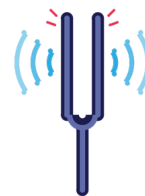


Sound and seismic waves

GCSE Physics — revision notes



How to use these notes: cover the right-hand column. Read each question and answer it from memory, out loud or on paper, then uncover and check. Mark the ones you missed and come back to them.

1. What a sound wave is

Questions	Key points
How is a sound made?	- an object vibrates (loudspeaker cone, guitar string, vocal cords) - moves forward → pushes air particles closer together - moves back → leaves particles more spread out - each layer of air pushes the next → pattern travels outwards
What are compressions and rarefactions?	compression: particles pushed closer together rarefaction: particles more spread out
Why is sound a longitudinal wave?	particles vibrate backwards and forwards along the direction the wave travels
Does the air travel with the wave?	- no: each particle vibrates about the same spot, passes the energy on - the wave travels; the air doesn't
Why can't sound travel through a vacuum?	- sound needs a medium (solid, liquid or gas) - vacuum (e.g. space) → no particles to pass the vibrations on

Summary vibrating object → compressions and rarefactions travel out. Longitudinal. Particles only vibrate in place. Needs a medium, so no sound in a vacuum.

2. Pitch, loudness and seeing a sound

Questions	Key points
What is frequency?	- number of vibrations (waves) each second - unit hertz (Hz); 1 kHz = 1000 Hz 500 Hz source → 500 waves every second
What does pitch depend on?	frequency: higher frequency → higher pitch - violin string vibrates faster than cello string → higher notes

What does loudness depend on?	• amplitude: bigger amplitude → louder • bigger amplitude → wave carries more energy • hit a drum harder → bigger amplitude
How does an oscilloscope show a sound?	• microphone turns sound into an electrical signal • oscilloscope draws it as a line: how the signal changes with time • taller trace → bigger amplitude → louder • more waves across the screen → higher frequency → higher pitch • trace <i>looks</i> transverse, but sound is still longitudinal
How do you find the frequency from the screen?	• read the time period, T: time for one complete wave (squares × time per square) • $f = 1 / T$ (T in seconds) • e.g. 4 squares × 0.5 ms = 2 ms = 0.002 s → $f = 1 \div 0.002 = 500 \text{ Hz}$
Pure note vs noise on the screen?	• tuning fork / signal generator + loudspeaker → smooth wave, repeats regularly • spoken word or crash → jagged trace, no repeating pattern

Summary pitch = frequency, loudness = amplitude. On an oscilloscope: taller = louder, more waves = higher pitch. $f = 1 / T$.

3. Sound passing from one material to another

Questions	Key points
How does sound get through a solid?	• sound reaches the solid → its particles vibrate → wave carries on through it • e.g. hearing through a closed door; the door makes the air on the far side vibrate
How does the speed of sound depend on the material?	• usually fastest in solids, slowest in gases • air about 340 m/s, water about 1500 m/s, steel about 5000–6000 m/s
What changes, and what doesn't, when sound enters a new material?	• frequency stays the same (set by the source: one vibration in → one vibration out) • speed changes • so wavelength changes • $v = f \times \lambda$ (wave speed = frequency × wavelength), so $\lambda = v \div f$ • faster → longer wavelength; slower → shorter
Example: 500 Hz sound from air into water?	• in air: $\lambda = 340 \div 500 = 0.68 \text{ m}$ • in water: still 500 Hz, $\lambda = 1500 \div 500 = 3.0 \text{ m}$
What if the wave meets the boundary at an angle?	• change in speed changes its direction → refraction

What can happen to sound at a boundary?

- **reflected:** bounces back = an **echo** (hard, smooth surfaces reflect well)
- **transmitted:** carries on into the new material
- **absorbed:** energy taken in by the material (curtains, carpet, foam absorb well)
- usually a mix of all three

Summary new material → same frequency, new speed, so new wavelength ($v = f \times \lambda$). At a boundary sound is reflected, transmitted or absorbed.

4. How you hear: inside the ear

Questions	Key points
What are the five stages of hearing?	• 1 outer ear collects sound → down the ear canal • 2 ear drum (thin, tight membrane) vibrates at the same frequency as the sound • 3 three tiny bones (middle ear) pass the vibrations to the inner ear • 4 vibrations pass into the liquid in the cochlea (coiled tube) → move tiny hair cells • 5 hair cells send electrical signals along the auditory nerve → brain
What is the key idea for exams?	• sound wave in air → vibrations of solids (ear drum, bones) → electrical signals
Other examples of sound turning into vibrations in solids (and back)?	• hearing through a wall: air → wall vibrates → air on the other side • tuning fork held on a table: table top vibrates too, moves more air → louder • microphone: sound makes a diaphragm vibrate → electrical signal • loudspeaker: the reverse

Summary air → ear drum → three bones → liquid in cochlea → hair cells → electrical signals along the auditory nerve to the brain.

5. The limits of human hearing

Questions	Key points
What is the range of human hearing?	• 20 Hz to 20 kHz (20 000 Hz) • outside this range: still sound waves, ears just can't detect them
What are ultrasound and infrasound?	• ultrasound: frequency above 20 000 Hz • infrasound: frequency below 20 Hz

Why is the range of hearing limited?	- hearing needs the ear drum and small bones to vibrate in step with the sound - a solid only vibrates well over a certain range of frequencies (set by its size, mass, stiffness) - outside that range, ear drum and bones hardly vibrate → almost nothing reaches the cochlea - however loud the sound, you won't hear it
Which range does the ear hear best?	- small bones pass on about 1 kHz to 3 kHz most efficiently - a quiet sound in this range is easier to hear
How does hearing change with age?	- range gets narrower; highest frequencies go first - hair cells in the cochlea for high frequencies are gradually lost - loud noise damages them too
Do other animals hear the same range?	no: dogs and bats hear ultrasound; elephants communicate using infrasound

Summary humans hear 20 Hz to 20 kHz, best 1 to 3 kHz. Above = ultrasound, below = infrasound. Limited because the ear drum and bones only vibrate over a set range. Top end falls with age.

