Sound Waves
To produce a sound the particles in an object must **vibrate**. This means that sound can travel through solids, liquids and gases. Sound cannot travel through a **vacuum** as it contains no particles.

Sound is a wave which carries energy. The number of waves in one second is called the frequency. Frequency is measured in a unit called Hertz (Hz). Most humans can hear sounds in the range 20Hz to 20,000Hz.

High frequency sounds, beyond the range of human hearing, are called **ultrasound**.

**Calculating the speed of sound**

In a laboratory the speed of sound can be calculated using the formula below.

\[
\text{speed} = \frac{\text{distance}}{\text{time}}
\]

**Apparatus:**

[Diagram of apparatus with microphone A, microphone B, electronic timer, and hammer]

A loud sound is made. As the sound reaches microphone A, the timer starts; when the sound waves reach microphone B, the timer stops. The distance between the microphones is measured with a metre stick.

**Example**

Time: 0.0030s, 0.0029s, 0.0031s, 0.0027s, 0.0029s

Average time = \( \frac{(0.0030 + 0.0029 + 0.0031 + 0.0027 + 0.0029)s}{5} = 0.0029s \)

Distance travelled = One metre = 1m

\[
\text{speed} = \frac{\text{distance}}{\text{time}}
\]

\[
\text{speed} = \frac{1}{0.0029}
\]

\[
\text{speed} = 345\text{ms}^{-1}
\]

The speed of sound in air is normally quoted as **340ms}^{-1} and can be found on the data sheet provided in Unit Tests.
CRO Traces

A Cathode Ray Oscilloscope (CRO) is a device that can display a “picture of sounds”. The “picture” can give information about the frequency and amplitude of the sound.

**Loud and quiet sounds**

A loud sound transfers more energy so the oscilloscope trace will have a large amplitude. The amplitude of a wave is the distance from the middle of the wave to the top or bottom of the wave.

![CRO Traces Diagram]

A soft / quiet sound transfers less energy so the oscilloscope trace will have a small amplitude.

**High and low frequency**

The effect of changing the frequency of a note can be seen on the oscilloscope screen.

![CRO Traces Diagram]

Sound B has a higher frequency than Sound A. Both sounds have the same amplitude.

**Noise**

Sounds that you do not like or do not want to hear are called noise. If you are forced to hear these noises it is called **noise pollution**. Some examples of noise pollution are:-

- Aircraft
- HGVs
- Pneumatic drills

Loud sounds are the most common type of noise pollution. Loudness of a sound is measured in **decibels (dB)** on a sound level meter.

Some common sound levels are shown below…

<table>
<thead>
<tr>
<th>Source of noise</th>
<th>Sound Level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold of hearing</td>
<td>0</td>
</tr>
<tr>
<td>Whispers</td>
<td>30</td>
</tr>
<tr>
<td>Classroom</td>
<td>60 to 70</td>
</tr>
<tr>
<td>Lorry</td>
<td>90</td>
</tr>
<tr>
<td>Rock concert</td>
<td>120</td>
</tr>
<tr>
<td>Threshold of pain</td>
<td>140</td>
</tr>
</tbody>
</table>

Hearing damage can happen if you regularly listen to sounds above 90dB. Ear muffsers can be used to reduce the sound level. Ear muffsers work by absorbing some of the energy before it reaches your ear. Noise cancelling headphones can also prevent damage to your hearing. These headphones use electronic components to identify and “cancel out” unwanted background noise.
S3 Physics – Unit Three – Summary Notes

Transverse Waves
A water wave is a transverse wave. The direction of vibration is at right angles to the direction of wave travel. In this diagram the water particles move up and down but the wave travels from left to right.

Direction of wave →
Direction of vibration of particles

Longitudinal Waves
A sound wave is a longitudinal wave. The direction of vibration is in the same direction as the travel of the wave.

Wave Calculations
A typical wave diagram is shown below:

For this wave a number of terms can be measured or calculated.

The frequency (f) of the wave is the number of waves that pass a point in one second.

The wavelength (λ) is the horizontal distance between any two corresponding points on adjacent waves.

The amplitude is the vertical distance measured from the middle of the wave to the top or to the bottom.

The speed of the wave can be calculated by measuring the horizontal distance between X and Y and dividing it by the time the wave takes to travel that distance.

\[ \text{speed} = \frac{\text{distance}}{\text{time}} \]
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It is also possible to find the speed of the wave by using the wave equation.

\[ \text{wavespeed} = \text{frequency} \times \text{wavelength} \]

Which is often written as:

\[ v = f\lambda \]

Where,

- \( v \) = wave speed measured in ms\(^{-1}\)
- \( f \) = frequency measured in Hz
- \( \lambda \) = wavelength measured in m

For wave calculations it is important to write down all the information from the question before selecting the appropriate method for calculating the speed of the wave.

