AS Level Physics

Chapter 5 – Waves and Particle Nature of Light

5.9.1 Pulse-Echo Technique (Edexcel Only)

Notes

Ultrasound

Any sound wave with a frequency greater than the upper frequency limit of human hearing (20,000 Hz) is referred to be ultrasound.

The ultrasound frequency range in medical imaging is $1\ to\ 15\ MHz$.

Ultrasound travels at different speeds depending on the substance it travels through.

The speed of ultrasound through air is $330\ ms^{-1}$, through muscle it is a range from $1545 - 1630\ ms^{-1}$ and through bone it is anywhere between $2700 - 4100\ ms^{-1}$.

In medical imaging high frequency ultrasound is used. This means the ultrasound wavelength will be very small and thereby detecting smaller details in a scan.

e.g. for ultrasound of $f = 5\ MHz$ travelling through muscle tissue (ultrasound speed = $1500\ ms^{-1}$), the wavelength (λ) is given by:

$$\lambda = \frac{v}{f} = \frac{1500\ ms^{-1}}{5 \times 10^{6}\ Hz} = 3 \times 10^{-4} m\ or\ 0.3mm$$

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Ultrasound Transducer

An ultrasound transducer is a device that transmits ultrasound waves while also detecting the reflected ultrasound waves.

Principles of Ultrasound Scanning

Echoes are utilised in ultrasound scanning. These echo's or ultrasound waves from a transducer are reflected at the boundary between one substance and another.

The boundary where the reflection occurs could be between the air and the skin, or between the tissue and the liquid, or between the tissue and the bone.

The basic ultrasound system uses the pulse echo technique, which is represented by the equation:

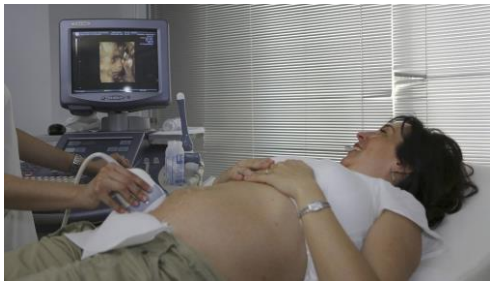
$$s = vt$$

Where:

s = distance from the transducer to the boundary and back,

v = speed of ultrasound in the substance,

t = time for the ultrasound to travel to the boundary and back.



Pulse-Echo Technique

The pulse-echo technique is used to image things using ultrasound waves, most notably for medical imaging. This method is based on the fact that when waves meet boundaries between different materials, they are reflected.

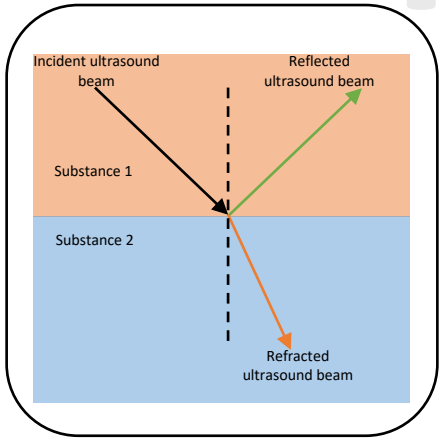
The pulse-echo technique is described briefly below:

1) Short pulse ultrasound waves are sent into the target (e.g. the body in medical imaging).

2) Inside the body, the pulse travels until it hits a boundary between two mediums, and the pulse is reflected back. The amount of reflection is determined by the density difference between the materials; the larger the difference, the greater the reflection.

3) The reflected waves are detected as they leave the target.

4) The structure of the target is determined by the intensities of the reflected waves, and the time it takes for these reflected waves to return is used to estimate the position of objects in the target (using $s = vt$).



Pulse-Echo Technique

Points to Note:

- If the duration of the pulses is too long, they will most likely overlap, reducing the quantity of information you receive (and hence reducing the image's resolution).
- Furthermore, as the wavelength of the waves used increases, the finer details can be distorted, resulting in a reduction in the amount of information obtained.
- A special gel is put between the patient's skin and the transducer to ensure that the majority of the ultrasound is transmitted into the patient. This ensures that only a small amount of ultrasound is reflected just off the skin, allowing for accurate imaging of internal structures.
- Ultrasound cannot detect much beyond the lungs or other gas-filled cavities.

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Please see '5.9.2 Pulse-Echo Technique (Edexcel Only) worked examples' pack for exam style questions.

For more revision notes, tutorials and worked examples please visit www.tutorpacks.co.uk.

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