A Level OCR Physics

Chapter 24 Medical imaging

Question	Answers	Extra information	Mark	AO Spec reference
1(a)	A (top line labelled) This is because the attenuation coefficient for muscle is less than bone/gradient less/X-rays absorbed less by muscle	Allow counter arguments i.e. muscle greater attenuation coefficient	1 1	6.5.1 AO1
(b)	Use of intercept – either line extrapolated ln I_0 = 6.9 I_0 = 990 W		1 1	6.5.1 1.1.3 1.1.4 AO2
(c)	$I = I_0\ e^{-\mu x}$ ln I = ln I_0 $-\mu x$ attenuation is the gradient Gradient calculated = 0.96		1 1 1	6.5.1 1.1.3 1.1.4 AO2
(d)	$I = I_0\ e^{-\mu x}$ when $x = x_{1/2}$ $I = I_0/2 = 0.5$ ln 0.5 = $-\mu\ x_{1/2}$ $-0.693 = -\mu\ x_{1/2}$ $x_{1/2}$ = $0.693/\mu$	Can also invert and use ln 2	1 1	
(e)	$\mu\ x_{1/2}$ = constant $x_{1/2\,A}$ / $x_{1/2\,B}$ = μ_B/μ_A Calculate gradient of line B = 2.8 $x_{1/2\,A}$ / $x_{1/2\,B}$ = 2.8/0.96 = 2.9 times		1 1 1 1	
2(a)	Any four from: • Piezoelectric effect • alternating/high frequency pd/emf applied • crystal expands and contracts • vibration of faces produces ultrasound/pressurewaves/greater than 20 kHz • backing material damps/stops vibrations	Must contain at least one point about received signal for full marks.	Max 4	6.5.3 AO1

Question	Answers	Extra information	Mark	AO Spec reference
	• short pulses • received signals cause crystal to vibrate • producing alt pd across the crystal			
(b)	Signal reflected/transmitted at <u>boundary</u> between two media proportion reflected depends on the acoustic impedance of each medium.		1 1	6.5.3 AO1
(c)	Correctly identifying B and C $T = 3 \times 2.5\times10^{-6}$ s $= 7.5\times10^{-6}$ s $2D = s \times t = 4080 \times 7.5\times10^{-6} = 0.031$ m $D = 0.015$ m	Allow 2 marks for correct working but wrong section identified	1 1 1	6.5.3 AO2
(d)	$v = f\lambda$ $\lambda = 4080/8\times10^{6} = 5.1\times10^{-4}$ m		1	4.4.1 AO1
(e)	The resolution is the ability to distinguish between objects close together (wtte) the smaller the wavelength the greater detail it is possible to see/mention of diffraction.		1 1	2.2.1 AO2
3(a)	These cannot pass through tissue so not needed for diagnosis/ are absorbed by tissue increasing harm/risk.		1 1	6.5.1 AO2
(b)	$I = P/A$ $I = 1\times10^{-3}/\pi \times (0.75\times10^{-3})^2 = 570$ W m^{-2}		1 1 1	4.4.1 A02
(c)	Decrease in intensity, decrease increasing at 3 cm then more steadily at 4.5 cm clear exponential drop shown for 1.5 cm of bone suitably labelled	Values of intensity can be ignored – looking for contrast between bone and muscle.	1 1	6.5.1 AO2
(d)	Max 3		Max 3	6.5.1

Question	Answers	Extra information	Mark	AO Spec reference
	• muscle and tissue have similar attenuation coefficients • heart does not stay still for long • image captured quickly/short exposure • contrast used/barium/iodine • with high coefficient/high Z.			AO2
4(a)	Pair production		1	6.5.1 AO1
(b)	Any two from: **Photoelectric effect:** X-ray photon ejects/removes an electron **Compton (scattering)**: Photon emerges with less energy/ longer wavelength/lower frequency and an electron escapes/ejected (from the atom) **Scattering**: Photon is scattered by an electron	Both name and description needed for mark	Max 2	6.5.1 AO1
(c)	**Level 3 (5–6 marks)** Clear description of the scan procedure and how 3D image formed *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Clear description of the scan procedure and a limited description of how 3D image formed *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description of scan procedure or how 3D image formed *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.*	**Indicative points:** **Scan procedure:** - X-ray tubes and detectors rotated round the body fan shaped/thin beam of X-rays 2D /cross-section slice of the patient X-ray tubes move/spiral across the body. Attenuated by different amounts by different tissues - Intensity of transmitted X-rays recorded by detectors 3D image formation: - Images are transmitted to a	Max 6	6.5.1 AO1