**Example One**

A water wave takes 0.2 seconds to travel 1.6 metres. What is the speed of the water wave?

\[
\begin{align*}
\text{time} &= 0.2 \text{ s} \\
\text{distance} &= 1.6 \text{ m} \\
\text{speed} &= \, ?
\end{align*}
\]

\[
\text{speed} = \text{distance} ÷ \text{time}
\]

\[
\text{speed} = 1.6 ÷ 0.2 = 8 \text{ ms}^{-1}
\]

**Example Two**

If water waves have a frequency of 640 Hz and a wavelength of 0.2 metres, what is the speed of the waves?

\[
\begin{align*}
\text{frequency} &= 640 \text{ Hz} \\
\text{wavelength} &= 0.2 \text{ m} \\
\text{speed} &= \, ?
\end{align*}
\]

\[
\text{speed} = \text{frequency} \times \text{wavelength}
\]

\[
\text{speed} = 640 \times 0.2 = 128 \text{ ms}^{-1}
\]

**Example Three**

A sound wave travelling at 340 ms\(^{-1}\), has a frequency of 2720 Hz. What is the wavelength of the wave?

\[
\begin{align*}
\text{speed} &= 340 \text{ ms}^{-1} \\
\text{frequency} &= 2720 \text{ Hz} \\
\text{wavelength} &= \, ?
\end{align*}
\]

\[
\text{speed} = \text{frequency} \times \text{wavelength}
\]

\[
340 = 2720 \times \text{wavelength}
\]

wavelength = 0.125 m

**Example Four**

How far does a sound wave travel in air in 15 s?

\[
\begin{align*}
\text{Time} &= 15 \text{ s} \\
\text{Speed} &= 340 \text{ ms}^{-1} \\
\text{Distance} &= \, ?
\end{align*}
\]

\[
\text{speed} = \text{distance} ÷ \text{time}
\]

\[
340 = \text{distance} ÷ 15
\]

distance = 5100 m

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S3 Physics – Unit Three – Summary Notes

The Electromagnetic Spectrum

The electromagnetic (EM) spectrum is a family of waves. Like all families the members have lots in common. But each family member is also unique.

The names of the members of the EM Spectrum are:-

- Radio
- Microwave
- Infrared
- Visible
- Ultraviolet
- X-ray
- Gamma Ray

All members of the EM Spectrum share two very important characteristics. They travel at the same speed \(3 \times 10^8 \text{ms}^{-1}\). (300 million metres per second) They are transverse waves.

Although only the visible part can be viewed, all parts can be identified by their frequency or wavelength.

The EM spectrum has many industrial and medical applications.
A summary table is shown below.

<table>
<thead>
<tr>
<th>EM Wave</th>
<th>Detector</th>
<th>Source</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio</td>
<td>Telescope</td>
<td>Transmitter</td>
<td>Radar</td>
</tr>
<tr>
<td>Microwave</td>
<td>Aerial</td>
<td>Transmitter</td>
<td>Mobile phones</td>
</tr>
<tr>
<td>Infrared</td>
<td>Photodiode</td>
<td>Lamp</td>
<td>TV remote</td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>Fluorescent pigments</td>
<td>The Sun</td>
<td>Reduce acne</td>
</tr>
<tr>
<td>X-ray</td>
<td>Photographic film</td>
<td>Particle accelerators</td>
<td>Crystallography</td>
</tr>
<tr>
<td>Gamma ray</td>
<td>GM Tube</td>
<td>Radioactive nuclei</td>
<td>Tracers</td>
</tr>
</tbody>
</table>

The members of the EM spectrum are often known as radiations. (You should review your knowledge of radiations from Unit One before the end of unit test.)

The other member of the EM spectrum is visible light which can be easily detected by the human eye. Light has many applications. Perhaps one of the most useful types of light comes from a laser.

Lasers can be used in eye surgery, removing tattoos, “reading” a CD or a bar code and they can even cut metal.
S3 Physics – Unit Three – Summary Notes

Light

As light is a member of the EM spectrum it will behave like a transverse wave and travel at $3 \times 10^8 \text{ms}^{-1}$ in air. As light travels almost a million times faster than sound, when you witness a thunderstorm the lightning always happens before you hear the thunder.

