1. Nov/2023/Paper_9702/41/No.10

Ultrasound and X-rays are both types of wave that are used in medical diagnosis to form images of internal body structures.

(a) Complete Table 10.1 to state, for each type of wave:

- the method of production of the wave
- whether the wave that is detected and used to form the image is the wave that has been absorbed, reflected or transmitted by the internal body structure.

Table 10.1

	ultrasound	X-rays
method of production	....	....
detected wave (absorbed, reflected or transmitted)	....	....

[4]

(b) **(i)** For one type of wave passing through tissue, the wave has 72% of its initial intensity after it has passed through 6.2 cm of the tissue.

Calculate the linear attenuation coefficient μ of the tissue for this wave.

μ = ... cm^{-1} [2]

(ii) Another wave of the same type as in **(b)(i)** passes through 9.3 cm of the same tissue.

Calculate the percentage of the initial intensity of the wave that is attenuated by the tissue.

percentage attenuated = ... % [2]

[Total: 8]

2. Nov/2023/Paper_9702/42/No.9

Fluorine-18 ($^{18}_{9}$F) is a radioactive nuclide that is used as a tracer in positron emission tomography (PET scanning). Fluorine-18 decays to a nuclide of oxygen (O) according to

$$^{18}_{9}\text{F} \longrightarrow {}^{Q}_{P}\text{X} + {}^{R}_{8}\text{O}.$$

(a) **(i)** State what is meant by a tracer.

....

.... [1]

(ii) State the symbol of the particle that is represented by X and the values of *P*, *Q* and *R*.

X: .... *P*: ....

Q: .... *R*: ....

[2]

(b) **(i)** Explain how the radioactive decay of fluorine-18 results in the emission from the body of the gamma-ray photons that are detected during a PET scan.

....

....

....

.... [2]

(ii) Explain how the detection of the gamma-ray photons is used to produce an image of the tissue being examined.

....

....

....

.... [2]

(c) The half-life of fluorine-18 is T.
A patient is injected with amount of substance n of fluorine-18.

(i) Determine an expression for the initial value R_0 of the rate R of production of gamma-ray photons by the tracer, in terms of n, T and the Avogadro constant N_A.

R_0 = ... [3]

(ii) On Fig. 9.1, sketch the variation with time t of R.

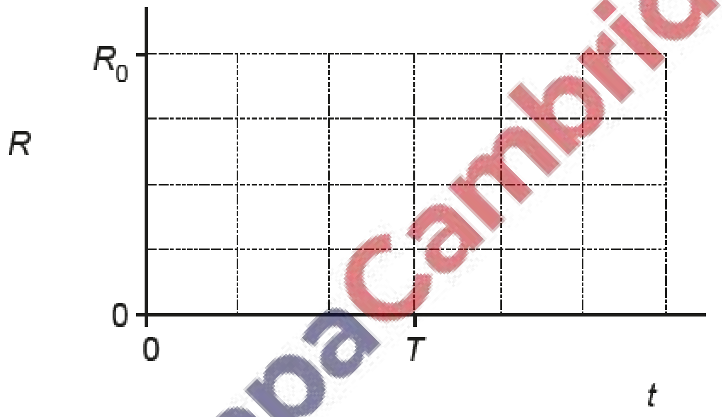

Fig. 9.1

[2]

[Total: 12]

3. June/2023/Paper_9702/41/No.8

(a) Table 8.1 shows some data relating to the properties of air, gel and body tissue. The data are given to three significant figures.

Table 8.1

material	density / $kg\,m^{-3}$	speed of sound / $m\,s^{-1}$	specific acoustic impedance / $kg\,m^{-2}\,s^{-1}$
air		340	440
gel	1200	1400	
tissue	1090		1.68×10^{6}

(i) Show that the specific acoustic impedance of gel is $1.68 \times 10^{6}\,kg\,m^{-2}\,s^{-1}$.

[1]

(ii) Complete Table 8.1 by calculating the missing values to three significant figures. Use the space below for any working that you need.

[2]

(b) Use the information in **(a)** to calculate the intensity reflection coefficient for:

(i) an air–tissue boundary

intensity reflection coefficient = ... [2]

(ii) a gel–tissue boundary.

intensity reflection coefficient = ... [1]

(c) Use your answers in **(b)** to explain why gel is applied to the skin during ultrasound scanning.

....

....

.... [2]

[Total: 8]

4. June/2023/Paper_9702/42/No.10

(a) X-rays for use in medical diagnosis are produced in an X-ray tube. In the X-ray tube, charged particles are accelerated towards a metal target by an applied potential difference (p.d.).

(i) State the name of the charged particles that are accelerated by the applied p.d.

.... [1]

(ii) Explain how X-rays are produced at the metal target.

....

....

....

.... [2]

(iii) Calculate the minimum wavelength of X-rays produced when the applied p.d. is 5.80 kV.

wavelength = ... m [3]

(b) X-rays pass through a medium that has an attenuation coefficient of 1.4 cm^{-1}.

Calculate the percentage of the X-ray energy that is **absorbed** by a 2.8 cm thickness of this medium.

percentage absorbed = ... % [3]

[Total: 9]

5. March/2023/Paper_9702/42/No.9

Ultrasound is used to produce diagnostic information about internal body structures.

(a) Explain how ultrasound waves are detected.

....

....

....

.... [3]

(b) An alternating voltage V varies with time t according to

$$V = V_0 \sin \omega t.$$

The voltage is applied to an ultrasound probe.

The root-mean-square (r.m.s.) voltage is 66 V. The frequency of the ultrasound generated by the probe is 4.3 MHz.

Determine the values of

(i) V_0

V_0 = ... V [1]

(ii) ω.

ω = ...rad s^{-1} [1]

(c) Table 9.1 contains information about air and soft tissue.

Table 9.1

	density / kg m^{-3}	speed of ultrasound / m s^{-1}	specific acoustic impedance / ....
air	1.30	330	4.3×10^2
soft tissue		1600	1.7×10^6

(i) Determine the unit for the specific acoustic impedance values shown in Table 9.1. [1]

(ii) Calculate the density of soft tissue.

density = ... $kg\,m^{-3}$ [1]

(iii) Use data from Table 9.1 to explain why ultrasound cannot be used to produce an image inside an air-filled cavity such as the lungs.

....

....

....

.... [2]

[Total: 9]