

1.

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

[1]

- ii. $^{99}_{43}\text{Tc}^m$ 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.

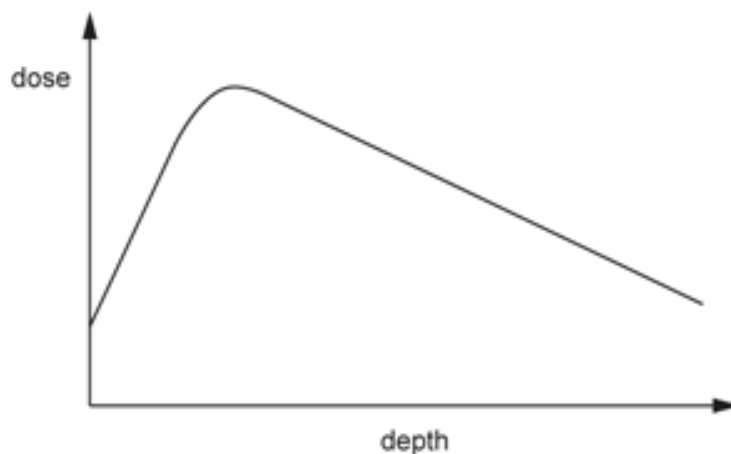


Fig. 6.2

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.

$\lambda = \dots\dots\dots\text{m}$ **[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.

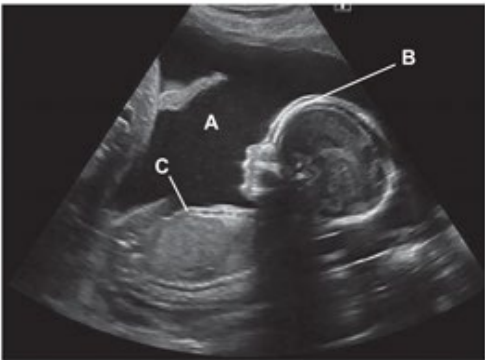


Fig. 17.2

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.

$v = \dots\dots\dots \text{ms}^{-1}$ [2]

(c). Explain what is meant by ultrasound.

[2]

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

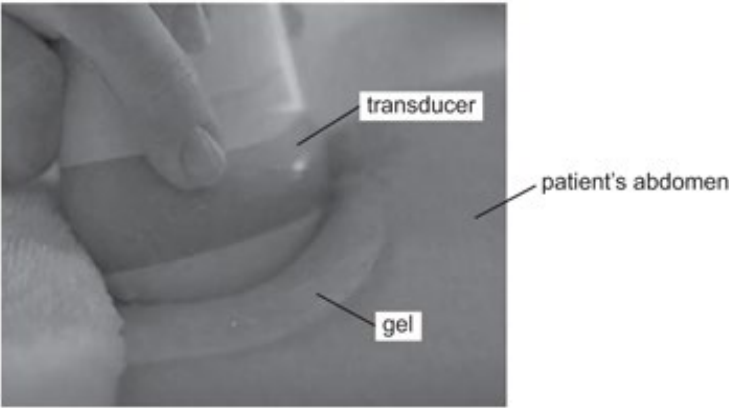


Fig. 17.1

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 $0.32 \mu\text{A}$ 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.

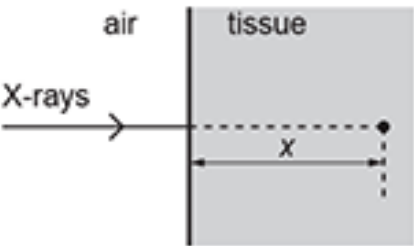


Fig. 24.1

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

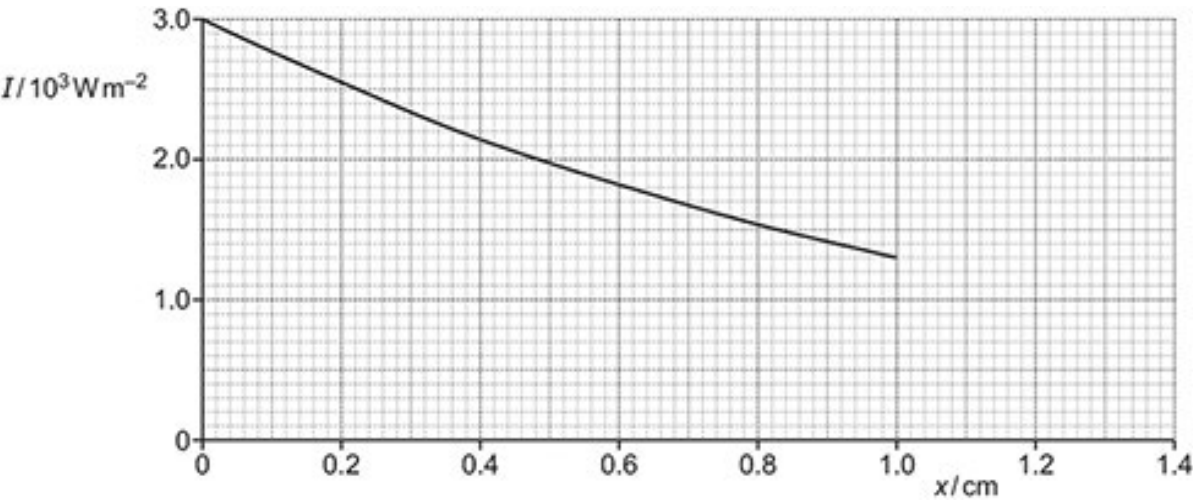


Fig. 24.2

The tissue has uniform structure between $x = 0$ and $x = 1.0 \text{ cm}$.

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

$\mu = \dots\dots\dots \text{cm}^{-1}$ [2]

- ii. Use the graph to determine the exposure time t for the total radiant energy incident per cm^2 at a depth of 1.0 cm to be 2.6 J.

$t = \dots\dots\dots$ 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** $1.76 \times 10^3 \text{ kg m}^{-2} \text{ s}^{-1}$
B $1.76 \times 10^4 \text{ kg m}^{-2} \text{ s}^{-1}$
C $1.76 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$
D $1.76 \times 10^{12} \text{ kg m}^{-2} \text{ s}^{-1}$

Your answer

☐

[1]

END OF QUESTION PAPER