SOUND WAVES

GUIDELINES

Light and sound

understand that sound waves are longitudinal waves which can be reflected, refracted and diffracted

know that the frequency range for human hearing is 20 Hz – 20 000 Hz

describe how to measure the speed of sound in air

understand how an oscilloscope and microphone can be used to display a sound wave

describe an experiment using an oscilloscope to determine the frequency of a sound wave

relate the pitch of a sound to the frequency of vibration of the source

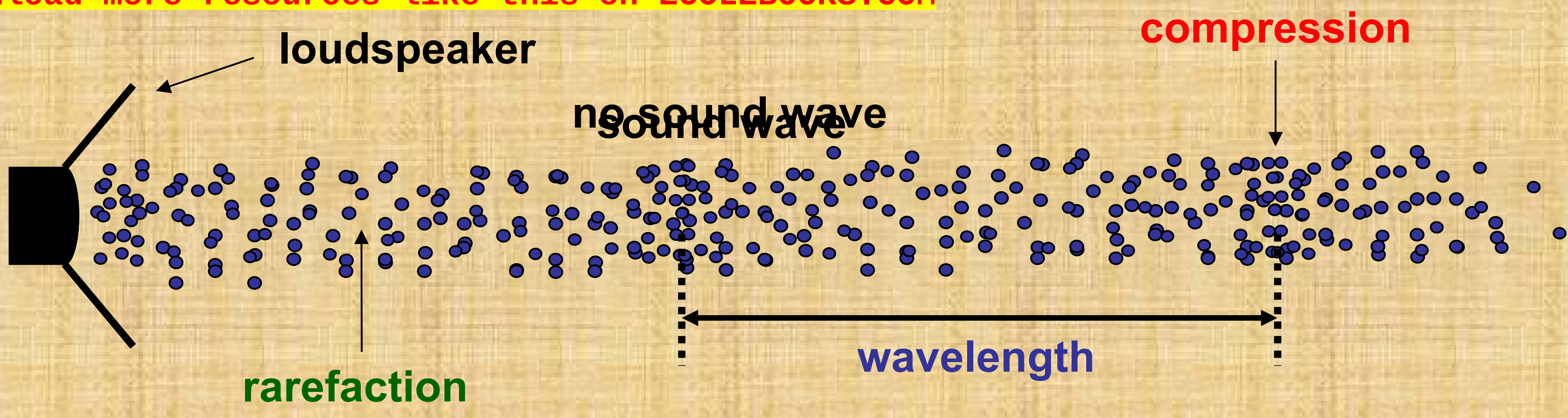
relate the loudness of a sound to the amplitude of vibration.

Sound

Sound is produced by vibrating objects.

A sound wave consists of mechanical vibrations in air and other substances.

Sound is a **longitudinal** wave in which the wave energy travels in the same direction as the particles within the wave vibrate.

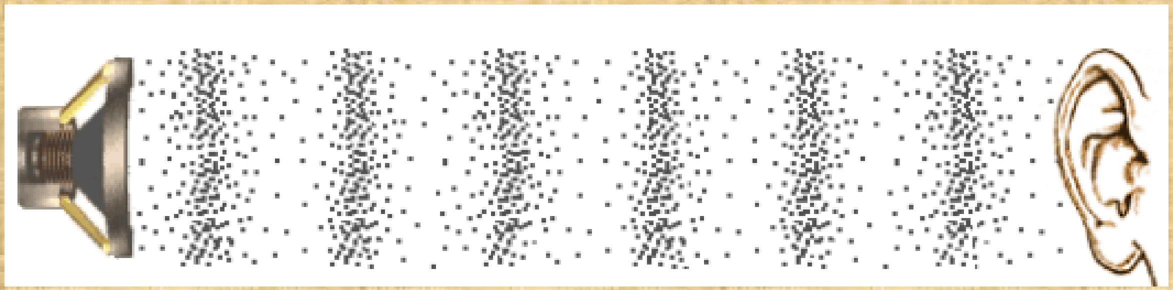


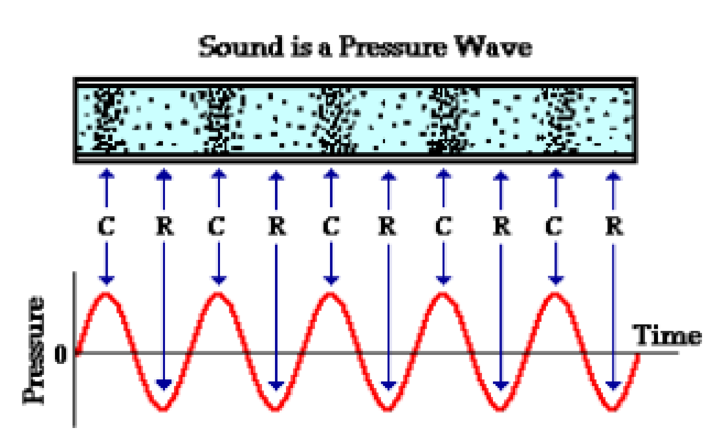
Through air a sound wave consists of a series of **compressions** and **rarefactions**.

A **compression** is a region of slightly higher pressure where the air molecules are closer together than usual.

A **rarefaction** is the opposite.

The **wavelength** of the sound wave is equal to the distance between the centres of two successive compressions.




