24. Medical Physics

24.2 Production and use of X-rays

Paper 4

Question Paper

1 **(b)** Fig. 8.1 shows a tube in which X-rays are produced at a metal target.

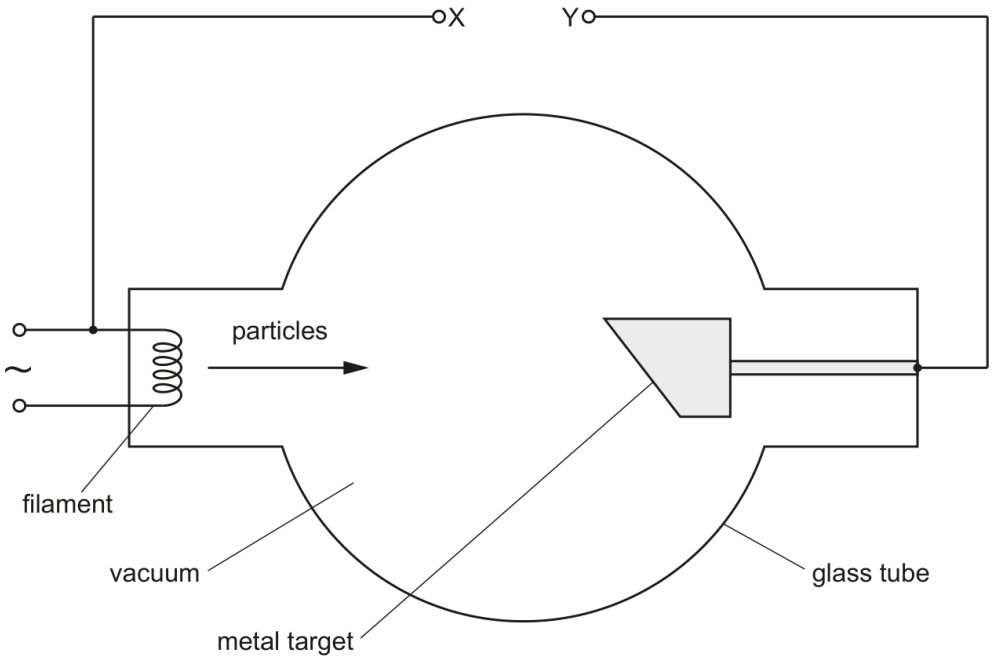


Fig. 8.1

Particles are accelerated from the filament to the target by a constant high voltage applied across the terminals X and Y.

(i) State the name of the particles.

..... [1]

(ii) On Fig. 8.1, use + and – signs to label terminals X and Y to indicate the polarity of the high voltage. [1]

(c) For an accelerating voltage of 32 kV in Fig. 8.1, determine:

(iii) the minimum wavelength of X-rays produced at the target.

minimum wavelength = ... m [3]

(d) Explain why X-rays can be used to produce images of internal body structures that have good contrast.

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..... [3]

2 **(a)** X-rays for use in medical diagnosis are produced in an X-ray tube. In the X-ray tube, charged particles are accelerated towards a metal target by an applied potential difference (p.d.).

(i) State the name of the charged particles that are accelerated by the applied p.d.

..... [1]

(ii) Explain how X-rays are produced at the metal target.

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..... [2]

(iii) Calculate the minimum wavelength of X-rays produced when the applied p.d. is 5.80 kV.

wavelength = ... m [3]

(b) X-rays pass through a medium that has an attenuation coefficient of 1.4 cm^{-1}.

Calculate the percentage of the X-ray energy that is **absorbed** by a 2.8 cm thickness of this medium.

percentage absorbed = ... % [3]

3 Ultrasound and X-rays are both types of wave that are used in medical diagnosis to form images of internal body structures.

(b) (i) For one type of wave passing through tissue, the wave has 72% of its initial intensity after it has passed through 6.2 cm of the tissue.

Calculate the linear attenuation coefficient μ of the tissue for this wave.

μ = ... cm^{-1} [2]

(ii) Another wave of the same type as in **(b)(i)** passes through 9.3 cm of the same tissue.

Calculate the percentage of the initial intensity of the wave that is attenuated by the tissue.

percentage attenuated = ... % [2]

4 **(a)** **(i)** Explain how X-rays are produced for use in medical diagnosis.

