Question			Expected Answers	Marks	Additional guidance
1	(a)		Less chance of infection	B1	
	(b)		Any <u>two</u> from: 1. Tracer is injected into the body / placed inside the body / circulates the body 2. Tracer is absorbed by organ / shows blockage 3. Beta detector / gamma camera (is used to detect radiation from the body)	B1×2	**Note:** No marks for ingesting substances (e.g barium)
	(c)		Any <u>five</u> from: 1. A positron / beta-plus emitting tracer / source is used 2. The positron annihilates with an electron (inside the patient) 3. This produces <u>two</u> gamma photons 4. The photons travels in opposite directions 5. The patient is surrounded by a ring of gamma detectors 6. The arrival times of the photons / delay time indicates location (of tumour inside the body) 7. A 3-D image is created (by the computer connected to the detectors)	B1×5	
			Total	**8**	

Question			Expected Answers	Marks	Additional guidance
2	(a)		Any <u>three</u> from 1 to 4: 1. A (piezoelectric) crystal / transducer is used to send <u>pulse</u>(s) of ultrasound (into the patient) 2. Wave / ultrasound / pulse / signal is <u>reflected</u> (at the boundary of tissue) 3. The (intensity of the) <u>reflected</u> signal depends on the acoustic impedances (at the boundary) 4. The (time of) delay is used to determine the depth / thickness ✎ QWC: Award a mark for correct sequencing of the steps in the process	B1×3 B1	**Must use ticks on Scoris to show where the marks are awarded** **Allow:** $\frac{I_{(r)}}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ without symbols defined for the 3rd marking point **Note**: Do not allow marking points 2 or 3 for gel-skin interface
	(b)		A-scan is one directional / B-scan involves different directions or angles / B-scan consists of many A-scans / B-scan produces 2-D or 3-D image	B1	
			Total	**5**	

Question			Expected Answers	Marks	Additional Guidance
3	a		Magnetic resonance: **some <u>nuclei</u> behave as small magnets / certain <u>nuclei</u> possess a net spin / <u>nuclei</u>** line up in the magnetic field **Need for a strong magnetic field** the frequency of precession is known as Lamor frequency (1) **Application of RF pulses** produces resonance / flip energy states (1) **RF pulse turned off nuclei relax / flip back (and emit RF signal)** RF detected (by coil receiver) and processed (1) Use of non-uniform field / gradient field (1) To locate position of nuclei in body (1) **QWC mark: difference in the relaxation times for hydrogen in different tissues / materials** MAX (3) **MAX 8**	**B1** **B1** **B1** **B1** **B1** **MAX B8**	Allow protons instead of nuclei in the context of hydrogen nuclei or a single proton instead of nuclei There are 5 essential marks **(in bold)** and a maximum of THREE extra marks (1) Maximum of **8 marks** Do not allow 'atoms' for nuclei but penalise once only **Please annotate scripts as follows:** **Essential marks: ✓(ticks) on left hand side of candidate's work** **Extra marks: ✓(ticks) on right hand side of candidate's work**

	b		Advantage: not ionising radiation (as with X-rays) / better soft tissue contrast Disadvantage: heating effect of metal objects /effect on cardiac pacemakers / takes a long time to perform MRI scan	**B1** **B1**	Accept can view soft tissue in brain / skull Do not allow not harmful Do not allow no side effects
			Total	**[10]**	

Question			Expected Answers	Marks	Additional Guidance
4	a		ANY ONE from X-rays interact with matter by: the photoelectric effect where an (orbital) electron is ejected from atom / atom is ionised Compton scattering where X-ray scattered by the interaction with (orbital) electron Pair production where X-ray photon interacts with the nucleus / atom and an electron and positron are produced [allow one mark for statement and one for explanation] **Max 2**	**(B2)** **(B2)** **(B2)** **B2**	Allow electrons ejected from metal surface if reference is made to <u>free</u> electrons Allow: X-ray diffraction **B1** X-ray passes through the 'slits' / atomic gap formed by the atoms **B1**

	b		$I = I_0 e^{-\mu x}$ $0.1 = e^{-\mu 3}$ $0.5 = e^{-\mu x}$ $\ln 0.5 / \ln 0.1 = x/3$ $x = 0.903$ (mm)	**C1** **C1** **A1**	Calculation of $\mu = 0.768$ C1 Substitution into second equation C1 Allow 0.9 (1sf) If question misread and 0.9 used for change $\mu = 0.035$ and $x = 19.7$ (allow 20) give 2/3
10	**c**	**(i)**	Absorption of X-rays by (silver halide molecules) by a photographic film Uses of fluorescent / scintillator/ phosphor Photon releases electron (that is accelerated onto a fluorescent screen) number of electrons increased /multiplied **MAX B2** QWC: Phosphor / Intensifier/ it converts X-ray photon into increased number of 'visible' photons	**(B1)** **(B1)** **(B1)** **(B1)** **B2** **B1**	

		(ii)	Different <u>soft</u> body <u>tissue</u> produce little difference in contrast/attenuation (Contrast media with) high atomic number / Z used / iodine or barium (used to give greater contrast) liquids injected or swallowed into soft tissue areas / or examples of such **MAX B2**	**(B1)** **(B1)** **(B1)** **B2**	This method produces good contrast for soft tissue /for similar Z values
			Total	**[10]**	

Question			Answer	Marks	Guidance
5	(a)		$\lambda = \frac{0.693}{6.6\times10^{3}}$ or $\lambda = \frac{\ln 2}{6.6\times10^{3}}$ decay constant = 1.1×10^{-4} (s^{-1})	C1 A1	**Note**: Answer to 3sf is 1.05×10^{-4} (s^{-1})
	(b)		$A = \lambda N$ $N = \frac{250\times10^{6}}{1.05\times10^{-4}}$ number = 2.38×10^{12} or 2.4×10^{12}	C1 A0	Possible ecf from **(a)** **Allow** full credit for bald 2.4×10^{12}
	(c)		mass of F-18 = $\frac{2.38\times10^{12}}{6.02\times10^{23}} \times 0.018$ (= 7.116×10^{-14} kg) mass of FDG= $7.116\times10^{-14} / 0.099$ mass of FDG = 7.2×10^{-13} (kg)	C1 C1 A1	Possible ecf from **(b)** **Allow** full credit for using 2×10^{12}; answer is 6.04×10^{-13} (kg)
	(d)		$A = 250 \times e^{-(1\,05\times10^{-4}\times20\times60)}$ activity = 220 (MBq)	C1 A1	Possible ecf from **(a)** **Allow**: 1 mark for 249 (MBq); factor of 60 omitted
	(e)		(FDG/positron-emitting substance is injected into the patient) Any <u>three</u> from: 1. Annihilation of electron and positron 2. Positron-electron annihilation produces <u>two</u> gamma photons 3. The gamma photons travels in opposite directions 4. The patient is surrounded by (a ring of) gamma detectors 5. A 3-D image is created (using the detector-signals with the aid of computer software) **QWC**: The arrival times / delay times of the photons (at diametrically opposite detectors) are used to pinpoint areas of increased activity (AW)	B1 × 3 B1	**Allow**: rays / waves instead of photons in 2 and 3
			Total	**12**	