Sound

Introduction

This topic explores the key concepts of sound as they relate to:

- the nature of sound
- the transmission of sound
- resonance
- the speed of sound
- sound and hearing.

Key concepts of sound

The activities in this topic are designed to explore the following key concepts:

- The production of sound requires an object to vibrate.
- The speed of the vibration of a sound source gives the frequency of the sound.
- The size or amplitude of the vibration gives the loudness of the sound.
- Sounds that reflect off objects are echoes.
- Sound travels much faster in solid objects than in air.
- Sound requires a medium to travel in. Sound can’t travel in space.
- The particles in the material in which the sound moves vibrate at the same frequency as the source.
- Sound is the transmission of kinetic energy from particles in the source to particles in the medium in which the sound travels.
- Sound travels as a travelling disturbance (wave) due to collisions in the material in which it moves.
- Soundwaves are disturbances called longitudinal waves; the particles in the material vibrate forwards and backwards in the forward-moving wave direction.
- Sound is pressure waves of compressions (high pressure) and rarefactions (low pressure) travelling away from a vibrating source.
- Most sounds that are heard are a result of resonance.
- Objects have their own natural vibration patterns (resonant frequencies) and can give a characteristic note (frequency) when hit (or blown).

- Resonance is the natural amplification of sound frequencies (resonant frequencies) in an area (resonating chamber) different from the sound source.
- Speaking and hearing are resonance effects. The mouth and nose cavity acts as a resonating chamber for speech; the ear canal acts as a resonating chamber for hearing.
- The speed of sound in air is approximately 340 m/s.
- We use two ears to judge the direction of a sound source.

Students’ alternative conceptions of sound

Research into students’ ideas about this topic has identified the following non-scientific conceptions:

- The loudness and pitch (or frequency) of sounds are confused with each other.
- You can hear and see a distant event at the same moment.
- Hitting an object harder changes its pitch.
- In a telephone, actual sounds, rather than electrical impulses, are carried through the wire.
- Human voice sounds are produced by a large number of vocal cords.
- Sound moves faster in air than in solids (air is ‘thinner’ and forms less of a barrier).
- Sound moves between particles of matter (in empty space) rather than through matter.
- Sound can travel through space.
- In wind instruments, the instrument itself, not the internal air column, vibrates.
- As soundwaves move, matter moves along with them.
- The pitch of whistles or sirens on moving vehicles is changed by the driver as the vehicle passes.
- The pitch of a tuning fork will change as the tines of the fork slow down (run out of energy).

The nature of sound

The activities in this section explore different aspects of the nature of sound. While some explanations are given here, it is best to revisit these activities once the key ideas have been discussed.

Making and investigating sounds

ACTIVITY: VIBRATING RULER

Place a ruler so it lies flat and protrudes over the edge of a table. Set the ruler vibrating by holding one end firmly against the table. What is happening in the ruler to make the sound? What must be done to the ruler to obtain a louder sound? What is happening in the ruler to get a loud sound? What must be done to obtain a higher pitched sound? What is happening in the ruler to obtain a higher pitched sound?

Explanatory note: The vibrating ruler is the sound source. The greater the amplitude of vibration, the louder the sound will be. A higher pitch is achieved when the ruler is shortened (the ruler extends a shorter distance over the edge of the table). In this situation, the speed of vibration is greater: the greater the speed of the vibrating source, the higher the pitch of the sound.

ACTIVITY: DETERMINING SOUND DIRECTION

Get a blindfolded person to identify the direction from which tapping sounds appear to come by first trying with one ear and then with two. What conclusions can you reach?

Explanatory note: We have what is called 'binaural hearing'. This means we hear with both ears. This helps us to determine the direction of a sound source. A source to the left of you will produce sound that reaches your left ear before it reaches your right ear. The brain interprets this time delay as a sound source to your left. Incidentally, you can't, using just your hearing, determine whether a sound is coming from directly in front of you or directly behind you. Try your own experiment.

ACTIVITY: EAR TRUMPET

Make an ear trumpet by folding a piece of paper into a conical shape and holding it near your ear. How would you describe the differences it makes to sounds? Why do you think it makes a difference?

Explanatory note: The sound entering the funnel reflects a number of times and converges at the centre of the trumpet. In this way, the intensity of the sound increases; it becomes louder.

ACTIVITY: TUNING FORK 1

If you can get access to a tuning fork, set it vibrating and dip the tines (ends of the fork) into a cup of water. What happens? Why?

Explanatory note: As the tuning fork makes sound, the tines vibrate. The vibrating tines collide with the water particles and make splashes.

ACTIVITY: TUNING FORK 2

Set a tuning fork vibrating and place the end that is not vibrating directly against the bone at the back of your ear. What do you notice? Can you explain why?

Explanatory note: The vibrations travel into the bone behind your ear and into your skull. You hear a louder sound, through a phenomenon called resonance (see the section 'Resonance' later in this topic), as your skull becomes a resonating cavity.

ACTIVITY: TUNING FORK 3

Have one person place the base of a tuning fork at one end of a piece of metal (the top of a metal fence). Move a few metres away and hold your ear close to the fence. What do you notice? Why? You don't need a tuning fork for this activity: you could tap with a ruler. If you have access to a long piece of metal (I *don't* suggest using a railway line), determine the maximum distance from the sound source from which the sound can still be heard.

