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 1999

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

Planck's constant = 6.6×10^{-34} J s
Speed of light in vacuum = 3.0×10^{8} m s^{-1}
Electron charge = 1.6×10^{-19} C

SECTION A - Answer any SIX parts of this question.

1.1) Describe with the aid of simple diagrams, the essential features of the normal gait cycle. List the key features of the cycle. What joints are principally involved in locomotion?

[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 how blood pressure can be measured using ultrasound. What typical Doppler frequency would you expect to hear generated by insonation of the femoral artery? (Assume a probe/vessel angle of 45° and an insonation frequency of 10 MHz).

[7 marks]

1.4) Explain the terms "microshock" and "macroshock" as applied to transmission of electric charge in the human body. With the aid of a simple diagram, describe the different physiological effects that occur as an electric current passed through the skin increases in magnitude from 1 mA to 1 A.

[7 marks]

1.5) Derive an expression for the effective half-life of a radioactive substance in the body, in terms of its physical and biological half-lives. If the physical half-life of the material is known to be six hours, and its effective half-life is measured to be three hours, what is its biological half-life?

[7 marks]

1.6) An x-ray machine is operated at 100 kVp. What is the wavelength of the maximum energy photons? What is the exposure suffered by a person who spends 15 minutes in the beam, at a distance of 3 m from the tube, if the exposure rate at 100 cm from the tube is 50 mR min^{-1}?

[7 marks]

1.7) An ultrasound wave is incident normally on a planar interface between two tissues with a characteristic acoustic impedance ratio of 0.5. By how many dB is the intensity of the reflected wave lower than that of the incident wave? By how much is the frequency of the wave changed as it crosses the interface?

[7 marks]

1.8) Explain the following terms and state, where appropriate, the units employed for their measurement: absorbed (x-ray) dose; (γ-ray) dose equivalent; relative biological effectiveness; the ALARA principle; the 10-day rule.

[7 marks]

SEE NEXT PAGE

SECTION B - answer ONE question from this section

2) Describe the structure of the ear with the aid of simple annotated diagrams. Pay particular attention to the physical principles involved in hearing.

[12 marks]

Explain what is meant by the threshold of hearing. With the aid of a diagram show how it varies with frequency.

[5 marks]

Describe a typical audiometric assessment of a patient.

[7 marks]

List six physiological effects which occur at sound intensities above 85 dB.

[6 marks]

3) With the aid of a simple diagram, describe the circulatory system of the human body.

[15 marks]

What is the electrical signal produced by the heart called? Describe its shape and magnitude and explain how it can be measured to reveal disease in the heart.

[15 marks]

SECTION C - answer ONE question from this section

4) Describe, with the help of a labelled diagram, the design of a modern x-ray tube for diagnostic imaging. Indicate those features that are specifically introduced for the radiation protection of both the patient and the operator.

[16 marks]

Describe the main characteristics of the propagation and interaction of ultrasound waves in soft tissues, and indicate one way in which each feature is exploited for medical purposes.

[14 marks]

5) Describe the methods used to control external radiation hazards in a medical environment, with respect to the protection of both patients and occupationally-exposed persons.

[8 marks]

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

[10 marks]

The counts recorded from measurements of many corresponding samples of a radioactive substance are 500 ± 40 for the sample plus background, and 200 ± 30 for the background alone. What is the net count and standard deviation for the sample?

[6 marks]

How many atoms of C^{11}, with a decay constant $\lambda = 2\ hr^{-1}$, are required to produce an activity of 10^6 Bq ?

[6 marks]