A plane mirror can be used to show the reflection of light.

This diagram shows the law of reflection as the angles $i$ and $r$ are the same size.

Transparent materials can be used to show the refraction of light.

The light changes direction as it enters the glass. This is known as refraction of light. The light also changes direction when it leaves the glass. These changes in direction happen because the speed of the light changes when it changes material. The light slows down when it enters the glass and returns to its original speed when it leaves the glass.

ALL LIGHT DIAGRAMS MUST USE ARROWS TO SHOW THE DIRECTION IN WHICH THE LIGHT IS TRAVELLING DUE TO THE REVERSIBILITY OF LIGHT.
S3 Physics – Unit Three – Summary Notes

Lenses

Lenses can be specially shaped to make use of the light.

When parallel rays of light enter a **convex (converging) lens** the refraction that takes place brings the parallel light rays to a focus or focal point. Convex (converging) lenses are used in spectacles when people are long-sighted.

![Convex Lens Diagram](image)

When parallel rays of light enter a **concave (diverging) lens** the refraction that takes place makes the rays of light spread out. Concave (diverging) lenses are used in spectacles when people are short-sighted.

![Concave Lens Diagram](image)
# S3 Physics – Unit Three – Summary Notes

## Speed of light in materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Speed in m/s(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>3.0 × 10(^8)</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>3.0 × 10(^8)</td>
</tr>
<tr>
<td>Diamond</td>
<td>1.2 × 10(^8)</td>
</tr>
<tr>
<td>Glass</td>
<td>2.0 × 10(^8)</td>
</tr>
<tr>
<td>Glycerol</td>
<td>2.1 × 10(^8)</td>
</tr>
<tr>
<td>Water</td>
<td>2.3 × 10(^8)</td>
</tr>
</tbody>
</table>

## Speed of sound in materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Speed in m/s(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>5200</td>
</tr>
<tr>
<td>Air</td>
<td>340</td>
</tr>
<tr>
<td>Bone</td>
<td>4100</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>270</td>
</tr>
<tr>
<td>Glycerol</td>
<td>1900</td>
</tr>
<tr>
<td>Muscle</td>
<td>1600</td>
</tr>
<tr>
<td>Steel</td>
<td>5200</td>
</tr>
<tr>
<td>Tissue</td>
<td>1500</td>
</tr>
<tr>
<td>Water</td>
<td>1500</td>
</tr>
</tbody>
</table>

## Gravitational field strengths

<table>
<thead>
<tr>
<th>Source</th>
<th>Gravitational field strength on the surface in Nkg(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth</td>
<td>9.8</td>
</tr>
<tr>
<td>Jupiter</td>
<td>23</td>
</tr>
<tr>
<td>Mars</td>
<td>3.7</td>
</tr>
<tr>
<td>Mercury</td>
<td>3.7</td>
</tr>
<tr>
<td>Moon</td>
<td>1.6</td>
</tr>
<tr>
<td>Neptune</td>
<td>11</td>
</tr>
<tr>
<td>Saturn</td>
<td>9.0</td>
</tr>
<tr>
<td>Sun</td>
<td>270</td>
</tr>
<tr>
<td>Uranus</td>
<td>8.7</td>
</tr>
<tr>
<td>Venus</td>
<td>8.9</td>
</tr>
</tbody>
</table>

## Specific heat capacity of materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific heat capacity in Jkg(^{-1})°C(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>2350</td>
</tr>
<tr>
<td>Aluminium</td>
<td>902</td>
</tr>
<tr>
<td>Copper</td>
<td>386</td>
</tr>
<tr>
<td>Glass</td>
<td>500</td>
</tr>
<tr>
<td>Ice</td>
<td>2100</td>
</tr>
<tr>
<td>Iron</td>
<td>480</td>
</tr>
<tr>
<td>Lead</td>
<td>128</td>
</tr>
<tr>
<td>Oil</td>
<td>2130</td>
</tr>
<tr>
<td>Water</td>
<td>4180</td>
</tr>
</tbody>
</table>

## Specific latent heat of fusion of materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific latent heat of fusion in Jkg(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>0.99 × 10(^5)</td>
</tr>
<tr>
<td>Aluminium</td>
<td>3.95 × 10(^5)</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>1.80 × 10(^5)</td>
</tr>
<tr>
<td>Copper</td>
<td>2.05 × 10(^5)</td>
</tr>
<tr>
<td>Iron</td>
<td>2.67 × 10(^5)</td>
</tr>
<tr>
<td>Lead</td>
<td>0.25 × 10(^5)</td>
</tr>
<tr>
<td>Water</td>
<td>3.34 × 10(^5)</td>
</tr>
</tbody>
</table>