Explanatory note: Sound travels faster and further in solid objects.

ACTIVITY: STRING TELEPHONE

You will need:

- **two plastic cups (or metal cans)**
- **approximately 5 m of string or thread**
- **an ice-cream stick or some matches.**

To make a string telephone, put (or drill) holes in the bases of the cups. Thread one end of the string through the hole in one of the cups and tie it to a piece of ice-cream stick; do the same using the other cup for the other end of the string. Stretch the string telephone tightly between two people. One person speaks into one of the cups and the other listens at the other end. What do you find? Why does this occur? What is the function of the string? What about the cups? Does the telephone work if the string is slack? What if someone is holding the string? Hold the string between your thumbnail and forefinger and scrape along it. How does this sound? Does the string telephone work around corners?

Explanatory note: The cups act as resonating chambers (see the section 'Resonance' later in this topic). As you speak into the cup, resonance occurs, so the sound is amplified. This amplified sound travels down the taut string as a vibration (sound is just a travelling vibration). The string needs to be taut for the vibrations to travel any appreciable distance. As the vibrations reach the second cup, resonance occurs again. If the taut string rests against other objects, the travelling vibrations pass into these objects. This leaves fewer vibrations to travel to the other cup and so the telephone will not work as well (or not at all!).

ACTIVITY: HOSE TELEPHONE

You will need:

- **two funnels**
- **a length of hose.**

To make a hose telephone, place a funnel in each end of the hose and investigate its ability to operate as a telephone. Does the hose need to be taut in the same way as the string telephone? Why?

Explanatory note: Sound in air travels in all directions, spreading out and losing its intensity quickly. However, in a tube or a pipe, the sound doesn't spread out; it just keeps reflecting along the walls of the tube or pipe. Therefore, in a pipe or tube, the sound intensity doesn't drop as significantly as in air and so will travel further.

ACTIVITY: DIFFICULTIES IN HUMMING

Try to hum while blocking your nose. What do you find?

Explanatory note: When making a sound, you push air up through your throat (and vocal cords) and out through your mouth or nose. When you hum, the expelled air passes out your nose as your mouth is closed. If your mouth and nose are closed, there is nowhere for the expelled air to pass. Therefore, the movement of air ceases, as does the humming.

Sound production: loudness and frequency

To produce sound, something must vibrate. However, the original source of the sound may not be the source of the sound you hear. For example, when a guitar string is plucked, you hear a clear sound. The source of the sound is the vibrating string, but vibrations in the air within the back of the guitar cause the sound you hear. These vibrations are an example of resonance and they are responsible for most sounds we hear. In fact, the processes by which we speak and hear are resonance effects. However, before giving a full explanation of resonance, we must explore the basic concepts of sound production.

Sound is produced when something vibrates—for example, vocal cords in the throat, or a guitar string. The sound source can vary in its vibrations in two ways: the size of the vibration and the speed of the vibration. You will notice in the activity *Vibrating ruler* that the larger the vibration is, the louder the sound is. Therefore, the loudness of a sound relates to the size of the vibration of the source. Large vibrations result in loud sounds and small vibrations result in soft sounds. The measure of the loudness of a sound is the decibel (dB). This is related to the human perception of sound. For example, the softest sound we can hear has a loudness of 0 dB. The loudest sound that doesn't do damage to our ears (called the threshold of pain) has a loudness of 120 dB. See the section 'Sound and hearing' later in this topic.

In the activity *Vibrating ruler*, the speed of vibration relates to the pitch, or frequency, of the sound. 'Pitch' is a term used by musicians; it relates to perceptions of sound in relation to the ear, whereas frequency is the scientific term, which we will use in this topic. Frequency is measured in hertz (Hz). A measurement of 1 Hz means the sound source is vibrating at one vibration per second. A source vibrating at 100 Hz is vibrating at 100 vibrations per second.

ACTIVITY: VIBRATIONS OF A LOUDSPEAKER

If you are able to take the material covering off the loudspeakers to your sound system, touch the speaker cone and contrast the feeling you get when the speaker is producing a loud sound with the feeling you get when the speaker is producing a soft sound. See if you can contrast the feeling from a low-pitched sound with a high-pitched sound.

Explanatory note: All sound sources vibrate. Explore other vibrating objects. For example, place some sand on a drum and hit it. Sometimes the vibrating object is not noticeable. For example, blow across the top of a bottle or play a flute. The vibrating sound source in both these cases is vibrating air above the opening of the bottle or flute.

ACTIVITY: FREQUENCY RANGE OF THE EAR

You will need an audio frequency oscillator. This is a device that produces vibrations in a range from 0 Hz to 20 000 Hz. Test your hearing ability by changing the range from 0 Hz up to the maximum 20 000 Hz. Which frequencies appear loud to the human ear? Which frequencies are the most irritating?

Explanatory note: The human range of hearing is from 20 Hz to 20 000 Hz. Your hearing is best when young and deteriorates with age. Animals have different hearing ranges. For example, elephants and whales can hear sounds of less than 20 Hz, and dolphins and bats can hear sounds of more than 20 000 Hz.