Sound is a Pressure Wave
C
R
C
R
C
R
C
R
C
R
Pressure
0
Time

Range of hearing

Humans can hear sound frequencies in the range
20 Hz to 20 000 Hz.

Age and damage reduces the upper limit.
For example an old person or someone exposed to prolonged high sound volume may no longer be able to hear above 10 000 Hz.

Some animals can hear much higher frequencies:

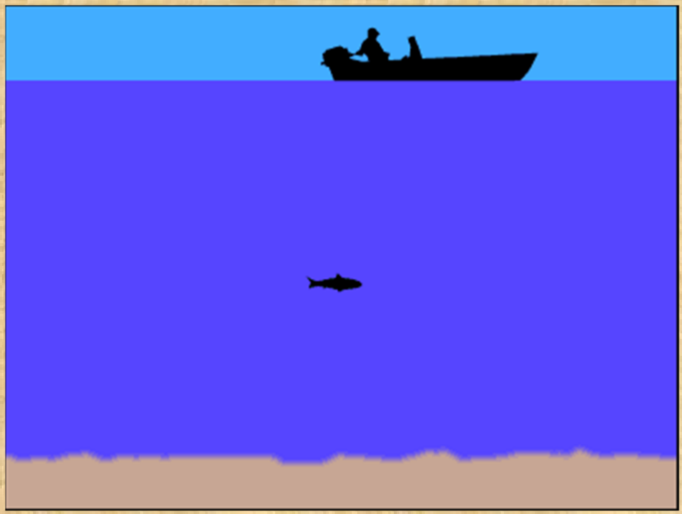
bats and dolphins:
up to 100 000 Hz

dogs – 40 000 to 60 000 Hz
(depends on the breed)


WANT TO PLAY?
I'LL KILL YOU!!!!

Ultrasound and Infrasound

Ultrasound is high frequency sound, above 20 000 Hz, too high to be heard by humans.



Ultrasound echoes can be used to measure distance (e.g. sonar) and to see inside objects (scans).

Infrasound is low frequency sound, inaudible to human, although we may feel the very slow vibrations.

Earthquake waves are a form of infrasound. Elephants and some other large animals can hear infrasound.

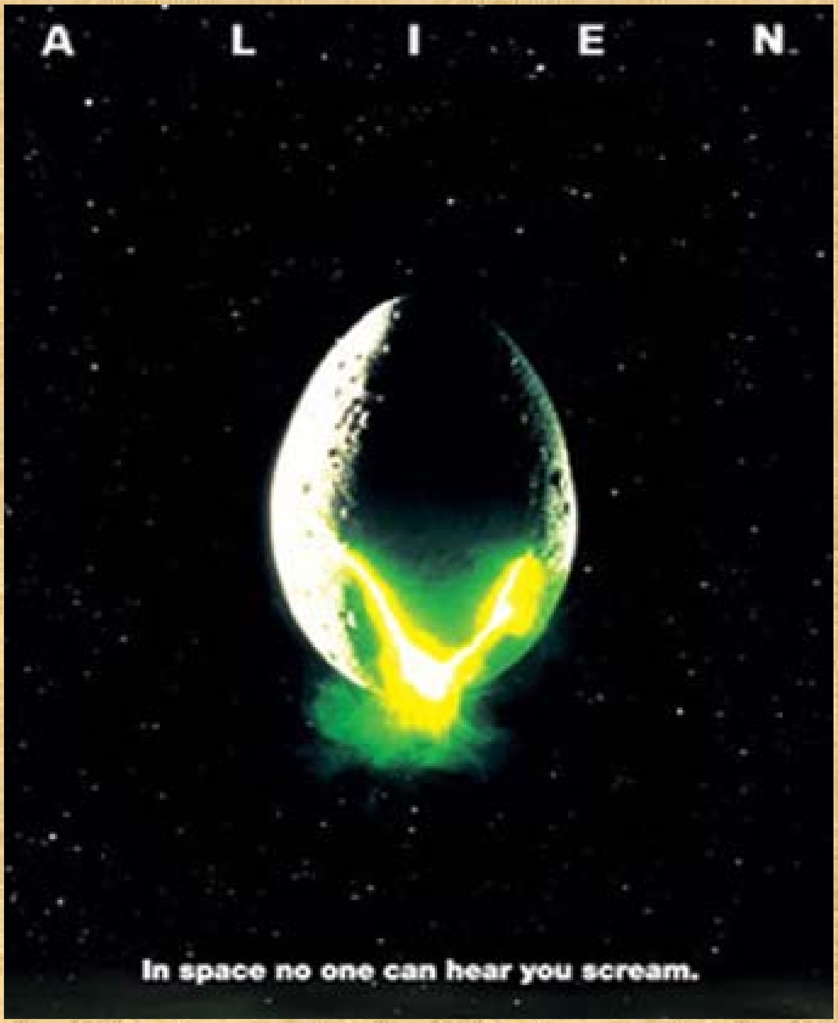
Sound waves in different materials

Sound travels quickest through solids.
A train can often be hared approaching through the rails before it can be heard through the air.

Sound travels well through liquids.
Whales can communicate over great distances under water.