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..... [3]

(ii) State why X-ray images are taken of multiple sections of the body during computed tomography (CT) scanning.

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..... [1]

(b) An X-ray image is taken of the structure shown in Fig. 9.1.

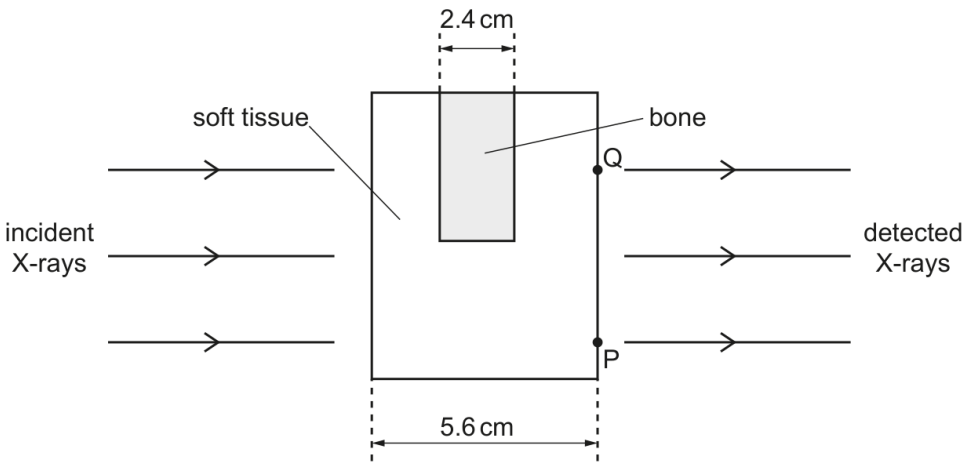


Fig. 9.1

The linear attenuation coefficient of bone is 3.4 cm^{-1}.
The linear attenuation coefficient of soft tissue is 0.89 cm^{-1}.

The incident X-rays are parallel and have a uniform intensity I_0 across the structure.

Determine, in terms of I_0, the intensity of the detected X-rays from:

(i) point P

detected intensity = ... I_0 [2]

(ii) point Q.

detected intensity = ... I_0 [2]

(c) Explain, with reference to your answers in **(b)**, whether the X-ray image of the structure in Fig. 9.1 has good contrast.

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..... [1]

5 **(a)** State how, in a modern X-ray tube, the intensity of the X-ray beam and its hardness are controlled.

intensity: .....

.....

hardness: .....

.....
[2]

(b) A model of a limb consists of soft tissue and bone, as illustrated in Fig. 11.1.

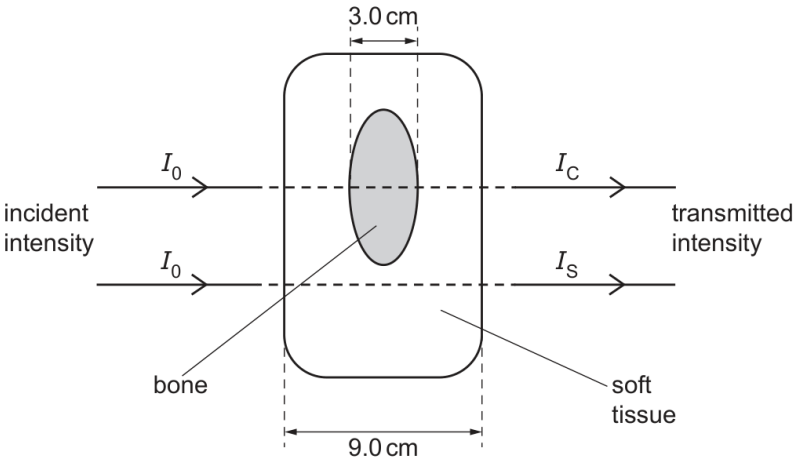


Fig. 11.1

The soft tissue has a thickness of 9.0 cm. The bone within the soft tissue has a thickness of 3.0 cm.

Data for the linear attenuation (absorption) coefficient μ of X-rays in soft tissue and in bone are shown in Table 11.1.

Table 11.1

	μ/cm^{-1}
soft tissue	0.92
bone	2.9

A parallel beam of X-rays of intensity I_0 is incident normally on the model.

