CfE Sound – B McMULLEN

Musical Instruments

musical instruments produce sound energy due to part of an instrument that vibrates.

Instrument	What is vibrating?
Guitar	Strings
Clarinet	Air column
Drum	Head of the drum
Voice box	Air

- All sounds are produced as a result of vibrations through the air.

- All sounds are made of some kind of vibration. If the vibrations are very fast or very small or both, our eyes cannot detect them and the object appears to be still.

Frequency

- This is defined as the number of waves produced per second.

- Frequency is measured in Hertz (Hz).

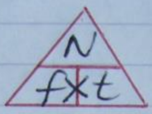
- The musical term for frequency is pitch.

Frequency formula

$$f = \frac{N}{t}$$

- N → Number of waves
- t → time (s)
- f → frequency (Hz)

ie * 1 Wave per second = 1 Hz *

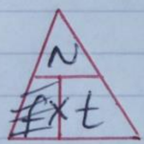


1. $N = f \times t$
2. $f = N/t$
3. $t = N/f$

Ex 1

Q Calculate the frequency of a source if it produces 300 waves in 2 minutes.

A
$N = 300$ waves
$f = ?$
$t = 2$ minutes $= 120$ s.

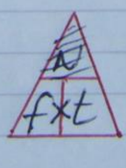


$f = \frac{N}{t} = \frac{300}{120} = \underline{2.5\text{Hz}}$

Ex 2

Q Calculate the number of waves produced from a 60Hz source in 4 minutes.

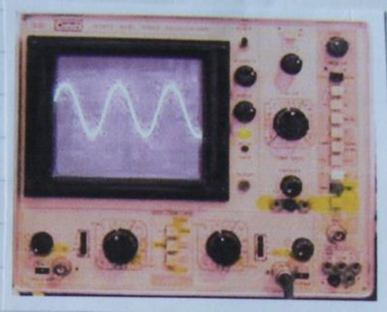
A
$N = ?$
$f = 60$ Hz
$t = 4$ minutes $= 240$ s



$N = f \times t$
$N = 60 \times 240$
$\underline{N = 14{,}400 \text{ waves}}$

Sound Waveforms

When we listen to sound waves through the air the waveforms can be viewed on an oscilloscope screen.



CRO
(Cathode Ray Oscilloscope)

We can analyse the waveforms on the screen in terms of the waves:

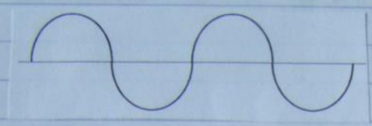
1) Amplitude ⇒ Height of the waveform
2) Frequency ⇒ Number of waves on the screen.

- The amplitude of the waveform is related to the energy of the sound wave ie how loud the sound is.

- The frequency of the waveform is related to the pitch of the sound wave. This is nothing to do with the loudness of the sound.

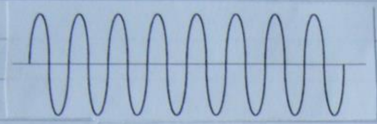
Sound Wave combinations

a)



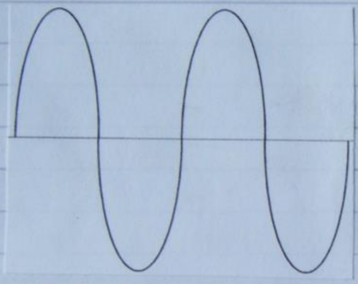
- Low Amplitude
- Low frequency

b)



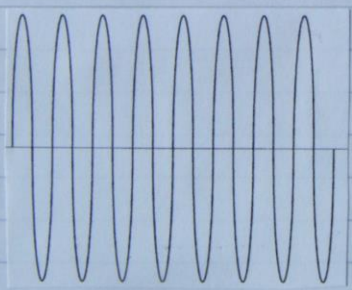
- Low Amplitude
- High Frequency

c)



- High Amplitude
- Low Frequency

d)



- High Amplitude
- High frequency

Conclusion

1) The taller the wave the louder the sound. (Amplitude).

2) The greater the number of waves the higher the pitch of the sound. (Frequency)

The Speed of Sound

The speed of sound can be compared when it travels through the three states of matter:
1) Solids
2) Liquids
3) Gases.

Ex3

Material	Speed of Sound (ms^{-1})
Air	340
Water	1,500
Glycerol	1900
Bone	4100
Aluminium	5200

Q a) i) Which state of matter has the largest speed of sound?

ii) Which state of matter has the lowest speed of sound?

b) Will high or low density materials have a low speed of sound?

