Production & Use of X-Rays

Question paper 1

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Quantum Physics
Sub Topic	Production & Use of X-Rays
Paper Type	Theory
Booklet	Question paper 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) State and explain how, in an X-ray tube, the hardness of the X-ray beam is controlled.

.....

.....

.....

..... [3]

(b) A parallel beam of X-rays has intensity I_0 and is incident on a medium having a linear absorption (attenuation) coefficient μ.

(i) State an equation for the variation of the intensity I with the thickness x of the medium.

..... [1]

(ii) Data for the linear absorption (attenuation) coefficient μ for an X-ray beam in blood and in muscle is shown in Fig. 11.1.

	μ / cm^{-1}
blood	0.23
muscle	0.22

Fig. 11.1

Suggest why, if this X-ray beam is used to image blood vessels in muscle, contrast on the image would be poor.

.....

.....

..... [2]

2 The use of X-rays in medical diagnosis gives rise to an increased exposure of the patient to radiation.

Explain why

(a) an aluminium filter may be placed in the X-ray beam when producing an X-ray image of a patient,

.....

.....

.....

.....

..... [3]

(b) the radiation dose received by a patient is different for a CT scan from that for a simple X-ray image.

.....

.....

.....

.....

.....

..... [4]

3 (a) Outline briefly the principles of CT scanning.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

(b) In a model for CT scanning, a section is divided into four voxels. The pixel numbers *P*, *Q*, *R* and *S* of the voxels are shown in Fig. 12.1.

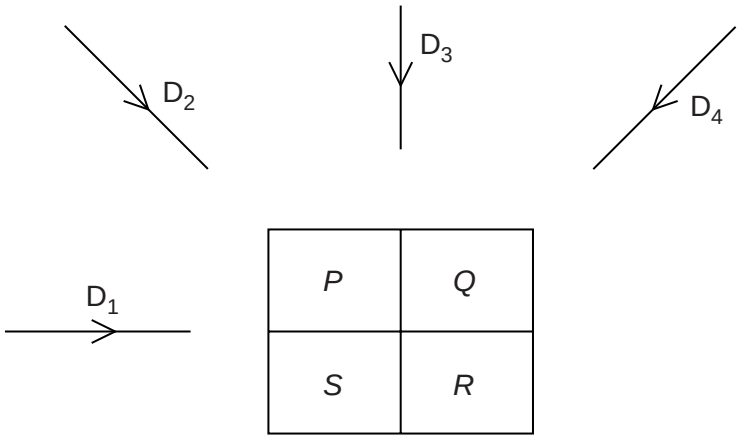

Fig. 12.1

The section is viewed from the four directions D_1, D_2, D_3 and D_4.
The detector readings for each direction are noted.

The detector readings are summed as shown in Fig. 12.2.

49	61
73	55

Fig. 12.2

The background reading is 34.

Determine the pixel numbers *P*, *Q*, *R* and *S* as shown in Fig. 12.3.

P	*Q*
S	*R*

Fig. 12.3

P = ... *Q* = ...

S = ... *R* = ...

[4]

4 **(a)** Distinguish between an X-ray image of a body structure and a CT scan.

X-ray image: .....

.....

.....

.....

.....

CT scan: .....

.....

.....

.....

.....

[5]

(b) Data for the linear absorption (attenuation) coefficient μ of X-ray radiation of energy 80 keV are given in Fig. 11.1.

metal	μ / mm^{-1}
aluminium	0.46
copper	0.69

Fig. 11.1

A parallel X-ray beam is incident on a copper filter, as shown in Fig. 11.2.

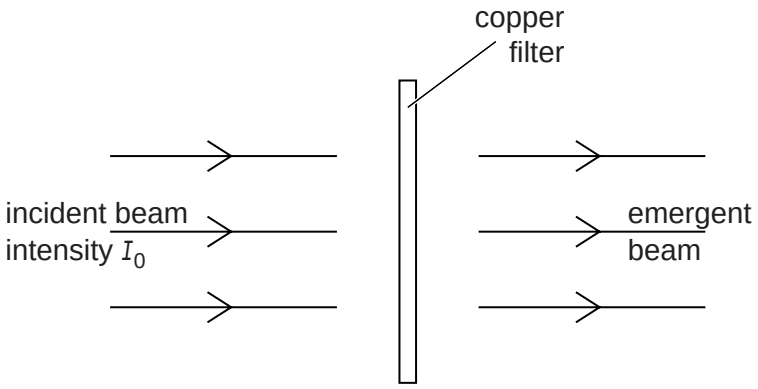

Fig. 11.2

The intensity of the incident beam is I_0.

(i) Calculate the thickness of copper required to reduce the intensity of the emergent beam to $0.25\,I_0$.

thickness = ... mm [2]

(ii) An aluminium filter of thickness 2.4 mm is now placed in the X-ray beam, together with the copper filter in **(i)**.

Calculate the fraction of the incident intensity that emerges after passing through the two filters.

fraction = ... [2]

(iii) Express your answer in **(ii)** as a gain in decibels (dB).

gain = ... dB [3]

5 **(a)** Distinguish between sharpness and contrast in X-ray imaging.

sharpness: .....

.....

contrast: .....

.....

[2]

(b) State two causes of loss of sharpness of an X-ray image.

1. .....

.....

2. .....

.....

[2]

(c) Data for the linear attenuation (absorption) coefficient μ of X-ray photons are given in Fig. 10.1.

