1 **(a)** Describe briefly how X-rays are produced in an X-ray tube.

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..... **[2]**

(b) Describe the Compton Effect in terms of an X-ray photon.

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..... **[2]**

(c) A beam of X-rays of intensity 3.0×10^9 W m^{-2} is used to target a tumour in a patient. The tumour is situated at a depth of 1.7 cm in soft tissue. The attenuation (absorption) coefficient μ of soft-tissues is 6.5 cm^{-1}.

(i) Show that the intensity of the X-rays at the tumour is about 5×10^4 W m^{-2}.

[2]

(ii) The cross-sectional area of the X-ray beam at the tumour is 5 mm^2. The energy required to destroy the malignant cells of the tumour is 200 J. The tumour absorbs 10% of the energy from the X-rays. Calculate the total exposure time required to destroy the tumour.

time = ... s **[3]**

(d) Describe the operation of a computerised axial tomography (CAT) scanner. State **one** of the advantages of a CAT scan image over a conventional X-ray image.

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..... **[5]**

[Total: 14]

2 **(a)** A magnetic resonance imaging (MRI) scanner is a valuable item of diagnostic equipment found in most hospitals. It is capable of generating a three-dimensional image of the patient. The following terms are used in the description of MRI scanners.

- Larmor frequency of the protons
- resonance of the protons
- relaxation times of the protons

Describe the operation of the MRI scanner with particular reference to these terms.

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 ..... **[6]**

(b) An MRI scan can take a long time and it does produce an unpleasant loud noise. State one other disadvantage and one advantage of an MRI scan.

disadvantage .....

.....

advantage .....

..... **[2]**

[Total: 8]

3 **(a)** Describe in simple terms how X-ray photons are produced in a hospital X-ray machine.

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..... **[2]**

(b) Fig. 7.1 shows a simple X-ray intensifier screen.

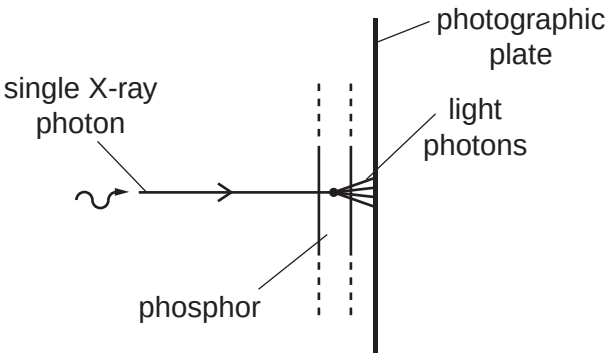

Fig. 7.1

A bright X-ray image can be produced using an image intensifier. A single X-ray photon incident on the phosphor produces about a thousand photons of visible light. The photons of visible light produce an image on a photographic plate.

(i) Explain what is meant by a *photon*.

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..... **[1]**

(ii) Explain why an X-ray photon has greater energy than a photon of visible light.

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..... **[1]**

(c) In an X-ray machine, accelerated electrons hit a metal target. Most of the kinetic energy of the electrons is converted into heat, but a small amount is converted into X-ray photons.
Electrons having maximum kinetic energy create the shortest wavelength X-ray photons.
Calculate the shortest wavelength of X-ray photons emitted from an X-ray machine operating at 120 kV.

wavelength = ... m **[3]**

(d) X-ray photons interact with matter. One of the interaction mechanisms of the X-ray photons with atoms is known as the **photoelectric effect**. State another interaction mechanism.
Describe what happens to the X-ray photon interacting with a single atom using the mechanism you have stated.

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..... **[2]**

[Total: 9]

4 **(a)** In the treatment of patients, explain what is meant by a non-invasive technique. State one of its advantages.

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..... **[2]**

(b) Explain what is meant by a medical tracer. Name a medical tracer commonly used to diagnose the function of organs.

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..... **[2]**

(c) The main components of a gamma camera are the collimator, scintillator, photomultiplier tubes and the computer. Describe the function of each of these components.

In your answer, you must make clear how one of these components governs the sharpness of the image.

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(d) Fig. 8.1 shows an ultrasound transducer placed above an artery.

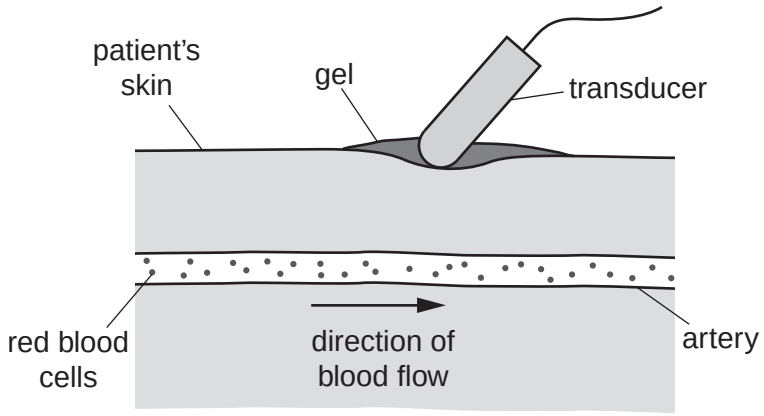

Fig. 8.1

(i) The speed of ultrasound in blood is 1500 m s^{-1}. Calculate the wavelength of the ultrasound of frequency 2.0 × 10^{6} Hz.

wavelength = ... m **[2]**

(ii) Describe how the ultrasound is used to determine the speed of the blood in the artery.

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..... **[3]**

[Total: 14]