The transmission of sound

The sounds that you hear are the result of energy being transferred from a source to your ear and finally to your brain. We characterise this energy as sound energy but we shall see when describing sound energy that it is kinetic energy, which is motion energy; any object in motion has kinetic energy.

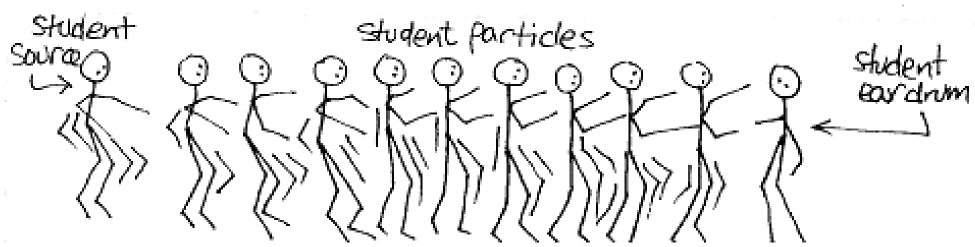
Objects that are in motion are said to possess kinetic energy. They can pass this energy on to other objects by colliding with them. When a fast moving object collides with another object, it slows down and so loses kinetic energy. However, the collision moves another object, thus increasing its kinetic energy. In this way, kinetic energy is transferred from one object to another. Sound transmission is a process of collisions between objects and, through these collisions, energy is passed from one object to another. We use various models to understand the transmission of sound. These models are needed to explain observations such as the following:

- Sound does not travel through space.
- Sound travels quicker and for a longer distance in solids.

A model of sound transmission: role-play

To understand sound transmission, let us take the example of the vibrating ruler and someone hearing the sound from a distance. To represent the transmission of sound from the ruler to the ear, consider the following role-play model. In this model, a person who moves forwards and backwards (vibrates) represents the sound source (in this case the ruler); another person represents the ear and is located some distance away from the person representing the ruler. To represent the air between the ruler, the model requires a line of people. Each person represents a particle of air (see Figure 1).

FIGURE 1: ROLE-PLAY MODEL OF SOUND TRANSMISSION



To ‘run’ the model, the first person (student source) moves forwards, thus bumping the next person (student particle), who then bumps the person next to them (neighbouring student particles) and so on. We then notice that a disturbance has moved along the entire row to the end person (student ear rum). Notice also that, although the student particles move only a short distance, the disturbance passes along the line of student particles. This travelling disturbance is a wave.

If we continue running the model, the first person moves backwards and forwards (vibrating ruler). This sets up a vibratory motion in the neighbouring people (air particles) as they rebound from the person in front of them and the person behind them. This model then predicts that the particles in the air vibrate at the same frequency as the sound source, and the travelling disturbance (wave) through the air will result in the eardrum also vibrating at the same frequency as the sound source. A soundwave is just a travelling disturbance through a medium.

ACTIVITY: ROLE-PLAY MODEL OF SOUND TRANSMISSION

Get a group of students to role-play the transmission of sound. How does your model change when comparing sound travel in wood versus air? What about sound travel through space? What does this model predict about the speed of sound in air compared to the speed in wood?

Explanatory note: This role-play model successfully explains the following:

- A disturbance can move along a material without the material moving with the disturbance; this is called a ‘wave’. Thus, energy can transfer from a source to surrounding material, including eardrums. Sound can be imagined as a travelling disturbance: a ‘soundwave’.
- The particles in the material surrounding the vibrating source vibrate at the same frequency as the source. This includes the eardrum, which therefore vibrates at the same frequency as the sound source.
- Sound cannot travel through empty space. If we run our model with no people between the first and last person, then a disturbance cannot be transmitted. We must assume in our model that the person representing the ruler can only move forwards a short distance before moving backwards. It is interesting to observe that, in some movies, spaceships get blown up in space and the sound can be clearly heard.
- Sound travels faster in denser materials, such as water and wood. If we perform the above activity over the same distance using many people rather than just a few, then it is quite noticeable that the disturbance moves more quickly. Particles in the air are much further apart than those in water or wood.
- As disturbances can travel much more easily in dense materials, sound travels further in dense materials.
- A travelling disturbance where the actual material that travels moves forwards and backwards, and not sideways, is called a ‘longitudinal wave’. Sound is classed as a longitudinal wave phenomenon. However, if the particles in a material move sideways to the travelling disturbance, as occurs in water waves, it is called a ‘transverse wave’. We shall see in the topic ‘Light’ that light can be imagined as a transverse wave phenomenon.

The role-play model does not explain the following:

- The kinetic energy that is transferred in each collision is less than the previous collision, as each particle can collide with a number of particles. This means that sound only travels a certain distance. With the role-play model, the students representing the air particles might give themselves extra energy to sustain the travelling vibration.
- Be careful to note that, in the model, the air between the people represents space between the actual air particles. Sound must be imagined to be a travelling disturbance caused by vibrations and collisions in the particles of the material in which the disturbance moves. Therefore, sound should not be considered a separate entity that travels through a material. It is related to the particles’ motion in the material.