	μ / cm^{-1}
bone	2.85
muscle	0.95

Fig. 10.1

A parallel beam of X-rays is incident, separately, on a thickness of 3.5 cm of bone and on a muscle of thickness 8.0 cm.

(i) Calculate the ratio

$$\frac{\text{intensity of X-ray beam transmitted through bone}}{\text{intensity of X-ray beam transmitted through muscle}}.$$

ratio = ... [3]

(ii) Use your answer in **(i)** to suggest whether an X-ray image of the bone and muscle would show good or poor contrast.

.....

.....

..... [2]

6 **(a)** Explain how the hardness of an X-ray beam is controlled by the accelerating voltage in the X-ray tube.

.....

.....

..... [2]

(b) The attenuation of a parallel beam of X-ray radiation is given by the expression

$$\frac{I}{I_0} = e^{-\mu x}$$

where μ is the linear attenuation (absorption) coefficient and x is the thickness of the material through which the beam passes.

(i) State

1. what is meant by *attenuation*,

.....

..... [1]

2. why the expression applies only to a parallel beam.

.....

.....

..... [2]

(ii) The linear attenuation coefficients for X-rays in bone and in soft tissue are $2.9\,\text{cm}^{-1}$ and $0.95\,\text{cm}^{-1}$ respectively.

Calculate, for a parallel X-ray beam, the ratio

$$\frac{\text{fraction } \frac{I}{I_0} \text{ of intensity transmitted through bone of thickness } 2.5\,\text{cm}}{\text{fraction } \frac{I}{I_0} \text{ of intensity transmitted through soft tissue of thickness } 6.0\,\text{cm}}.$$

ratio = ... [2]

7 Outline the principles of CT scanning.

.....

.....

.....

.....

.....

.....

.....

.....

..... [6]

8 A simple model of one section of a CT scan is shown in Fig. 10.1.

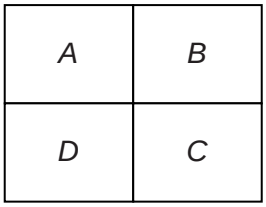

Fig. 10.1

The model consists of four voxels with pixel numbers *A*, *B*, *C* and *D*.

In this model, the voxels are viewed in turn along four different directions D_1, D_2, D_3 and D_4 as shown in Fig. 10.2.

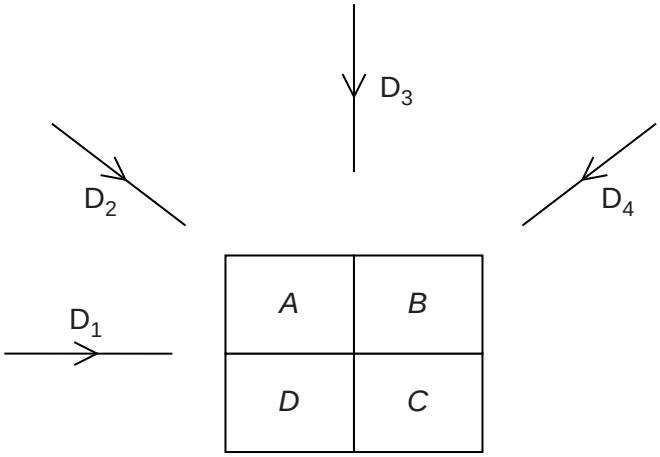

Fig. 10.2

The pixel readings in each of the four directions are noted.
The total pixel reading for any one direction is 19.
The pixel readings for all of the directions are summed to give the pattern of readings shown in Fig. 10.3.

25	34
28	46

Fig. 10.3

(a) State the background reading in this model.

background reading = ...[1]

(b) Determine each of the pixel readings.

A = ...	*B* = ...
D = ...	*C* = ...

[4]

(c) Use your answers in **(b)** to determine the pixel readings along

(i) the direction D_3,

.....[1]

(ii) the direction D_4.

.....[2]

9 High-speed electrons are incident on a metal target. The spectrum of the emitted X-ray radiation is shown in Fig. 11.1.

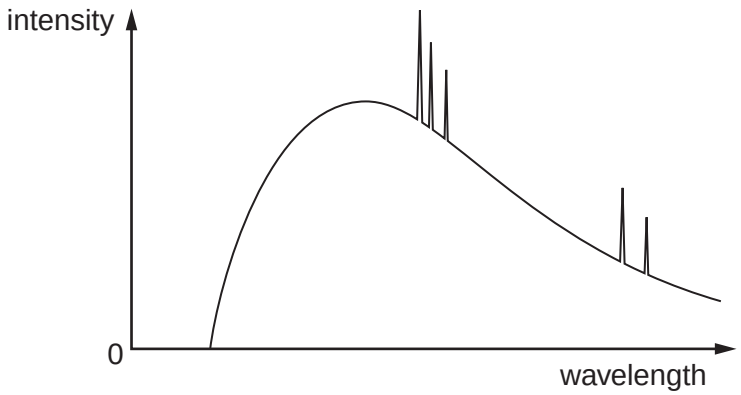

Fig. 11.1

(a) Explain why

(i) there is a continuous distribution of wavelengths,

.....

.....

..... [2]

(ii) there is a sharp cut-off at short wavelength.

.....

.....

..... [2]

(b) State

(i) what is meant by the *hardness* of an X-ray beam,

.....

.....

..... [2]

(ii) how hardness is controlled.

.....

.....

..... [2]

(c) **(i)** Suggest why, when producing an X-ray image, long-wavelength X-ray radiation poses a greater hazard to health than short-wavelength radiation.

.....

..... [1]

(ii) Suggest how this hazard is minimised.

.....

..... [1]