A a) i) Solids

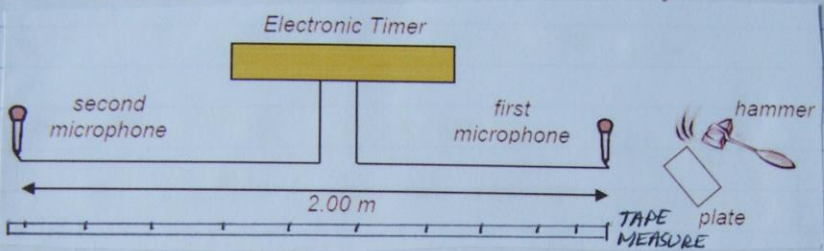
ii) Gases

b) Low density materials have a low speed of sound.

Speed of Sound Experiment

Aim: To measure the speed of sound in air.

Apparatus:



- Set the apparatus up as shown above
- Measure the distance between the two microphones with a tape measure.
- Hit the hammer off the plate at microphone 1 and the electronic timer starts.
- When the sound created reaches microphone 2, the electronic timer stops.

Results:

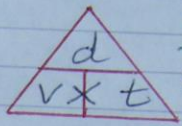
$$\text{Speed of sound} = \frac{\text{distance between microphones}}{\text{time taken for sound to travel from mic 1 to mic 2}}$$

Evaluation: Repeat readings of the times recorded will reduce the uncertainties.

Calculations with the speed of sound

$d = v \times t$

- d → distance travelled (m)
- v → Speed/velocity ($m.s^{-1}$)
- t → time taken (s)

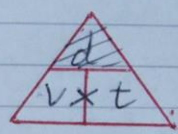


1. $d = v \times t$
2. $v = \frac{d}{t}$
3. $t = \frac{d}{v}$

Ex 4

Q Calculate how far sound will travel through air in 5 seconds.

A $d = ?$
$v = 340ms^{-1}$ (In DB!!)
$t = 5s$



$d = v \times t$
$d = 340 \times 5$
$d = 1700m$

(Speed of sound in air $= 340ms^{-1}$)

Ex 5

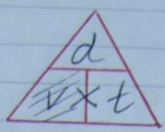
Q A clap of thunder is heard 8 seconds after the flash of light.

If the thunderstorm is 4km away then:

a) Calculate the speed of the sound in the air.

b) Why would the calculated speed in a) differ from $340ms^{-1}$, the accepted value for the speed of sound in air?

A a) $d = 4km = 4000m$
$v = ?$
$t = 8s$



$$v = \frac{d}{t} = \frac{4000}{8} = 500ms^{-1}$$

b) The speed of sound calculated (500ms⁻¹) is greater than $340ms^{-1}$.
This will be due to the moisture content in the air which will increase its density.

Ex6

Sonar equipment is used by fisherman to detect a shoal of fish swimming below them to catch in their nets.

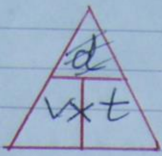
A pulse of sound is transmitted from the fishing boat with an echo detected 0·04 seconds later.

Q a) Calculate the total distance travelled by the sound pulse if the speed of sound in salt water is $1600ms^{-1}$.

b) Calculate the depth of the shoal of fish detected.

c) i) Predict the echo time recorded if no shoal of fish was present.
ii) Explain your answer in c) i).

A a) $d = ?$
$v = 1600 ms^{-1}$
$t = 0.04 s$



$d = v \times t$
$d = 1600 \times 0.04$
$d = 64m$

b) depth of shoal of fish $= \frac{\text{Total distance travelled}}{2}$

$= \frac{64m}{2} = 32m$

c) I) Echo time recorded would be greater than 0.04s.

II) The sound pulse would have to travel further before it reflected off the sea bed.

Sound Level

- Sound level is measured in decibels. (dB)
- Sound level is measured with a sound level meter or sound level indicator or a decibel meter.
-

Sound Level (dB)	Key Indicator
0	Threshold of hearing
80/90	Danger Level
140	Threshold of pain.

From the three key indicators you can estimate the sound level for any situation.

eg Quiet country lane = 20dB
Pneumatic drill at 5m = 100dB
Normal conversation at 1m = 60dB
etc

NB Sound level in decibels is a measure of the loudness of the sound and is not related to the frequency of the sound.

However the range of human hearing lies between 20Hz and 20,000Hz.

Sounds below 20Hz are called Infrasound.

Sounds above 20,000Hz are called Ultrasound.

Conclusion

- When we discuss sound level in decibels we assume that the frequency of the sound is between 20Hz and 20,000Hz.
- Unfortunately Mr McMullen cannot hear frequencies greater than 16,000Hz due to his age!!

How is the decibel reading related to loudness?

- If the sound level increases by 10dB then the sound is 10 times louder.
- If the sound level decreases by 10dB then the sound is 10 times quieter.