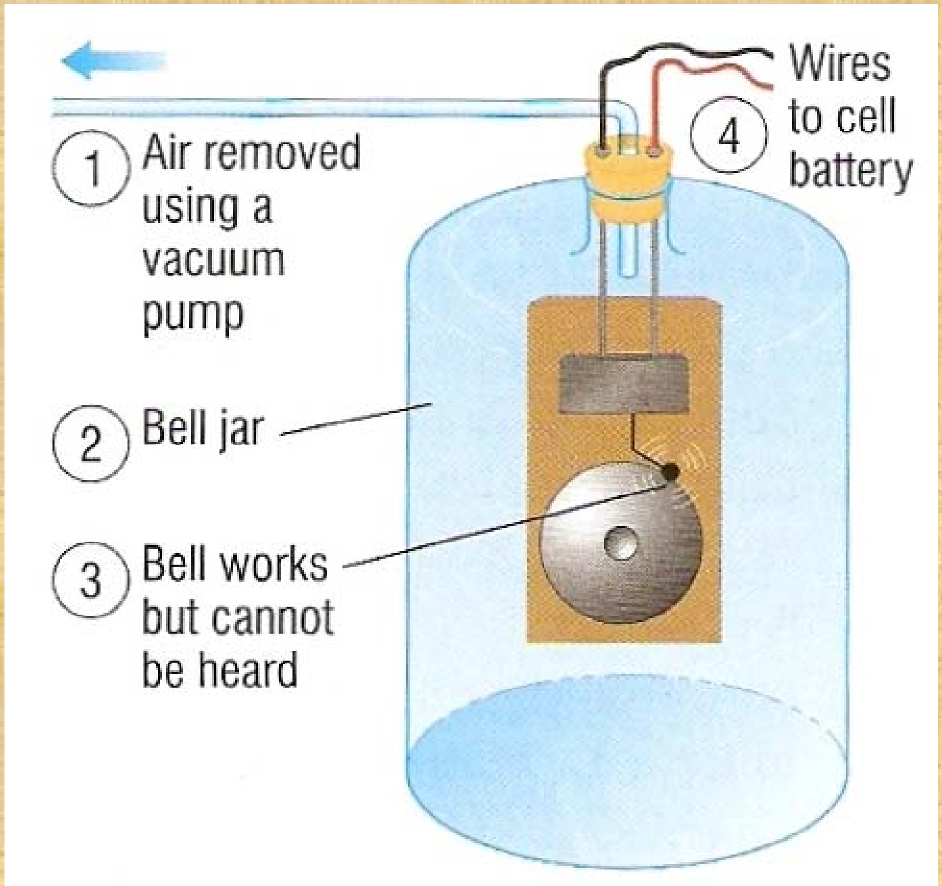
Sound travels slowest through gases.
The speed of sound increases with temperature.

Sound does not travel through a vacuum.
Sound does not travel in space.



Poster for the movie 'Alien' (1979)

Bell jar experiment



This experiment shows that sound needs a material medium for transmission.

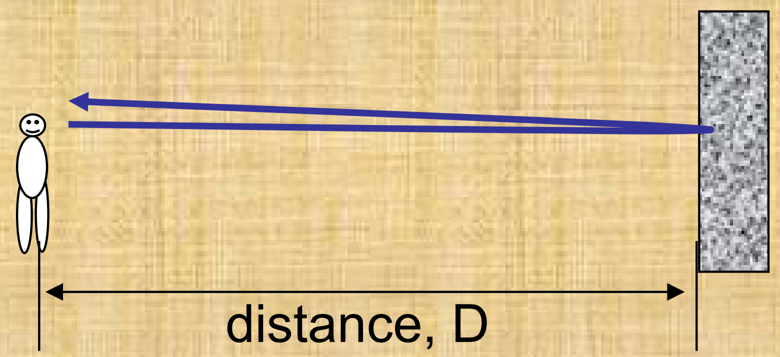
As the air pressure inside the bell jar is reduced the loudness of the sound heard outside decreases.

The bell can be still seen to be working normally.

Reflection of sound

An **echo** is a reflected sound wave.

Question:
A misguided child shouts 'Chelsea!' at a nearby cliff and hears an echo 1.4 s later. How far away is the cliff?
Take the speed of sound = 340 m/s.



