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 2000

Time allowed: THREE Hours

Candidates must answer SIX parts of SECTION A,
ONE question from SECTION B and ONE question from SECTION C.

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

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

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

TURN OVER WHEN INSTRUCTED

Speed of light in a vacuum	$c = 2.998 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Planck constant	$h = 6.626 \times 10^{-34}\,\mathrm{J\,s}$
Charge of an electron	$e = -1.602 \times 10^{-19}\,\mathrm{C}$

SECTION A – Answer SIX parts of this section

1.1) Describe briefly how blood pressure can be measured non-invasively. If the normal femoral artery is insonated using a 5 MHz continuous wave Doppler velocimeter, what range of Doppler-shift frequencies might be produced? (Assume a probe/vessel angle of 30°.)

[7 marks]

1.2) What is the name given to the electrical signal which drives the heart? What are the principal features of this signal and its magnitude measured at the skin?

[7 marks]

1.3) Describe, with the aid of simple diagrams, the essential features of the normal gait cycle. How might the pattern of gait be affected in a unilateral above-knee amputee wearing a prosthesis?

[7 marks]

1.4) Describe, with the aid of diagrams, one electrical method which can be used for the measurement of temperature. List the advantages and disadvantages of the method you have described.

[7 marks]

1.5) Give a brief explanation of the following terms and state, where appropriate, their units: *absorbed dose*; *dose equivalent*; *relative biological effectiveness*; *the ALARA principle*.

[7 marks]

1.6) The minimum wavelength of the x-rays emitted from a radiographic device is 0.0124 nm. At what peak kilovoltage is the device being operated? What is the minimum frequency of the x-rays emitted?

[7 marks]

1.7) 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 substance is known to be 6 hrs, and its effective half-life is measured to be 240 min, what is its biological half-life ?

[7 marks]

1.8) An ultrasound wave is incident normally 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 amplitude reflection coefficient of the interface?

[7 marks]

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SECTION B – Answer ONE question

2) With the aid of diagrams, describe the structure and function of the human ear.

[14 marks]

Define the term *acoustic impedance* and show how it may be used to calculate the intensity reflected at an interface between two materials.

[6 marks]

The sound emitted by the earpiece of a pair of headphones has an intensity of $2 \times 10^{-3}\ \mathrm{W\,m^{-2}}$ and travels through a thick layer of protective foam before it reaches the ear. Some of the sound is reflected by the single air/foam interface. If the velocity of sound in air is $331\ \mathrm{m\,s^{-1}}$ and that in foam is $150\ \mathrm{m\,s^{-1}}$, with the respective densities being $1.2\ \mathrm{kg\,m^{-3}}$ and $10\ \mathrm{kg\,m^{-3}}$, calculate the intensity of the sound which is transmitted to the ear. Determine, in decibels, the difference between the emitted sound intensity and that reaching the ear.

[10 marks]

3) Name the five parameters associated with the assessment of lung function, giving typical values of each for a healthy lung.

[10 marks]

Sketch the relationship between oxygen pressure and the percentage of haemaglobin saturated with oxygen. How is this curve affected by the pressure of carbon dioxide present?

[8 marks]

In the assessment of lung function, a pneumotachograph, which incorporates a differential pressure transducer, is used. Sketch a simple electrical circuit incorporating the transducer with which respiratory flow could be measured. When measuring a flow of $5\ \mathrm{litre\ s^{-1}}$, the resistance of a strain gauge bonded to the diaphragm of the pressure transducer changes by $100\ \Omega$ from its resting value of $1\ \mathrm{k}\Omega$. Show, with appropriate explanation and stating any assumptions made, how a voltage output of about 2.5 V could be produced for this flow.

[12 marks]

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SECTION C – Answer ONE question

4) (a) Draw a labelled diagram showing the design of a modern diagnostic x-ray tube. Indicate those features that are specifically introduced for the radiation protection of the patient and the operator.

[14 marks]

(b) List 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]

(c) An x-ray machine is operated at 120 kVp. It is found that the exposure rate at a distance of 100 cm from the tube is 75 mR/min. What is the exposure suffered by a person who spends 10 minutes in the beam while standing at a distance of 3 m from the tube?

[4 marks]

(d) A narrow beam containing 2×10^6 mono-energetic photons is reduced to 1×10^6 photons by a copper slab 1 cm thick. What is the total linear attenuation coefficient of the copper slab for these photons?

[4 marks]

5) (a) Describe the main characteristics of the propagation and interaction of (longitudinal) ultrasound waves in human (soft) tissues, and indicate one way in which each characteristic is exploited in medical applications.

[12 marks]

(b) Draw a labelled diagram illustrating the construction of a portable scintillation device for radiation monitoring.

[10 marks]

(c) 1000 Bq of a radioactive pharmaceutical, with a half-life of 6 hours, is injected into a patient's blood-stream at 11.00 a.m. The next day, at 2.00 p.m., a 10 ml blood sample is taken, and is found to have an activity of 0.9 Bq. Estimate the patient's blood volume. Clearly state the approximations made in your calculation.

[8 marks]

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