Question			Answer	Marks	Guidance
1	(a)		Quantum / packet of (electromagnetic) energy Any one from: Can travel in a vacuum / has speed of 3×10^8 m s^{-1} in a vacuum / has no charge / has no (rest) mass / causes ion-isation / has momentum	B1 B1	**Allow**: Particle of energy **Allow**: Travels at the speed of light / c in a vacuum
	(b)	(i)	number per second = $4.8 \times 10^{-3}/1.6 \times 10^{-19}$ number per second = 3.0×10^{16} s^{-1}	M1 A0	**Note**: This must be seen to gain a mark
		(ii)	(incident power =) $150 \times 10^3 \times 4.8 \times 10^{-3}$ or (incident power =) $3.0 \times 10^{16} \times 150 \times 10^3 \times 1.6 \times 10^{-19}$ ($P = mc[\Delta\theta/\Delta t]$) $0.99 \times 720 = 0.0086 \times 140 \times [\Delta\theta/\Delta t]$ rate of temperature increase = 590 (°C s^{-1})	C1 C1 A1	**Note** an incident power of 720 (W) scores this C1 mark **Note**: Answer to 3 sf is 592 (°C s^{-1}) **Allow**: 2 marks for 598 (°C s^{-1}) or 600 (°C s^{-1}); 99% omitted **Allow**: 2 marks for 1.97×10^{-14} (°C s^{-1}); 3.0×10^{16} omitted
		(iii)	(photon energy = maximum KE of electron) $E = 150 \times 10^3 \times 1.6 \times 10^{-19}$ or $E = 2.4 \times 10^{-14}$ (J) $2.4 \times 10^{-14} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{\lambda}$ (Allow any subject) wavelength = 8.3×10^{-12} (m)	 C1 A1	 **Allow**: $E = 720/3.0 \times 10^{16}$ **Allow**: 1 mark 8.3×10^{-10} (m); $E = 2.4 \times \underline{10^{-16}}$ (J) used
	(c)		Contrast material / iodine is injected (into the vessels) Any one from: The contrast material • large attenuation / absorption coefficient • has high Z (atoms) (and hence reveal the outline of the blood vessels)	B1 B1	**Not**: barium for this B1 mark **Not** 'large μ'
			Total	**10**	

Question			Answer	Marks	Guidance
2	(a)		Gamma radiation will pass through the patient (and hence can be detected) / beta particles will be absorbed by the patient (and hence cannot be detected)	B1	
			Gamma radiation is not (very) ionising / gamma radiation does little damage to cells / beta particles are (very) ionising / beta particle damage cells	B1	**Allow**: 'Body' in place of 'cells'
	(b)		X-ray tube rotates around (the patient) / X-ray beam passes through the patient at different angles	B1	**Not**: Detector rotates around (the patient)
			A thin X-ray beam is used	B1	
			Image(s) of slice(s) / (cross) section(s) through the patient are taken	B1	
			X-ray tube moves / spirals along (the patient)	B1	**Allow**: Detectors moves / spirals along (the patient)
			The signals / information / pulses / data (from the detectors) are used by the computer (and its software) to produce a 3D image	B1	
			Total	**7**	

Question			Answer	Marks	Guidance
3	(a)		Change in the frequency / wavelength because of source / 'observer' moving	B1	**Allow**: There is blue / red shift because of relative motion between source and observer
	(b)		Any <u>two</u> from: 1. Ultrasound transducer / device / probe emits and detects ultrasound 2. The transducer / device / probe is placed at an angle (to the artery) 3. Ultrasound is <u>reflected</u> by the blood / cells QWC mark - change in frequency / wavelength (of the reflected ultrasound) is related to speed of blood	B1 × 2 B1	**Allow**: speed of blood ∝ change in frequency **Allow**: $\Delta f = 2vf\cos\theta/c$, where v is the speed of blood, c = speed of ultrasound; no need to define the other labels **Note**: Do not award this mark if $\Delta f = fv/c$ is used to determine the speed v of the blood
	(c)	(i)	$Z = \rho c$ density = $1.66 \times 10^6/1570$ density = 1060 (kg m^{-3})	B1	**Allow**: 1100 (kg m^{-3})
		(ii)	$\lambda = 1570/2.4 \times 10^6$ wavelength = 6.5×10^{-4} (m)	B1	
	(d)		(fraction of intensity reflected =) $\frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ (fraction of intensity reflected =) $3^2/5^2$ (= 0.36) intensity = 64%	C1 C1 A1	**Note**: 2 marks for 36% or 0.36
	(e)		Gel is used (between transducer and skin). The acoustic impedance / Z of gel is similar to that for skin hence less <u>reflection</u> (at the skin)	B1 B1	**Allow**: There is acoustic / impedance matching so less <u>reflection</u> **Allow**: Without the gel, there is large difference between acoustic impedances of air and skin, hence large <u>reflection</u> **Note**: Must have reference to reflection
			Total	**11**	

Question			Answers	Marks	Guidance
4	(a)	(i)	Discrete energy (of electrons in an atom) / quantised energy (of electrons in an atom) / permitted energy (states of electrons in an atom).	B1	
		(ii)	($E = \frac{hc}{\lambda}$) $E = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{7.2\times10^{-11}}$ or $E = 2.763 \times 10^{-15}$ (J) value of energy level = - (3.2 - 2.763) $\times 10^{-15}$ (J) value of energy level = - 4.4 $\times 10^{-16}$ (J)	C1 C1 A1	**Note**: The answer must be <u>negative</u> to score the A1 mark **Note:** 4.4×10^{-16} (J) scores 2 marks
		(iii)	(λ_0 is) halved. Explanation: Reference to (photon / electron kinetic) energy doubled <u>and</u> E = hc/λ or $E \propto 1/\lambda$.	M1 A1	**Allow** explanation in terms of $eV = hc/\lambda$.
	(b)	(i)	($I = I_0 e^{-\mu x}$) fraction transmitted = $e^{-(0.96\times2.3)}$ fraction transmitted = 0.11 fraction absorbed or scattered = 1 – 0.11 fraction absorbed or scattered = 0.89	C1 C1 A1	**Allow** 3 marks for 89%. **Allow** 89/100
		(ii)	Bone and muscle have different (values for) μ hence better contrast. or Muscle and fat have similar (values for) μ hence poor contrast.	B1	
			Total	**10**	

Question			Answers	Marks	Guidance
5	(a)		Ultrasound reflected at boundary (between materials). B-scan takes place in different directions. QWC: The intensity of the reflected ultrasound depends on the acoustic impedances of the materials (and this is greater when the difference between the acoustic impedances is greater).	B1 B1 B1	**Allow** B-scan is 'multiple A-scans'. **Allow** *Z* instead of acoustic impedance. **Not** attenuation coefficient for *Z.*
	(b)		Any **four** from: 1. The brain / body is surrounded by a ring of (gamma) detectors /gamma camera(s). 2. The positrons (from the F-18 nuclei) annihilate electrons. 3. The annihilation of a positron and an electron produces two (identical gamma) photons travelling in opposite directions. 4. The delay time between these two photons / gamma rays is used to determine the location of the annihilation / F-18 / tracer. 5. Computer connected to detectors / gamma camera and an image is formed by the computer (using the electrical signals from the detectors).	B1×4	**Not** positron**s** and electron**s** annihilate to produce photons travelling in opposite directions for 3. **Allow** an answer in terms of arrival times.
			Total	**7**	