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 2001

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, with the aid of a diagram, the principal components of a lower limb (above knee) prosthesis. What are the three major medical reasons for amputation in the UK today?

[7 marks]

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

[7 marks]

1.3) The intensity of sound emitted by an ear piece of a pair of headphones is 2×10^{-3} watts m^{-2}. The sound 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. Calculate the intensity of sound transmitted to the ear.
(Velocity of sound in air = 331 m s^{-1}; velocity of sound in foam = 150 m s^{-1}; density of air = 1.2 kg m^{-3}; density of foam = 10 kg m^{-3}.)

[7 marks]

1.4) Draw a labelled diagram to illustrate the main components of a typical physiological measurement system. Give three examples of electrical signals which may be obtained from the human body, indicating an approximate magnitude in each case.

[7 marks]

1.5) How many atoms of radioactive C-11, with a decay constant of 2 hr^{-1}, are required to produce an activity of 10^{6} Bq? What is the half-life of C-11?

[7 marks]

1.6) 1.6×10^{5} 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 14 Bq. Estimate the patient's blood volume.

[7 marks]

1.7) A beam of ultrasound of frequency 1 MHz travels through 69.3 mm of tissue with an attenuation coefficient of 0.1 neper cm^{-1}. Calculate (a) the fractional decrease in the pressure amplitude of the beam; (b) the attenuation of the beam in decibels.

[7 marks]

1.8) 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 6 hrs, and its effective half-life is measured to be 180 min, what is its biological half-life ?

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[7 marks]

SECTION B – Answer ONE question

2) With the aid of diagrams, describe the structure and function of the musculo-skeletal system of the human body, listing the types of joints present.

[15 marks]

Describe the mechanical and material requirements for total hip replacement and the modes under which prostheses fail.

[15 marks]

3) Describe, with the aid of diagrams, the essential features of the circulatory system of the human body.

[15 marks]

The heart is driven by an electrical signal. With the aid of diagrams, describe how the signal is generated and propagated. What is the signal called, what are its principal features and what is its magnitude measured at the skin?

[15 marks]

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SECTION C – Answer ONE question

4) (a) Describe the two important mechanisms whereby diagnostic x-ray photons interact with body tissues. How do the interactions depend on photon energy and tissue properties?

[12 marks]

(b) An X-ray machine is operated at 100 kVp. What is the wavelength of the photons emitted with maximum energy? It is found that the exposure rate at 100 cm from the tube is 27.2 mR min^{-1}. What is the exposure suffered by a person who spends 20 minutes in the beam, at a distance of 3 m from the tube? The half-value layer of aluminium for this x-ray beam is 12 mm. What thickness of aluminium shielding is needed to reduce the dose rate at a distance of 1 m to 3.4 mR min^{-1}?

[9 marks]

(c) Describe the methods used to control external radiation hazards in a medical environment, with respect to the protection of both patients and radiation workers exposed in the course of their duties.

[9 marks]

5) (a) Describe, with the aid of a labelled diagram, the design of a portable scintillation device for radiation monitoring.

[10 marks]

(b) Describe four important characteristics associated with the propagation and interaction of longitudinal ultrasound waves in soft human tissues. Indicate one way in which each characteristic is exploited in medical applications.

[12 marks]

(c) Explain the following terms and state, where appropriate, the units employed for their measurement: activity of a radioactive nuclide; characteristic acoustic impedance; (ultrasound) attenuation coefficient; decibel.

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[8 marks]

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