Question			answer	Marks	Guidance
1	(a)		(Fast-moving) electrons hit a metal / an anode The kinetic energy of the electrons is transferred into X-rays / photons / EM waves	B1 B1	**Allow**: (X-rays are produced by large) deceleration of electrons
	(b)		An X-ray photon interacts an electron (within the atom) The electron is ejected and the energy / frequency of the (scattered) photon is reduced	B1 B1	 **Allow**: The electron is ejected and the wavelength of the (scattered) photon is increased
	(c)	(i)	$I = I_0 e^{-\mu x}$ $I = 3.0 \times 10^9 \times e^{-(6.5 \times 1.7)}$ intensity = 4.8×10^4 (W m^{-2})	C1 C1 A0	
		(ii)	power of beam = $4.8 \times 10^4 \times 5.0 \times 10^{-6}$ (= 0.24 W) power absorbed by tumour = 0.24/10 = 0.024 (W) time = 200/0.024 time = 8.3×10^3 (s)	C1 C1 A1	Possible ecf from **(c)(i)** **Allow**: 2 marks for 8.3×10^2 (s) if 10% is omitted **Note**: Using 5×10^4 (W m^{-2}) gives an answer of 8000 (s)
	(d)		X-ray beam passes through the patient at different angles / X-ray tube rotates around the patient A <u>thin</u> fan-shaped beam is used (AW) Images of 'slices' through the patient (in one plane are produced with the help of computer software) X-ray tube / detectors are moved along (the patient for the next slice through the patient) Advantage: 3D image / better contrast between different (soft) tissues	B1 B1 B1 B1 B1	
			Total	**14**	

Question			Answer	Marks	Guidance
2	(a)		Any <u>six</u> from: 1. Protons / nuclei have spin or they behave like (tiny) magnets 2. Protons precess around the magnetic field (provided by the strong electromagnet) 3. The frequency of precession is known as the *Larmor frequency* 4. (Transmitting) coils provide (pulses of) radio waves (of frequency equal to the Larmor frequency) 5. The protons absorb energy (from the radio waves) / resonate and enter into a high energy state (AW) 6. When protons return back to their low energy state and they emit (photons of) radio waves 7. Th *relaxation time* is the (average) time taken for the protons to return back to their normal / low energy state 8. The relaxation time depends on the tissues (A computer processes all the signals from the receiving coils and with the help of computer software generates a 3D image)	B1 × 6	**Not**: Atoms / particles **Note**: Must have reference to radio (waves) in 4 and 6 **Allow** 'excited' for 'high-energy state' **Allow**: Relaxing protons emit radio waves
	(b)		Disadvantage: Patient with metallic objects cannot be scanned / patient has to remain still (for a long time) / confined space / difficult for patient suffering from claustrophobia / or another suitable suggestion Advantage: Non-ionising /non invasive / better contrast (between soft tissues) / or another suitable suggestion	B1 B1	**Not** '3 D image' because it is given in **(a)**
			Total	**8**	

Question			Answers	Marks	Guidance
3	(a)		Any **two** from: 1. Electrons are accelerated through high voltage 2. (High speed) electron(s) hit metal 3. kinetic energy of electron(s) 'produces' X-ray (photons)	B1×2	**Allow**: X-rays are produced by (large) deceleration of electrons
	(b)	(i)	Packet /quantum of (electromagnetic) energy	B1	**Allow**: 'particle of (electromagnetic) energy'
		(ii)	$E = hc/\lambda$ and X-rays have shorter wavelength Or $E = hf$ and X-rays have higher frequency	B1	
	(c)		(KE of electron =) $1.6\times10^{-19}\times120\times10^{3}$ $eV = \frac{hc}{\lambda}$ $1.6\times10^{-19}\times120\times10^{3} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda}$ wavelength = 1.0×10^{-11} (m) or 1.04×10^{-11} (m)	C1 C1 A1	**Allow**: 2 marks for $1.0(4) \times 10^{-n}$ (m) ($n \neq 11$ - powers of ten error) **Allow**: 1×10^{-11} (m)
	(d)		Compton (scattering) Incoming photon collides with an electron, the electron is ejected and the photon is scattered / has lower energy Or Pair production Incoming photon (disappears and) produces electron-positron pair	M1 A1 -------- M1 A1	**Must use ticks on Scoris to show where the marks are awarded** **Allow**: (Simple) scatter(ing) M1 The photon is absorbed and re-emitted without change in energy/wavelength/frequency A1
			Total	**9**	

Question			Answers	Marks	Guidance
4	(a)		No entry into body / no cutting/incision of patient / no surgery Lower risk of infection / less trauma	B1 B1	
	(b)		Radioactive substance that is ingested / injected (into patient) Technetium(-99m) / Iodine(-131) / fluorine(-18)	B1 B1	 **Not**: barium
	(c)		**Collimator** – gamma (ray photons) travel along the axis of lead tubes or allows parallel gamma (ray photons travel to the scintillator) Having thin / long / narrow (lead) tubes makes the image sharper / less blurred (**QWC mark**) **Scintillator** – gamma ray photon produces many/thousands of photons of (visible) light **Photomultiplier** - An electrical pulse is / electrons are produced from the light (photons) **Computer** – Signals (from photomultiplier tubes) are used to produce an image	B1 B1 B1 B1 B1	**Must use ticks on Scoris to show where the marks are awarded**
	(d)	(i)	$v = f\lambda$ $1500 = 2.0 \times 10^6 \times \lambda$ wavelength = 7.5×10^{-4} (m)	 C1 A1	
		(ii)	Ultrasound is reflected by (moving) blood (cells) The frequency / wavelength (of ultrasound) is changed (AW) The change of frequency is related to speed of blood / change of wavelength is related to speed of blood / 'Δfrequency $\propto$ speed of blood'	B1 B1 B1	**Must use ticks on Scoris to show where the marks are awarded** **Not**: Doppler effect mentioned
			Total	**14**	