Physics

Medical Imaging 1 - Answers

1.

(a)		Any **three** from: **Photoelectric effect:** Photon ejects / removes an electron (from the atom / metal) **Compton (scattering):** Photon emerges with less energy / longer wavelength / lower frequency and an electron escapes / ejected (from the atom) **Pair-production:** Photon produces an electron-positron (pair) **Scattering** : Photon is scattered by an electron **QWC:** (Intensity decreases in the original direction because) there are fewer photons	B1×3 B1	**Allow** consistent use of plurals throughout, e.g: Photons eject electrons
(b)	**(i)**	$(E = \frac{hc}{\lambda})$ $(E =) \frac{6.63\times10^{-34}\times3.0\times10^{8}}{1.4\times10^{-11}}$ or $(f =) 2.14\times10^{19}$ (Hz) energy = 1.4×10^{-14} (J)	C1 A1	
(b)	**(ii)**	gradient = (-) μ $\mu = 0.20$ (cm^{-1})	C1 A1	**Allow** correct substitution into $\ln I = \ln I_0 - \mu x$; coordinates read to ± ½ small square **Allow** 1 SF answer of 0.2 (cm^{-1}) **Allow** answer in the range 0.19 to 0.21 (cm^{-1}) **Ignore** sign

2.

(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 ionisation / has momentum	B1 B1	**Allow**: Particle of energy **Allow**: Travels at the speed of light / c in a vacuum
(b)	**(i)**	number per second = $4.8\times10^{-3}/1.6\times10^{-19}$ number per second = 3.0×10^{16} s^{-1}	M1 A0	**Note**: This must be seen to gain a mark
	(ii)	(incident power =) $150\times10^{3}\times4.8\times10^{-3}$ or (incident power =) $3.0\times10^{16}\times150\times10^{3}\times1.6\times10^{-19}$ $(P = mc[\Delta\theta/\Delta t])$ $0.99\times720 = 0.0086\times140\times[\Delta\theta/\Delta t]$ 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) $E = 150\times10^{3}\times1.6\times10^{-19}$ or $E = 2.4\times10^{-14}$ (J) $2.4\times10^{-14} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda}$ (Allow any subject) wavelength = 8.3×10^{-12} (m)	C1 A1	**Allow**: $E = 720/3.0\times10^{16}$ **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 <u>one</u> 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'

3.

(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) Gamma radiation is not (very) ionising / gamma radiation does little damage to cells / beta particles are (very) ionising / beta particle damage cells	B1 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 A <u>thin</u> X-ray beam is used Image(s) of slice(s) / (cross) section(s) through the patient are taken X-ray tube 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 B1 B1 B1 B1	**Not**: Detector rotates around (the patient) **Allow**: Detectors moves / spirals along (the patient)

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 $E = 2.763\times10^{-15}$ (J) value of energy level = - (3.2 - 2.763) × 10^{-15} (J) value of energy level = - 4.4 × 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	