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QUESTION WORKBOOK

Ultrasound imaging

Medical physics · Year 13

AQA 3.10.4.1, 3.10.4.2, 3.10.4.3 · CIE 24.1.1, 24.1.2, 24.1.3, 24.1.4, 24.1.5, 24.1.6
OCR A 6.5.3(a), 6.5.3(b), 6.5.3(c), 6.5.3(d), 6.5.3(e), 6.5.3(f), 6.5.3(g)

21 questions · 62 marks

NAVY SCREEN EDITION

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SECTION A · Warm-up

A1 Describe how a piezoelectric transducer both generates and detects ultrasound. [2]

A2 An echo returns 90 μs after a pulse enters soft tissue, where ultrasound travels at 1540 m s^{-1}. Calculate the depth of the reflecting boundary. [2]

A3 State what is meant by the acoustic impedance of a medium, and give its defining equation. [2]

A4 A scanner uses ultrasound of frequency 3.0 MHz. Calculate the wavelength of this ultrasound in soft tissue, where its speed is 1540 m s^{-1}. [2]

A5 The acoustic impedance of bone is 7.8×10^{6} kg m^{-2} s^{-1} and its density is 1900 kg m^{-3}. Calculate the speed of sound in bone. [2]

SECTION B · Standard

B1 Calculate the acoustic impedance of liver tissue, of density 1075 kg m^{-3}, in which sound travels at 1590 m s^{-1}. [2]

B2 A boundary lies 3.5 cm below the skin. Calculate the time after the pulse enters the tissue at which its echo returns (speed of sound in tissue 1540 m s^{-1}), and state why the scanner must finish listening before it sends the next pulse. [3]

B3 Distinguish between an A-scan and a B-scan. [2]

B4 Ultrasound meets a boundary between muscle ($Z = 1.70 \times 10^6$ kg m^{-2} s^{-1}) and liver ($Z = 1.63 \times 10^6$ kg m^{-2} s^{-1}). Calculate the fraction of the incident intensity that is reflected. [3]

B5 Explain, in terms of acoustic impedance, why coupling gel is needed between the transducer and the skin. [3]

B6 A scanner sends 5000 pulses each second and must receive all the echoes from one pulse before it sends the next. Show that the greatest depth this scanner can image is about 15 cm. The speed of ultrasound in tissue is 1540 m s^{-1}. [3]

B7 An A-scan, rather than a B-scan, is used to measure the length of a patient's eye before surgery. Suggest why an A-scan is sufficient for this task. [2]

B8 Explain why an MR scan is usually the instrument of choice for imaging soft tissue such as the brain, and state what property of the tissue the returning radio signal depends on. [3]

SECTION C · Stretch

C1 The acoustic impedance of air is about 430 kg m^{-2} s^{-1} and of soft tissue about 1.63 × 10^{6} kg m^{-2} s^{-1}. Calculate the fraction of intensity reflected at an air-tissue boundary, and comment on the result. [3]

C2 In an A-scan of an organ, echoes return 52 µs and 78 µs after the pulse enters the tissue (c = 1540 m s^{-1}). Calculate the depth of each surface of the organ and hence its thickness along the beam. [4]

C3 A student says higher-frequency ultrasound always gives a better scan. Discuss whether this is true. [3]

C4 Give two reasons why ultrasound, rather than X-rays, is used for antenatal scanning, and one limitation of ultrasound imaging. [3]

C5 A sonographer can use one of two coupling gels. Gel P has acoustic impedance 1.50×10^{6} kg m^{-2} s^{-1} and gel Q has acoustic impedance 1.10×10^{6} kg m^{-2} s^{-1}. The acoustic impedance of skin is 1.63×10^{6} kg m^{-2} s^{-1}. Deduce which gel transmits the greater fraction of the ultrasound intensity into the patient, supporting your answer with calculations. [4]

C6 A scanner converts echo times to depths using a speed of 1540 m s^{-1} everywhere. A reflecting boundary lies at the bottom of a layer of fat 3.0 cm thick, in which ultrasound actually travels at 1450 m s^{-1}. Determine the depth the scanner displays for this boundary, and the error in the displayed depth. [4]

C7 A B-scan is used to produce an image of a foetus. Describe fully how the image is produced, from the generation of each ultrasound pulse to the formation of the two-dimensional image. [6]

C8 For each of the following patients, choose the most suitable imaging method from MR, CT and ultrasound, giving a reason for each choice: (a) routine monitoring of a foetus; (b) a detailed image of suspected soft-tissue damage inside a knee; (c) urgent imaging of the brain of a patient fitted with an older pacemaker labelled MR Unsafe. [4]