The sound travels to and from the cliff, a total distance of 2D

speed = distance / time

becomes: ***distance = speed x time***

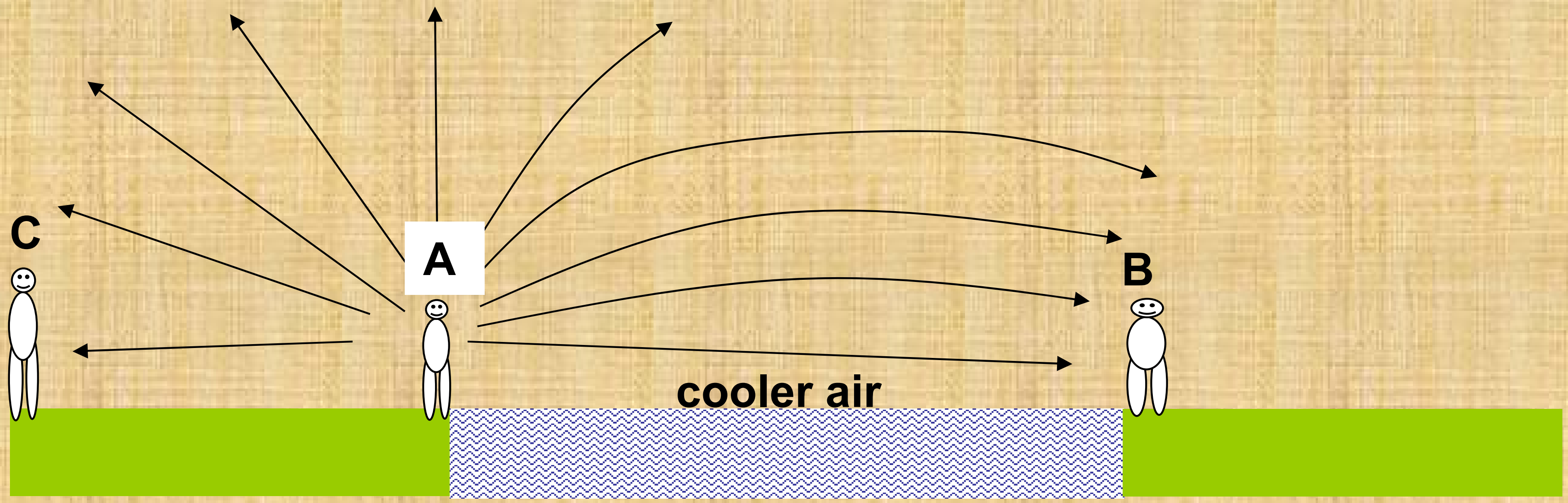
= 340 m/s x 1.4 s

= 476 m

= 2D !

Therefore distance to the cliff = 238 m.

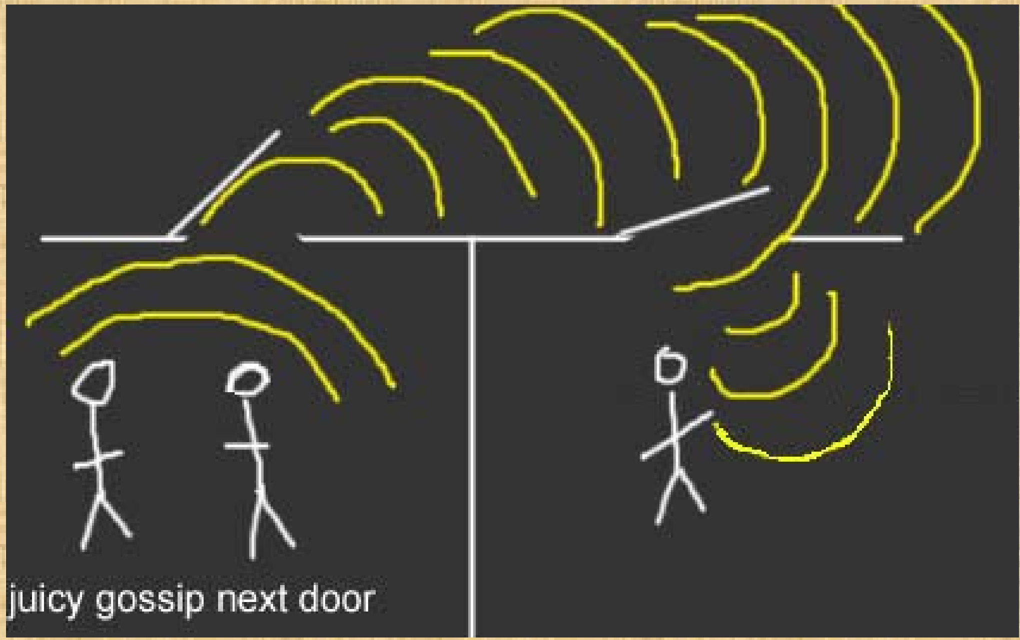
Sound refraction



The sound produced by person **A** may be heard more clearly by person **B** than by person **C**.

The cooler air over the water refracts the sound waves downwards.

Sound diffraction



A typical sound wave has a wavelength of about 1m.

This is similar in size to the aperture of a doorway.

Therefore sound undergoes significant diffraction at a doorway or around the corner of a building.

This is why we can hear someone in such circumstances even thought we cannot see them.

Why does light not diffract as much as sound?

The wavelength of light is about 0.000 5mm – much smaller than a door aperture.

Measuring the speed of sound

Method 1: Using a visible loud event

Use a stopwatch to time the difference between seeing and hearing the event (for example an explosion).

Measure the distance between the event an the timing position.

Speed = distance / time.

Note: The distance should be as large as possible in order to avoid significant reaction time error in the timing measurement.

Question

A group of students measured the time taken between seeing and hearing another student, 250 m away, clashing two pieces of wood together. They obtained the following timings in seconds: 0.73, 0.78, 0.69, 0.81, 0.77. Use their measurements to obtain a speed of sound estimate.

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average time = (0.73 + 0.78 + 0.69 + 0.81 + 0.77) / 5

= 3.78 / 5

= 0.756 s

speed = distance / time

= 250 m / 0.756 s

= 4 080 m

speed of sound = 331 m/s

Measuring the speed of sound

Method 2: Using echoes

Facing a flat vertical surface (wall or cliff) at least 50m away one person clashes two pieces of wood together. This person should try to clap the pieces of wood in time with the echo they hear coming back from the flat surface.