6. Ultrasound and echoes

Questions	Key points
What happens when ultrasound meets a boundary?	- boundary between two different materials (e.g. two body tissues) partial reflection: part reflected, the rest carries on to the next boundary - one pulse in → a series of echoes, one from each boundary
What does a transducer do?	- sends out short pulses of ultrasound and detects the echoes - further away boundary → echo takes longer to come back
How do you work out the distance to a boundary?	- echo goes there and back distance travelled = speed × time distance to the boundary = $\frac{1}{2} \times \text{speed} \times \text{time}$
Example: soft tissue, 1500 m/s, echo after 80 μs?	80 μs = 0.000 08 s - distance travelled = 1500 × 0.000 08 = 0.12 m - boundary is half: 0.06 m = 6 cm below the skin

Summary ultrasound partly reflects at each boundary. Time the echo, then distance = $\frac{1}{2} \times \text{speed} \times \text{time}$.

7. Ultrasound imaging in medicine and industry

Questions	Key points
How is a body scanned with ultrasound?	- transducer moved across the skin - echoes from each tissue boundary are timed → computer builds a picture - uses: prenatal scans (baby in the womb), organs (e.g. kidneys), damaged ligaments and muscles
Why ultrasound, not X-rays, for a baby scan?	- ultrasound is non-ionising: not enough energy to ionise atoms → doesn't damage cells like X-rays can → safe for mother and baby - reflects from boundaries between soft tissues → shows organs; X-rays pass through soft tissue, mostly show bone
How does ultrasound find flaws in metal?	- a crack in a casting or weld is a boundary - pulse reflects partly from the crack, partly from the far side - screen shows an extra spike between the front and back spikes - its position shows how deep the crack is; no need to cut the part open

Summary timed echoes build images: prenatal scans, organs, cracks in metal. Ultrasound is non-ionising, so safer than X-rays.

8. Echo sounding and sonar

Questions	Key points
What is echo sounding?	pulses of high-frequency sound used to measure water depth and find objects under water
How does echo sounding measure depth?	- transmitter under the ship sends a pulse down - pulse reflects from the seabed - receiver on the ship detects the echo - time measured → depth = $\frac{1}{2} \times \text{speed} \times \text{time}$
Example: sea water 1500 m/s, echo after 0.4 s?	depth = $\frac{1}{2} \times 1500 \times 0.4 = \mathbf{300 \text{ m}}$
What else can it find? What is sonar?	- shoals of fish, shipwrecks, submarines: anything that reflects the pulse → earlier echo sonar = SOund Navigation And Ranging

Summary ship times the echo from the seabed; depth = $\frac{1}{2} \times \text{speed} \times \text{time}$. Objects give earlier echoes. This is sonar.

9. Infrasound and seismic waves: looking inside the Earth

Questions	Key points
What are seismic waves?	- produced by earthquakes, travel through the Earth - mostly low frequency, well below 20 Hz → infrasound - recorded by seismometers at stations around the world
How do P-waves and S-waves differ?	P-waves: longitudinal; travel through solids and liquids; faster, arrive first S-waves: transverse; travel through solids only, not liquids; slower
What do S-waves tell us about the core?	- S-waves never arrive on the far side of the Earth from an earthquake - can't travel through liquids → part of the core is liquid: the outer core
What do P-waves tell us?	- they get through, but change speed at the edge of the core → refracted (bent) - leaves a ring on the surface where no P-waves arrive: a shadow zone
Why do the waves curve through the mantle?	their speed changes with depth
How was the size of the core worked out?	- from where the shadow zones start and end - new evidence about places no one can see directly (nobody has drilled near the core)

Summary P = longitudinal, solids and liquids, faster. S = transverse, solids only. No S-waves on the far side → liquid outer core. Shadow zones give the core's size.

10. The mistakes that cost marks

Questions	Key points
"The frequency changes when sound goes into water." What's wrong?	- it doesn't - write: "the frequency stays the same; the speed changes, so the wavelength changes"
What do people forget in echo calculations?	- to halve: the echo goes there and back - distance to the boundary = $\frac{1}{2} \times \text{speed} \times \text{time}$
"We can't hear ultrasound because it's too quiet." What's wrong?	- loudness has nothing to do with it - write: "its frequency is above 20 000 Hz, the upper limit of human hearing"

"The brain can't process high frequencies." What's the right reason?	• "the ear drum and small bones can only vibrate over a limited range of frequencies"
"Ultrasound is safer because it's weaker." What's the right reason?	• "ultrasound is non-ionising, so it doesn't damage cells the way X-rays can"
"S-waves can't travel through the core." How do you make it exact?	• "S-waves can't travel through liquids, and the outer core is liquid"
Is sound transverse because the oscilloscope trace looks transverse?	• no: the screen draws it as a line; sound is longitudinal
Which units slip people up?	• 20 kHz = 20 000 Hz • 1 ms = 0.001 s; 1 μs = 0.000 001 s • change to hertz and seconds before using an equation
Summary frequency never changes between materials. Halve echo distances. Ultrasound is too high, not too quiet. Non-ionising, not weaker. S-waves stop at liquid. Convert units first.	