## Melting and boiling points of materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Melting point in °C</th>
<th>Boiling point in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>-98</td>
<td>65</td>
</tr>
<tr>
<td>Aluminium</td>
<td>660</td>
<td>2470</td>
</tr>
<tr>
<td>Copper</td>
<td>1077</td>
<td>2567</td>
</tr>
<tr>
<td>Glycerol</td>
<td>18</td>
<td>290</td>
</tr>
<tr>
<td>Lead</td>
<td>328</td>
<td>1737</td>
</tr>
<tr>
<td>Iron</td>
<td>1537</td>
<td>2737</td>
</tr>
</tbody>
</table>

## Specific latent heat of vapourisation of materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific latent heat of vapourisation in Jkg(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>11.2 × 10(^5)</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>3.77 × 10(^5)</td>
</tr>
<tr>
<td>Glycerol</td>
<td>8.30 × 10(^5)</td>
</tr>
<tr>
<td>Turpentine</td>
<td>2.90 × 10(^5)</td>
</tr>
<tr>
<td>Water</td>
<td>22.6 × 10(^5)</td>
</tr>
</tbody>
</table>

## Radiation weighting factors

<table>
<thead>
<tr>
<th>Type of radiation</th>
<th>Radiation weighting factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>alpha</td>
<td>20</td>
</tr>
<tr>
<td>beta</td>
<td>1</td>
</tr>
<tr>
<td>fast neutrons</td>
<td>10</td>
</tr>
<tr>
<td>gamma</td>
<td>1</td>
</tr>
<tr>
<td>slow neutrons</td>
<td>3</td>
</tr>
</tbody>
</table>
### Scientific Notation

**Scientific Notation** or **standard form** is a way of expressing a number in terms of power of ten. In other words, it’s expressed in the form

\[ a \times 10^n \]

where \( a \) is a real number that satisfies \( 1 \leq |a| < 10 \) and \( n \) is an integer. \( a \) is called the **significand** and \( n \) is called the **exponent**.

Please note that the absolute value of \( a \) must be at least 1 and less than 10, hence \( 0.34 \times 10^2 \) and \( -11.23 \times 10^7 \) are not in standard form.

Examples of converting numbers to scientific notation:

- 1234 becomes \( 1.234 \times 10^3 \)
- \(-0.000023 \) becomes \(-2.3 \times 10^{-5} \)
- \( 50000000 \) becomes \( 5 \times 10^7 \)

### Rounding

Some decimal numbers go on for ever! To simplify their use, we decide on a cut off point and “round” them up or down.

If we want to round 2.734216 to two decimal places, we look at the number in the third place after the decimal, in this case, 4. If the number is 0, 1, 2, 3 or 4, we leave the last figure before the cut off as it is. If the number is 5, 6, 7, 8 or 9 we “round up” the last figure before the cut off by one. 2.734216 therefore becomes 2.73 when rounded to 2 decimal places.

If we are rounding to 2 decimal places, we leave 2 numbers to the right of the decimal. If we are rounding to 2 significant figures, we leave two numbers, whether they are decimals or not.
S3 Physics – Unit Three – Summary Notes

\[ Q = It \]

\[ P = ma \]

\[ V = IR \]

\[ E_a = Fd \]

\[ R_{\text{total}} = R_1 + R_2 + R_3 \ldots \text{etc} \]

\[ W = mg \]

\[ \frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots \text{etc} \]

\[ E_a = mL_v \]

\[ P = \frac{E}{t} \]

\[ P = IV \]

\[ P = I^2R \]

\[ P = \frac{V^2}{R} \]

\[ \% \text{ efficiency} = \frac{\text{useful } E_a}{E_i} \times 100\% \]

\[ \% \text{ efficiency} = \frac{\text{useful } P}{P_i} \times 100\% \]

\[ E_a = Cn\Delta T \]

\[ P = \frac{F}{A} \]

\[ \frac{P_{V_1}}{T_1} - \frac{P_{V_2}}{T_2} \]

\[ v = \frac{d}{t} \]

\[ v = f \lambda \]

\[ H = D\pi \]

\[ D = \frac{E}{\pi} \]

\[ \bar{v} = \text{total displacement / total time} \]

\[ v = \text{displacement / time} \]

\[ v = u + at \]