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/MP33 Medical Engineering

Summer 2006

Time allowed: THREE Hours

Candidates should answer ALL parts of SECTION A,
and no more than TWO questions from SECTION B.
No credit will be given for answering further questions.

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

Physical Constants

Permittivity of free space	ε_0	=	8.854×10^{-12}	F m^{-1}
Permeability of free space	μ_0	=	$4\,\pi \times 10^{-7}$	H m^{-1}
Speed of light in free space	c	=	2.998×10^{8}	m s^{-1}
Gravitational constant	G	=	6.673×10^{-11}	N m^2 kg^{-2}
Elementary charge	e	=	1.602×10^{-19}	C
Electron rest mass	m_e	=	9.109×10^{-31}	kg
Unified atomic mass unit	m_u	=	1.661×10^{-27}	kg
Proton rest mass	m_p	=	1.673×10^{-27}	kg
Neutron rest mass	m_n	=	1.675×10^{-27}	kg
Planck constant	h	=	6.626×10^{-34}	J s
Boltzmann constant	k_B	=	1.381×10^{-23}	J K^{-1}
Stefan-Boltzmann constant	σ	=	5.670×10^{-8}	W m^{-2} K^{-4}
Gas constant	R	=	8.314	J mol^{-1} K^{-1}
Avogadro constant	N_A	=	6.022×10^{23}	mol^{-1}
Molar volume of ideal gas at STP		=	2.241×10^{-2}	m^3
One standard atmosphere	P_0	=	1.013×10^{5}	N m^{-2}

SECTION A – Answer ALL parts of this section

1.1) What are the two primary functions of the articular cartilage found in the knee joint?

Explain, with the aid of a diagram, the function of the patella in the mechanics of knee extension.

[6 marks]

1.2) Give two reasons why evoked potentials are found useful in electro-encephalogram (EEG) studies.

An evoked EEG signal has an amplitude of 1 μV rms. The same detection channel also contains an interfering signal of amplitude 10 μV rms. How many stimuli would be needed to obtain the evoked signal with a signal to noise ratio of 10?

[6 Marks]

1.3) Mechanical ventilation involves the bulk movement of volumes of gas into and out of the lungs.

Identify and define the gas law(s) that apply to the increased workload on the patient resulting from the use of too small an artificial airway.

Demonstrate what would be the result of reducing the internal diameter of a breathing tube from 8 mm to 4mm?

Indicate potential causes for such a reduction in diameter. [7 marks]

1.4) How does the dialysate fluid enable a balance of body electrolytes to be achieved?

Describe the mechanisms that control the transport of electrolytes and water across the semi-permeable membranes used in artificial kidneys.

Identify the techniques that can enable fine-tuning of the transfer of electrolytes and water either into or out of the blood circuit of the patient.

[7 marks]

1.5) How can measurement of pulse wave velocity be used to measure ageing in arteries?

Why is peak systolic pressure in the ankle arteries higher than in the aorta in a normal subject lying horizontally?

[7 marks]

1.6) Sketch a probe used for pulse oximetry showing the important components. Briefly explain the principles used to measure arterial oxygen saturation.

[7 Marks]

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SECTION B – Answer TWO questions

2)

a) Draw a diagram to show the forces acting on the foot about the ankle joint, modelling the joint as a simple pivot.

[4 marks]

b) Define the terms ‘agonist muscle’ and ‘antagonist muscle’ and explain what is meant by the term ‘co-activation of muscle’. Explain why this is important during movement.

[6 marks]

A person with cerebral palsy has contractures of the left ankle plantarflexor muscles.

c) Describe briefly the effects of the 3 main types of cerebral palsy.

[7 marks]

d) How might the contractures described affect the position of the left ankle joint? Describe, with explanation, any gait defects that you would expect to see as a result of this contracture?

[8 marks]

e) Suggest an orthotic device that may improve this person’s gait. Outline the important design characteristic of such a device.

[5 marks]

3)

a) Discuss the haemodynamics through an arterial stenosis, particularly with respect to the relationship between flow and pressure drop. Illustrate your answers with diagrams of the change in velocity vectors through a severe stenosis and the corresponding energy changes in the fluid through the stenosis.

[14 Marks]

b) Briefly outline what clinical consequences may arise from a 70% diameter stenosis (that is, a reduction in vessel diameter of 70% at the point of narrowing).

[6 Marks]

c) What are the advantages and disadvantages of current methods used to measure stenoses.

[10 Marks]

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4)

a) An electro-cardiogram (ECG) signal is to be digitised for computer analysis. It has frequency components from 0.05 to 100 Hz. What sampling frequency would you choose, and why?

The analogue to digital converter (ADC) is preceded by a low pass filter with critical frequency 150 Hz. What should be the maximum width of the transition band for the sampling frequency you have chosen?

What order of filter would be needed if the stop band is taken as -40 dB?

[12 Marks]

b) The input range of the ADC is 10V and the ECG signal is 1 mV peak of true ECG waveform superimposed on a wandering baseline of 5 mV peak to peak. What gain would you choose for the pre-amplifier?

How many bits should the ADC have to be able to resolve fine detail of 1 μV in the P wave?

What signal to noise ratio should the preamplifier have? (rms quantisation noise is $s / \sqrt{12}$, where s is the size of the least significant bit).

[12 Marks]

c) Describe the artefacts and noise commonly seen in ECG signals. How may their effect be reduced?

[6 Marks]