CAIE Physics A-level

24 - Medical Physics

Flashcards

What happens when mechanical stress is applied to a piezoelectric crystal?

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The crystals are forced to change shape. As a result, an emf is generated across them.

What happens when a potential difference is passed across piezoelectric crystals?

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An internal stress is felt within the crystals, causing them to change shape.

How can the piezoelectric effect be used to produce ultrasound waves?

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If an alternating potential difference is applied across a piezoelectric material, the material will vibrate at the same frequency as the applied voltage. If applied at the natural frequency of the material, resonance will occur. The amplitude of a resonating piezoelectric material is sufficient to produce ultrasound waves.

How is it possible that a piezoelectric transducer can receive as well as emitting ultrasound waves?

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The alternating potential difference is only applied across piezoelectric materials for a few short pulses. After this the transducer is open to receiving reflected ultrasound waves. When receiving reflected waves, the pressure changes inflicted by the ultrasound cause the piezoelectric crystals to change shape, generating a potential difference in the transducer.

Why are piezoelectric transducers useful in the context of prenatal screenings?

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Ultrasound is partially reflected at tissue boundaries as a result of acoustic impedance variations between tissues. Consequently the ultrasound will reflect off several tissue boundaries and subsequently picked up by the transducer. These reflected waves can be used to establish an picture of the unborn child, checking that there are no prenatal defects in the foetus. If there are defects, these can then be treated.

Give an equation for acoustic impedance.

Give an equation for acoustic impedance.

$$Z = \varrho c$$

Where ‘Z’ is acoustic impedance, ‘ϱ’ is density and ‘c’ is the speed of sound in the relevant medium.

Give an equation for the intensity of ultrasound reflected at a tissue boundary (in terms of the acoustic impedance of the two tissues and the original sound intensity).

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$$I_R = I_O((Z_1 - Z_2)/(Z_1 + Z_2))^2$$

Where 'I_O' is the incident intensity, 'I_R' is the reflected intensity, 'Z_1' and 'Z_2' are the impedance of the two tissues.

When a wave passes through a medium, is 100% of its energy transmitted or is some absorbed?

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Some is absorbed.

Give an equation that defines the change in intensity of a wave, according to the amount that has been absorbed.

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$$I = I_0 e^{-\mu x}$$

Where ‘I’ is the intensity, ‘I_0’ is the original intensity, μ is the total linear attenuation coefficient, which is specific to each material and ‘x’ which is the thickness of the material travelled through.

Explain how X-rays can be produced through ‘electron bombardment’.

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- Passing a current through a tungsten filament causes it to heat up and emit electrons: an effect known as ‘thermionic emission’.
- The electrons are attracted to a positively charged tungsten anode and collide with it.
- This interaction (Bremsstrahlung) gives off energy in the form of heat and X-ray photons.
- X-rays are reflected in a particular direction such that an electron beam is created.

Draw a diagram of apparatus that could be used to produce X-rays through ‘electron bombardment’.

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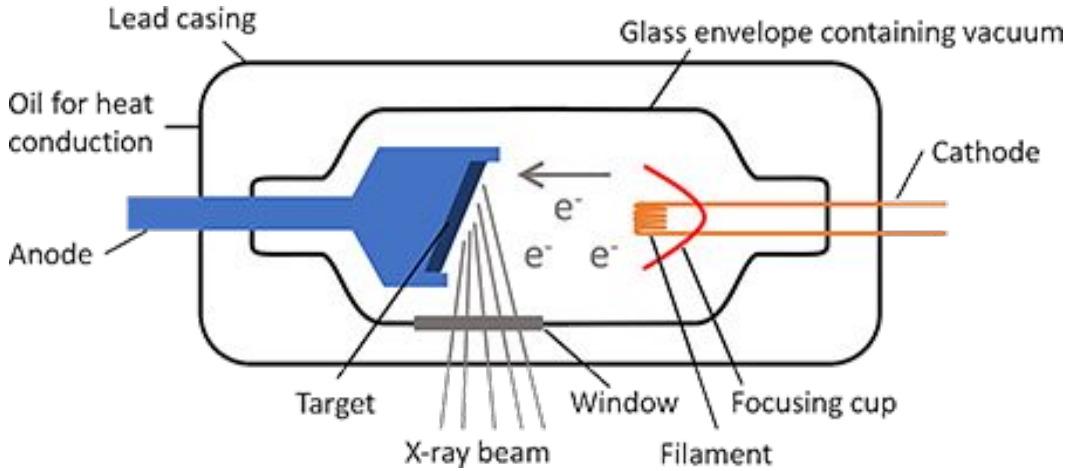

Give the equation allows one to calculate the minimum wavelength of the X-rays emitted.

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$$\lambda_{min} = hc/E = hc/(eV_a)$$

Where 'λ_{min}' is the minimum wavelength of the X-rays produced, 'E' is the maximum X-ray photon energy, 'e' is the charge of an electron and 'V_a' is the accelerating p.d.

How might you increase the intensity of an X-ray beam produced using electron bombardment?

How might you increase the intensity of an X-ray beam produced using electron bombardment?

By increasing the accelerating voltage or by increasing the current passed though the electron emitting thermister.

What is meant by X-ray intensity?

What is meant by X-ray intensity?

The energy that passes through an area, per unit area, per unit time.

Why is contrast important in X-ray imaging?

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Contrast allows body tissues to be seen as clearly distinct in X-ray images.

Is higher contrast achieved by higher or lower intensity X-ray beams?

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Higher intensity X-ray beams achieve greater contrast.

How do CT scans produce high contrast 3D X-ray images of the human body?

How do CT scans produce high contrast 3D X-ray images of the human body?

The process involves incorporating multiple high intensity X-ray images, taken from different angles around the body/region of concern. Complex computer software then combines these images to establish a 3D anatomical map called a CT scan.

What is a tracer?

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A tracer is a substance, containing radioactive nuclei, that is ingested or otherwise introduced to the body. It becomes absorbed by the tissue under study and helping to highlight any potential issues.

What does PET stand for?

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Positron Emission Tomography

How does PET work?

How does PET work?

- A positron-emitting radionuclide is injected into the patient.
- The positrons emitted by the tracer collide with electrons in the bodies tissue and they annihilate one another.
- As a product of annihilation, two high-energy gamma ray photons are emitted, travelling in opposite directions.
- More annihilation events take place in regions of high metabolic activity. These regions of high gamma ray emission concentration can be identified through receiver processing of arrival times of gamma ray photons, highlighting body parts of concern.

What is the energy of each gamma ray photon emitted during electron-positron annihilation?

What is the energy of each gamma ray photon emitted during electron-positron annihilation?

$$E = \Delta mc^2$$

$$E = 2 \times 9.11 \times 10^{-31} \times (3 \times 10^8)^2 / 2$$

$$= 2.73 \times 10^{-22} J$$