A Level AQA Physics

24 Medical imaging – answers

Question	Answers	Extra information	Mark	AO Spec reference
01.1	Time = 0.7 s Pulse rate = $\frac{60}{0.7}$ = 86 beats per minute		1 1	3.10.3.1 AO1
01.2	Suitable scale added 0 to 1 mV Each small square is 0.2 mV		1 1	3.10.3.1 AO1
01.3	Max 4 marks from: (should be in this order) • Sino-atrial node fires/depolarisation • Atria contracts • Impulse delayed at the atrio-ventricular node/to allow ventricles to fill • Ventricular node fires/depolarisation • Ventricle contracts • Heart muscle repolarises/heart muscle relaxes	A suitably labelled diagram can gain all marks	max 4	3.10.3.1 AO1
01.4	Max 2 marks from: • *T* would decrease • Flat part of the trace would be shorter • The trace will have noise		1 1	3.10.3.1 AO2
01.5	Hair and dead skin removed Use of conducting gel/no air gap		1 1	3.10.3.1 AO1
02.1	Max 4 marks from: • Alternating/high frequency pd/emf applied • Crystal expands and contracts • Vibration of faces produces ultrasound/pressure waves/greater than 20 kHz • Backing material damps/stops vibrations • Short pulses • Received signals cause crystal to vibrate • Producing alt pd across the crystal	Must contain at least one point about received signal for full marks	max 4	3.10.4.1 AO1
02.2	Signal reflected/transmitted at <u>boundary</u> between two media Proportion reflected depends on the acoustic impedance of each medium		1 1	3.10.4.1 AO1

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02.3	Correctly identifying **B** and **C** $T = 3 \times 2.5\times10^{-6}$ s $D = s \times t = 4080 \times 3 \times 2.5\times10^{-6} = 0.031$ m	Allow 2 marks for correct working but wrong section identified	1 1 1	3.10.4.1 AO2
02.4	$v = f\lambda$ $\lambda = \frac{4080}{8\times10^{6}} = 5.1\times10^{-4}$ m		1	3.3.1.1 AO1
02.5	The resolution is the ability to distinguish between objects close together (or wtte) The smaller the wavelength, the greater detail it is possible to see		1 1	3.10.4.1 AO2
03.1	Max 2 marks from: • Use of lead diaphragm/cone perpendicular to the beam • Film is close to object • Distance from source to film is large • Grid used to absorb scattered X-ray photons		max 2	3.10.5.1 AO2
03.2	Filters out low-energy photons These cannot pass through tissue, so not needed for diagnosis/are absorbed by tissue increasing harm/risk		1 1	3.10.5.1 AO2
03.3	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	3.10.5.3 AO3
03.4	Max 3 marks from: • Muscle and tissue have similar attenuation coefficients • Heart does not stay still for long • Image captured quickly/short exposure • Contrast used • With high coefficient/high Z		max 3	3.10.5.3 AO2

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04.1	$\sin C = \frac{n_2}{n_1}$ $\sin C = \frac{1.43}{1.55}$ $C = 67°$		 1 1	3.3.2.3 AO1
04.2	This decreases the angle of incidence, making it more likely to be less than the critical angle Increases probability		1 1	3.10.4.2 AO2
04.3	Max 3 marks from: • Coherent has fixed arrangement of fibres at each end • Incoherent has a random arrangement of fibres • Coherent is used to transmit an image • Incoherent is used to light up the inside of the body		max 3	3.10.4.2 AO3
04.4	Cutting tissue/cauterising/stopping bleed/removing tumour Comparatively non-invasive/less scaring/less risk to patient	Allow any sensible suggestion here	1 1	3.10.4.2 AO1
05.1	Max 4 marks from: • Patient lies in strong/superconducting/intense magnetic field • Pulse of specific radio frequency/RF radiation is applied • Hydrogen nuclei align to a different position • When RF stops H/nuclei return to original/equilibrium positions • Releases RF radiation which is detected and processed by computer • This release of energy happens at different relaxation times for different tissues		max 4	3.10.4.3 AO1

