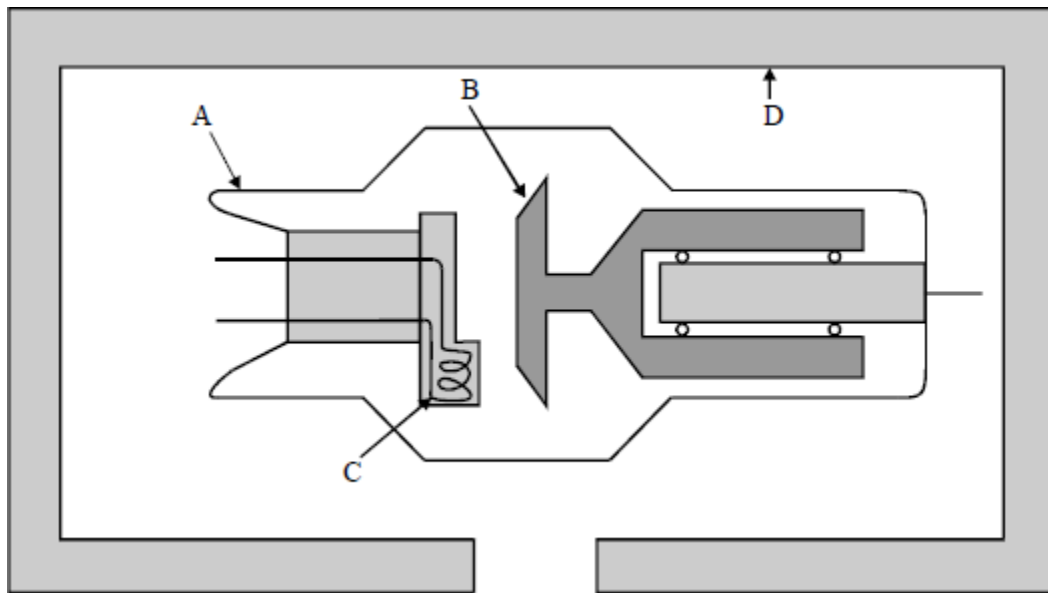


1

The simplified diagram shows a modern X-ray tube.



(a) For each of the labelled parts, state what it is and explain its purpose.

A name

purpose

.....

B name

purpose

.....

C name

purpose

.....

D name

purpose

.....

(8)

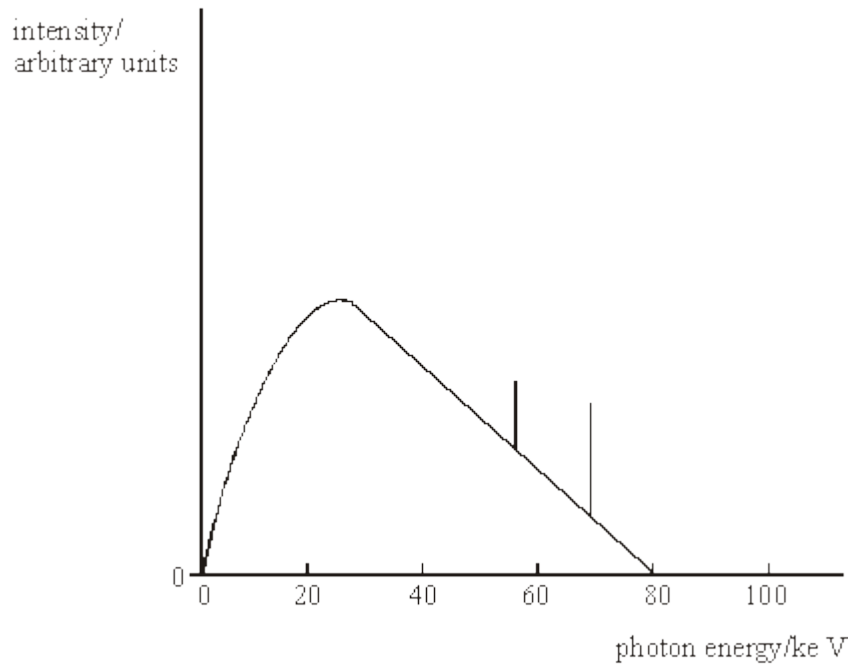
(b) On the diagram draw and label

(i) the direction of the electron beam,

(ii) the direction of the useful X-ray beam.

(2)

(Total 10 marks)



- (a) An X-ray tube operates with a pd across the tube of 80 kV. The figure above shows the X-ray spectrum emitted. Explain why the spectrum has spikes at specific photon energies.

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(2)

- (b) The pd across the tube is increased to 90 kV. Sketch on the figure above the X-ray spectrum produced at this new pd.

(3)

- (c) At the working pd of 80 kV, the anode current was 120 mA. The X-ray tube has an efficiency of 0.70 %. Calculate the rate of production of heat at the anode.