- From the way we understand matter, the particles that make up matter are in constant motion, continually colliding with each other. The travelling disturbances we call sound are added collisions that occur constantly. The particles in a gas, such as air, are moving around faster than those in a solid, such as a piece of wood. This natural movement of particles inhibits the progress of a travelling vibration (soundwave), which is another reason why soundwaves travel further in solids, such as wood, than in gases, such as air.
- The reflection of sound is not explained by the role-play model, although you may picture how it could be done.

Another model of sound transmission: waves on a spring

Another model of sound transmission uses a spring as a medium for a travelling disturbance. Complete the following activity and notice the two types of waves that can be produced. These waves are called longitudinal and transverse waves. They are pictured in the figure *Waves on a slinky*.

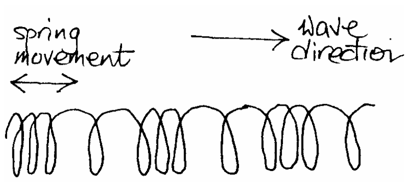
ACTIVITY: WAVES ON A HELICAL SPRING (SLINKY)

Another model of sound transmission uses waves on a helical spring (a 'slinky'). We can picture soundwaves on a spring. Remember that soundwaves are a travelling disturbance where the particles in the material vibrate forwards and backwards. Extend a helical spring between two people while it rests on the floor. To produce a longitudinal wave pulse, make a sudden push in a forwards and backwards motion on the end of the spring. You should then observe a disturbance that travels along the spring. What does the disturbance look like? If the person at the other end is holding the spring tightly, you should notice reflection of the disturbance. Based on what we have already discussed about sound, is this a good model for it?

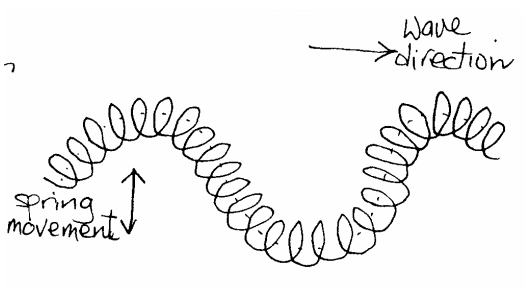
A different vibration of the slinky will produce transverse waves. Instead of making an initial push forwards and backwards, try a quick sideways movement. This produces a transverse wave pulse. A series of travelling disturbances in the coil for each type of wave should look like the diagrams in the figure *Waves on a slinky*.

FIGURE: WAVES ON A SLINKY

Longitudinal wave



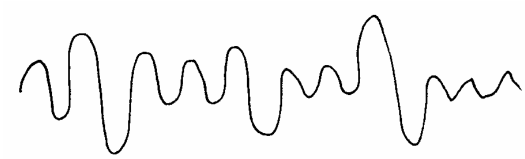
Transverse wave



Soundwaves as pressure waves: another perspective

Soundwaves are sometimes represented on view screens, like a television screen, as water waves viewed side-on, as in Figure 2. These representations tell us how the pressure of the air varies with distance from the sound source or how the air pressure changes as a soundwave passes a particular point.

FIGURE 2: PRESSURE WAVE

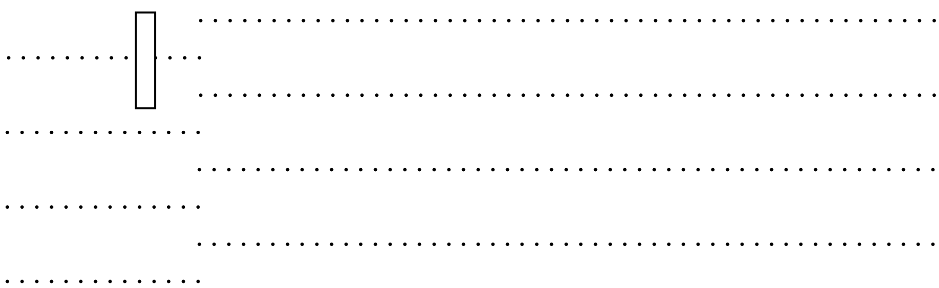


To understand pressure, such as atmospheric pressure, you need to picture the particles in the air moving very fast and bumping into each other and into you. You don't notice these collisions, but they are there and have the effect of applying forces (pushes) to all parts of your body. At the same time, the particles in your skin are pushing out against the air particles, thus cancelling out their effect (however, note that in space, where there are no particles, if you were not enclosed in a pressure suit, your body would expand and explode). The scientific meaning of pressure is the amount of force per unit area that is applied to an object. So, more air particles hitting an object produce a higher pressure than fewer particles. When blowing up a balloon, you place more air particles inside the balloon, thus increasing the pressure. This has the effect of increasing the size of the balloon.

