Production & Use of X-Rays

Question paper 2

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 2

Time Allowed: **80 minutes**

Score: **/66**

Percentage: **/100**

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

1 (a) An aluminium block is placed near to a small source of X-ray radiation, as shown in Fig. 10.1.

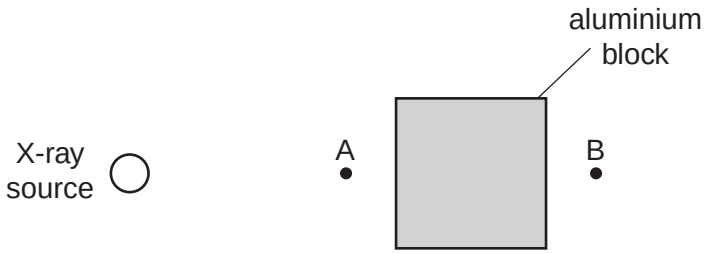

Fig. 10.1

X-rays from the source are detected at point A and at point B.

State two reasons why the intensity of the X-ray beam at point B is not as great as the intensity at point A.

1. .....

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2. .....

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[2]

(b) A cross-section through a model of a finger is shown in Fig. 10.2.

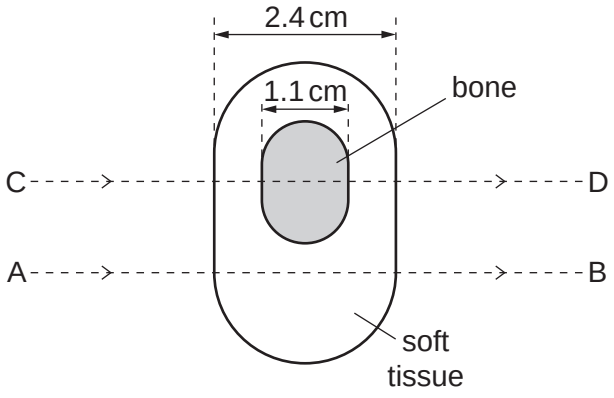

Fig. 10.2

The thickness of the model is 2.4 cm and that of the bone in the model is 1.1 cm.
Parallel beams of X-rays are incident on the model in the directions AB and CD, as shown in Fig. 10.2.

Data for the linear attenuation (absorption) coefficient μ for the bone and the soft tissue in the model are given in Fig. 10.3.

	μ / cm^{-1}
bone soft tissue	3.0 0.27

Fig. 10.3

Calculate the ratio

$$\frac{\text{intensity of X-ray beam incident on the model}}{\text{intensity of X-ray beam emergent from the model}}$$

for

(i) the beam AB,

ratio = ...[2]

(ii) the beam CD.

ratio = ...[2]

(c) Use your answers in **(b)** to suggest why, for this model, an X-ray image with good contrast may be obtained.

.....

.....[1]

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

sharpness: .....

.....

contrast: .....

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[2]

(b) A student investigates the absorption of X-ray radiation in a model arm. A cross-section of the model arm is shown in Fig. 11.1.

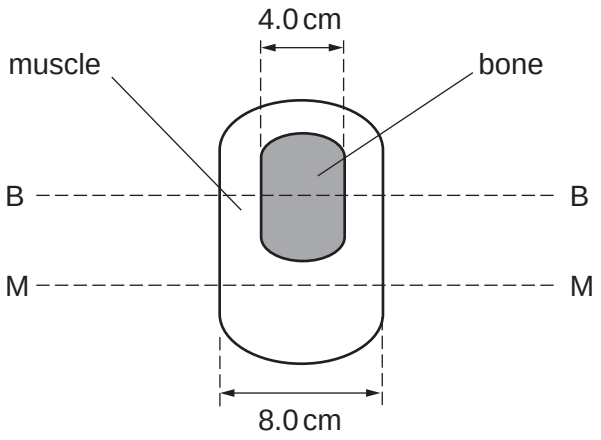

Fig. 11.1

Parallel X-ray beams are directed along the line MM and along the line BB.
The linear absorption coefficients of the muscle and of the bone are 0.20 cm^{-1} and 12 cm^{-1} respectively.

Calculate the ratio

$$\frac{\text{intensity of emergent X-ray beam from model}}{\text{intensity of incident X-ray beam on model}}$$

for a parallel X-ray beam directed along the line

(i) MM,

ratio = ... [2]

(ii) BB.

ratio = ... [3]

(c) State whether your answers in **(b)** would indicate that the X-ray image

(i) is sharp,

..... [1]

(ii) has good contrast.

..... [1]

3 **(a)** **(i)** State, with reference to X-ray images, what is meant by *sharpness*.

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..... [1]

(ii) Describe briefly two factors that affect the sharpness of an X-ray image.

1. .....

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2. .....

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[3]

(b) An X-ray image is taken of the skull of a patient. Another patient has a CT scan of his head.
By reference to the formation of the image in each case, suggest why the exposure to radiation differs between the two imaging techniques.

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..... [4]

4 The linear attenuation (absorption) coefficient μ for X-ray radiation in bone, fat and muscle is given in Fig. 11.1.

	μ / cm^{-1}
bone	2.9
fat	0.90
muscle	0.95

Fig. 11.1

(a) A parallel X-ray beam of intensity I_0 is incident either on some bone or on some muscle.
The emergent beam has intensity I.