Another person times 20 claps on a stop-watch. They should count: 0, 1, 2 ,3 …. 20.

Measure the distance, ***D*** between the clapping person an the flat surface.

The total distance travelled by the sound will be 20 x **2*D***

Speed = total distance / time for 20 claps.

Question

In an experiment to measure the speed of sound by the echo method when a student stands 75m away from a wall 20 claps are heard over a time of 8.77s. Calculate the speed of sound.

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total distance travelled by the sound

= (20 x 2 x 75)m

= 3000m

speed = total distance / time for 20 claps

= 3000m / 8.77s

speed of sound = 342 m/s

Speed of sound examples

Substance and temperature	Speed in m/s
Air at 0ºC	330
Air at 20ºC	342
Air at -10ºC	325
Fresh water at 25ºC	1 497
Sea water at 25ºC	1 560
Steel at 20ºC	5 000
Vacuum	0

Mach numbers

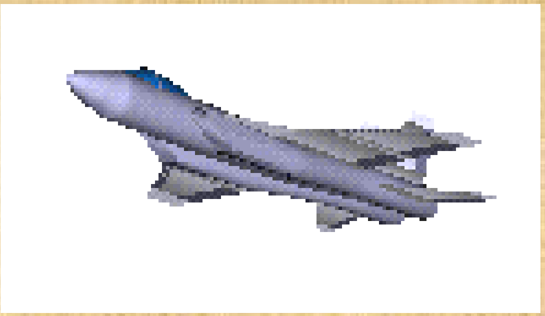
$$\text{Mach number} = \frac{\text{object speed}}{\text{speed of sound}}$$

Subsonic
Mach < 1.0

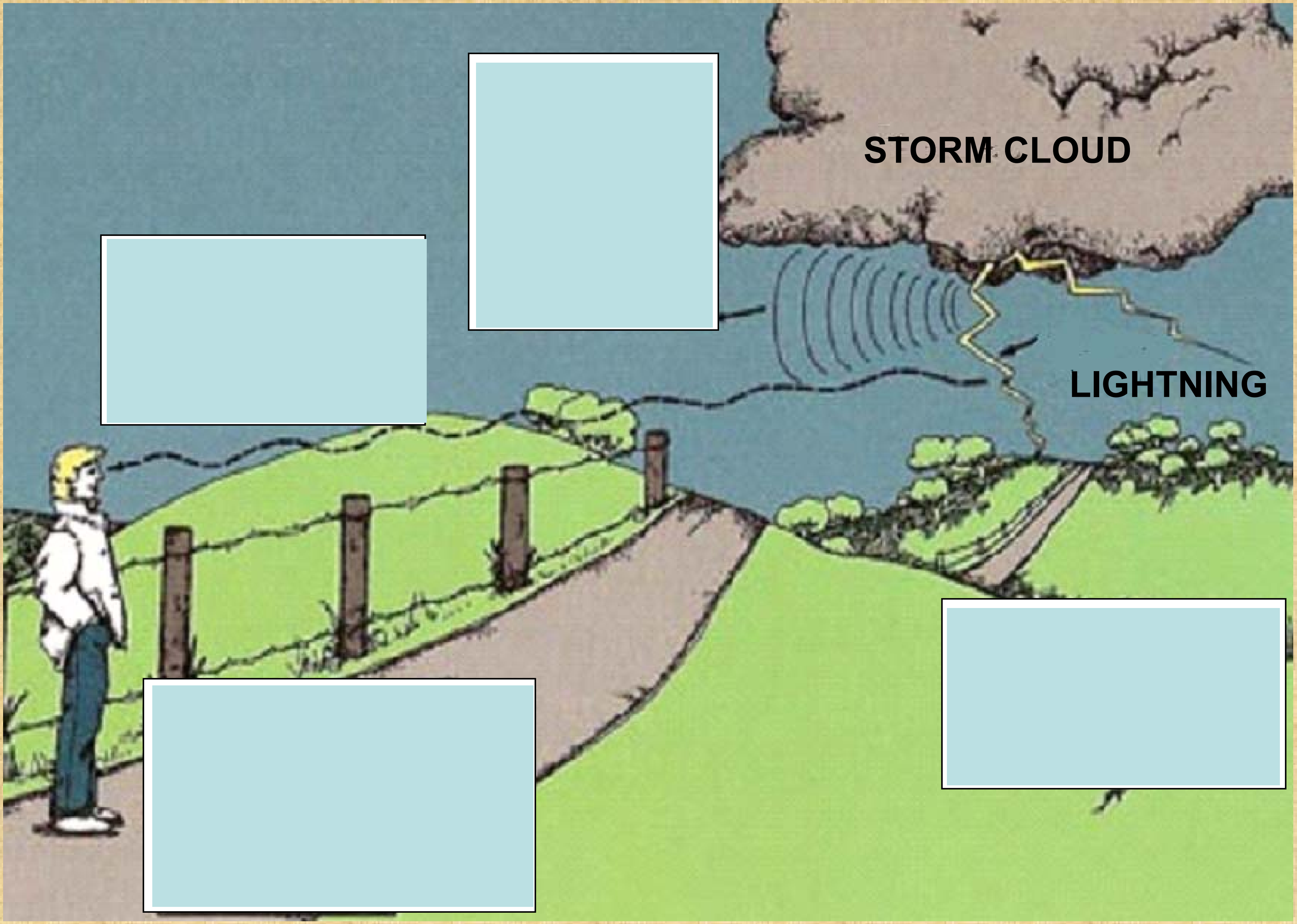
Transonic
Mach = 1.0

Supersonic
Mach > 1.0

Hypersonic
Mach > 5.0



Thunder and lightning



Thunder and lightning question

A thunderclap is heard 12 seconds after a lightning flash. Calculate the distance to the lightning flash.