If we use normal conversation at 1m at 60dB as our standard, then the following table shows the relationship between sound level and loudness.

Sound Level (dB)	Loudness factor
30	÷ 1000
40	÷ 100
50	÷ 10
60	Standard Comparison
70	X 10
80	X 100
90	X 1000

ie
- A residental area at night at 40dB is 100 times quieter than standard conversation at 1m of 60dB.
- A heavy goods vehicle from the pavement at 90dB is 1000 times louder than standard conversation at 1m of 60db.

Applications involving sound

• Ultrasound with the unborn baby

Ultrasound scans are used to build up a picture of the unborn baby in the mothers womb (uterus).

High frequency sound waves reflect off the baby tissue as echoes. These echoes are built up and are turned into a computerised image. This image then shows the position and movement of the baby.

• Soundbars in flatscreen televisions

Flatscreen TV's are very thin compared to CRT (tube televisions)

They are a huge improvement aesthetically and in terms of HD picture quality.

However, the loudspeakers that they contain in such a small enclosure will not be able to reproduce the full range of audio frequencies.
The addition of a soundbar will bring the sound quality up to the same level as the HD picture quality.

• pneumatic drill operators

Pneumatic drill operators wear ear protectors to protect their hearing. (Not to protect their ears!!)

• materials used in ear protectors.

Foam should be used as it moulds itself to the contours of the ears. This stops the sound waves from entering the hearing mechanism as it absorbs most of the sound energy.

• Future uses of sound in medicine

Scientists are finding many more advanced applications of sound in medicine. It can be focussed and used for imaging and treating a variety of ailments. The ailments include cancer, strokes and Parkinson's disease.

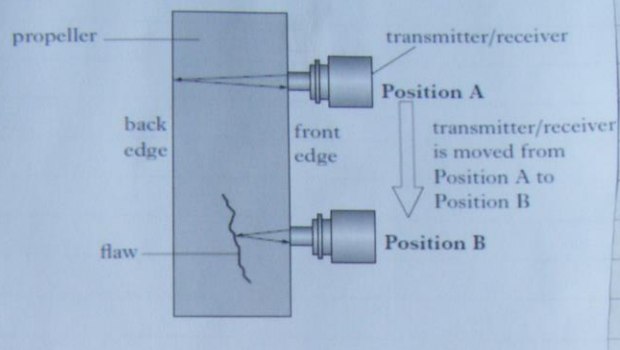
Sound waves can be focussed deep inside the body to control haemorrhages, they can assist doctors in delivering drugs to specific areas in the body tissue and can disrupt adverse bacterial biofilms.

Ex 7 Q

14

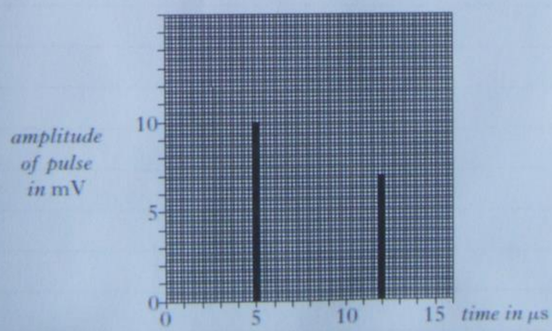
In the aircraft industry non-destructive metal testing is used to look for flaws in aluminium propellers.

Ultrasound pulses are sent from a transmitter into the propeller being tested. If there are no flaws in the propeller the ultrasound will be reflected from the back edge of the propeller as shown at position A. The reflected signal is detected by a receiver. If a flaw is present inside the propeller a reflection from the flaw will take place inside the propeller as shown at position B.



(*a*) What is meant by ultrasound?

(*b*) The graph shows the time taken between transmitting and receiving the pulses at positions A and B.



(i) State the time taken between transmitting and receiving the pulse at position B.

(ii) Use the data sheet to find the speed of the ultrasound waves in the aluminium propeller.

(iii) Calculate the distance of the flaw from the front edge of the propeller.

A a) Sounds of frequency greater than 20,000 Hz.

b) i) From graph $\Rightarrow t = 5\mu s$
$= 5\times10^{-6}s$.

ii) Speed of ultrasound waves in the aluminium propeller $= 5200ms^{-1}$.

iii) $d = ?$
$v = 5200ms^{-1}$
$t = 5\times10^{-6}s$

$d = v\times t$
$\Rightarrow d = 5200\times5\times10^{-6}$
$\Rightarrow d = 0.026m$

$d = 0.026m$ is the total distance travelled from the front edge of the propeller to the flaw and back

$\therefore$ distance from the front edge of the propeller to the flaw

$$= \frac{0.026m}{2} = 0.013m$$