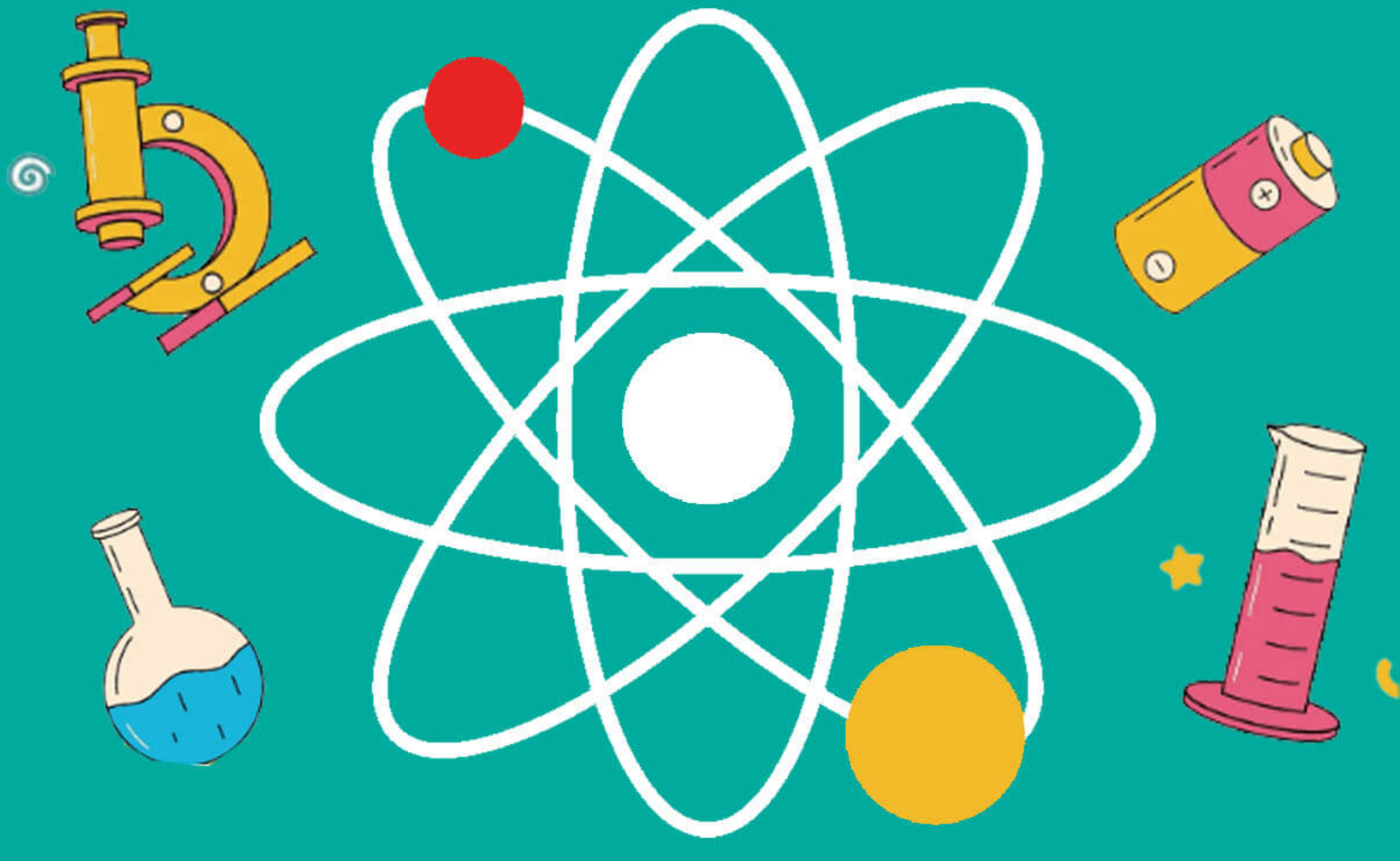
Exam Papers Practice

10.4 Non-Ionising Imaging



AQA A Level Physics Revision Notes

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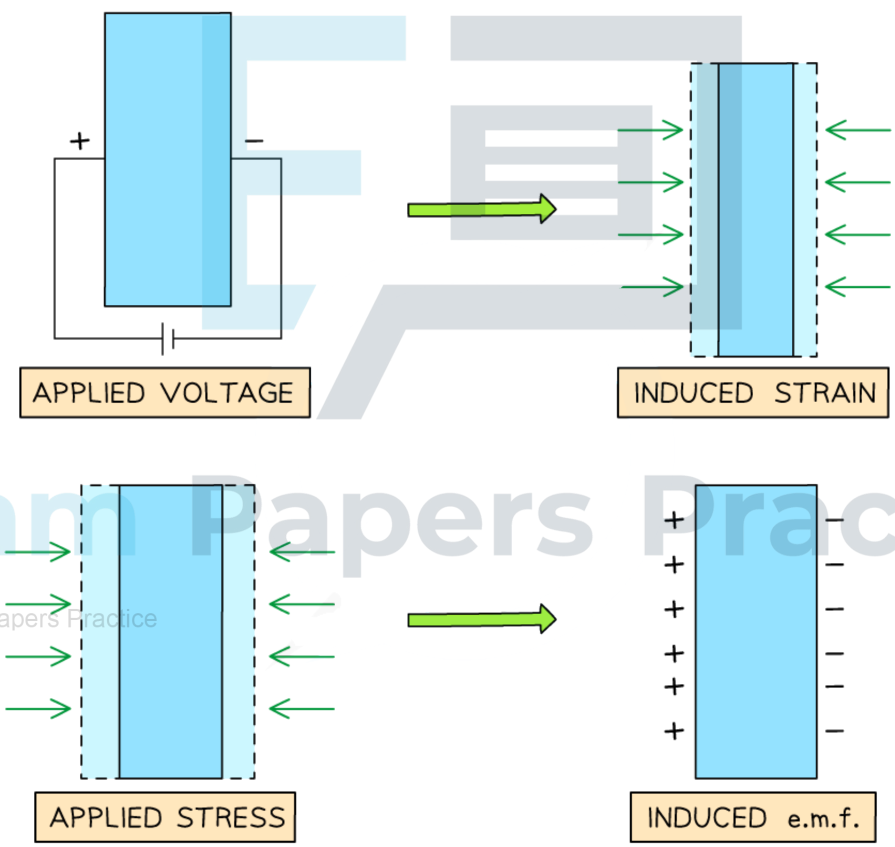
10.4.1 The Piezoelectric Transducer

The Piezoelectric Transducer

- The piezoelectric effect is defined as:
  The ability of particular materials to generate a potential difference (p.d.) by transferring mechanical energy to electrical energy
- A **transducer** is any device that converts energy from one form to another

How does a Piezoelectric Crystal Work?