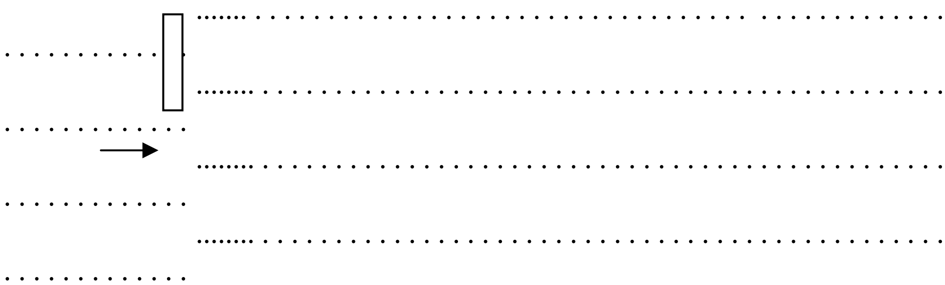
The sequence of diagrams in Figure 3 shows how a soundwave moves away from a source, causing areas of high pressure and low pressure. Remember, areas of high pressure are where particles have been pushed together and areas of low pressure are where particles have been pushed apart.

FIGURE 3: MOVEMENT OF SOUND FROM A SOURCE

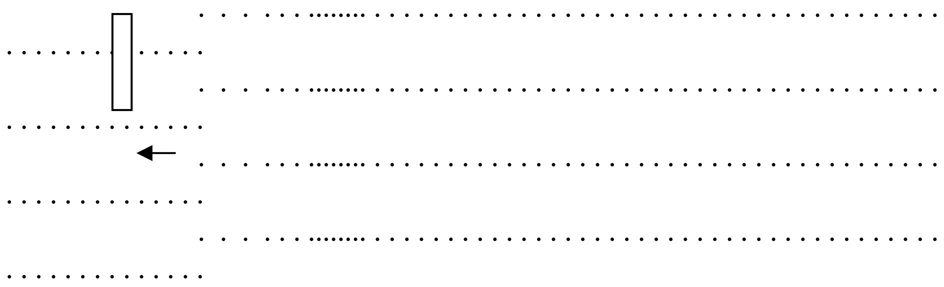
Stationary source



Source moves to the right, pushing air particles together

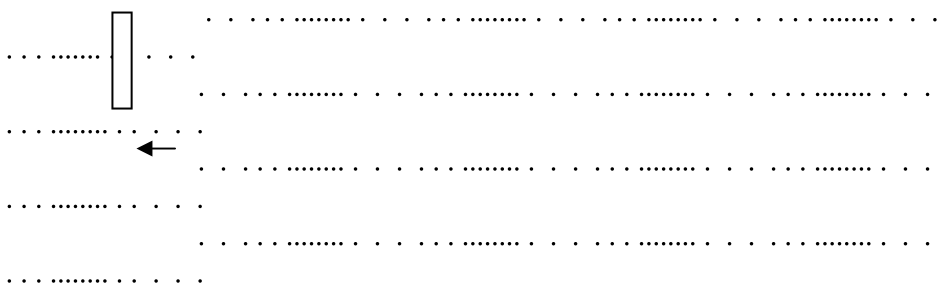


Source moves to the left, pushing particles apart



The individual particles move backwards and forwards (vibrate) at the same frequency as the source, so, after a while,

the pattern looks like this



The regions of high pressure are called ‘compressions’. The regions of low pressure are called ‘rarefactions’. These pressure regions move away from the source in all directions in the form of pressure waves. We call these pressure waves ‘soundwaves’.

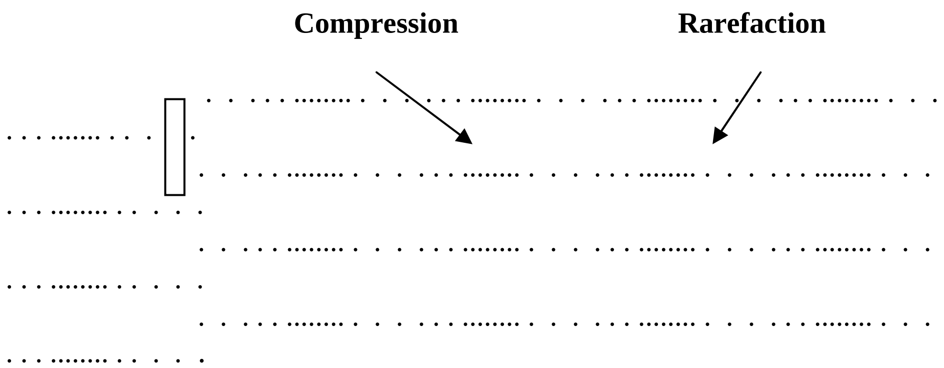
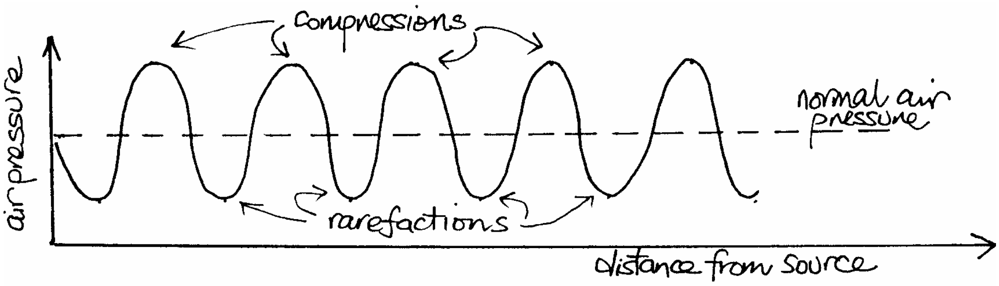


FIGURE 4: COMPRESSIONS AND RAREFACTIONS IN SOUNDWAVES

A graph of pressure in the air from the source is shown in Figure 5.

