24. Medical Physics

24.2 Production and use of X-rays

Paper 4

Marking Scheme

Q1.

(b)(i)	electron(s)	**B1**
(b)(ii)	X labelled – **and** Y labelled +	**B1**
(c)(iii)	$E = hf$ **and** $\lambda = c / f$	**C1**
	$\lambda = hc / E$ $= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (0.032 \times 1.60 \times 10^{-13})$	**C1**
	$\lambda = 3.9 \times 10^{-11}$ m	**A1**
(d)	discussion of bone and soft tissue	**B1**
	discussion of different attenuation (coefficients) **or** discussion differences in penetration / transmission / absorption	**B1**
	transmitted intensities (by bone and tissue) are very different (leading to good contrast images)	**B1**

Q2.

(a)(i)	electrons	**B1**
(a)(ii)	electrons are decelerated / stopped on impact with the target	**B1**
	(kinetic) energy lost by electrons emitted as (X-ray) photons	**B1**
(a)(iii)	$eV = hc / \lambda$	**C1**
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (1.60 \times 10^{-19} \times 5800)$	**C1**
	$= 2.14 \times 10^{-10}$ m	**A1**
(b)	$I = I_0 \exp(-\mu x)$	**C1**
	$I_T / I_0 = \exp(-(1.4 \times 2.8))$ $= 0.020$	**C1**
	% absorbed $= (1.000 - 0.0198) \times 100$ $= 98\%$	**A1**

Q3.

(b)(i)	$I = I_0 \exp(-\mu x)$	**C1**
	$\ln(0.72) = -6.2\mu$ $\mu = 0.053\ \text{cm}^{-1}$	**A1**
(b)(ii)	$I / I_0 = \exp(-9.3 \times 0.053)$ $(= 0.61)$	**C1**
	percentage attenuated $= 100 \times (1.00 - 0.61)$ $= 39\%$	**A1**

Q4.

(a)(i)	electrons are accelerated (by an applied p.d.)	**B1**
	electrons hit target	**B1**
	X-rays produced when electrons decelerate	**B1**
(a)(ii)	images of the multiple sections are combined to create a 3-D image	**B1**
(b)(i)	$I = I_0 \exp(-\mu x)$	**C1**
	$= I_0 \exp(-0.89 \times 5.6)$ $= 0.0068\ I_0$	**A1**
(b)(ii)	$I = I_0 \exp(-2.4 \times 3.4) \times \exp(-0.89 \times 3.2)$	**C1**
	$= 1.7 \times 10^{-5}\ I_0$	**A1**
(c)	comparison of intensities or values in **(b)** leading to conclusion consistent with these values	**B1**

Q5.

(a)	intensity: vary filament current/p.d. across filament	**B1**
	hardness: vary accelerating potential difference	**B1**
(b)(i)	$I = I_0 e^{-\mu x}$	**C1**
	$I_S = I_0 \exp(-0.92 \times 9.0)$ $= 2.5 \times 10^{-4}\ I_0$	**A1**
(b)(ii)	$I_C = [\exp(-0.92 \times 6.0) \times \exp(-2.9 \times 3.0)]\ I_0$	**C1**
	$= 6.7 \times 10^{-7}\ I_0$	**A1**
(c)	conclusion consistent with values in **(b)(i)** and **(b)(ii)** e.g. $I_S \gg I_C$ so good contrast	**B1**

Q6.

(a)	to produce a 3-dimensional image of structure/body	**B1**
(b)	X-rays (are used)	**B1**
	scanning in sections	**B1**
	scanning from many angles	**B1**
	image of each section is 2-dimensional	**B1**
	scanning repeated for many sections **or** images of many sections combined together	**B1**

Q7.

(a)(i)	ease with which edges can be distinguished	**B1**
(a)(ii)	difference in degrees of blackening	**B1**
(b)	$I = I_0 \exp(-\mu x)$	**C1**
	$0.12 = \exp(-\mu \times 2.3)$ $\ln 0.12 = -2.3 \times \mu$	**C1**
	$\mu = 0.92\ \text{cm}^{-1}$	**A1**
(c)	advantage: produces 3-dimensional image	**B1**
	disadvantage: (much) greater exposure to radiation	**B1**

Q8.

(a)	X-rays are used	**B1**
	section (of object) is scanned	**B1**
	scans/images taken at many angles/directions **or** images of each section are 2-dimensional	**B1**
	(images of (many)) sections are combined	**B1**
	(to give) 3-dimensional image of (whole) structure	**B1**
(b)	K = 6 L = 7 M = 2 N = 9 3 marks: all four correct 2 marks: three correct and one incorrect **or** all correct with two numbers transposed 1 mark: two correct and two incorrect	**B3**

Q9.

(a)	X-ray photon produced when electron is decelerated	**B1**
	larger acceleration results in larger photon energy	**B1**
	continuous range of accelerations so continuous spectrum of wavelengths/frequencies	**B1**
(b)	electron in (inner shell of) target atom is excited (on collision)	**B1**
	electron de-excites causing emission of a photon	**B1**
	discrete energy levels so discrete photon wavelengths	**B1**

Q10.

	X-rays are used	**B1**
	section (of object) is scanned	**B1**
	scans/images taken at many angles/directions **or** images of each section are 2-dimensional	**B1**
	images of (many) sections are combined	**B1**
	(to give) 3-dimensional image of (whole) structure	**B1**

Q11.

(a)(i)	$I = I_0 e^{-\mu x}$	**C1**
	$= I_0 \exp(-0.90 \times 2.8)$ $= 0.080\, I_0$	**A1**
(a)(ii)	$I = I_0 \exp[(-0.90 \times 1.5) \times (-3.0 \times 1.3)]$	**C1**
	$= I_0\ (0.259 \times 0.20)$ $= 0.0052\, I_0$	**A1**
(b)(i)	difference in degrees of blackening	**M1**
	between structures	**A1**
(b)(ii)	large difference in intensities so good contrast	**B1**

Q12.

(a)	X-ray image(s) taken of one slice	**M1**
	(many images) taken from different angles	**A1**
	(computer) produces 2D image of slice	**B1**
	(this is) repeated for (many) slices	**M1**
	to build up a 3D image (of structure)	**A1**
(b)(i)	combining of images involves (very) large number of calculations	**B1**
(b)(ii)	CT scan consists of (very) many (single X-ray) images	**B1**

Q13.

(c)	$I = I_0 \exp(-\mu x)$	**C1**
	$I = I_0\,[\exp(-\mu x)_{\text{bone}} \times \exp(-\mu x)_{\text{soft tissue}}]$ $I = I_0\,[\exp(-2.9 \times 0.40) \times \exp(-0.92 \times 1.4)]$	**C1**
	$I / I_0 = 0.0865$	**C1**
	ratio / dB = 10 lg 0.0865 = –11 dB	**A1**