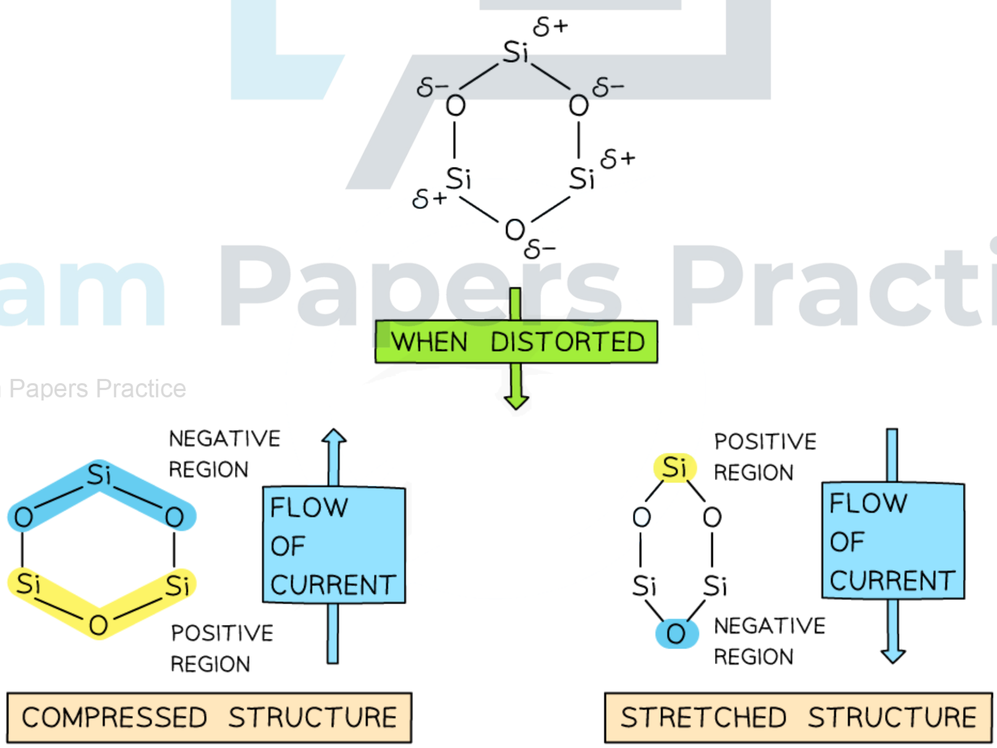


In the piezoelectric effect, an applied voltage causes a piezo-crystal to contract or expand, and vice versa

Piezoelectric Crystals

- At the heart of a piezoelectric transducer is a **piezoelectric crystal**
- Piezoelectric crystals are materials which produce a p.d. when they are **deformed**
  - This deformation can be by compression or stretching
- If a p.d. is applied to a piezoelectric crystal, then it deforms, and if the p.d. is reversed, then it expands
  - If this is an alternating p.d. then the crystal will vibrate at the same frequency as the alternating voltage
  - Crystals must be cut to a certain size in order to induce resonance
- One of the most common piezoelectric crystals is **quartz**, which is made from a lattice of silicon dioxide atoms
  - When the lattice is distorted, the structure becomes charged creating an electric field and, as a result, an electric current
  - If an electric current is applied to the crystal, then this causes the shape of the lattice to alternate which produces a sound wave
  - Due to the conventional direction of electric current, it will flow from the positive to the negative region of the crystal

Distortion of a Piezoelectric Crystal



A molecule in a quartz crystal. When the compression and stretching alternates, an alternating e.m.f. is induced

Applications of the Piezoelectric Transducer

- Microphone
  - A piezoelectric microphone detects pressure variations in sound waves
  - These can then be converted to an electrical signal for processing
- Ultrasound
  - In a piezoelectric transducer, an alternating p.d. is applied to produce ultrasound waves and sent into the patient's body
  - The returning ultrasound waves induce a p.d. in the transducer for analysis by a healthcare professional

10.4.2 Generation & Detection of Ultrasound

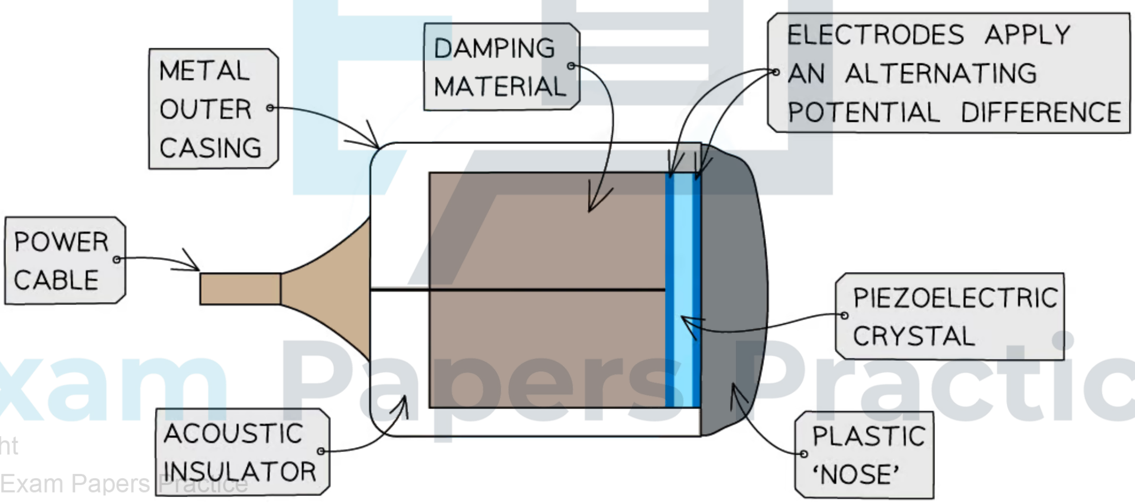
Generation & Detection of Ultrasound

- An ultrasound is defined as:

A high frequency sound above the range of human hearing

- This is above 20 kHz, although in medical applications the frequencies can be up to the MHz range
- An ultrasound transducer is made up of a piezoelectric crystal and electrodes which produce an alternating p.d.
- The crystal is heavily damped, usually with epoxy resin, to stop the crystal from vibrating too much
  - This produces short pulses and increases the resolution of the ultrasound device

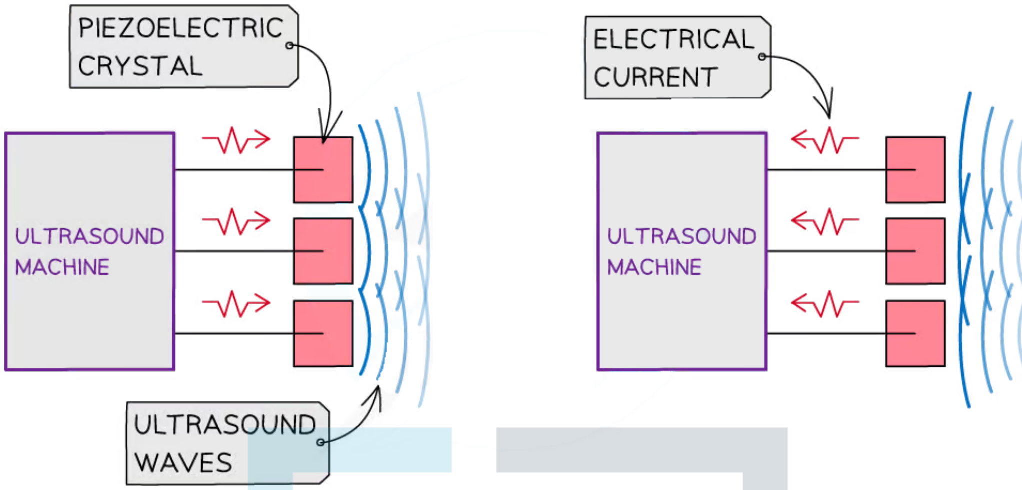
An Ultrasound Transducer



The structure of an ultrasound transducer

- A piezoelectric crystal can act as both a receiver or transmitter of ultrasound
  - When it is **receiving** ultrasound, it converts the sound waves into an alternating p.d.
  - When it is **transmitting** ultrasound, it converts an alternating p.d. into sound waves