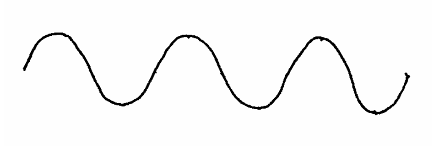
FIGURE 5: GRAPH OF PRESSURE WAVE



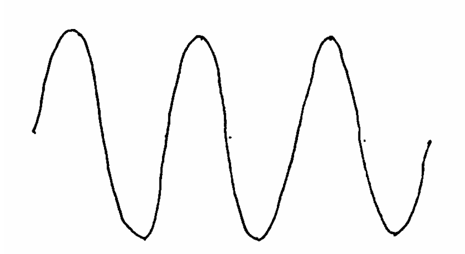
Graphs like that shown in Figure 5 are produced using a microphone, amplifier and cathode ray oscilloscope (CRO), which acts like a television screen. The vibrations in the microphone cause alternating currents and voltages in the electrical circuit, which are then viewed on the CRO screen: the larger the vibrations (this gives a louder sound), the higher the peaks and troughs on the pressure graph. The higher the frequency of vibration, the more quickly the variation in pressure occurs, and the pressure pattern bunches up (see Figure 6).

FIGURE 6: PRESSURE WAVE PATTERNS FOR DIFFERENT SOUNDS

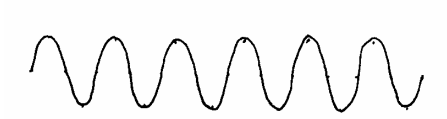
Normal sound pressure pattern



Louder sound pressure pattern



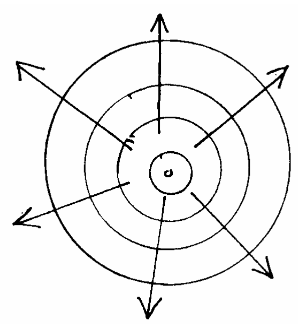
Higher frequency sound pressure pattern



Soft high-frequency sound pressure pattern

In two dimensions, sound is often pictured as water waves. Imagine a pebble thrown into the centre of a pond. The ripples caused by the pebble move away in ever-expanding circles. This analogy models a sound source where the compressions/rarefactions move away from the source in ever-expanding circles (see Figure 7). A continuing sound will have compressions followed by rarefactions followed by more compressions and rarefactions.

FIGURE 7: WAVES IN TWO DIMENSIONS

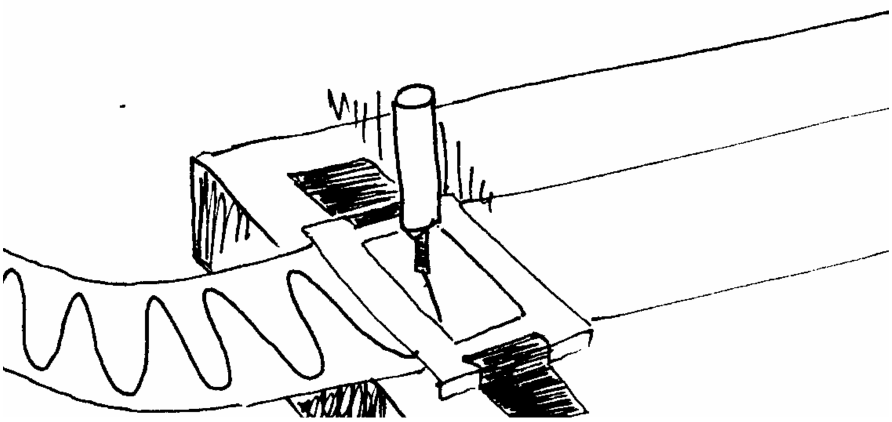


ACTIVITY: VISUALISING PRESSURE PATTERNS FROM SOUNDWAVES

You need a long strip of paper, such as a roll of paper used in a cash register for printing receipts. Make a sleeve so that the strip can move freely through it. The top of the sleeve should have a rectangular window (refer to the figure below). Attach the sleeve to a bench.

The strip of paper should be fed through the sleeve at a constant rate. At the same time, someone vibrates a texta pen, drawing on the paper through the window. A wave pattern is then observed on the paper that has been fed through the sleeve. Look at the patterns for large vibrations (these model loud sounds) and high/low frequencies with the pen (these model high/low frequency sounds).

FIGURE: VISUALISING PRESSURE PATTERNS



Explanatory note: After completing a few patterns, make predictions as to the shape of the patterns formed. Connect each pattern to the type of sound it represents: soft/loud sound and/or high/low frequency.

