King's College London

UNIVERSITY OF LONDON

This paper is part of an examination of the College counting towards the award of a degree. Examinations are governed by the College Regulations under the authority of the Academic Board.

B.Sc. EXAMINATION

CP/MP10 Introductory Medical Physics

Summer 1997

Time allowed: THREE Hours

Candidates must answer SIX parts of SECTION A, and TWO questions from SECTION B.

Separate answer books must be used for each Section of the paper.

The approximate mark for each part of a question is indicated in square brackets.

You must not use your own calculator for this paper. Where necessary, a College Calculator will have been supplied.

TURN OVER WHEN INSTRUCTED

Elementary charge, $e = 1.60 \times 10^{-19}$ C

Planck constant, $h = 4.1 \times 10^{-15}$ eV s

SECTION A - answer **SIX** parts of this question

1.1) Explain how an electrocardiogram is generated and how it may be recorded. What effect does recorder bandwidth have on the reproduction of physiological waveforms?

[7 marks]

1.2) Name the five main parameters associated with the assessment of lung function, giving typical values for each.

[7 marks]

1.3) Describe the essential features of the hospital scientific service as it relates to medical physics provision in the NHS within a Trust hospital. Give four examples of activities in which a medical physicist might be engaged.

[7 marks]

1.4) Describe, with the aid of simple diagrams, the essential features of the normal gait cycle. What features of an above-knee lower-limb prosthesis are important in ensuring near normal gait in an amputee?

[7 marks]

1.5) How many atoms of C^{11}, with a decay constant $\tau = 2$ hr, are required to produce an activity of 10^6 Bq ?

[7 marks]

1.6) Draw a schematic, but typical, spectrum of the X-rays emitted by a diagnostic imaging device. Briefly discuss the physical mechanisms operative in shaping the spectrum.

[7 marks]

1.7) List the methods used to control external radiation hazards to both patients and occupationally-exposed persons, in a medical environment.

[7 marks]

1.8) An ultrasound wave is incident perpendicularly on a planar interface between two tissues. The intensity of the reflected wave is measured to be 6 dB less than that of the incident wave. What is the ratio of the characteristic acoustic impedances of the two tissues?

[7 marks]

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SECTION B - Answer **ONE** question from this section

2) Describe how you might use ultrasound to measure blood flow velocity and estimate blood pressure non-invasively. Give typical values of these parameters for normal subjects. Draw a diagram showing the principal components of a continuous wave Doppler velocimeter.

[15 marks]

If a continuous wave Doppler velocimeter is used to investigate flow in the femoral vein, what range of Doppler shift frequencies would you expect to hear? (Assume an insonation frequency of 10 MHz, a velocity of sound of 1500 m s^{-1}, and a probe/vessel angle of 45°).

[15 marks]

3) What part of the back is most at risk from injury during lifting?

[7 marks]

With the aid of a diagram derive an expression for calculating the tension in the back muscles and the reaction force on the lower lumbar vertebrae when lifting a weight with the back bent. (Assume that the mass of the head and neck, thorax and arms, and weight lifted can each be represented as single masses acting through their centres of mass).

[23 marks]

SECTION C - Answer **ONE** question from this section

4) Describe the two main mechanisms whereby diagnostic X-ray photons interact with body tissues, and indicate how the interactions depend on photon energy and tissue properties. How is the design of a mammography unit influenced by the nature of the two effects ?

[10 marks]

An X-ray machine is operated at 100 kVp. What is the wavelength of the emitted photons with maximum energy? It is found that the exposure rate at 100 cm from the tube is 75 mR min^{-1}. What is the exposure suffered by a person who spends 10 minutes in the beam, at a distance of 3 m from the tube?

[8 marks]

Explain the following terms and state, where appropriate, the units employed for their measurement: absorbed dose; dose equivalent; relative biological effectiveness; the ALARA principle; mass attenuation coefficient; linear attenuation coefficient.

[12 marks]

5) Explain what is meant by the 'pulse-echo principle', and show how it is incorporated into the design of a real-time, linear array, medical B-mode scanner.

[12 marks]

Describe with a well-labelled sketch, the design of a portable scintillation device for radiation monitoring. List the advantages of using NaI as the scintillator in such a device.

[10 marks]

Explain the following terms, and state (where appropriate) the units employed for their measurement: Larmor frequency; 'π/2-pulse' (as utilised in MRI); gyromagnetic ratio; intensity of an ultrasound wave.

[8 marks]

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