A Piezoelectric Crystal Emitting and Receiving Ultrasound

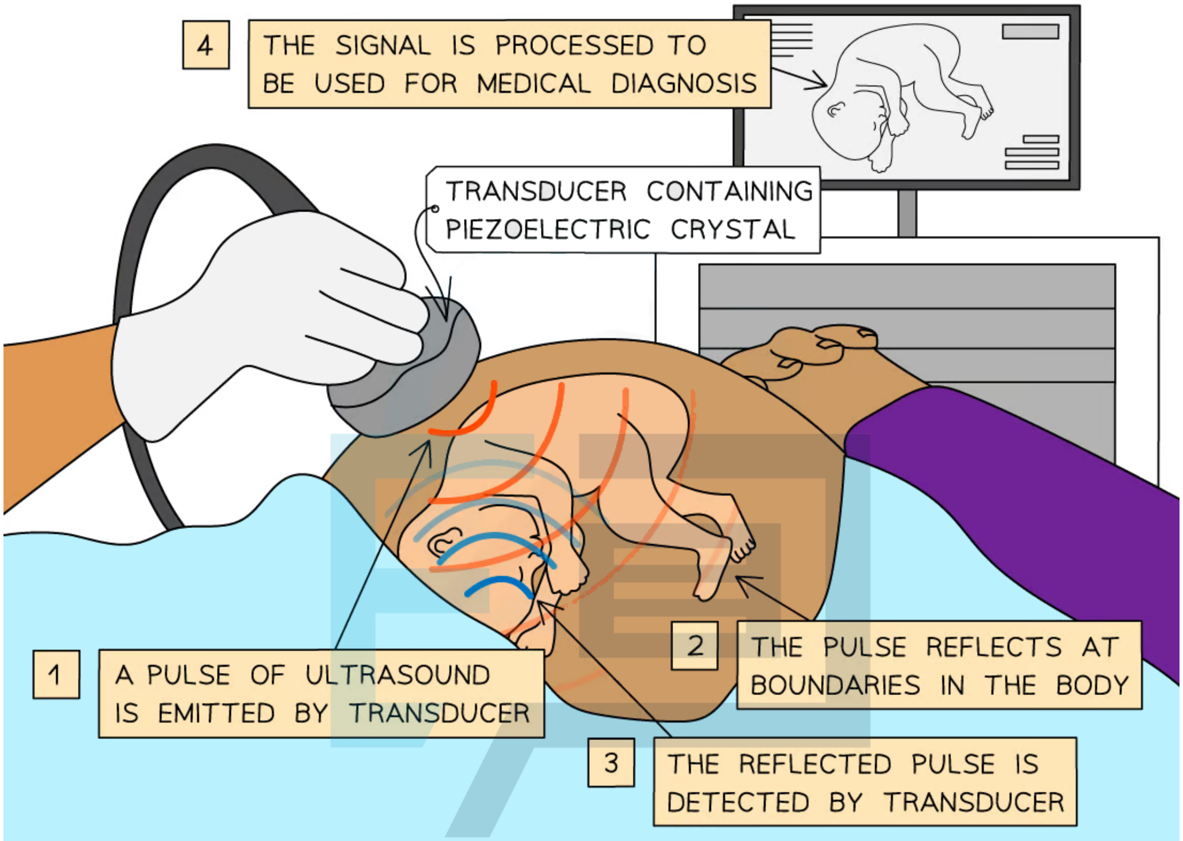


A piezoelectric crystal can act as both a receiver or transmitter of ultrasound

Using Ultrasound to Obtain Diagnostic Information

- In an ultrasound scanner, the transducer sends out a beam of sound waves into the body
- The sound waves are reflected back to the transducer by boundaries between tissues in the path of the beam
  - For example, the boundary between fluid and soft tissue or tissue and bone
- When these echoes hit the transducer, they generate electrical signals that are sent to the ultrasound scanner
- Using the speed of sound and the time of each echo's return, the scanner calculates the distance from the transducer to the tissue boundary
- These distances can be used to generate two-dimensional images of tissues and organs
- The frequency of the ultrasound is important because:
  - The higher the frequency of the ultrasound, the higher the resolution and the smaller structures that can be distinguished

Obtaining an Ultrasound of a Baby



Using ultrasound to obtain information about an unborn child

- The ultrasound gives two main pieces of information about the boundary:
  - **Depth**: the time between transmission and receipt of the pulse (the time delay)
  - **Nature**: amount of transmitted intensity received (will vary depending on the type of tissue)

Worked example

Explain the principles of the generation and detection of ultrasound waves.

Answer:

Generation:

- An alternating p.d. is applied across a piezo-electric crystal, causing it to change shape
- The alternating p.d. causes the crystal to vibrate and produce ultrasound waves
- The crystal vibrates at the frequency of the alternating p.d., so, the crystal must be cut to a specific size in order to produce resonance

Detection:

- When the ultrasound wave returns, the crystal vibrates which produces an alternating p.d. across the crystal
- This received signal can then be processed and used for medical diagnosis

Worked example

Explain the main principles behind the use of ultrasound to obtain diagnostic information about internal body structures.

Answer:

- A pulse of ultrasound is emitted by the piezo-electric crystal
- This is reflected by the boundaries between media
- The reflected pulse is detected by the ultrasound transmitter
- The signal is then processed and displayed on the screen for the healthcare worker to analyse and use for medical diagnosis
- The **intensity of the reflection** gives information about the nature of the boundary
- The time between transmission and receipt of the pulse (**the time delay**) gives information about the depth of the boundary

Exam Tip

6 mark exam questions about this topic are very common, make sure you practice writing about using and detecting ultrasounds in full, coherent sentences with correct spelling and grammar. Writing short or vague answers could lose you marks, as well as misspelling words!

10.4.3 Ultrasound Imaging

Specific Acoustic Impedance

- The **acoustic impedance**, Z, of a medium is defined as:

  The product of the speed of the ultrasound in the medium and the density of the medium

- This quantity describes how much resistance an ultrasound beam encounters as it passes through a tissue
- Acoustic impedance can be calculated using the equation:

$$Z = \rho c$$

- Where:
  - Z = acoustic impedance (kg m^{-2} s^{-1})
  - ρ = the density of the material (kg m^{-3})
  - c = the speed of sound in the material (m s^{-1})

