InkPhysics

ANSWER BOOK

Ultrasound imaging

Medical physics · Year 13

AQA 3.10.4 · CIE 24.1 · OCR A 6.5.3

12 questions · 32 marks

NAVY EDITION

inkphysics.co.uk

SECTION A · Warm-up

A1 To generate: an alternating pd applied across the crystal makes it deform and vibrate at the driving frequency, launching an ultrasound pulse. To detect: a returning echo deforms the crystal, which produces a measurable pd across it. [2]

A2 $d = ct/2 = (1540 \times 90 \times 10^{-6})/2 = 6.9 \times 10^{-2}$ m ≈ 6.9 cm. The factor of two accounts for the there-and-back journey. [2]

A3 Acoustic impedance is the product of the density of a medium and the speed of sound in it: $Z = \rho c$. Its unit is kg m^{-2} s^{-1}. [2]

SECTION B · Standard

B1 $Z = \rho c = 1075 \times 1590 = 1.71 \times 10^{6}$ kg m^{-2} s^{-1} ≈ 1.7×10^{6} kg m^{-2} s^{-1}. [2]

B2 $t = 2d/c = 2 \times 0.035/1540 = 45$ μs. If a new pulse left before the deepest echoes of the last one arrived, the scanner could not tell which pulse an echo belonged to, and depths would be assigned wrongly. [3]

B3 An A-scan plots echo strength against time along a single line through the body, giving depths along that one direction. A B-scan sweeps the beam and turns each echo into a brightness point, building a two-dimensional image of the boundaries. [2]

B4 $I_r/I_0 = (Z_2 - Z_1)^2/(Z_2 + Z_1)^2 = (0.07/3.33)^2 = 4.4 \times 10^{-4}$, about 0.04%. [3]

B5 Air's acoustic impedance is thousands of times smaller than tissue's, so at an air-skin boundary the impedance mismatch is enormous and nearly all the intensity reflects before entering the body. The gel displaces the air with a medium whose impedance is close to that of tissue, so the pulse is transmitted rather than reflected at the surface. [3]

SECTION C · Stretch

C1 $I_r/I_0 = ((1.63 \times 10^{6} - 430)/(1.63 \times 10^{6} + 430))^2 = 0.9989 \approx 0.999$. Nearly everything reflects, which is exactly why an air gap makes imaging impossible and why the gel must exclude it. [3]

C2 Front surface: $d = ct/2 = (1540 \times 52 \times 10^{-6})/2 = 4.0$ cm. Back surface: $d = (1540 \times 78 \times 10^{-6})/2 = 6.0$ cm. Thickness = 2.0 cm ≈ 2.0 cm. [4]

C3 Higher frequency means shorter wavelength, so finer detail can be resolved, which argues for high frequency. But attenuation in tissue increases with frequency, so a high-frequency pulse fades before reaching deep structures. The choice is a trade: high frequency for shallow, detailed work such as eye measurements, lower frequency for deep organs. [3]

C4 Ultrasound is non-ionising, so it carries no radiation dose to the foetus, and it images in real time, showing movement. A limitation: it cannot image through bone or air-filled spaces, since the impedance mismatch reflects the pulse, so structures behind the skull or lungs are hidden. [3]