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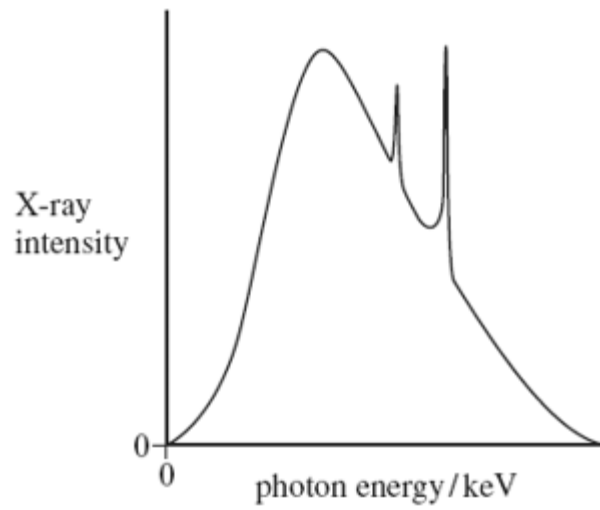
(3)

(Total 8 marks)

3

- (a) The X-ray spectrum for a certain X-ray tube target is shown in **Figure 1**. Explain the process which gives rise to spikes at certain photon energies.

Figure 1



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(3)

- (b) A film cassette, placed under a patient being X-rayed, is shown in **Figure 2**.

Figure 2



Explain how the intensifying screens in the film cassette achieve their purpose and state their benefit to the patient.

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(3)
(Total 6 marks)

4

- (a) In an X-ray tube, electrons are accelerated from rest through a pd of 72.4 kV before they hit the target anode.
- (i) Calculate the kinetic energy of an electron as it reaches the anode. Give your answer to an appropriate number of significant figures.

answer = J

(2)

- (ii) Assuming that the electron gives up all this energy to form an X-ray photon, calculate the wavelength of the photon.

answer = m

(2)

- (b) X-rays are used in a CT scanner. Describe briefly how a CT scanner produces an image.

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(3)

(Total 7 marks)

5

- (i) Explain what is meant by the *half-value thickness* of lead for X-rays.

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- (ii) Calculate the linear attenuation coefficient of lead for 90 keV X-ray photons.

half value thickness of lead for 90 keV X-ray photons = 12mm.

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- (iii) Calculate the thickness of lead needed to reduce the intensity of a beam of 90 keV X-ray photons to 5.0 % of the intensity incident on the lead.

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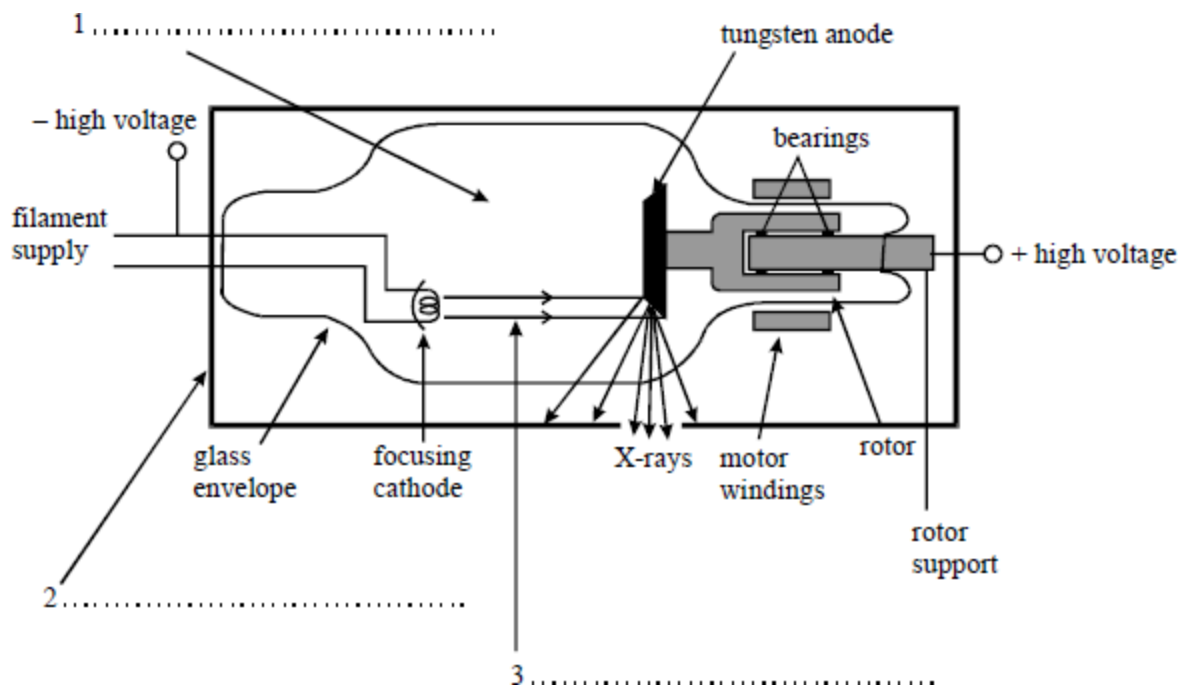
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(Total 6 marks)

6

- (a) The diagram shows a rotating-anode X-ray tube. Complete the labelling of the **three** numbered arrows in the diagram.