Resonance

As mentioned earlier, most sounds we hear are a result of resonance. Resonance is responsible for sounds, such as those heard from musical instruments, and for speech and hearing. The simple tapping of a pencil on a desk is a resonance effect. Resonance is simply the amplification of certain frequencies from a sound source. Resonance occurs when a sound source is near a region called a resonating cavity or resonating chamber. For example, an acoustic guitar has strings and a sound box. When a string is plucked, it begins to vibrate with a large number of frequencies. Sounds of these different frequencies travel into the sound box reflecting back and forth inside the box. Some of the frequencies reflect back on themselves in such a way as to add to the incoming wave, thus producing an enhanced wave effect. To imagine this effect, consider a child on a swing being pushed by another person. If the pushes on the child are timed just right (that is, at a certain frequency) the child will reach ever-increasing heights. However, if the pushes occur at other times (other frequencies), greater heights cannot be reached.

The frequencies where this enhanced wave effect occurs in the resonating chamber are called ‘resonant frequencies’. These amplified waves do not change the frequency of the wave, only the size of the travelling disturbances, so the loudness of the wave increases. In this way, the frequencies in the sound box match many of those in the string, so sound is amplified. The resonating chamber does not amplify all the frequencies in the sound source. Each time you pluck the string of a guitar, different combinations of frequencies are generated but we hear the same note each time because of the resonant frequencies.

Quite simple sounds, such as tapping on a table, produce many frequencies at the point of tapping, but the tabletop itself becomes the resonating chamber to amplify the resonant frequencies that we hear. Your own voice is the product of resonance. The vocal cords at the base of the throat are caused to vibrate by bringing air up through them. Many frequencies are produced here. However, the throat, mouth and nasal cavity form the resonant chamber for resonant frequencies to be produced. These resonant frequencies in the throat and mouth are called ‘formant frequencies’. To change the frequencies of our voice (that is, to speak different words), we just change the shape of the resonant chamber, mainly by the placement of our tongue and the shape of our mouth. In doing so, we amplify a different set of frequencies that are present at the vocal cords.

The resonating chamber does not need to be enclosed. For example, a flute has an open end. Blowing over the mouthpiece creates turbulence in the air and a number of frequencies are produced. The resonating chamber is the cylinder of the flute, where soundwaves are not only reflected at the closed end but also at the open end. Differently shaped resonating chambers can be achieved by opening and closing holes along the cylinder. This has the same effect as changing the length of the resonating chamber. Therefore, closing and opening holes amplifies different frequencies generated at the mouthpiece.

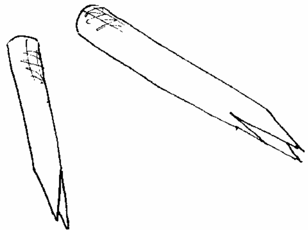
You may now wish to consider other musical instruments. For each instrument:

- What is producing the sound source?
- What is the resonating chamber?
- How does the resonating chamber change to produce different resonant frequencies? If the resonating chamber does not change (such as in a guitar), how does the sound source change to produce different frequencies?

Amplifying sounds

ACTIVITY: STRAW WHISTLE

Squeeze the end of a drinking straw so that approximately 2 to 3 cm is flattened. Trim the corners with scissors as shown in the figure below. Place the trimmed end in your mouth and try to produce a steady musical sound by blowing. How is the sound being made? Cut the straw in half. What effect does this have on the sound produced? You can join straws together to make one long straw. Alternatively, if you have a wider straw to fit over your first straw, you can slide it up and down to change the length. What musical instrument works like this?



Explanatory note: The sound source is the vibrating pointed end of the whistle. The resonating chamber is the tube part of the straw: the longer the tube, the lower the resonant frequencies produced.

ACTIVITY: RECORDER NOTES

Play some notes covering and uncovering the holes on a recorder. Investigate how the frequency of the sound played varies with covering and uncovering the holes.

Explanatory note: Opening and closing the holes has the effect of changing the shape of the resonating chamber.

ACTIVITY: SINGING BOTTLES

Collect a number of bottles (for example, wine bottles, soft-drink bottles) and fill them to varying heights with water. Place the bottles in a line from most full to empty. Blow over the top of each bottle to create a sound. How is the sound produced? What effect does the water level have on the sound? Now tap each bottle on the side with a pencil. How is the sound produced? What effect does the water level have on the sound produced?

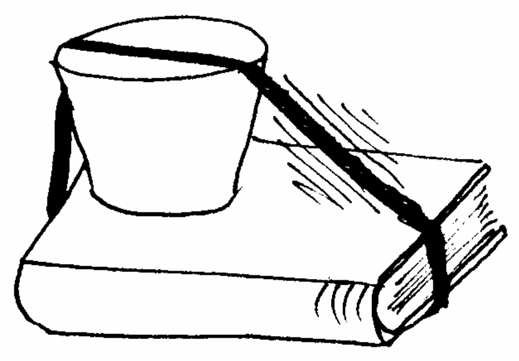
Explanatory note: When you blow over the top of the bottle, the sound source is the vibrating air at the mouth of the bottle. The resonating chamber is the air space inside the bottle: the greater the space, the lower the frequencies that are amplified. When you tap the bottle, the sound source is at the point of contact. The resonating chamber is the glass and water inside the bottle: the greater the depth of water, the greater the size of the resonating chamber and the lower the frequencies that are amplified.