Calculate, in terms of I_0:

(i) the transmitted intensity I_S through soft tissue alone

I_S = ... I_0 [2]

(ii) the transmitted intensity I_C through soft tissue and bone.

I_C = ... I_0 [2]

(c) By reference to your answers in **(b)**, suggest, with a reason, whether good contrast on an X-ray image would be obtained.

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..... [1]

6 **(a)** State the purpose of computed tomography (CT scanning).

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..... [1]

(b) Outline the principles of CT scanning.

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..... [5]

7 **(a)** State, for an X-ray image, what is meant by:

(i) *sharpness*

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..... [1]

(ii) *contrast*.

.....

..... [1]

(b) A parallel X-ray beam passes through a thickness of 2.3 cm of soft body tissue. The intensity of the emerging beam is 12% of the intensity of the incident beam.

Calculate the linear attenuation (absorption) coefficient μ of the soft body tissue. Give a unit with your answer.

μ = ... unit ..... [3]

(c) In medical diagnosis, X-rays may be used to produce a single X-ray image or may be used in computed tomography (CT scanning).

Suggest an advantage and a disadvantage of CT scanning compared with single X-ray imaging for diagnosis.

advantage: .....

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disadvantage: .....

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[2]

8 **(a)** Outline briefly the principles of computed tomography (CT scanning).

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..... [5]

(b) One section of a model designed to illustrate CT scanning is divided into four voxels. The pixel numbers K, L, M and N of the voxels are shown in Fig. 10.1.

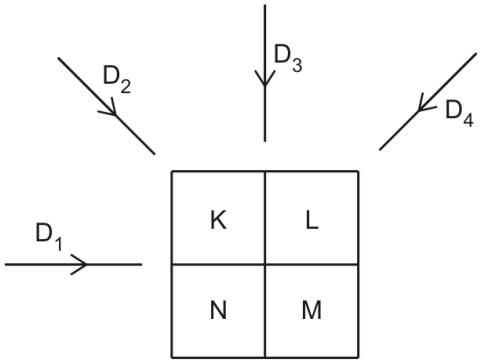


Fig. 10.1

The section is viewed, in turn, from four different directions D_1, D_2, D_3 and D_4, as shown in Fig. 10.1.

The detector readings for each direction are noted and these are summed to give the values shown in Fig. 10.2.

42	45
51	30

Fig. 10.2

The background reading is 24.

Determine the pixel numbers K, L, M and N shown in Fig. 10.1.

K = ...

L = ...

M = ...

N = ...

[3]

9 Electrons in a beam are travelling at high speed in a vacuum. The electrons are incident on a metal target, causing X-ray radiation to be emitted.

The variation with wavelength λ of the intensity I of the emitted X-ray radiation is shown in Fig. 7.1.

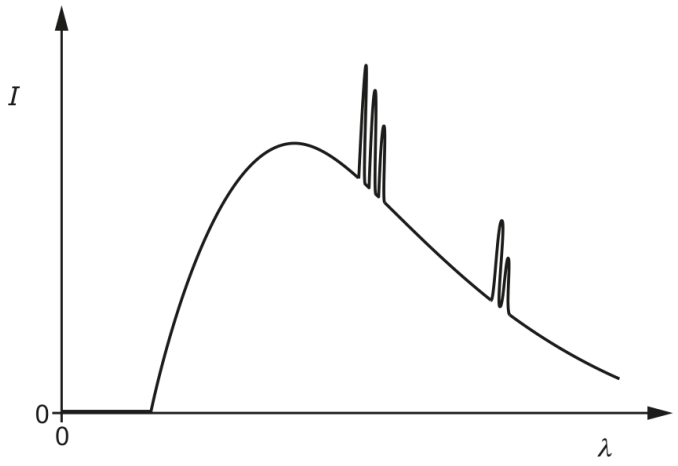


Fig. 7.1

Explain why:

(a) there is a continuous distribution of wavelengths

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..... [3]

(b) at certain wavelengths, there are narrow peaks of increased intensity.

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..... [3]

10 Describe the principles of computed tomography (CT) scanning.

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..... [5]

11 An X-ray beam is used to produce an image of a model of a thumb.
A parallel beam of X-ray radiation of intensity I_0 is incident on the model, as illustrated in Fig. 12.1.