(3)

(b) Explain why the anode

(i) is rotated,

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.....

(ii) has a bevelled edge.

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(3)

(c) Define for a material,

(i) the linear attenuation coefficient, μ ,

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(ii) the half-value thickness.

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(2)

(d) A monochromatic X-ray beam of intensity 6.0 W m^{-2} is incident on an aluminium sheet of thickness 2.0 mm. For these X-rays, the half-value thickness of aluminium is 3.2 mm. Calculate the intensity of the transmitted beam.

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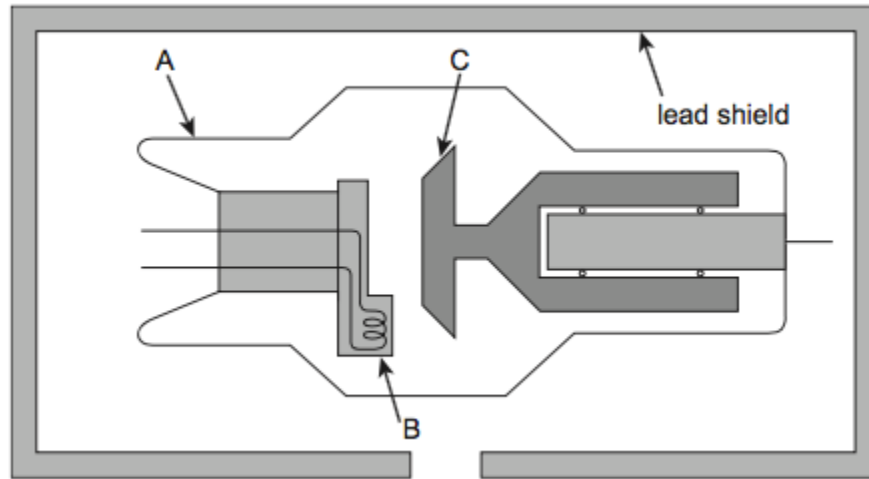
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(3)
(Total 11 marks)

7

The diagram shows a simplified modern X-ray tube with a rotating anode.



- (a) Explain the design and operation of the X-ray tube and the purposes of the components labelled on the diagram.

In your answer you should include:

- reference to the components labelled A, B, C and the lead shield
- an explanation of the physical processes by which X-rays are produced.

The quality of your written communication will be assessed in your answer.

(6)

- (b) The X-ray tube produces photons of energy 50 keV. The half-value thickness of bone for photons of this energy is 15 mm.

- (i) Explain what is meant by half-value thickness.

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(1)

- (ii) Show that for 50 keV X-ray photons, the attenuation coefficient of bone μ is 0.046 mm^{-1} .

(1)

- (iii) A beam of 50 keV X-ray photons is incident on a bone of thickness 12 mm.
Calculate the percentage of the incident photons that leave the far side of the bone.

percentage of incident photons = %

(2)

(Total 10 marks)

8

Diagnostic X-rays are produced using a rotating anode X-ray tube.

- (a) (i) State **two** methods which can be used to increase the intensity of the X-ray beam produced by the tube.

method 1

method 2

- (ii) For each method of increasing intensity, state the effect on the maximum X-ray photon energy.

method 1

method 2

(3)

- (b) Before taking an X-ray photograph, the X-ray beam emerging from the tube is passed through an aluminium filter. State and explain the reason for filtering the X-rays.

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(3)

(Total 6 marks)

9

- (a) When an X-ray image is obtained of certain organs, *image contrast enhancement* is necessary. Explain why image contrast enhancement is needed and describe how this might be achieved.

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(3)

- (b) A monochromatic X-ray beam of intensity $3.2 \times 10^{-2} \text{ W m}^{-2}$ is incident on an aluminium sheet. Calculate the thickness of aluminium required to reduce the intensity of the X-ray beam to $1.2 \times 10^{-2} \text{ W m}^{-2}$.

mass attenuation coefficient of aluminium, $\mu_m = 0.012 \text{ m}^2 \text{ kg}^{-1}$

density of aluminium, $\rho = 2700 \text{ kg m}^{-3}$

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(3)

(Total 6 marks)

10

A diagnostic X-ray tube produces a beam of X-rays. The beam passes through a diaphragm consisting of two pairs of lead sheets which can be moved at right angles to each other, and then through an aluminium filter.

- (a) (i) State the use of the lead sheets.

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(1)

(ii) State the use of the aluminium filter.

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(1)

- (b) When a monochromatic beam of X-ray photons is passed through an aluminium sheet of thickness 2.7 mm, its intensity is reduced by 8.3%.

Calculate the mass attenuation coefficient of aluminium for these X-rays.

State an appropriate unit for your answer.

density of aluminium = 2700 kg m^{-3}

mass attenuation coefficient unit

(5)

(Total 7 marks)