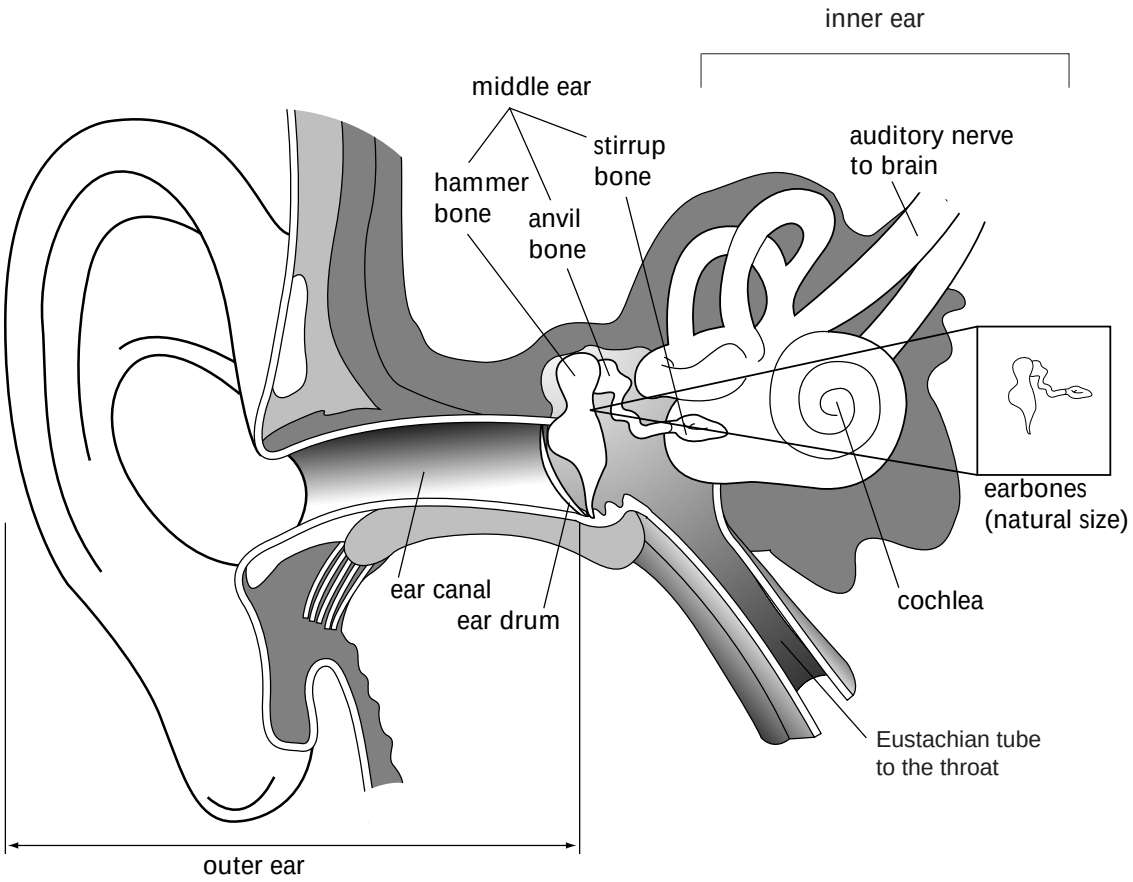


Figure 3. The human ear

Hearing loss

There are at least 18.5 million people in the United Kingdom with hearing loss. There are many ways in which people can lose their hearing. These include illness, old age, infections in the ear, drugs and exposure to loud noises. Some of these types of hearing loss need not happen, especially if the cause is loud noise. The two main ways that hearing loss occurs are described below.

