OCR

A Level

A Level Physics

Medical Physics (Answers)

Name:

M M E

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Total Marks: /30

1. Ultrasound imaging is quick, cheap, non-invasive and non-ionising. It is therefore a regularly used diagnostics tool in medicine. In this question you will explore two types of ultrasound imaging: Doppler scans and regular ultrasound.

Total for Question 1: 11

(a) Define ultrasound waves. [1]

Solution: Longitudinal waves whose frequency is greater than 20 kHz

(b) State the major difference between A-type and B-type ultrasound images. [1]

Solution: An A-scan is 1D and does not produce an image; B-scans are 2D and produce an image on a screen.

(c) Why is a special gel used in ultrasound imaging? Perform calculations to back up your explanation. [4]
The densities and ultrasound speeds of some relevant media are listed below.

Medium	Density / $\mathrm{kgm^{-3}}$	Ultrasound velocity / $\mathrm{ms^{-1}}$
Air	1.300	340
Gel	1040	1590
Skin	1070	1590

Solution: The gel is used so that the impedance contrast between the gel/air and the skin is low.
For air-skin: $\frac{I_r}{I_0} = 0.99$
For gel-skin: $\frac{I_r}{I_0} = 0.00023$

(d) Why, for Doppler ultrasound scans, must the transducer be held at an angle to skin? [1]

Solution: If held at right angle to skin, the cosine term in the doppler scan equation would be zero so there would be no apparent doppler shift.

(e) Ultrasound with a frequency of 10 MHz is directed at 60° to a blood vessel measuring 1 mm in diameter. A Doppler shift of 700 Hz is observed; the speed of ultrasound in blood is 1650 ms^{-1}. Calculate the volume of blood that passes a given point in the vessel in a period of 1 minute. [4]

Solution: $5.4 \times 10^{-6}\ m^3$

2. X-ray scans take many forms. However, the basic mechanisms are uniform to all. This question tackles the fundamental aspects of x-ray imaging.

Total for Question 2: 13

(a) Briefly describe how an x-ray is produced. What would be the minimum wavelength produced if the accelerating potential difference is 60 kV? [4]

Solution: Large PD is generated between a hot filament and a target metal. Thermionic emission from the filament produces electrons which then accelerate towards the target. Their impacts produce photons, whose energies/frequencies depend on the accelerating potential.
2.07×10^{-11} m

(b) State two examples of scattering mechanisms. [2]

Solution: Simple scatter, Compton scattering, photoelectric effect and pair production.

(c) Give two advantages and two disadvantages of CAT scans compared to standard x-ray imaging techniques. [2]

Solution: Disadvantages: more expensive, slower, higher radiation dose, need for patient to remain still.
Advantages: able to distinguish soft tissues, 3D.

(d) Explain why iodine might be given to a patient who is about to undergo an x-ray scan? [2]

Solution: Iodine is a contrast medium in liquids. It is used, therefore, to examine blood flow through the circulatory system and the associated organs.

(e) 1 cm slices of bone and muscle are subjected to x-rays of the same intensity. In the case of the bone sample, the transmitted intensity is 10 W and the attenuation coefficient is 0.60 cm^{-1}. Calculate the attenuation coefficient of muscle, given that the transmitted intensity of the x-rays is 15 W. [3]

Solution: 0.19 cm^{-1}

3. As well as ultrasound and x-ray imaging, many other types of diagnostic scans are used. In some, medical tracers are needed to highlight the particular body part.

Total for Question 3: 6

(a) Briefly describe how an image is produced using a gamma camera. [3]

Solution: Gamma photons travel towards the collimator, which allows only photons travelling parallel to its tubes to pass. They then reach the scintillator, which produces thousands of visible light photons for each gamma photon impact. These travel through the light guide into the photomultiplier tubes. A single photon entering the tubes is converted to an electrical pulse. The pulses are then sent to a computer, which constructs a mapped image of the impacts of the original gamma photons.

(b) When might technetium-99m and fluorine-18 be used in medical diagnostics? Why must they be produced in proximity to the site on which they are used? [3]

Solution: Gamma camera and PET scanner, respectively.
Because their half-lives are very low (less than 2 hours).