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**THE OPEN UNIVERSITY OF SRI LANKA**

**BACHELOR OF SCIENCE DEGREE PROGRAMME – LEVEL 05**

**FINAL EXAMINATION 2023/2024**

**MEDICAL PHYSICS –PHU5307/PHE5307**

**Duration: TWO HOURS (2 Hrs)**

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**Date: 18th March 2024** **Time 1.30 pm – 3.30 pm**

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**Answer Any Four (4) questions only**

*Plank Constant, $h = 6.62 \times 10^{-34}$ J s, Speed of light $C = 3 \times 10^{8}$ m $s^{-1}$,*
Charge of an electron $e = 1.6 \times 10^{-19}$ C and Mass of an electron $m_e = 9.11 \times 10^{-31}$ kg,
Avegadro's number $A = 6.02 \times 10^{23}$

**1 (a).** Distinguish between ordinary light and laser light, providing four characteristics that differentiate them from each other. ***(20 marks)***

**(b).** Define population inversion in laser production and list three techniques which can be used to achieve it. ***(20 marks)***

**(c).** List four medical applications of lasers. ***(20 marks)***

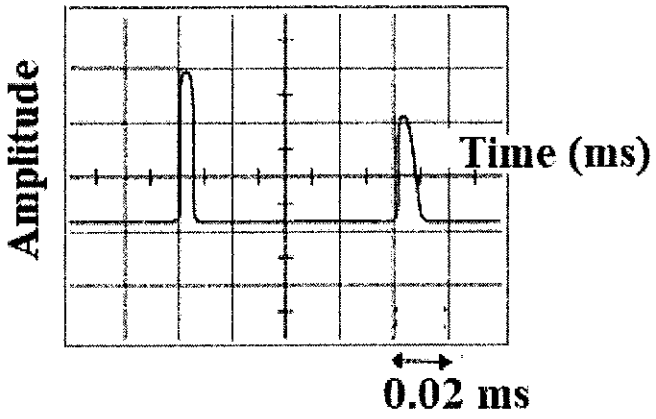
**(d).** Explain the structure of an optical fiber using an appropriate diagram. Highlight a crucial factor in designing of optical fibers that facilitates the transmission of light through it.
***(20 marks)***

**(e).** The core of a glass fibre has refractive index 1.5, while its cladding is doped to give a fractional change in refractive index equal to 0· 005. Find (i) refractive index of cladding (ii) acceptance angle and (iii) numerical aperture when the fibre is in air. ***(20 marks)***

**2.(a).** The time delay between transmission and the arrival of the reflected wave of a signal using ultrasound traveling through a piece of fat tissue was 0.13 ms. At what depth did this reflection occur? The speed of ultrasound in the human body is 1500 m $s^{-1}$. **(20 marks)**

**(b).** Draw a diagram of a single crystal transducer and label the key components. ***(20 marks)***

**(c).** An ultrasound transducer is used to obtain an A-scan of an internal organ. The A-scan pulses shown in the diagram below were identified as coming from the front and rear surfaces of the organ.



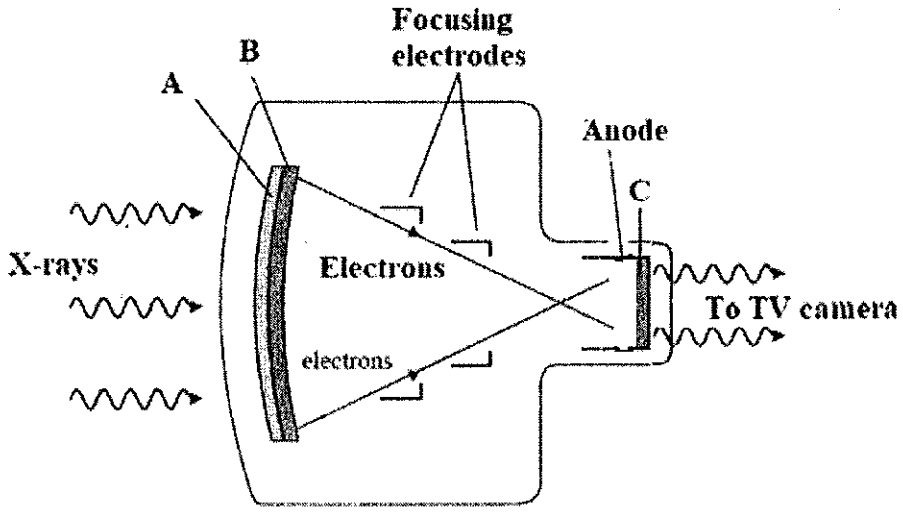

Estimate the thickness of the organ if the speed of ultrasound in the tissue is 1500 m $s^{-1}$. ***(20 marks)***

(d). When an ultrasound wave is incident on a boundary between two materials, some of the wave is reflected at the boundary and the rest is transmitted across the boundary. The acoustic impedance of the coupling gel and skin are 1.48 x$10^6$ kg $m^{-2}$ $s^{-1}$ and 1.65 x$10^6$ kg $m^{-2}$ $s^{-1}$ respectively. Calculate the percentage of the ultrasound which would be transmitted across the gel–skin boundary. ***(20 marks)***