Take the speed of sound = 340 m/s

Thunder and lightning question

A thunderclap is heard 12 seconds after a lightning flash. Calculate the distance to the lightning flash.

Take the speed of sound = 340 m/s

speed = distance / time

becomes: ***distance = speed x time***

= 340 m/s x 12 seconds

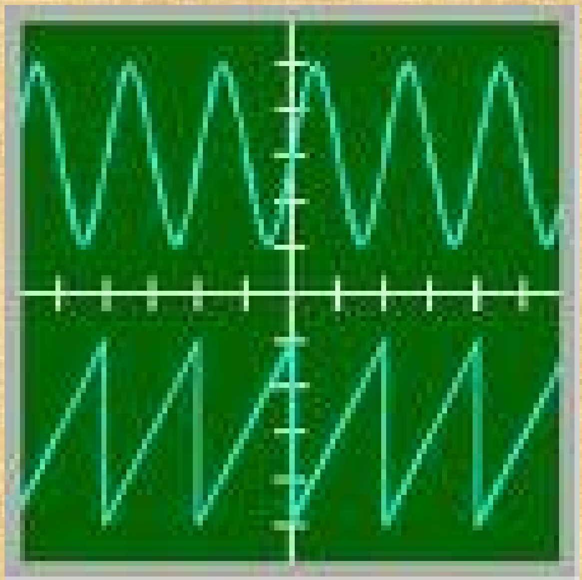
= 4 080 m

Distance = 4.08 km

Sound waves on oscilloscopes

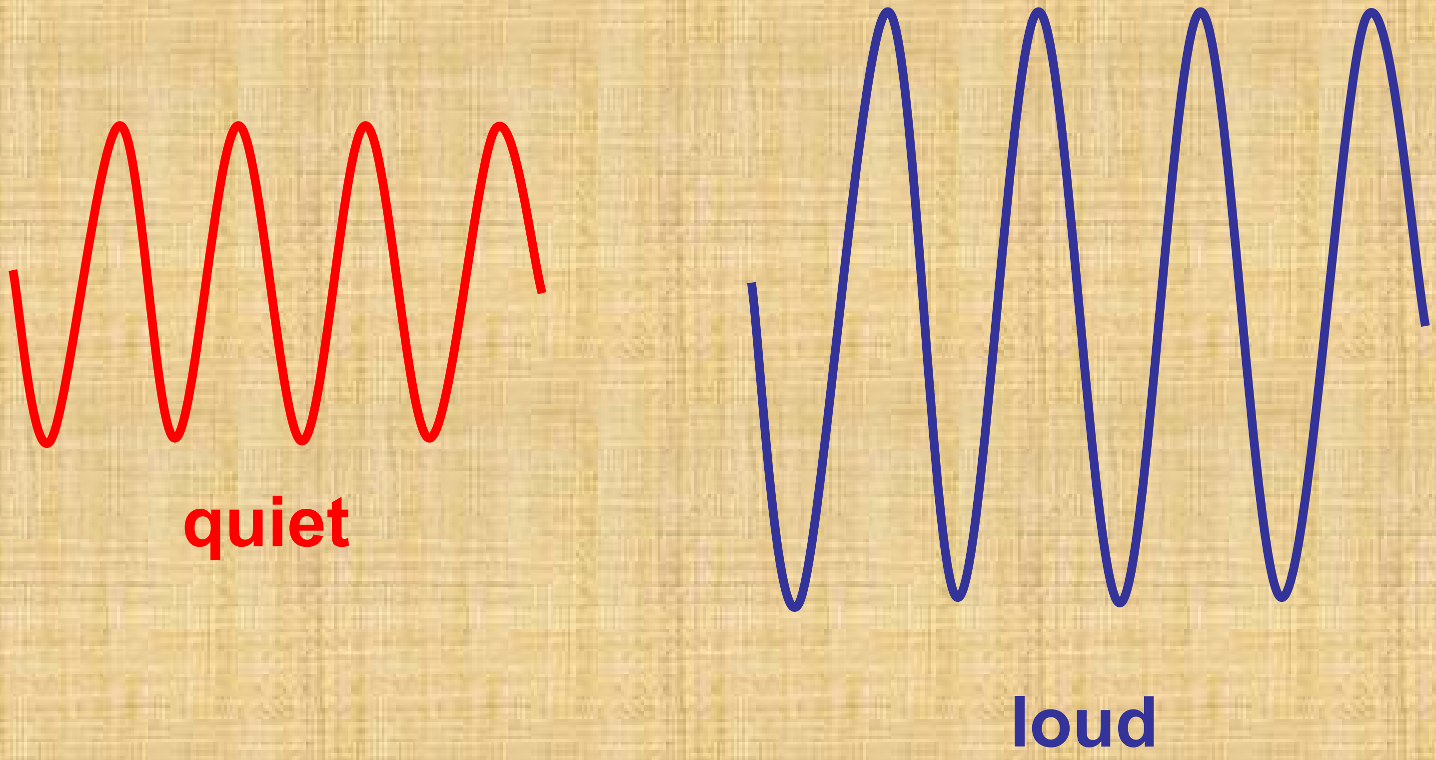
An oscilloscope is a device that with a microphone attached can be used to display a sound wave.

