1.

i. Explain what is meant by a ***tracer***.

____ **[1]**

ii. $^{99}_{43}Tc^{m}$ only emits gamma radiation.

Give **two** advantages of using a tracer which only emits gamma radiation.

1 ____

____

2 ____

____ **[2]**

2. High-energy X-ray photons can destroy living cells. In radiotherapy, these photons are targeted at cancer cells.

The radiation **dose** is the amount of energy that a patient's body absorbs from the high-energy X-ray photons.

Fig. 6.2 shows how this dose changes with depth below the surface of the skin.

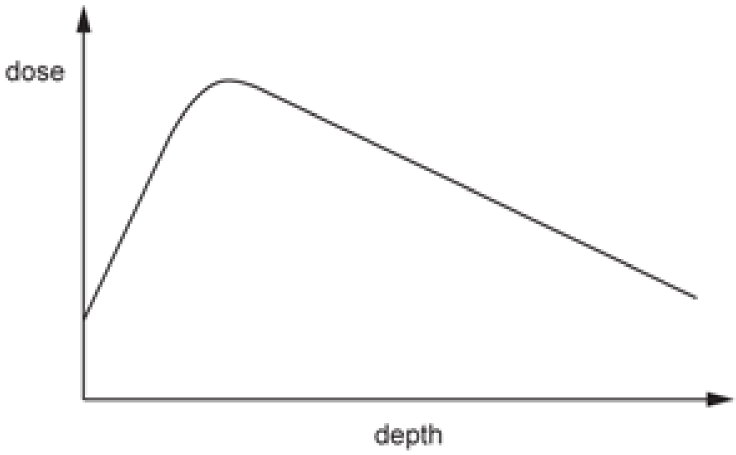

Fig. 6.2

The dose initially rises with depth because the high-energy X-ray photons produce electrons and positrons as they pass through the body. These electrons and positrons are quickly absorbed, increasing the dose.

i. Explain why high-energy X-ray photons produce electrons **and** positrons as they pass through the body.

____

____

____

____ **[2]**

ii. A 3D object called a **bolus** is used in radiotherapy for patients with skin cancer. A bolus targets the maximum radiation dose near the surface of the skin. So using a bolus makes the radiotherapy more effective.

A bolus can be made from PLA using a 3D printer. The bolus must fit the shape of the patient's body exactly. This shape is found beforehand by giving the patient either a CAT scan or a PET scan.

- Explain how CAT scans and PET scans work.
- Discuss the advantages and disadvantages of having a scan to produce a bolus for radiotherapy.

[6]

3(a). Radiographers commonly use molecules containing fluorine F-18 as tracers in positron emission tomography (PET) scanning.

Fluorine has a proton number of 9.

F-18 decays to oxygen (O) by β^+ decay.

Write the equation for the decay of a nucleus of F-18 using nuclear notation.

[2]

(b). The β^+ particle (positron) produced travels only a short distance in the patient before it meets an electron and is annihilated.

Calculate the wavelength λ of gamma photons produced.

λ = ...m **[3]**

(c). X-rays and gamma-rays are produced by different physical processes.
Briefly describe both processes.

[2]

(d). F-18 has a half-life of 109.7 minutes.

Explain the advantage that this has for the patient but the disadvantage that this has for the radiographers.

[3]

4(a). Ultrasound B-scans can be used to image unborn babies.
The figure below shows a B-scan of an unborn baby.

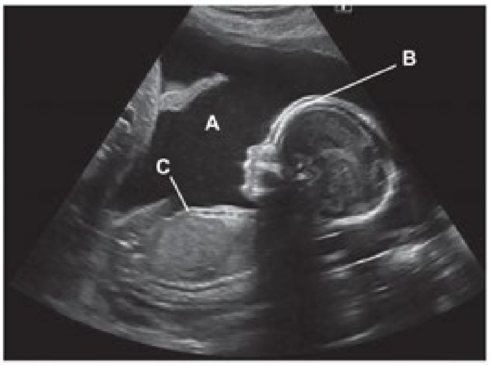

Fig. 17.2

i. Explain why no signal is received back from **A**.

[1]

ii. Explain why a greater signal is received back from **B** than **C**.

____

____

____ **[2]**

(b). Doppler ultrasound can be used to measure the speed of blood flow through blood vessels.

The speed of ultrasound in blood is 1600 ms^{-1}.

A transducer emitting ultrasound of frequency 10.0000 MHz is placed at 50° to the blood vessel.

The reflected ultrasound has a frequency of 9.9987 MHz.

Calculate the speed *v* of the blood flow.

v = ... ms^{-1} **[2]**

(c). Explain what is meant by ultrasound.

____

____

____ **[2]**

(d). Fig. 17.1 is a labelled photograph of an ultrasound examination of a patient.