**(e).** During a Doppler ultrasound examination of a blood vessel, the sonographer measures a Doppler shift of 60 Hz using a 4 MHz transducer. If the ultrasound beam is directed at the blood vessel at an angle of 40°, what is the velocity of blood in the vessel? Assume that the speed of ultrasound propagation in the vessel is 1540 m $s^{-1}$. ***(20 marks)***

**3. (a).** High-speed electrons hitting a metal target in an X-ray tube produce X-ray photons. Calculate the accelerating potential difference required for the electrons to produce X-Ray photons of maximum wavelength of 0.18 Å. ***(20 marks)***

**(b).** The figure below shows a design of an X-ray image intensifier. Some of the main components are labelled as A, B and C. Write down the name of each component and state its purpose in the process of image intensification. **(20 marks)**




**(c).** Before taking an X-ray photograph, the X-ray beam emerging from the tube is passed through an aluminium filter. State and explain the reason for filtering the X-rays. **(20 marks)**

**(d).** Name three methods by which X-rays can interact with matter. ***(20 marks)***

**(e).** A parallel beam of X-ray radiation is incident, separately on a bone and a muscle. The thicknesses and the linear attenuation coefficients of the bone and the muscle are given below.

| | Thickness (cm) | Linear attenuation coefficient ($\mu$) ($cm^{-1}$) |
|---|---|---|
| Bone | 1.5 | 2.90 |
| Muscle | 4.0 | 0.95 |

Calculate the ratio

$$\frac{\text{Intensity of radiation transmitted through the bone}}{\text{Intensity of radiation transmitted through the muscle}}$$

**(20 marks)**

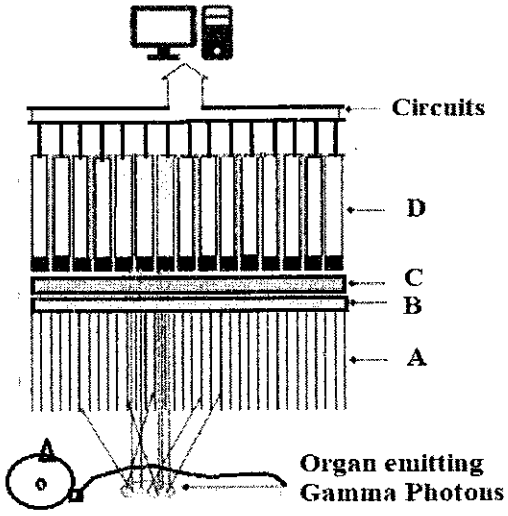
**4. (a).** What is the activity of one gram of 131- I, whose half-life is 8 days? ***(20 marks)***

**(b).** A freshly prepared sample of unknown radioactive isotope X-80 has an initial activity of $3.6 \times 10^8$ Bq. After 4.0 h time, the activity drops to $4.5 \times 10^7$ Bq. Calculate the decay constant of the radioactive isotope. ***(20 marks)***

**(c).** On a Monday morning at 6.00 am, a technologist is preparing a 99mTc ( $T_{1/2} = 6$ hours) ethyl cysteine dimer (ECD) kit that is to be used for the SPECT brain scans at 10.00 am on the same day. Patient should be received 10 mCi for this scan. What should be the activity of the kit during the preparation? ***(20 marks)***

**(e).** Calculate the exposure rate at 0.3m from a syringe containing 500MBq of 99mTc for a brain scan. The gamma constant, $\Gamma = 1.9 \times 10^{-6}$ R $m^2$ $MBq^{-1}$ $h^{-1}$ ***(20 marks)***

**5 (a).** The figure below shows the key components of a gamma camera (not displayed to scale). Some of the main components are labelled as A, B, C and D. Write down the name of each component. ***(20 marks)***



**(b)** What material is used to make the crystal in a gamma camera, and what is its role or purpose within the gamma camera? ***(20 marks)***

**(c)** What is the purpose of having a collimator in a gamma camera? **( 20 marks)**

**(d).** What are radiopharmaceuticals in nuclear medicine? and how do they differ from conventional pharmaceuticals?. ***(20 marks)***

**(e)** What is the main difference between a CT scan and a PET scan in terms of their radiation sources? **(20 marks)**

**6. (a)** List 4Rs used in radiobiology. ***(20 marks)***

**(b).** Discuss the concept of fractionation in radiation therapy and its impact on normal and cancerous tissues. ***(20 marks)***

**(c).** Discuss the role of radiosensitizers and radioprotectors in modifying cellular response to radiation. ***(20 marks)***

**(d).** Explain the concept of direct and indirect effects of ionizing radiation on cellular components of a human body. ***(20 marks)***

**(e).** Cancer can be treated by several methods depending on the site and the stage of the disease. List three main methods of treating cancer in humans. ***(20 marks)***

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