The screen displays a graph of how the amplitude of the sound wave varies with time.



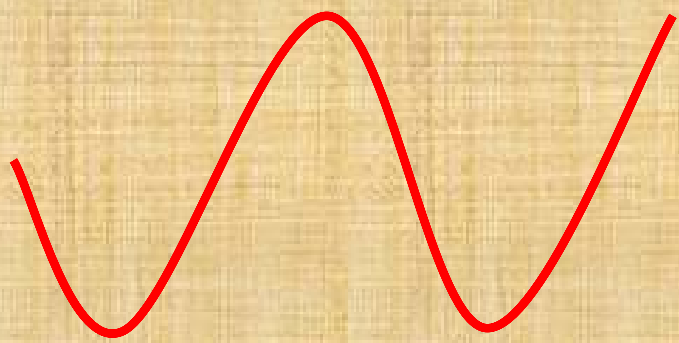
Loudness

The loudness of a sound increases with the amplitude of the sound wave.

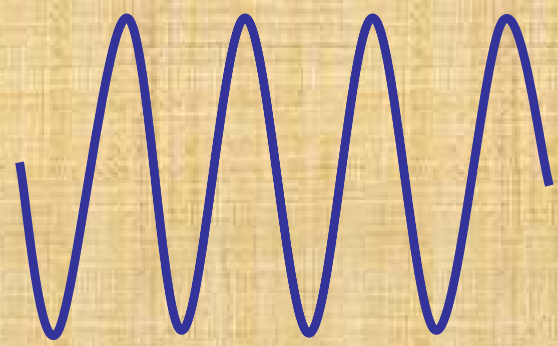


Pitch

The pitch of a musical note increases with frequency.



low pitch



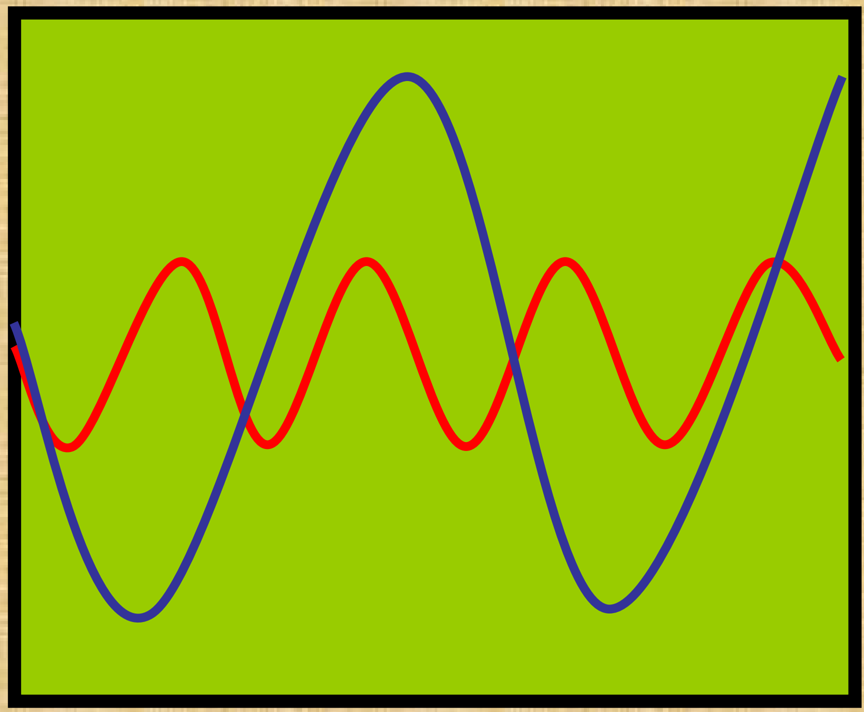
high pitch

Examples:
Concert pitch A = 440 Hz; Top C = 523 Hz

Doubling the frequency increases the pitch by one octave.
Therefore the 'A' above top C will have frequency 880 Hz.

Question

The diagram opposite shows the appearance of a sound wave on an oscilloscope. Draw a second diagram showing the appearance of a sound wave of lower pitch but greater loudness.