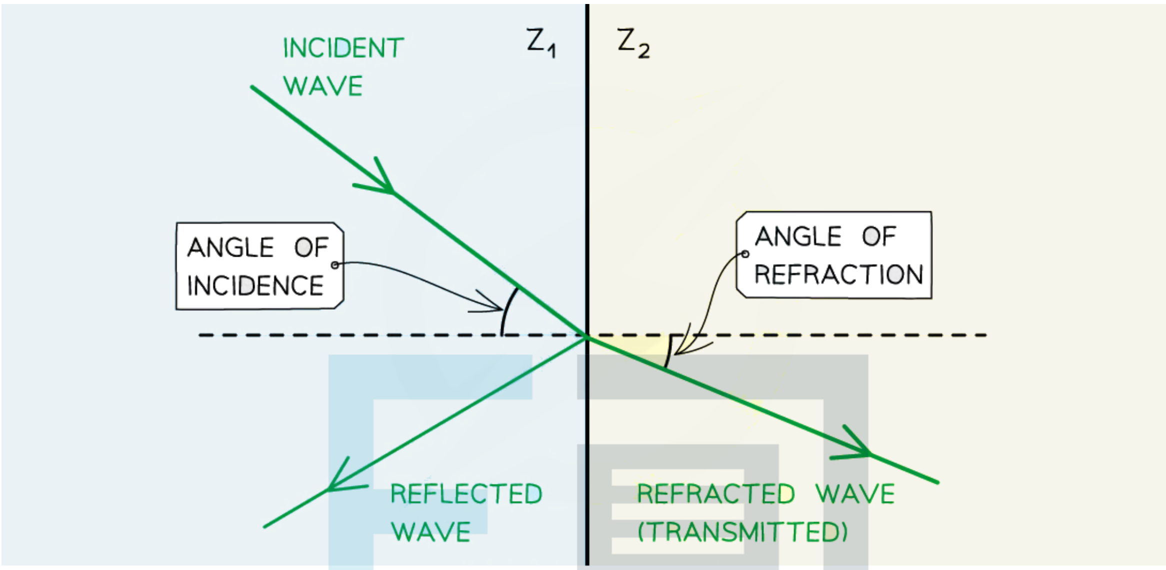
- This equation shows:
  - The **higher** the **density** of a tissue, the greater the **acoustic impedance**
  - The **faster** the ultrasound travels through the material, the greater the **acoustic impedance** also

- This is because sound travels faster in **denser** materials
  - Sound is **fastest** in solids and **slowest** in gases
  - The closer the particles in the material, the faster the **vibrations** can move through the material

- At the boundary between media of different acoustic impedances, some of the wave energy is **reflected** and some is **transmitted**
- The greater the **difference** in acoustic impedance between the two media, the greater the reflection and the smaller the transmission
  - Two materials with the same acoustic impedance would give no reflection
  - Two materials with a large difference in values would give much larger reflections

- Air has an acoustic impedance of Z_{air} = 400 kg m^{-2} s^{-1}
- Skin has an acoustic impedance of Z_{skin} = 1.7×10^6 kg m^{-2} s^{-1}
  - The large difference means ultrasound would be significantly reflected, hence a coupling gel is necessary
  - The coupling gel used has a similar Z value to skin, meaning that very little ultrasound is reflected

A Refracting Wave Between the Boundary of Two Media with Different Acoustic Impedence



Refraction and reflection of ultrasound waves at a boundary between two materials with different acoustic impedances (in this case, $Z_1 < Z_2$)

Worked example

The table shows the speed of sound acoustic impedance in four different materials.

medium	speed of ultrasound / $m\ s^{-1}$	acoustic impedance / $kg\ m^{-2}\ s^{-1}$
air	330	4.3×10^2
gel	1500	1.5×10^6
soft tissue	1600	1.6×10^6
bone	4100	7.0×10^6

Use the data in the table to calculate the value for the density of bone.

Answer:

Step 1: Write down known quantities

- Acoustic impedance of bone, $Z = 7.0 \times 10^6$ kg m^{-2} s^{-1}
- Speed of ultrasound in bone, $c = 4100$ m s^{-1}

Step 2: Write out the equation for acoustic impedance

$$Z = \rho c$$

Step 3: Rearrange for density and calculate

$$\rho = \frac{Z}{c} = \frac{7.0 \times 10^6}{4100} = 1700 \text{ kg m}^{-3}$$

Exam Tip

A common mistake is to confuse the *c* in the acoustic impedance equation for the speed of light - don't do this!

Reflection & Transmission of Ultrasound

- The intensity reflection coefficient α is defined as:

  The ratio of the intensity of the reflected wave relative to the incident (transmitted) wave

- This can be calculated using the fraction:

$$\alpha = \frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

- Where:
  - α = intensity reflection coefficient
  - I_R = intensity of the reflected wave (W m^{-2})
  - I_O = intensity of the incident wave (W m^{-2})
  - Z_1 = acoustic impedance of one material (kg m^{-2} s^{-1})
  - Z_2 = acoustic impedance of a second material (kg m^{-2} s^{-1})

- This ratio shows:
  - If there is a large difference between the impedance of the two materials, then most of the **energy** will be reflected
  - If the impedance is the same, then there will be **no reflection**

Coupling Medium

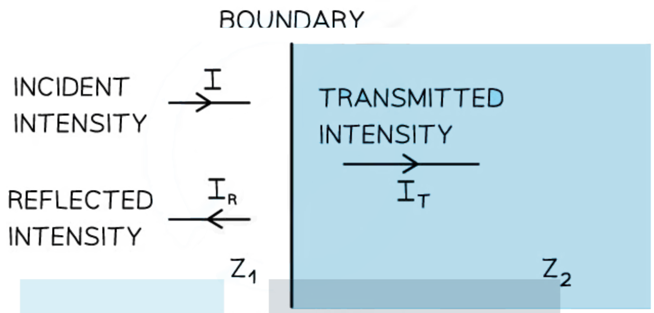
- When ultrasound is used in medical imaging, a **coupler** is needed between the transducer and the body
  - This is because the soft tissues of the body are **much denser** than air
- If air is present between the transducer and the body, then almost all the ultrasound energy will be **reflected**
- To counter this, a coupling gel is placed between the transducer and the body
  - This is because skin and coupling gel have a **similar density**, so little ultrasound is reflected
- This is an example of impedance matching, which is defined as when:

  Two media have a similar acoustic impedance, resulting in little to no reflection of the ultrasound wave

- In terms of intensity reflection coefficient, α, between the two media:
  - At **lower** values of α, the media are impedance matched, so **less** reflection occurs
  - At **higher** values of α, the media are not impedance matched, so **more** reflection occurs

Worked example

A beam of ultrasound is incident at right-angles to a boundary between two materials, as shown in the diagram.



The materials have acoustic impedances of Z_1 and Z_2. The intensity of the transmitted ultrasound beam is I_T, and the reflected intensity is I_R.

medium	speed of ultrasound / m s^{-1}	acoustic impedance / kg m^{-2} s^{-1}
air	330	4.3×10^2
gel	1500	1.5×10^6
soft tissue	1600	1.6×10^6
bone	4100	7.0×10^6

(a) State the relationship between I, I_T and I_R.

(b) Use the data from the table to determine the reflection coefficient, α, for a boundary between

(i) Gel and soft tissue

(ii) Air and soft tissue

(c) Explain why gel is usually put on the skin during medical diagnosis using ultrasound.

