24. Medical Physics

24.1 Production and use of ultrasound

Paper 4

Marking Scheme

Q1.

(a)	time gives information about depth (of boundary)	**B1**
	intensity gives information about nature of boundary	**B1**
(b)(i)	product of density and speed	**M1**
	speed of ultrasound in medium (and density of medium)	**A1**
(b)(ii)	$Z_{water} = 1000 \times 1420$ ($= 1.42 \times 10^6$ kg m^{-2} s^{-1}) **and** $Z_{glass} = 2500 \times 4560$ ($= 11.4 \times 10^6$ kg m^{-2} s^{-1})	**C1**
	intensity reflection coefficient = $(11.4 - 1.42)^2 / (11.4 + 1.42)^2$	**C1**
	$= 0.61$	**A1**

Q2.

(a)(i)	specific acoustic impedance = $1200 \times 1400 = 1.68 \times 10^6$ kg m^{-2} s^{-1}	**A1**
(a)(ii)	density of air shown in table as 1.29	**A1**
	speed of sound in tissue shown in table as 1540	**A1**
(b)(i)	intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ $= (1680000 - 440)^2 / (1680000 + 440)^2$	**C1**
	$= 0.999$	**A1**
(b)(ii)	intensity reflection coefficient $= (Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ $= (1680000 - 1680000)^2 / (1680000 + 1680000)^2$ $= 0$	**A1**
(c)	without gel, (almost) all of the (incident) ultrasound is reflected (from skin)	**B1**
	with gel, (almost) all of the (incident) ultrasound is transmitted (into the body)	**B1**

Q3.

(a)	ultrasound production:	vibrating quartz crystal	**B1**
	X-ray production:	electrons hitting metal target	**B1**
	ultrasound detected wave:	reflected	**B1**
	X-ray detected wave:	transmitted	**B1**

Q4.

(b)(i)	(alternating p.d. makes) the crystal vibrate	**B1**
	vibrations (of crystal) causes air to vibrate	**B1**
	frequency is in ultrasound range	**B1**
(b)(ii)	(air makes) crystal vibrate, which causes an e.m.f. to be generated across the (second) crystal	**B1**

Q5.

	(ultrasound) pulse	**B1**
	reflected at boundaries	**B1**
	gel is used to minimise reflection at skin **or** generated and detected by quartz crystal	**B1**
	time delay between generation and detection gives information about depth	**B1**
	intensity (of reflected wave) gives information about nature of boundary	**B1**

Q6.

(a)	generates ultrasound	**B1**
	detects reflected ultrasound	**B1**
	applied p.d. causes crystal to vibrate **or** vibrations cause crystal to generate an e.m.f.	**B1**
(b)(i)	product of density and speed	**M1**
	speed of ultrasound in medium	**A1**
(b)(ii)	difference between (the specific acoustic impedances)	**C1**
	• if similar/same then reflection coefficient is zero/very low • if very different then reflection coefficient is (nearly) 1 • the lower the difference means lower the reflection coefficient (*any one point*)	**A1**

Q7.

(a)(i)	product of density and speed	**M1**
	speed of ultrasound in medium	**A1**
(a)(ii)	the greater the difference between Z_1 and Z_2, the closer the ratio is to 1 **or** if difference between Z_1 and Z_2 large, ratio is close to 1	**B1**
	the closer together Z_1 and Z_2, the closer the ratio is to 0 **or** if difference between Z_1 and Z_2 small, ratio close to 0	**B1**
(b)(i)	loss of intensity/amplitude/power (of the wave)	**B1**
(b)(ii)	$I = I_0 e^{-\mu x}$	**C1**
	$0.35 = e^{-0.046\mu}$ $\mu = 23\ m^{-1}$	**A1**

Q8.

(a)	pulses of ultrasound	**B1**
	ultrasound incident on quartz crystal	**B1**
	waves make crystal oscillate	**B1**
	oscillations (of crystal) generates an e.m.f. (across the crystal)	**B1**
(b)	specific acoustic impedances of air and skin are very different	**B1**
	intensity reflection coefficient depends on difference between acoustic impedance	**B1**
	most ultrasound reflected so little transmission	**B1**

Q9.

(a)	quartz crystal	**B1**
	alternating p.d. across crystal causes it to vibrate	**B1**
	resonance occurs when frequency of p.d. matches natural frequency of crystal	**B1**
	natural frequency of crystal is in ultrasound range	**B1**
(b)	$I = I_0 e^{-\mu x}$	**C1**
	$I / I_0 = e^{-1.2 \times 3.5}$ $= 0.015$	**C1**
	ratio / dB $= -10 \lg (1 / 0.015)$ **or** $10 \lg (0.015)$	**C1**
	$= -18$ dB	**A1**

Q10.

(a)	product of density and speed	**M1**
	speed of sound in medium	**A1**
(b)	Any two from: • if $Z_A \gg Z_B$ then ratio is (nearly) zero **or** if $Z_B \gg Z_A$ then ratio is (nearly) zero **or** if Z_B and Z_A are very different then ratio is (nearly) zero **or** the greater the difference the lower the ratio • if $Z_A \approx Z_B$ then ratio is (nearly) 1 **or** if $Z_A = Z_B$ then ratio is 1 **or** the smaller the difference the closer the ratio to 1 (**not** 'large') • $I_T / I_0 = 1 - [(Z_A - Z_B)^2 / (Z_A + Z_B)^2]$	**B2**
(c)	$I = I_0 e^{-\mu x}$	**C1**
	$0.34 = \exp(-23 \times x)$	**C1**
	$x = 0.047$ m	**A1**

Q11.

(a)(i)	product of density and speed	**M1**
	speed of sound in the medium	**A1**
(a)(ii)	$Z_B = 1.8 \times 10^3 \times 4.1 \times 10^3$ $= 7.4 \times 10^6$ kg m^2 s^{-1}	**A1**
(b)	$\alpha = (1.7 - 1.3)^2 / (1.7 + 1.3)^2 = 0.018$ fraction = 0.98	**A1**
(c)(i)	reduction in power/intensity (of wave)	**M1**
	as the wave passes through the medium	**A1**
(c)(ii)	**1.** ratio $= e^{-\mu x}$	**C1**
	$= 0.90$	**A1**
	2. ratio $= 0.62$	**A1**
(d)	fraction $= 0.898 \times 0.617 \times 0.98$ $= 0.54$	**A1**

Q12.

(a)	e.g. microphone weighing scales/pressure sensor lighters/spark generation watches/clocks/regulation of time	**B1**
(b)	pulses (of ultrasound)	**B1**
	reflected at boundaries (between media)	**B1**
	(reflected pulses) detected by (ultrasound) generator	**B1**
	Any three from: • time delay (between transmission and receipt) gives information about depth (of boundary) • intensity of reflected pulse gives information about (nature of) boundary • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	**B3**

Q13.

(a)	pulses (of ultrasound from generator)	**B1**
	reflected at boundaries (between media)	**B1**
	time delay (between transmission and receipt) gives information about depth	**B1**
	intensity of reflected pulse gives information about nature (of tissues)/type (of tissues)/boundary	**B1**
	Any two from: • (reflected pulses) detected by the (ultrasound) generator • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	**B2**
(b)(i)	product of density and speed	**M1**
	speed of ultrasound in medium	**A1**
(b)(ii)	Z_1 about equal to Z_2 results in negligible/no reflection	**B1**
	$Z_1 \gg Z_2$ (or $Z_1 \ll Z_2$) results in mostly reflection	**B1**