Measuring frequency using an oscilloscope

The time taken between peaks on an oscilloscope trace is equal to the time period, ***T*** of the sound wave.

frequency = 1 / period

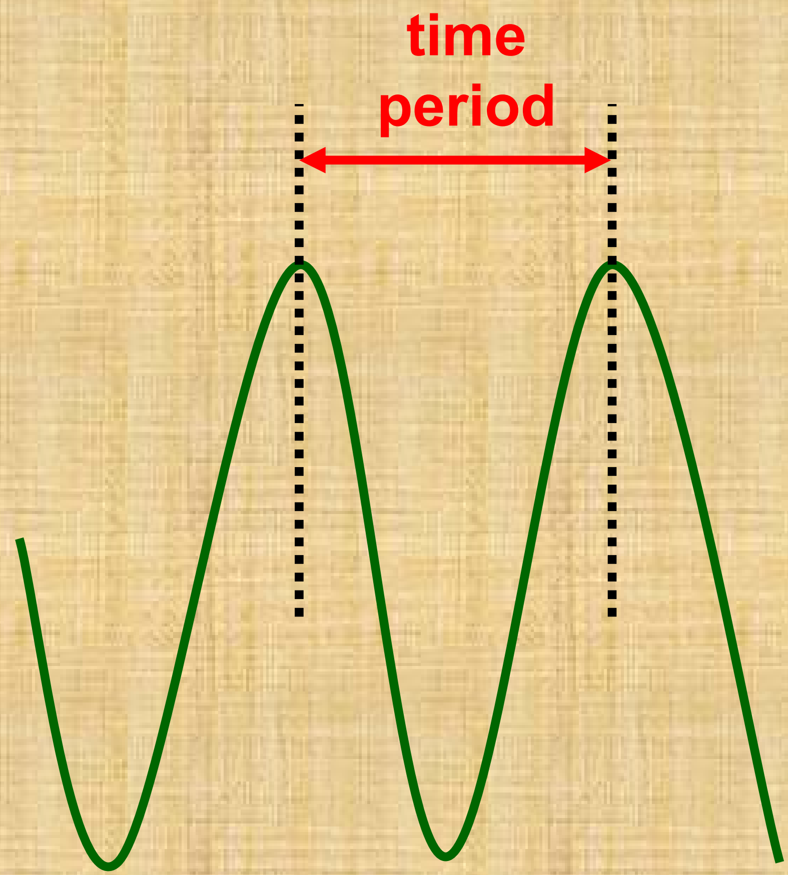
f = 1 / T

example:

if ***T*** = 0.05s

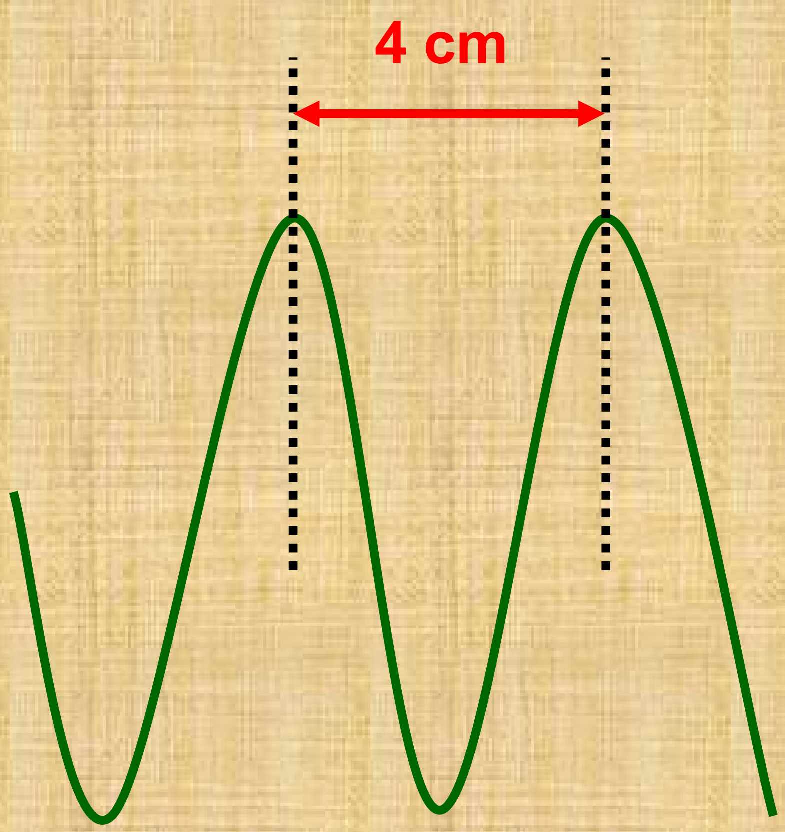
f = 1 / 0.05

frequency = 20Hz



Question

The distance between peaks on an oscilloscope trace is 4cm. If the oscilloscope time scale is set at 1ms/cm calculate the frequency of the sound.



1ms/cm means that the trace covers 1cm in one millisecond (0.001s)

time period, ***T*** = 4cm x 1ms/cm
= 4ms (0.004s)

f* = 1 / *T
f = 1 / 0.004
frequency = 250Hz

Choose appropriate words to fill in the gaps below:

Sound is a ____________ wave that in air consists of a series of compressions and ______________.

Sound travels fastest through _______ but does not travel at all through a __________.

A _____________ sound wave is called an echo. Sound also undergoes ____.

On average, humans can hear sound frequencies from __________ to _____________.

WORD SELECTION:

rarefactions refraction vacuum 20 Hz solids

longitudinal reflected 20 000 Hz

ANSWERS:

Sound is a _longitudinal_ wave that in air consists of a series of compressions and _rarefactions_.

Sound travels fastest through _solids_ but does not travel at all through a _vacuum_.

A _reflected_ sound wave is called an echo. Sound also undergoes _refraction_.

On average, humans can hear sound frequencies from _20 Hz_ to _20 000Hz_.