1   **(a)** State **two** main properties of X-ray photons.

....

....

.... **[2]**

(b) Fig. 7.1 shows an X-ray photon interacting with an atom to produce an electron-positron pair in a process known as pair production.
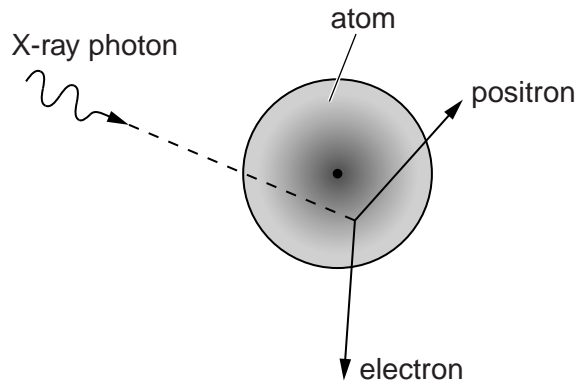
Fig. 7.1

Calculate the maximum wavelength of X-rays that can produce an electron-positron pair.

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

(c) Name an element used as a contrast material in X-ray imaging. Explain why contrast materials are used in the diagnosis of stomach problems.

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.... **[3]**

[Total: 8]

2 Technetium-99m is a common medical tracer injected into patients before they have a scan with a gamma camera. Technetium-99m is a gamma emitter with a half-life of about 6 hours. Each gamma ray photon has energy 2.2×10^{-14} J.

A patient is given a dose with an initial activity of 500 MBq.

(a) Explain what is meant by *activity*.

....

.... **[1]**

(b) Calculate the initial rate of energy emission from the dose of technetium-99m.

rate of energy emission = ... $J s^{-1}$ **[2]**

(c) Name and describe the function of the main components of a gamma camera.

In your answer you should make clear how a good quality image can be achieved with these components.

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.... **[5]**

[Total: 8]

3 **(a)** State **two** main properties of ultrasound.

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.... **[2]**

(b) Describe how the piezoelectric effect is used in an ultrasound transducer both to emit and receive ultrasound.

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.... **[2]**

(c) Explain why a gel is used between the ultrasound transducer and the patient's skin during a scan.

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.... **[2]**

(d) Explain a method using ultrasound to determine the speed of blood in an artery in the arm.

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.... **[4]**

[Total: 10]

4 **(a)** State two properties of X-rays.

1. ....

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2. ....

.... **[2]**

(b) Explain what is meant by the *Compton effect*.

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.... **[2]**

(c) The intensity I of a collimated beam of X-rays decreases exponentially with thickness x of the material through which the beam passes according to the equation $I = I_0\,e^{-\mu x}$. The attenuation (absorption) coefficient μ depends on the material.

(i) State what I_0 represents in this equation.

.... **[1]**

(ii) Bone has an attenuation coefficient of $3.3\,cm^{-1}$. Calculate the thickness in cm of bone that will reduce the X-ray intensity by half.

thickness = ... cm **[3]**

(d) Explain the purpose of using a contrast medium such as barium when taking X-ray images of the body.

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.... **[2]**

[Total: 10]

5 (a) Fig. 8.1 shows an MRI scanner.

Fig. 8.1

The main components of an MRI scanner are a strong electromagnet, radio frequency transmitting coils, radio frequency receiving coils, gradient coils and a computer.

- Outline the principles of magnetic resonance.

- Describe how these components are used to obtain diagnostic information about the internal organs.

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.... **[7]**

(b) Discuss the major differences between an MRI scan and a positron emission tomography (PET) scan of the brain.

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.... **[2]**

[Total: 9]