Answer:

Part (a)

Step 1: List the known quantities

- Intensity of incident wave = I
- Intensity of the transmitted wave = I_T
- Intensity of the reflected wave = I_R

Step 2: Relate the quantities:

- The incident intensity is equal to the sum of the transmitted and reflected intensities:

Incident intensity = Transmitted intensity + Reflected intensity

$$I = I_T + I_R$$

Part (b)(i)

Step 1: List the known quantities

- Acoustic impedance of gel, $Z_1 = 1.5 \times 10^6$ kg m^{-2} s^{-1}
- Acoustic impedance of soft tissue, $Z_2 = 1.6 \times 10^6$ kg m^{-2} s^{-1}

Step 2: Write down the equation for intensity reflection coefficient α

$$\alpha = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

Step 3: Calculate the intensity reflection coefficient

$$\alpha = \frac{(1.6 \times 10^6 - 1.5 \times 10^6)^2}{(1.6 \times 10^6 + 1.5 \times 10^6)^2} = \frac{0.1^2}{3.1^2} = 0.001$$

- This result means that only **0.1%** of the incident intensity will be reflected, with the remaining being transmitted

Part (b)(ii)

Step 1: List the known quantities

- Air, $Z_1 = 4.3 \times 10^2$ kg m^{-2} s^{-1}
- Soft tissue, $Z_2 = 1.6 \times 10^6$ kg m^{-2} s^{-1}

Step 2: Calculate the intensity reflection coefficient

$$\alpha = \frac{(1.6 \times 10^6 - 4.3 \times 10^2)^2}{(1.6 \times 10^6 + 4.3 \times 10^2)^2} \approx \frac{(1.6 \times 10^6)^2}{(1.6 \times 10^6)^2} \approx 1$$

- This result means that **100%** of the incident intensity will be reflected, with none being transmitted

Part (c)

Why gel is usually put on the skin during medical diagnosis using ultrasound

- At the air-soft tissue boundary, the intensity reflection coefficient is $\alpha \approx 1$
  - Therefore, without gel, there is almost complete reflection - no ultrasound is transmitted through the skin
- At the gel-soft tissue boundary, the intensity reflection coefficient is $\alpha = 0.001$
  - Therefore, the gel enables almost complete transmission of the ultrasound through the skin, with very little reflection

10.4.4 Applications of Ultrasound

Applications of Ultrasound

- The two main types of ultrasound used to obtain diagnostic information are:
  - **A-scan**, or amplitude scan
  - **B-scan**, or brightness scan

A-scan

- An A-scan, or amplitude scan, uses a single transducer to emit a signal and then later receive the reflected signal back
- It is defined as:

  A one-dimensional ultrasound scan used to determine the distance or depth of an internal structure

- This is achieved by:
  - Measuring the time delay between generating and receiving the signal
  - Using the speed of sound in the media to calculate the distance travelled by the signal
- This type of scan is used for:
  - Determining **distances** from the ultrasound device to the point of reflection (usually the boundary between two media)
  - For example, the length of an eye needs to be determined in planning surgeries or assessing the presence of abnormalities, such as tumours
- This type of scan gives **measurements only** and does **not** produce an image

B-scan

- A B-scan, or brightness scan, is a more complex scan that produces a 2D or 3D image of internal structures in the body

- It is defined as:

  An ultrasound scan used to build up a two or three-dimensional image of an internal structure using a number of sensors or one sensor in different positions

- This is achieved by:
  - Using pulsed ultrasound waves in **different positions** to produce **several** measurements of time intervals between generating and receiving pulses
  - Moving the transducer over the patient's skin, or using several transducers, to produce a series of A-scans that are combined to form an image
- This type of scan is used for:
  - Creating **images** of internal structures for diagnostic purposes
  - For example, bones, muscles and organs or checking on the progress of an unborn child
- To achieve the clearest images:

- Pulsed ultrasound waves are used to allow time for the reflected waves to be received and not interfere with transmitted waves
- Smaller wavelengths are used to give more detailed images as they will allow the sound waves to diffract around finer points of detail on the internal structure being studied

Exam Tip

Make sure you can summarise the key differences between A-scans and B-scans:

Direction:

- A-scan = one direction
- B-scan = many directions / angles

End result:

- A-scan = measurement of distance
- B-scan = 2D or 3D image

Pros & Cons of Ultrasound

- Ultrasound is an important medical tool when a **quick**, **safe** and **non-invasive** method is required to image an internal structure, this is particularly useful for
  - Examining a **developing foetus**
  - Getting an **initial prognosis** of a medical issue before deciding whether a riskier scan (e.g. CT, PET) or a more invasive method (e.g. endoscope) is required
- However, as with all imaging methods, it has its advantages and disadvantages

Advantages of Ultrasound

- Ultrasound is non-invasive (compared to the insertion of an endoscope or injection of radioactive nuclide in PET scans)
- Ultrasound involves no ionising radiation
- There are no side effects to an ultrasound scan
- It can image soft tissue (organ structure, muscles) as well as bone
- Can produce real-time images and videos to show moving systems
- Patients do not have to remain completely still
- Cheaper, faster and more portable than magnetic resonance (MR) or computerised tomography (CT) scans

Disadvantages of Ultrasound

- Ultrasound produces lower resolution images compared to MR or X-ray scans
- Cannot penetrate bone or gas as these reflect or dampen the sound waves (hence, can't image the brain or lungs)
- The depth of the scan is limited, causing issues for patients with higher amounts of body fat
- To increase the penetration of the scan, the resolution must be reduced further
- The transducer must be held normally to the surface and there must be no air bubbles in the coupling gel - this requires a skilled operator to carry out the examination and interpret the image
- Cannot distinguish between benign and malignant tumours (both solids with different acoustic impedances) unlike PET scans

Exam Tip

These points may well appear in a question comparing different imaging techniques. Make sure you use comparative statements such as 'the resolution of ultrasound imaging is **lower than** that of magnetic resonance imaging'.

10.4.5 Fibre Optics & Endoscopy

Fibre Optics in Medicine

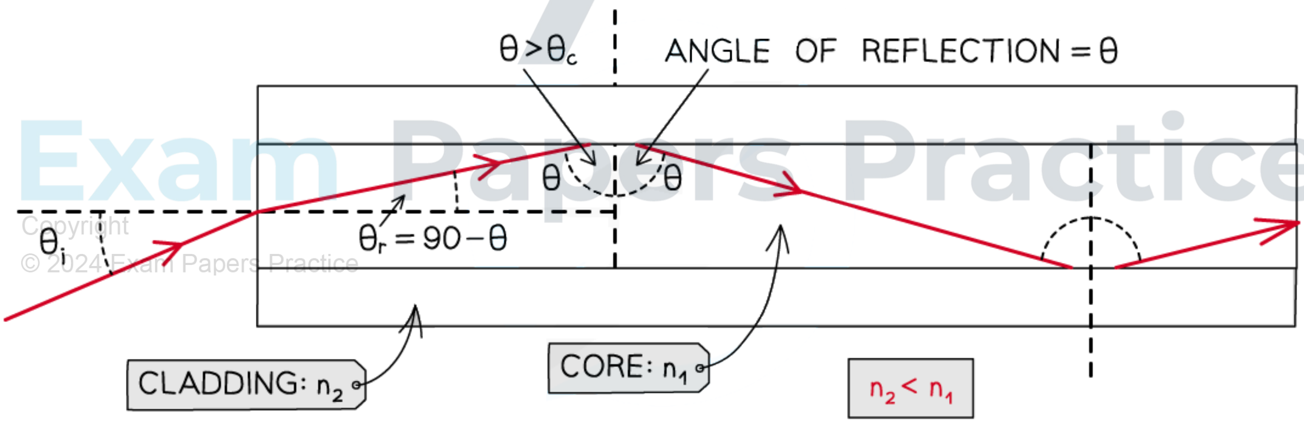
What does 'Fibre Optics' Mean?

- Fibre optics refers to the use of light travelling along a flexible fibre to produce an image
  - This is particularly useful in medicine, as it allows medics to view internal structures with the flexible fibre, without the need for surgery

What is an Endoscope?