1. The sound vibrations don't get passed to the cochlea.
Sound passes from the eardrum to the three bones to get to the cochlea. The eardrum can be damaged by loud noises, but it usually grows back. The 3 bones can stop moving if they are infected. The muscles holding them can become stiff if they are exposed to loud noises for a long time. The bones can also be shattered by very loud sounds

2. The electrical signals don't get to the brain.
This is usually caused by damage to the cochlea. Damage can occur from diseases or from noise. Loud sounds heard for a long time can make the hairs inside the cochlea break off. They don't grow back, and so they can't make the signals any more.
It is rare for people to lose all their hearing. There are different types of hearing problems. Sometimes all sounds are faint. Often, people lose the ability to hear some sounds clearly (see **Figure 1**). So the sentence '*Would you like a cup of coffee?'* may sound like '*oo oo aye a uh oh ohee?*' to a person with hearing problems. People with severe hearing difficulties will hear much less than this, (see **Figure 2** on the next page). People with hearing problems can sometimes be helped with an operation, but it is more common for them to be fitted with a **hearing aid**.

Figure 1(a). Behind-the-ear hearing aid

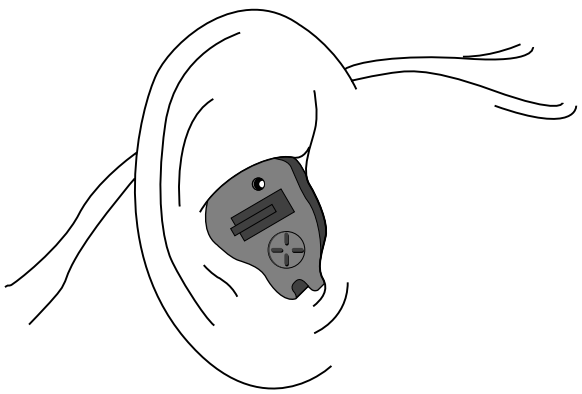


Figure 1(b). In-the-ear hearing aid

Hearing aids

A hearing aid is simply a microphone, an amplifier and a loudspeaker made very small. The microphone converts the sound waves into electrical signals, the amplifier increases the strength of these signals and the loudspeaker (or earpiece) converts these amplified signals back into sound waves. This is usually placed *inside* the ear canal, directing the sound towards the eardrum. Many people think that hearing aids make a hearing impaired person's hearing normal. This is not true. A hearing aid amplifies all sounds. So in a noisy room **all** the sounds will be made louder, not just those you want to hear. You can hear the same thing if you record someone speaking, using a tape recorder in a normal room with a small amount of background sound. All the sounds will be picked up by the microphone and the recording will seem much noisier than you would expect.

What is it like to be deaf?

It may sound like this	slight ‘high tone’ deafness
or it may be like this	severe ‘low tone’ deafness
or it may be like this	profound ‘low tone’ deafness

Figure 2. What is it like to be deaf? Solid letters will be heard clearly, shaded ones will be heard faintly, absent letters will not be heard at all

This is why it is important to have quiet rooms for people who need to use hearing aids. Otherwise their hearing aids will be almost useless. **Figure 3** shows a diagram of the ear, and the places where hearing loss can occur.