Question	Answers	Extra information	Mark	AO Spec reference
	0 marks No response or no response worthy of credit	computer - Computer compiles 2D slices to build up a 3D image		
(d)	Max 2 from: • patients are exposed to ionising radiation • increased risk of cancer • expensive • time consuming/waste of resources		1 1	6.5.1 AO2
5(a)	The acoustic impedance of air is too different from skin / too much reflected from skin. Gel has similar acoustic impedance to skin/tissue.		1 1	6.5.3 AO1
(b)	$\Delta flf = 2v \cos \theta / c$ cos 90 = 0 so no measurements possible.	Accept that there is no movement towards/away from detector so no Doppler Shift can be recorded	1	6.5.3 AO1
(c)	$\Delta flf = 2v \cos \theta / c$ $\Delta f = 2vf \cos \theta / c = 2 \times 0.12 \times 5 \times 10^6 \times \cos 50 / 1600$ $\Delta f = 480$ Hz		1 1	6.5.3 AO2
(d)	Small change in frequency /reflected frequency 4.999×10^6 – need sensitive scale to detect change Decrease the angle between blood vessel/increase incident frequency		1 1	6.5.3 AO3
6(a)	**Collimator:** Only gamma rays/photons travel along the axes of lead tubes are detected / ensures only photons originating from directly below that point reach the scintillator **Scintillator:** A gamma ray photon produces thousands/many photons of (visible) light. **Photomultiplier**: An electrical pulse is produced from each photon of visible light /one electron released, accelerated and then releases 4 more etc until electric pulse achieved		1 1 1	6.5.2 AO1

A Level OCR Physics

Chapter 24 Medical imaging

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(b)	Fluorine-18		1	6.5.2 AO1
(c)	Any four from: • Fluorine-18 beta minus decay/releases positrons • Annihilation when electron meets positron • Pair of gamma photons produced • Conservation of momentum /photons have equal and opposite momenta • Gamma photons are detected at different times at opposite points. • Array of gamma cameras around the patient • Computer calculates of point of origin using Distance = speed of light × time difference	Max 4	1 1 1 1	6.5.2 AO1
(d)	$E = mc^2$ $E = 2 \times 9.11\times10^{-31} \times (3\times10^{8})^2$ Total $E = 1.6398\times10^{-13}$ J E of 1 photon = 8.199×10^{-14} J/1.6×10^{-19} E of 1 photon = 0.51 MeV		1 1 1	6.4.4 2.1.2 AO2
7(a)	$1/t_e = 1/t_p + 1/t_b$ $1/t_e$ = 1/21 700 + 1/86 400 t_e = 17 300 s t_e = 4.8 hours.		1 1 1	M2 A03
(b)	$\lambda = \ln 2/t_{1/2}$ $\lambda = \ln 2/4.8 = 0.144\ h^{-1}$ Or $\lambda = \ln 2/17300 = 4.0 \times 10^{-5}\ s^{-1}$	1 mark for answer, 1 for correct unit Unrounded answer gives $4.0 \times 10^{-5}\ s^{-1}$	1 1	6.4.3 AO2

A Level OCR Physics

Chapter 24 Medical imaging

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(c)	Use of $A = A_0\ e^{-\lambda t}$ $t = 2 \times 24 \times 60 \times 60$ s or $t = 2 \times 24$ $A = 4.0 \times 10^3$ Bq	decay constant and time must be in same units using hours gives $A = 4.0\times10^3$ Bq	1 1	6.4.3 AO2
(d)	Allow time between 1 and 5 hours By 5 hours activity halved so needs to be within that time But needs time to be taken up by tissues so greater than 1 hour	Allow any sensible suggestion	1 1 1	6.5.2 A03
8(a)	Thermionic emission		1	6.5.1 AO1
(b)(i)	To prevent collisions of electrons with molecules		1	6.5.1 AO1
(ii)	To stop the target overheating/melting		1	6.5.1 AO1
(c)	Use of $E = eV$ $E = hc/\lambda$ or $eV = hc/\lambda$ $\lambda = hc/eV = 6.63\times10^{-34} \times 3\times10^8/1.6\times10^{-19} \times 180\ 000$ $\lambda = 6.9\times10^{-12}$ m		1 1 1	4.5.1 AO2
(d)	Use of $Q = It$ or number of photons needed = 1.2/eV = 4.166×10^{13} Number of electrons per second = $25\times10^{-3} / 1.6\times10^{-19}$ 1% photons produced = $0.01 \times 25 \times 10^{-3} / 1.6\times10^{-19}$ Only 4% produced used photons per second= $0.04 \times 0.01 \times 25 \times 10^{-3} / 1.6\times10^{-19} = 6.25\times10^{13}$ per second Time = number of photons/photons per second Time = $4.1666\times10^{13} / 6.25\times10^{13} = 0.67$ s		1 1 1 1	4.1.1 4.5.1 AO3