- The piece of equipment used to do this is called an **endoscope**
  - Endoscopes contain bundles of **optical fibres** along which light is transmitted to an eyepiece
- An optical fibre is a flexible fibre, or **core**, along which light is transmitted
- The core is surrounded by **cladding**
  - This protects the core - light escapes if it is unclean or if it makes contact with neighbouring fibres
  - It also has a slightly lower refractive index than the core, allowing light in the core to be **totally internally reflected**

Cross-section of an optical fibre



Light passing through the core is internally reflected with a large critical angle, θ_c

- The core's refractive index is only just less than the cladding's refractive index
  - This makes the critical angle **large**
- Therefore, the only light transmitted by the fibre undergoes a **small** number of reflections and there is a very low amount of **loss** of information (some energy is absorbed each reflection)
  - Light that would undergo a large number of reflections, and losing information as a result, just passes through the cladding instead

Worked example

The core of an endoscope has a refractive index of 1.46. The critical angle is 80°.

Calculate the refractive index of the cladding.

Answer:

Step 1: Recall Snell's Law for the critical angle:

$$\sin \theta_c = \frac{n_2}{n_1}$$

Step 2: Rearrange this for the index of the cladding, n_2:

$$n_2 = n_1 \sin \theta_c$$

Step 3: Insert the core's refractive index and the critical angle:

$$n_2 = 1.46 \times \sin 80° = 1.44$$

Operation of the Endoscope

- Optical fibres are utilised in medicine in order to see within the human body
  - The piece of equipment using these optical fibres is called an **endoscope**
- In an endoscope, fibre optics can be bundled together as
  - Coherent bundles
  - Incoherent bundles

Coherent Bundles

- A **coherent** bundle of optical fibres is:

  A bundle of optical fibres with fixed positions relative to each other at each end and along its length

- This type of bundle is used for transmitting an image to the viewer of the endoscope
- The optical fibres are grouped together in a **regular** pattern
  - Each fibre is in a fixed position relative to its neighbours
- Each fibre receives and transmits a portion of the image to the endoscope's eyepiece
  - Collectively, the fibres make the whole image
- The fibres in a coherent bundle have a diameter of ~10 μm
  - This is small, for a high resolution
  - Any smaller than this, however, and diffraction affects the image quality

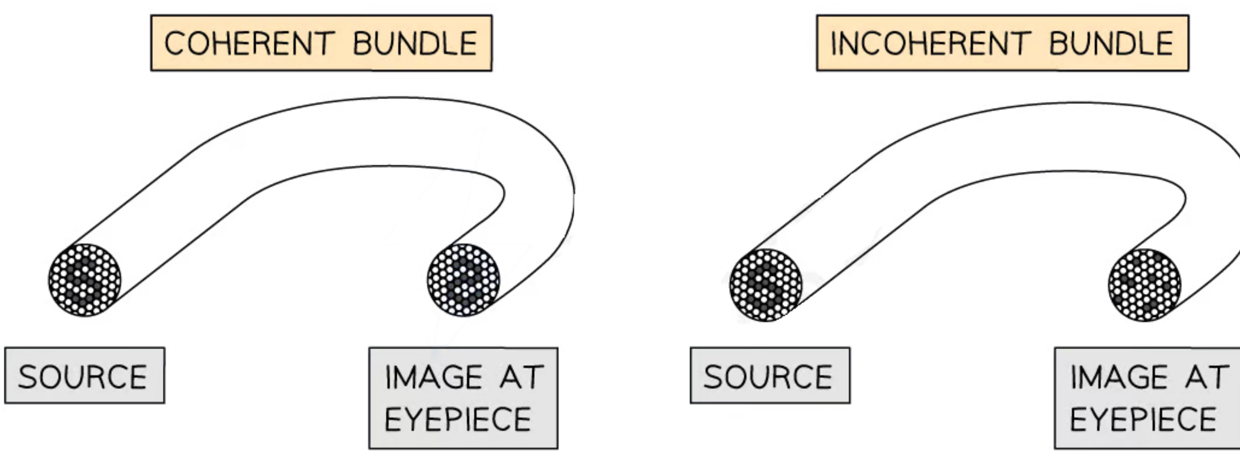
Incoherent Bundles

- An **incoherent** bundle of optical fibres is:

  A bundle of optical fibres grouped together in a random arrangement

- This type of bundle is used to transmit light from a source to the endoscope's target
- The optical fibres do not keep their position relative to their neighbours in the bundle
  - No image needs to be transmitted, this bundle only transmits light to illuminate the target tissue
  - The light reflected by the tissue is transmitted by the coherent bundle to produce an image
- Optical fibres in this bundle have a diameter range of 50 - 100 μm
  - These bundles are cheaper to produce than coherent bundles

Cross-Sections of Coherent and Incoherent Bundles



Fibres in a coherent bundle are regularly spaced. The diameters and spacing of fibres in an incoherent bundle are less crucial, as their role is illumination rather than transmitting a clear image.

