Question			Answer	Marks	Guidance
1	(a)		Any <u>two</u> from: • Can travel in a vacuum • Travel at the speed of light / c / 3×10^8 <u>m s^{-1}</u> in <u>vacuum</u> • No charge / no (rest) mass • (Highly) ionising	B1 × 2	**Not**: EM radiation / wave because not *particulate* nature **Not**: Short wavelength or high frequency **Not**: High energy photons **Not**: reflect / refract / diffract
	(b)		$\frac{hc}{\lambda}$ <u>and</u> $E = mc^2$ $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda} = 2\times9.11\times10^{-31}\times(3.0\times10^{8})^{2}$ wavelength = 1.2×10^{-12} (m)	C1 C1 A1	**Allow**: $\frac{hc}{\lambda}$ and 1.02 <u>MeV</u> or 0.51 <u>MeV</u> for this first C1 mark **Allow**: Correct use of mass = 0.00055 u **Allow**: 2 marks for 2.4×10^{-12} (m) for omitting factor of 2 **Note**: Using the de Broglie equation with $v = c$, also gives an answer of 2.4×10^{-12} (m); this scores zero – see below: $\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times3.0\times10^{8}} = 2.4\times10^{-12}$ m scores zero
	(c)		Barium / iodine (Contrast medium absorbs X-rays because it) has large attenuation coefficient / has large absorption coefficient / has large Z values Ideal for imaging the <u>outline</u> (of soft tissues)	B1 B1 B1	 **Not**: X-rays are (easily) absorbed by the contrast material **Allow**: If there is a hole then the barium shows this up by flowing out / Barium is used to find blockage with explanation
			Total	**8**	

Question			Answer	Marks	Guidance
2	(a)		Rate of decay / disintegration of nuclei or Number of γ (photons) emitted per unit time	B1	The question has 500 Bq. Hence a**llow** the following: Number of nuclei decaying per second / number of γ (photons) emitted per second **Not**: Rate of decay of atoms / molecules / particles
	(b)		(rate of energy =) $500 \times 10^{6} \times 2.2 \times 10^{-14}$ rate of energy emission = 1.1×10^{-5} (J s^{-1})	C1 A1	
	(c)		**Collimator / lead tubes** and ..... gamma (ray photons) travel along the axis of lead tubes (AW) **Scintillator / Sodium Iodide (crystal)** and ..... gamma ray / gamma photon produces (many) photon**s** of (visible) light **Photomultiplier (tubes) / photocathode and dynodes** and ..... (electrical) pulse / signal / electrons produced by photon(s) of visible light **Computer** and ..... signals / pulses /electrons (from photomultiplier tubes) are used to generate an image QWC: Quality of image improved by narrower / thinner / longer collimators OR longer scanning time	B1 B1 B1 B1 B1	**Not** 'it collimates' **Allow**: parallel rays / uni-directional rays travel along the lead tubes (AW) **Not** 'information / data' in place of signals
			Total	**8**	

Question			Answer	Marks	Guidance
3	(a)		Longitudinal (wave) Frequency (sound) ≥ 20 kHz	B1 B1	**Allow**: high frequency (sound) that cannot be heard **Allow** any value of frequency ≥ 20 kHz **Not**: It is non-ionising
	(b)		Emission: (Piezoelectric film / crystal connected to an) alternating e.m.f / p.d / current making it vibrate / contract and expand / resonate (and hence emits ultrasound) (AW) Reception: (Ultrasound makes the piezoelectric film / crystal) vibrate / contract and expand / resonate and this produces (alternating) e.m.f. / p.d / current (AW)	B1 B1	**Note**: The alternating p.d. can be implied by the term *frequency* **Not** varying p.d.
	(c)		Without the gel, the ultrasound would be reflected (at the skin /air interface) or The gel allows (maximum) transmission of ultrasound (into the body) Gel and skin has similar acoustic impedance / *Z* (values) or There is a large difference between the *Z* (values) of air and skin	B1 B1	**Allow**: Gel is used for impedance matching
	(d)		Transducer placed at an angle to the artery / arm Ultrasound (pulses) are reflected by (moving) blood (cells) The frequency / wavelength (of ultrasound) is changed Change in frequency is related to the speed (of blood) or change in wavelength is related to the speed	B1 B1 B1 B1	**Allow**: The wavelength / frequency is Doppler shifted (AW) **Allow**: $\frac{\Delta f}{f} = \frac{2v\cos\theta}{c}$ where *c* is the speed of ultrasound and *v* is the speed of blood; no need to define the angle
			Total	**10**	

Question			Answer	Marks	Guidance
4	(a)		Any <u>two</u> from: (X-rays) are EM waves Travel at speed of light / 3×10^8 <u>m s^{-1}</u> (in a vacuum) Travel in a vacuum / empty space Transverse waves Can cause ionisation Have wavelength of about 10^{-10} <u>m</u> (X-rays are high energy) photons (AW)	B1×2	**Allow**: reference to diffraction / interference / refraction / reflection / polarisation for 1 mark
	(b)		(X-ray) <u>photon</u> interacts with an (orbital) <u>electron</u> The (scattered) photon has a longer wavelength / lower frequency / lower energy **AND** The electron is ejected (from the atom at high speed)	B1 B1	**Allow**: 'X-rays' instead of 'photons' for the second B1 mark
	(c)	(i)	Initial / original / incident <u>intensity</u>	B1	**Allow**: Initial / original / incident <u>power</u> <u>per</u> (unit) <u>area</u>
		(ii)	$0.5 = e^{-(3.3x)}$ $\ln(0.5) = -3.3x$ $x = \ln(0.5)/(-3.3)$ $x = 0.21$ (cm)	C1 C1 A1	**Allow**: $\ln(2) = 3.3x$ **Allow**: 2 marks for 2.1×10^n; $n \neq -1$ (POT error)
	(d)		A contrast material has large attenuation coefficient / large atomic number / large Z (and hence easily absorbs X-rays) Idea of revealing tissue	B1 B1	
			Total	**10**	

Question			Answer	Marks	Guidance
5	(a)		Any <u>seven</u> from: 1. Protons / nuclei have spin / behave like (tiny) magnets 2. Protons / nuclei precess about the magnetic field (provided by the strong electromagnet) 3. Transmitting coils provide (pulses of) radio waves of frequency equal to the Larmor frequency 4. The protons / nuclei absorb energy / radio waves / resonate and flip into a higher energy state 5. When protons / nuclei flip back to a lower energy state they emit (photons of) radio waves 6. The relaxation time (of the protons/nuclei) depends on the (surrounding) tissues 7. The radio waves are picked up by the receiving coils 8. The gradient coils alter the magnetic flux density (through the body) 9. The Larmor frequency (of the protons / nuclei) varies through the body 10. The computer (processes all the signals from the receiving coils and) generates the image(s)	B1 × 7	**Show annotation on Scoris** **Not**: Atoms / particles for nuclei /protons. **Allow**: The protons / nuclei absorb energy / radio waves / resonate and get excited **Allow**: When protons / nuclei relax they emit (photons of) radio waves
	(b)		Ay <u>two</u> from: 1. PET scan: uses radioactive substance / uses positron-emitting substance / uses F(-18) / mention of gamma rays / mention of gamma photons 2. PET scan reveal the 'function' of the brain (AW) 3. MRI scan show variation in tissues (in the brain) (AW)	B1×2	**Allow**: MRI scan: no radioactive substance is required / mention of radio waves **Allow**: PET scans are used to diagnose dyslexia / Alzheimer (disease)
			Total	**9**	