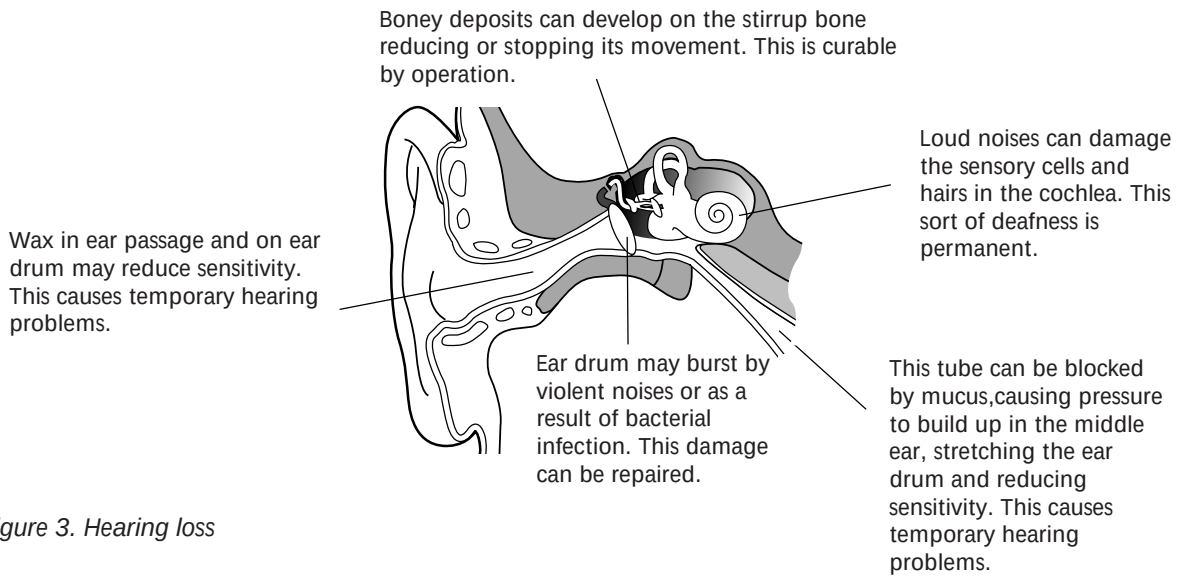


Figure 3. Hearing loss

Investigating classroom acoustics

The Education Act of 1981 said that Special Needs pupils must not be prevented from going to ordinary schools. Most experts in education think that it is better for children with disabilities to mix with all types of people of their own age. The trouble is that many schools aren't designed to cater for children with certain types of disability. If a school has a lot of steps, it is hard for people in wheelchairs to get around. This is not difficult to understand. Many people think that it would be easier to put children with hearing problems into mainstream schools. This may not always be the best for these children. Work has been done by scientists at **Heriot-Watt University** in Edinburgh on testing the **acoustics** of classrooms. Acoustics is the study of how sound behaves in rooms. They have found that many classrooms would be bad for hearing impaired pupils. Children who use hearing aids need rooms where the teacher's voice can be heard clearly. They have shown that there are three things that affect the acoustics of a classroom:

1 background noise levels
2 reverberation time
3 layout of the room

Background noise levels

The loudness of a sound is measured with something called a sound intensity meter. This instrument measures loudness and the unit for loudness is called the **decibel** (dB).

Level (dB)	Sound
160	Rifle shot close to ear (eardrum ruptures)
140	Aeroplane at 25m (threshold of pain)
120	Disco close to speakers (threshold of discomfort)
100	Very noisy factory
90	Road Drill at 7m (upper limit of acceptable noise level, by law)
70	Busy street
50	Quiet street
40	Quiet talking
30	Whisper
20	Library reading room
0	Threshold of hearing

Table 1. The loudness of some common sounds

Background noise can affect how clearly pupils can hear the teacher's voice. It also affects their concentration and their memory. This is for all pupils and not just those who have hearing problems. The background noise level in a classroom should be as low as possible. **Table 2** on the next page shows the background noise levels for different places in a school. The figures are for people with normal hearing. Pupils who have hearing problems need a background noise level which is much lower.

Background noise can come from the sound of traffic nearby, or sounds from the next room. The sounds from overhead projectors, fan heaters, computer printers, and even a ticking clock can all add to the background noise level.

Type of space	Noise level
Workshops	50
Teaching groups of less than 15	45
Library	45
Teaching groups of 15 - 35	40
Teaching groups of more than 35	35

Table 2. Maximum background noise levels for schools

Reverberation time

If you go into a large building like a church you will notice that a sound will echo around it for some time before it dies away. This is **reverberation.** Sounds bounce off hard surfaces such as bare walls. They are absorbed by soft things. This is why a room with a thick carpet and heavy curtains in it can seem to deaden the sound. We notice reverberation most in big spaces, but even small rooms have reverberation. If you get sounds bouncing off walls, floors and ceilings when someone talks, the speech can sound very "fuzzy". You can't hear it clearly any more. **Reverberation time** is the time taken for a sound to fade away. A classroom should have a reverberation time of no more than 0.75s for children with normal hearing. The reverberation time for a classroom that has children with hearing problems in it should be 0.5s or less.