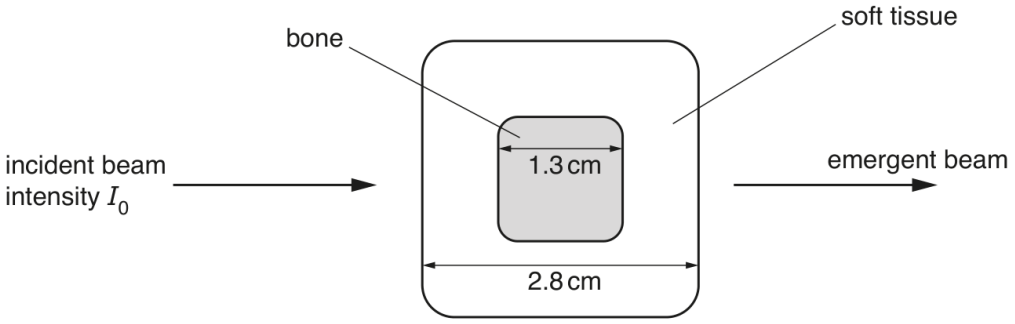


Fig. 12.1

Data for the attenuation (absorption) coefficient μ in bone and in soft tissue are shown in Fig. 12.2.

	μ / cm^{-1}
bone	3.0
soft tissue	0.90

Fig. 12.2

(a) Calculate, in terms of the incident intensity I_0 of the X-ray beam, the intensity of the beam after passing through

(i) a thickness of 2.8 cm of soft tissue,

intensity = ... I_0 [2]

(ii) the bone and soft tissue, as shown in Fig. 12.1.

intensity = ... I_0 [2]

(b) (i) State what is meant by the *contrast* of an X-ray image.

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.....[2]

(ii) By reference to your answers in **(a)**, suggest whether the X-ray image of the model has good contrast.

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.....[1]

12 **(a)** Describe the basic principles of CT scanning (computed tomography).

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.....[5]

(b) By reference to your answer in **(a)**, suggest why

(i) CT scanning was not possible before fast computers with large memories were available,

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.....[1]

(ii) the radiation dose for a CT scan is much larger than for an X-ray image of a leg bone.

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.....[1]

13 (c) A parallel beam of X-rays of intensity I_0 is incident normally on some soft tissue and bone, as illustrated in Fig. 10.1.

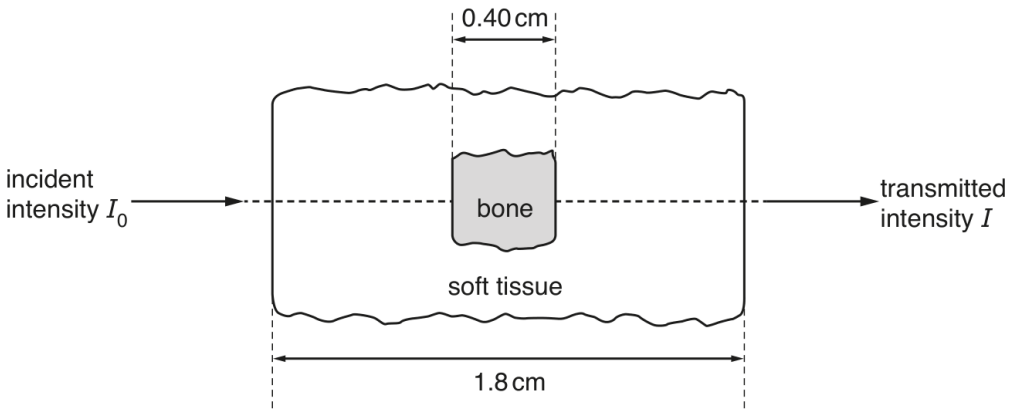


Fig. 10.1

The bone is 0.40 cm thick and the total thickness of the bone and the soft tissue is 1.8 cm. The intensity of the transmitted beam is I.

Data for the linear attenuation (absorption) coefficient μ of bone and of soft tissue are given in Fig. 10.2.

	μ/cm^{-1}
bone	2.9
soft tissue	0.92

Fig. 10.2

Calculate, in dB, the ratio

$$\frac{\text{transmitted intensity } I}{\text{incident intensity } I_0}.$$

ratio = ... dB [4]