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Question	Answers	Extra information	Mark	AO Spec reference
05.2	Points to consider: Advantages CT scanner: • Good for bone fractures; will also give good image of the brain and abdominal organs • Good resolution • Gives full cross-sectional image • It is non-invasive Disadvantages CT scanner: • Highly ionising • Limited contrast between tissues of similar density • Often requires patients to hold their breath, which some may find hard to do Advantages MR scanner: • No ionising radiation • Can distinguish between different types of soft tissue better than a CT scan • The resolution for soft tissue is better than a CT scan • It can show both three-dimensional and cross-sectional images • It is non-invasive Disadvantages MR scanner: • MR scans cannot be used if the patient has any metallic implants, such as a pacemaker • The patient might have to be still for up to an hour • Bone and calcium do not show up on this type of scan	6 marks will clearly explain the advantages and disadvantages of both scanners in a range of situations 4 marks will include at least one advantage and disadvantage for each or consider one scanner in detail 2 marks will address at least one of the bullet points 1 mark will have any sensible comment 0 marks has no relevant physics	max 6	AO2 3.10.4.3 3.10.5.4
06.1	**Collimator:** Only gamma rays/photons which 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	AO1 3.10.6.3

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06.2	Annihilation when electron meets positron Conservation of momentum means they have to travel in opposite directions		1 1	3.1.2.3 AO2
06.3	$E = mc^2$ $E = 2 \times 9.11\times10^{-31} \times (3\times10^8)^2$ Total $E = 1.6398\times10^{-13}$ J E of 1 photon $= \dfrac{8.199\times10^{-14}\text{ J}}{1.6\times10^{-19}}$ E of 1 photon = 0.51 MeV		1 1 1	3.1.2.3 AO2
06.4	Gamma photons are detected at different times at opposite points Computer calculates point of origin using distance = speed of light × time difference		1 1	3.10.6.1 AO1
07.1	The time taken for half the initial sample of material to be excreted from the body by biological means		1	3.10.6.2 A01
07.2	$\dfrac{1}{T_e} = \dfrac{1}{T_p} + \dfrac{1}{T_b}$ $\dfrac{1}{T_e} = \dfrac{1}{21\,700} + \dfrac{1}{86\,400}$ $T_e = 17\,000$ s $T_e = 4.8$ hours		1 1	3.10.6.2 A03
07.3	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	3.10.6.2 A03
07.4	Longer half-life so that activity is higher for longer period (or wtte) Beta emitter so ionises local tissue/tumour only	Must have description and explanation for mark	1 1	3.10.6.5 A01
08.1	Thermionic emission		1	3.10.5.1 AO1

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08.2	to prevent collisions of electrons with molecules to stop the target overheating/melting		1 1	3.10.5.1 AO1
08.3	Use of $E = eV$, $E = \frac{hc}{\lambda}$ or $eV = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{eV} = \frac{6.63\times10^{-34} \times 3\times10^{8}}{1.6\times10^{-19} \times 180\,000}$ $\lambda = 6.9\times10^{-12}$ m		1 1	3.2.1.3 3.10.5.1 AO2
08.4	Use of $Q = It$ or number of photons needed $= \frac{1.2}{eV} = 4.166\times10^{13}$ Number of electrons per second $= \frac{25\times10^{-3}}{1.6\times10^{-19}}$ 1% photons produced $= 0.01 \times \frac{25\times10^{-3}}{1.6\times10^{-19}}$ Only 4% produced used photons per second $= 0.04 \times 0.01 \times \frac{25\times10^{-3}}{1.6\times10^{-19}} = 6.25\times10^{13}$ per second Time $= \frac{\text{number of photons}}{\text{photons per second}} = \frac{4.1666\times10^{13}}{6.25\times10^{13}} = 0.67$ s		1 1 1 1	3.5.1.1 3.2.1.3 3.10.5.1 AO3

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Skills box answers

Question	Answer
1	Oxygen atoms are found in many compounds used by the body, so radioactive ^{15}O incorporated into water or glucose molecules will be carried by the blood and travel through the body to the brain.
2(a)	$^{15}O \rightarrow {}^{15}N + e^{+} + \nu$ (positron + neutrino)
2(b)	$\frac{\ln 2}{2.03\,\text{min}} = 0.34\,\text{min}^{-1}$ or $\frac{\ln 2}{(2.03 \times 60\,\text{s})} = 5.7 \times 10^{-3}\,\text{s}^{-1}$
3	Activity after 3 days: $A = A_0\,e^{-\lambda t} = 14.8\,\text{MBq} \times e^{(-0.053\text{h}^{-1} \times (24 \times 3)\text{h})} = 0.33\,\text{MBq}$. Activity after 11 days: $A = 14.8\,\text{MBq} \times e^{(-0.053\text{h}-1 \times (24 \times 11)\text{h})} = 12\,\text{Bq}$. Two days after the test, the patient will still be emitting gamma rays with an activity of 0.33 MBq. If they were to sleep next to someone else for about 7 h this would increase the radiation dose of that person too, so they should keep at a distance for 11 days until the ^{123}I has decayed to an activity of tens of becquerels. However, in public they would not be so close to another person for such long periods so it is not a risk to other people to go out while the activity is still slightly raised.