Production & Use of X-Rays

Mark Scheme 1

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Quantum Physics
Sub Topic	Production & Use of X-Rays
Paper Type	Theory
Booklet	Mark Scheme 1

Time Allowed: **89 minutes**

Score: **/74**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)**	change/increase/decrease anode/tube voltage	B1	
	electrons striking <u>anode</u> have changed (kinetic) energy/speed	B1	
	X-ray/photons/beam have different wavelength/frequen	B1	[3]
(b) **(**	$I = I_0 e^{-\mu x}$	B1	[1]
(ii)	contrast is difference in degree of blackening (of regions of the image)	B1	
	μ (very) similar so similar absorption of radiation (for same thickness) so little contrast		[2]

2 **(a)**	X-ray beam contains many wavelengths	B1	
	aluminium filter absorbs long wavelength X-ray radiation	M1	
	that would be absorbed by the body (and not contribute to the image)	A1	[3]
(b)	CT scan consists of (many) X-ray <u>images</u> of a slice	M1	
	and there are many slices	A1	
	X-ray image is a single exposure	B1	
	(so much) greater exposure with CT scan	B1	[4]

3 **(a)**	series of X-ray images (for one section/slice	M1	
	taken from different angles	M1	
	to give image of the section/slice	A1	
	repeated for many slices	M1	
	to build up three-dimensional image (of whole object)	A1	[5]
(b)	deduction of background from readings	C1	
	division by three	C1	
	$P = 5$ $Q = 9$ $R = 7$ $S = 13$		
	(four correct 2/2, three correct 1/2)	A2	[4]

4 **(a)** X-ray: flat / shadow / 2D image B1
regardless of depth of object / depth not indicated B1

CT scan: built up from (many) images at different angles B1
image is three-dimensional B1
image can be rotated / viewed at different angles B1 [5]

(b) **(i)** $I = I_0 e^{-\mu x}$ C1
$0.25 = e^{-0.69x}$
x = 2.0 mm (*allow 1 s.f.)* A1 [2]

(ii) for aluminium, $I / I_0 = e^{-0.46 \times 2.4}$
$= 0.33$ C1
fraction $= 0.33 \times 0.25$
$= 0.083$ A1 [2]

(iii) gain / dB $= 10 \lg(I / I_0)$ C
$= 10 \lg(0.083)$
$= (–)\ 10.8$ dB (*allow 2 s.f.)* A1
with negative sign B1 [3]

5 **(a)** sharpness: how well the edges (of structures) are defined B1
contrast: difference in (degree of) blackening between structures B1 [2]

(b) e.g. scattering of photos in tissue/no use of a collimator/no use of lead grid
large penumbra on shadow/large area anode/wide beam
large pixel size
(any two sensible suggestions, 1 each) B2 [2]

(c) **(i)** $I = I_0 e^{-\mu x}$ C1
ratio $= \exp(–2.85 \times 3.5) / \exp(–0.95 \times 8.0)$ C1
$= (4.65 \times 10^{-5}) / (5.00 \times 10^{-4})$
$= 0.093$ A1 [3]

(ii) *either* large difference (in intensities)
or ratio much less than 1.0 M1
so good contrast A1 [2]

(*answer given in* **(c)(ii)** *must be consistent with ratio given in* **(c)(i)**)

6 **(a)**	changing voltage changes energy / speed of <u>electrons</u>		M1	
	changing electron energy changes maximum X-ray photon energy		A1	[2]
(b)	**1.** loss of power / energy / intensity		B1	[1]
	2. intensity changes when beam not parallel		C1	
	decreases when beam is divergent		A1	[2]
(ii)	ratio = (exp {–2.9 × 2.5}) / (exp {–0.95 × 6.0})		C1	
	= 0.21 *(min. 2 sig. fig.)*		A1	[2]
	(values of both lengths incorrect by factor of 10^{-2} to give ratio of 0.985 scores 1 mark)			
7	X-ray images taken from different angles / X-rays directed from different angles		B1	
	of one section / slice	(1)		
	all images in the same plane	(1)		
	images combined to give image of section / slice		B1	
	images of successive sections / slices combined		B1	
	image formed using a computer		B1	
	image formed is 3D image	(1)		
	that can be rotated / viewed from different angles	(1)		
	(*four B-marks plus any two additional marks*)		B2	[6]
8 **(a)**	background reading = 19		B1	[1]
(b)	A = 2		A1	
	B = 5		A1	
	C = 9		A1	
	D = 3		A1	[4]
	(*Allow 1 mark if only subtracts background reading*)			
(c) (	*either* 5, 14 *or* 14, 5 (A+D, B+C or *v.v.*)		B	[1]
(ii)	Three numbers and 'inside' number is 8 (B+D)		B1	
	Three numbers and 'outside' numbers are *either* 2,9 *or* 9,2 (A,C or *v.v.*)		B	[2]

9	**(a)**	**(i)**	e.m. radiation produced whenever charged particle is accelerated	M1	
			electrons hitting target have distribution of accelerations	A1	[2]
		(ii)	*either* wavelength shorter/shortest for greater/greatest acceleration		
			or $\lambda_{min} = hc/ E_{max}$		
			or minimum wavelength for maximum energy	B1	
			all electron energy given up in one collision/converted to single photon	B1	[2]
	(b)	**(i)**	hardness measures the penetration of the beam	C1	
			greater hardness, greater penetration	A1	[2]
		(ii)	controlled by changing the anode voltage	C1	
			higher anode voltage, greater penetration/hardness	A1	[2]
	(c)		long-wavelength radiation more likely to be absorbed in the body/less likely to penetrate through body	B1	[1]
		(ii)	(aluminium) filter/metal foil placed in the X-ray beam	B1	[1]