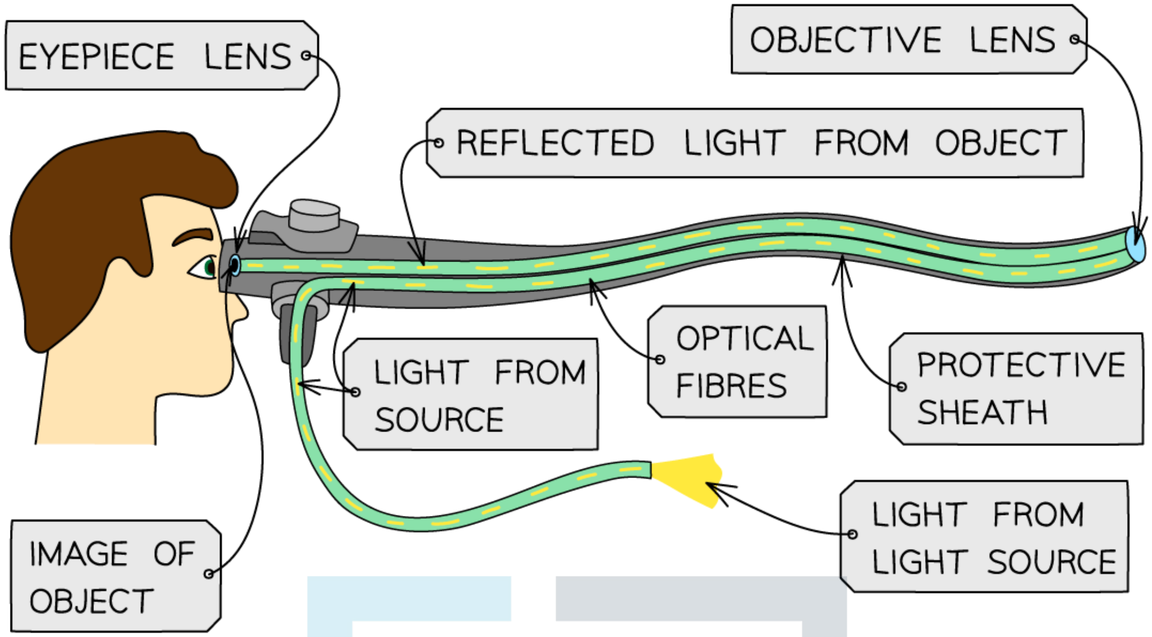
Features of an Endoscope

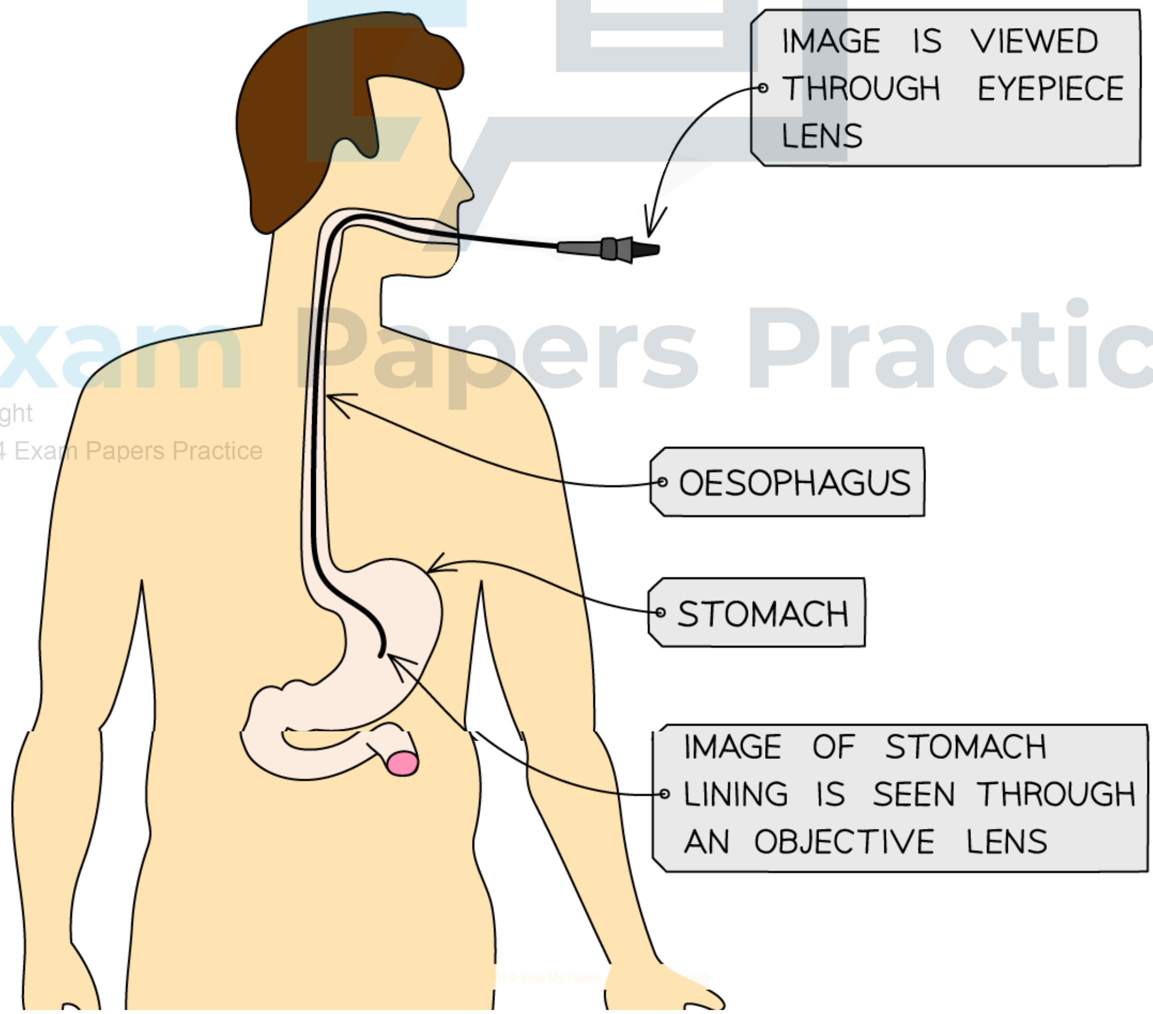
- An endoscope features a long flexible shaft connected to an eyepiece
- Within this shaft is contained:
  - An aperture (hole along the length of the endoscope) through which to operate medical instruments
  - A channel for air or water
  - An incoherent bundle for illumination
  - A coherent bundle for transmitting an image

Uses of an Endoscope

- Endoscopes can be used simply for viewing an internal system, e.g. looking for a tumour in the digestive system
- They can also be used to perform small medical procedures, using tools through the aperture e.g. taking tissue samples for further study
- Some examples of procedures using an endoscope:
  - Gastroscopy (examining the upper digestive system, see the diagram below)
  - Colonoscopy (examining the lower digestive system)
  - Arthroscopy (examining joints for issues such as arthritis, through a small incision)

Basic Structure and Use of an Endoscope





The structure of an endoscope allows internal organs to be viewed or sampled. The lower image shows a gastroscopy, in which the upper digestive system can be viewed.

- Endoscopy is commonly used instead of surgery because:
  - Endoscopy is less painful than surgery
  - There is a lower infection risk than surgery
  - The recovery time is faster than that of surgery
- Of course, endoscopy is limited to small procedures and certain systems - sometimes surgery, magnetic resonance scans or other forms of imaging are more appropriate

Exam Tip

When studying this topic, make sure you are building on a strong foundation of knowledge about total internal reflection. You may have to refer to this to form part of your descriptions and explanations of endoscopy in your exam.
For example, an endoscope can only bend a certain amount before light can no longer undergo total internal reflection in the core, because it doesn't strike the interface at (or above) the critical angle.

10.4.6 Magnetic Resonance Imaging

Principles of MRI Scanning

What is MR Scanning?

- Magnetic resonance (MR) scanning, or magnetic resonance imaging (MRI) is an imaging technique which takes **cross-sectional** images of a patient's body
- The basic principle is that by exposing the patient to a magnetic field, hydrogen nuclei in the body respond, and the location of these responses can be determined
  - This information is then used to show **structures** in the body (but not how much they are functioning)
- This makes MR scanning a powerful tool for imaging organs and locating masses, such as tumours, in the body

Cross-Sectional MR Image of the Brain

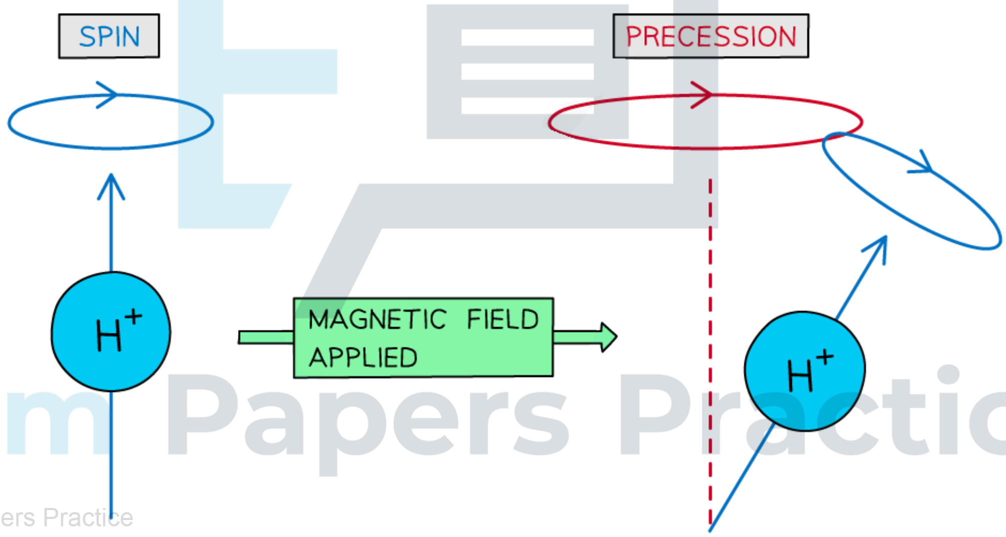
MRI produces several cross-sectional images that can be used in combination to show the extent of structures throughout the patient's body.