The layout of the room

The size and shape of a classroom play a big part in the background noise and reverberation time of the room. The layout of the room and where the teacher normally stands can have a big impact on how clearly pupils can hear speech.

To sum up, classrooms should have as quiet a background noise level as possible and they shouldn't be echoey. This is vital if pupils with hearing problems are to use these rooms, but also good classroom acoustics help pupils with normal hearing to work better in their lessons.

The investigations

Your task is to investigate how good (or bad) your school's classroom acoustics are. You should test your laboratory first.

If you can do it, you should also test a normal classroom, a technology workshop, the gym, an art room and the school hall. You will have to get permission to test these other rooms. Below are the tests you should carry out (remember you must be quiet during these tests).

1 Your own impression of the room.

Use the sheet **classroom survey: *impressions*** to record your impressions of the room you are surveying.

2 The classroom survey

Use the upper half of the sheet **classroom survey: *measurements*** to record data about the room.

3 Measure the background noise level

Use the lower half of the sheet **classroom survey: *measurements*** to record results to the background noise level tests.

Using a sound level meter (or sound sensor) take at least **10** readings in different places in each room, as set out in the table on the ***measurements*** sheet. Then find the average value. These are the sorts of measurements made by scientists from Heriot-Watt University when they carry out tests in schools.

4 See if there are any 'hot spots'

Use the sheet **classroom survey: *hot spots*** to record results to these tests.

This is an interesting experiment and shows how sound can be distributed around a room. Use the same room as before. Place a loudspeaker at the location where the teacher is likely to be for the majority of teaching time, and if possible at the head height of the teacher (remember safety here - this may not be possible with a large loudspeaker).

Use a noise generator to produce ‘white noise’ through the loudspeaker. (White noise is a hissing sound. You can get this by turning on a radio and turning the tuner to a place where there is no station). At a point 1 metre away from the face of the loudspeaker adjust the control on the generator to give a noise level of 67.5 dB(A). This level has been found to be average level of a teacher’s voice in a classroom situation. If you think it is too quiet for a large room, such as a gymnasium, adjust the volume upwards and take a note of the reading 1m from the face of the speaker.

Draw a floor plan of the room with all the desks, chairs, benches and other furniture marked accurately on the drawing. Using the sound level meter set to measure dB(A) measure the sound level at the approximate head height of each pupil as if they were seated at their desk or bench area. The sensor or sound level meter should face forwards as if the person were facing forward.

Analyse your results: if the desks are set out to a regular pattern you should be able to draw sound level contours using the measured values. Identify quiet or loud areas ('hot spots') within the room. Examine whether the noise level increases or decreases near the back or side walls.

5 Measure the reverberation time of the room.

Your teacher may have to do this, or give you guidance on how to do it.

6 Carry out the Fairbanks Test.

This measures how clear speech is in the room. Your teacher will explain how it works. It is a very interesting test, which can provide us with a lot of information. No special equipment is needed. The test is used to see how clearly you can hear speech in a room. This is called *speech intelligibility*.

The teacher who normally uses the room reads out a series of sentences in which there is a key word. The listener has part of the word written down on a form and after the sentence has been read by the speaker the listener then completes the word. The number of correct words then gives a score of the speech intelligibility of the room. The test can be repeated with noise sources in the room, perhaps with the window open, etc. It is a good test to identify whether the room is adequate for teaching purposes or whether there are areas within the room where it is difficult to hear what is being said.

7 Write a report

When you have done these tests you should write a report of your findings. Your report should include your suggestions for improving classroom acoustics in your school. It may even be possible to try out some of your ideas for making rooms quieter. (You can only do this if you have the time and equipment available.)

Some of the things you will have to think about include, for example:

- reducing unnecessary noise
- types of surfaces (walls, ceilings, floors)
- ways of absorbing sound
- class sizes
- doors and windows (open and closed)