ACTIVITY: ELASTIC-BAND GUITAR

You will need:

- **an elastic band**
- **a hardcover book**
- **a plastic cup.**

Stretch the elastic band around the book and the cup (refer to the figure below). Pluck the band in various places. Can you create three notes with this instrument? How is the sound being produced? Without changing the position of the cup, by adjusting the elastic band, can you make the longest section of the band give a higher frequency note? Can you make it play the lowest frequency note? Can you think of a reason why?



Explanatory note: The elastic band provides the sound source and the cup is the resonating chamber. The chamber cannot be changed, so, to amplify different frequencies, the sound source is changed. This is achieved by changing the tension in the elastic band: the tighter the elastic band, the higher the frequencies that are amplified by the cup.

The speed of sound

It has already been mentioned that sound travels at different speeds depending on the material through which it travels. The following table gives some common values. If you multiply the speeds in m/s by 3.6, the values will then be in km/h.

TABLE 1: COMMON VALUES FOR THE SPEED OF SOUND IN DIFFERENT MATERIALS

Material	**Speed (m/s)**
Air (0 ˚C)	266
Air (20 ˚C)	331
Rock	1500–3500
Water	1410–1500
Iron	5000

Determining the speed of sound in air

ACTIVITY: STARTING PISTOL METHOD

You will need:

- **a calculator**
- **stopwatches**
- **a starting pistol**
- **a measuring tape.**

You can obtain a reasonable value for the speed of sound in air using this method. Over distances of 100 m, 200 m and 300 m, record the time between seeing the smoke of the pistol shot and hearing the sound that the pistol makes. Take several readings at each distance and average out your results. By dividing the average time into the distance travelled, you can obtain the speed in m/s. Multiplying your speed calculation by 3.6 will give the speed in km/h.

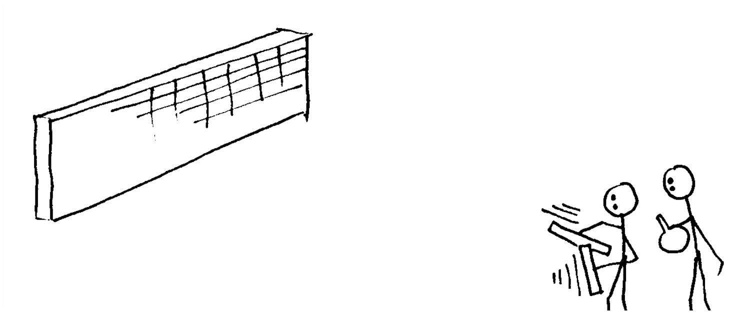
ACTIVITY: ECHO METHOD

You will need:

- **a stopwatch**
- **a long measuring tape**
- **a hammer**
- **a piece of steel.**

Another method for obtaining a value for the speed of sound in air makes use of echoes. You will need to do this outdoors where you have a distance of at least 100 m of open space facing a brick or concrete wall, without any nearby walls on either side. The idea is that you make a repeated sound (banging the metal with a hammer) at a constant rate so that the echo (reflection) of one sound arrives back at you at exactly the time you make the next sound. When the person making the sound is beating in rhythm with the echo, another person times the completion of ten hits. As the sound travels 200 m for each echo, then for ten beats this is the equivalent of the sound travelling 2000 m. By dividing the time into 2000 m you will have calculated the speed of the sound in m/s.

FIGURE: DETERMINING THE SPEED OF SOUND THROUGH ECHOES



Sound and hearing

Our ears can detect an enormous range of sound energies, which relate to a large variation in vibrations or pressure differences. Our perception of variation of sound is based on changes in the loudness and frequency of the sound. However, the sensitivity to our hearing of sounds varies with the frequency of the sound.

A scale of loudness that is commonly used for sound levels is the decibel scale. Some typical values are found in Table 2.

TABLE 2: SOME TYPICAL VALUES OF SOUND INTENSITY

Sound intensity (dB)	**Example**
0	Gently rustling leaves
35	Talking
60	Cheering at the football
80	A lawn mower
100	Lightning close by
120	A jet taking off close by

ACTIVITY: MEASURING THE LOUDNESS OF SOUNDS

A sound-level meter measures the loudness of sounds. Obtain a sound-level meter and test out the sound levels for different sounds. How does the loudness of a sound vary with distance from a source inside a room? Is there any difference to the way sound varies with distance in the open? Do two people talking double the sound level in decibels?

Explanatory note: The loudness of a sound drops by 3 dB as you double the distance from the source. The loudness increases by approximately 3 dB when the sound from one source is doubled. The effects can change in an area with walls versus an area in the open. Loudness levels vary little in a room, as sounds reflect from walls, floors and other objects in the room.

ACTIVITY: MEASURING THE FREQUENCY OF SOUNDS

You need two audio frequency oscillators that give out sound at specific frequencies. If two sound sources have frequencies that are only slightly different, the combined sound will be heard as beats. When a sound is beating, the sound will wax and wane in a regular pattern. Investigate this phenomenon with the two audio frequency oscillators. Try this technique to determine the frequency at which you hum. This technique is used by guitarists in tuning their instruments.