Nuclear spin & precession

- Hydrogen nuclei (protons) possess a property known as spin
  - When a charge moves, it generates a magnetic field
  - Therefore, the spin of a proton generates a very small magnetic field around it
  - This magnetic field has an associated magnetic moment
- Protons have **two** possible spin states, they can either be in a **spin up** state or a **spin down** state
- In the **absence** of an applied magnetic field:
  - Both spin states of a proton have the **same energy**

- Equal numbers of protons occupy one of the two states
  - Therefore, the magnetic moments (the magnetic fields produced by the protons) **cancel out**
- However, when a magnetic field is applied:
  - A **difference in the energy** arises between the two spin states
  - Most protons occupy the lower energy level state
  - Therefore, there is a **net magnetic moment** which can be detected
- The two energy states depend on the direction of the proton's magnetic moment:
  - When the magnetic moment is **parallel** to the applied magnetic field - this is the **lower** energy level
  - When the magnetic moment is **antiparallel** to the applied magnetic field - this is the **higher** energy level
- Another effect of the applied magnetic field on a proton is precession
- The spinning protons **precess** about the direction of the applied field

Precession of a Hydrogen Nucleus



The spin axis of a hydrogen nucleus (proton) precesses around the direction of the applied magnetic (like a spinning top toy on a table)

How does MR Scanning Work?

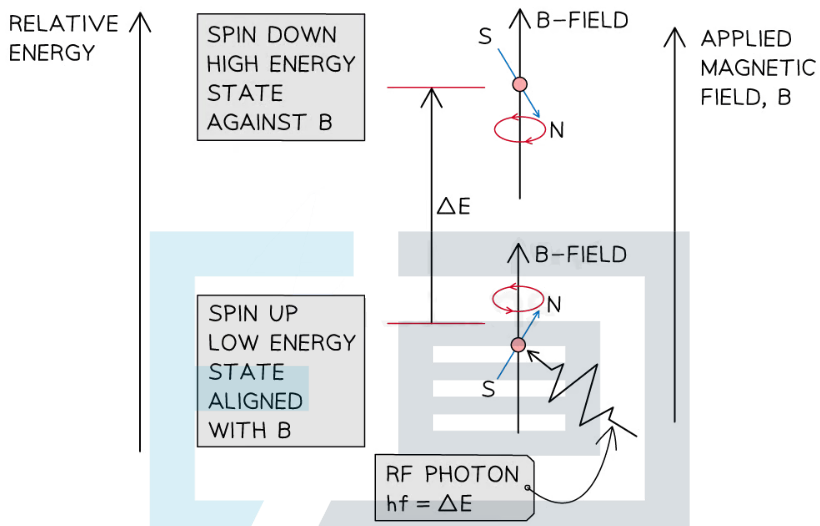
- MR machines operate on the basis of nuclear magnetic resonance (NMR), which is

  When a proton absorbs a photon of exactly the energy required to flip its spin from a lower energy state (spin up) to a higher energy state (spin down)

- The tissues in the human body contain more **hydrogen nuclei** (protons) than any other element
  - Therefore, if all their magnetic fields could be aligned, then nuclear magnetic resonance can be observed

- The patient lies along the axis of a large solenoid, which generates a very **strong** uniform magnetic field
- When the uniform field is applied, the magnetic moments of the nuclei **align** with the applied field
  - The spinning hydrogen nuclei begin to **precess** about the direction of the applied magnetic field
- A pulse of electromagnetic radiation in the **radio-frequency** (RF) range is emitted which **changes** the alignment of the spins of the hydrogen nuclei
  - This is an excited state for the hydrogen nuclei

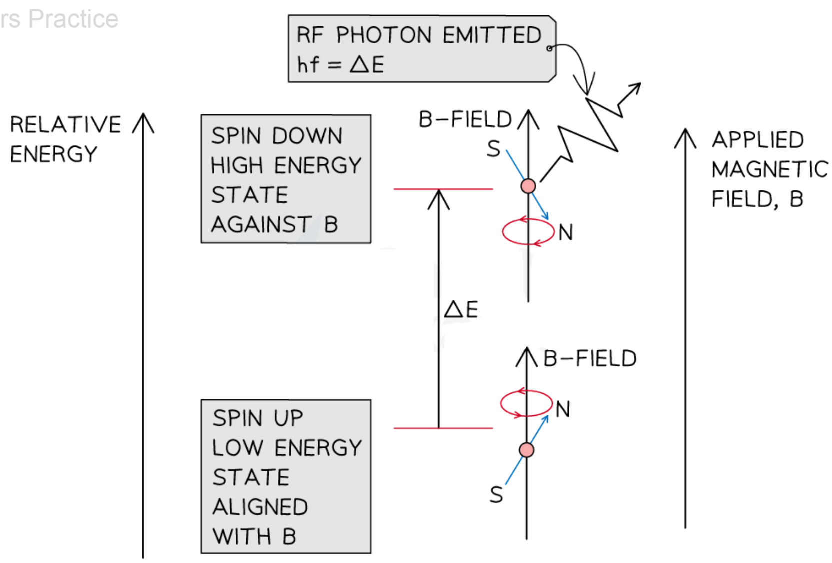
Hydrogen nucleus absorbing an RF Photon



The nucleus in a lower energy spin state (aligned with B) absorbs an RF photon with the exact energy to excite it to the higher energy spin state (aligned against B)

- The hydrogen nuclei then **de-excite**, realigning with the external field
  - In this process, they **emit** photons with the **same RF**
  - These photons are detected by a ring of detectors

Hydrogen nucleus emitting an RF Photon



The hydrogen proton emits an RF photon as it relaxes to the lower energy spin state

- Another set of coils generates the **gradient field**
  - For a given cross-section of the body, this slightly varies the magnetic flux density, *B*, at different positions
  - This means the hydrogen nuclei emit RF photons with **frequencies** that depend on the **position** of the hydrogen protons
- This information is fed into a computer, which then identifies the **density** of hydrogen nuclei at each position for a cross-section

Advantages & Disadvantages of MRI Scanning

- The main **advantages** of an MRI scan are:
  - It is non-ionising and non-invasive
  - It produces extremely high-resolution images
  - It can diagnose very small differences between cells e.g. cancerous cells
- The main **disadvantages** of an MRI scan are:
  - It is a time-consuming procedure which can be uncomfortable for patients
  - It is very expensive

Worked example

During an MRI scan, the torso of of a man in a magnetic field is exposed to pulses of radio frequency photons.

Summarise the main concept of a magnetic resonance scan which allows this process to produce a cross-sectional image of the man's torso.

Answer:

Step 1: State the purpose of the radio frequency pulses

- The magnetic field aligns hydrogen nuclei
- The radio frequency pulses excite hydrogen nuclei in the man's body

Step 2: Describe the change in the states of the hydrogen nuclei

- The nuclei de-excite (by changing spin alignment), emitting radio frequency photons

Step 3: Explain how these photons are used to produce the images

- These signals / photons are detected and passed to a computer

Step 4: Explain how the locations of the protons are found

- A gradient is applied to the uniform magnetic field
- Which allows locations of hydrogen nuclei to be determined (based on photon energies)

Exam Tip

Don't just say protons when referring to this process. Hydrogen nuclei or hydrogen protons is fine. All atoms in the body contain protons, but the fact that protons are isolated in hydrogen nuclei allow them to behave in this way.