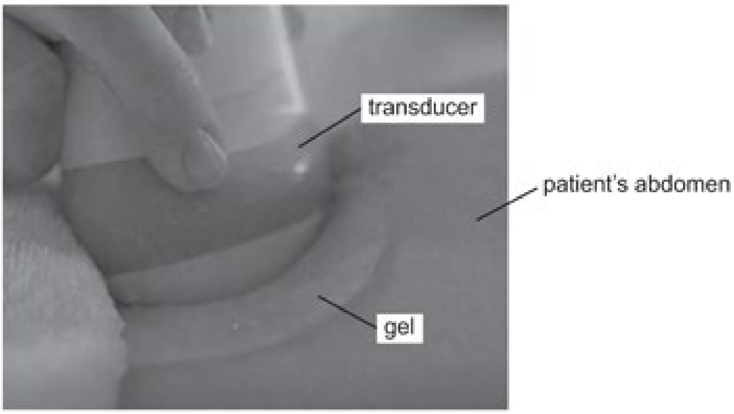

Fig. 17.1

Explain how the transducer both produces and receives ultrasound waves.

Explain the purpose of the gel.

____

____

____

[6]

5. Technetium-99m (Tc-99m) is a metastable isotope used in medical diagnosis.

Which ionising radiation does Tc-99m emit?

A alpha
B beta-minus
C beta-plus
D gamma

Your answer **[1]**

6(a). A gamma camera has several important components including a collimator, scintillator and photomultiplier tubes.

Suggest why the collimator needs to be long and narrow.

[1]

(b). State the function of the scintillator.

[1]

(c). In a single photomultiplier tube, a photon of light produces a 0.32 μA pulse of current for a duration of 1.2 ns.

Calculate the number of electrons responsible for this pulse of current.

number of electrons = ... **[2]**

(d). State one diagnostic application of a gamma camera.

-- **[1]**

7(a).

Describe, in terms of X-ray photons, the attenuation mechanism of Compton scattering.

-- **[2]**

(b). A parallel beam of X-rays is incident normally on a tissue as shown in **Fig. 24. 1**.

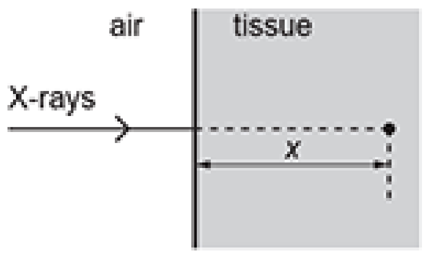

Fig. 24.1

The variation of the intensity *I* of the X-rays with depth *x* in the tissue is shown in **Fig. 24. 2**.

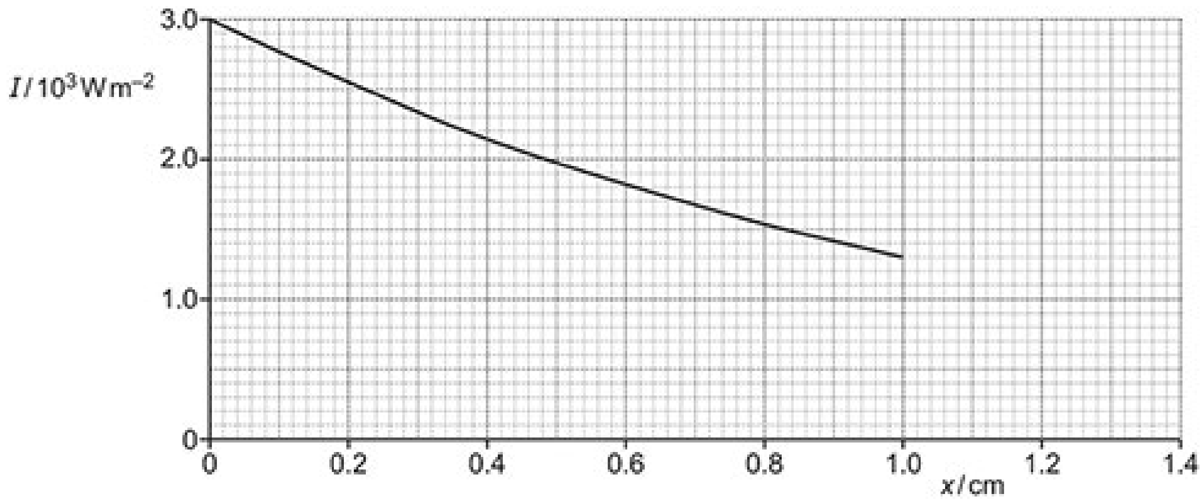

Fig. 24.2

The tissue has uniform structure between $x = 0$ and $x = 1.0$ cm.

i. Use the graph to determine the attenuation (absorption) coefficient μ in cm^{-1} of the tissue.

μ = ... cm^{-1} **[2]**

ii. Use the graph to determine the exposure time *t* for the total radiant energy incident per cm2 at a depth of 1.0 cm to be 2.6 J.

t = ... s **[3]**

iii. Beyond x = 1.0 cm, the tissue has a larger attenuation coefficient than the value calculated in **(i)**.

On **Fig. 24.2**, sketch the variation of I with x beyond x = 1.0 cm.

[2]

8. A small sample of muscle has volume 1.0 cm^3 and mass 1.10 g.
The speed of ultrasound in the muscle is 1600 ms^{-1}.
What is the acoustic impedance of the muscle?

A 1.76×10^{3} kg m^{-2} s^{-1}
B 1.76×10^{4} kg m^{-2} s^{-1}
C 1.76×10^{6} kg m^{-2} s^{-1}
D 1.76×10^{12} kg m^{-2} s^{-1}

Your answer ☐ **[1]**

END OF QUESTION PAPER