Calculate the ratio $\frac{I}{I_0}$ for a thickness of

(i) 1.5 cm of bone,

ratio = ... [2]

(ii) 4.6 cm of muscle.

ratio = ... [1]

(b) Suggest why, on an X-ray plate, the contrast between bone and muscle is much greater than that between fat and muscle.

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..... [3]

5 (a) Briefly explain the principles of CT scanning.

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..... [6]

(b) A simple section through a body consists of four voxels, as illustrated in Fig. 10.1.

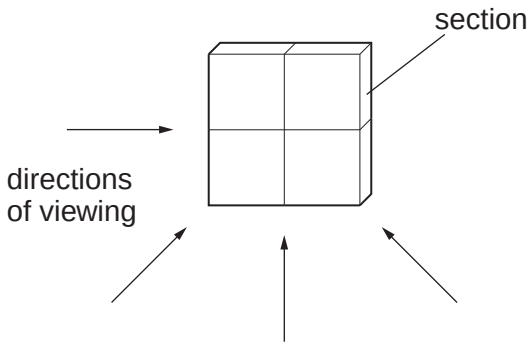

Fig. 10.1

An X-ray image of the section is obtained by viewing along each of the directions shown in Fig. 10.1.
The detector readings for each direction of viewing are summed to give the pattern of readings shown in Fig. 10.2.

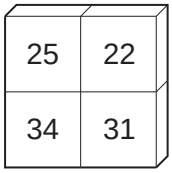

Fig. 10.2

For any one direction, the total of the detector readings is 16.

(i) For the pattern of readings of Fig. 10.2, state the magnitude of the background reading.

background reading = ... [1]

(ii) On Fig. 10.1, mark the pattern of pixels for the four-voxel section. [2]

6 **(a)** A typical spectrum of the X-ray radiation produced by electron bombardment of a metal target is illustrated in Fig. 10.1.

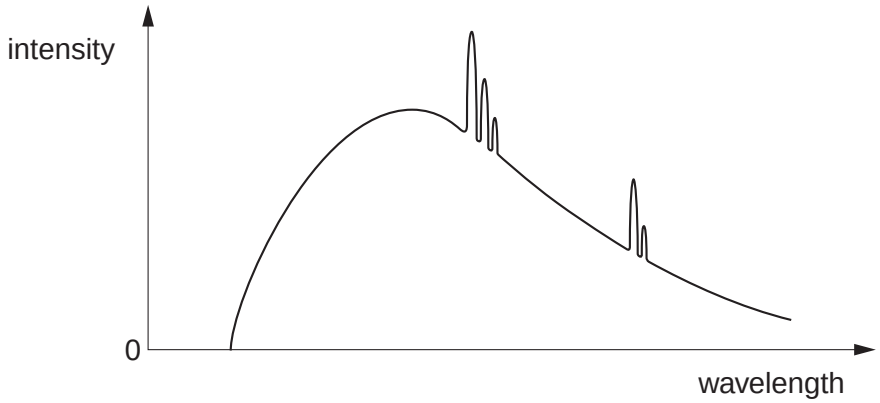

Fig. 10.1

Explain why

(i) a continuous spectrum of wavelengths is produced,

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..... [3]

(ii) the spectrum has a sharp cut-off at short wavelengths.

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..... [1]

(b) The variation with photon energy E of the linear absorption coefficient μ of X-rays in soft tissue is illustrated in Fig. 10.2.

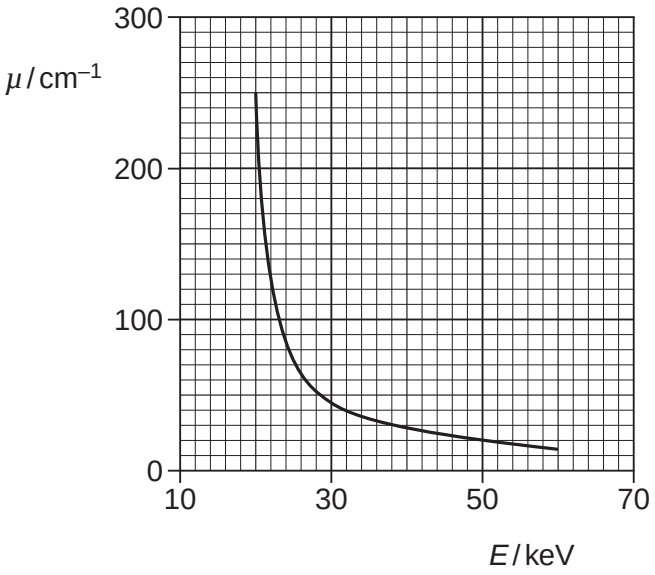

Fig. 10.2

(i) Explain what is meant by *linear absorption coefficient*

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..... [3]

(ii) For one particular application of X-ray imaging, electrons in the X-ray tube are accelerated through a potential difference of 50 kV.

Use Fig. 10.2 to explain why it is advantageous to filter out low-energy photons from the X-ray beam.

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..... [3]

7 **(a)** Distinguish between the images produced by CT scanning and X-ray imaging.

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..... [3]

(b) By reference to the principles of CT scanning, suggest why CT scanning could not be developed before powerful computers were available.

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..... [5]

8 **(a)** Explain the principles behind the use of X-rays for imaging internal body structures.

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..... [4]

(b) Describe how the image produced during CT scanning differs from that produced by X-ray imaging.

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..... [5]