# King's College London

UNIVERSITY OF LONDON



B.Sc. EXAMINATION

CP/MP33 Medical Engineering

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**

**SECTION A - Answer SIX parts of this section.**

1.1) Give block diagrams of (i) an open loop, and (ii) a closed loop insulin delivery control system.

[7 marks]

1.2) Contrast pulse-wave and colour flow mapping methods for blood velocity measurement using ultrasound.

[7 marks]

1.3) Describe the principles involved, and note the technical limitations of a strain-gauge transducer for blood pressure measurement.

[7 marks]

1.4) Derive Fick's second law from the equation of continuity. State clearly any assumptions that are made.

[7 marks]

1.5) Make some plausible assumptions to prove the cardiologist's 'rule-of thumb' that the pressure drop (in mmHg) through a stenosis is approximately four times the square of the velocity (in m $s^{-1}$) of the blood jet through the blockage.

[7 marks]

1.6) Describe the principles involved in using a fiber-optic probe for body temperature measurement. Note the specific advantages of this type of probe over other types of thermometer.

[7 marks]

1.7) Show how the blood flow rate in a leg may be determined from measurements of the electrical impedance of the limb. Indicate any assumptions that are made in the calculation.

[7 marks]

1.8) Derive an expression for the cardiac output in terms of the arterial and venous concentrations of oxygen, and the rate of oxygen consumption by the body.

[7 marks]

## SECTION B - answer TWO questions

**2.** Explain what is meant by the digitisation of an analogue signal. Include a description of aliasing, and how it may be avoided in the acquisition of a sampled analogue signal.

[11 marks]

An analogue signal with a frequency spectrum extending from 0 to 4.5 MHz is to be digitised. Electronic noise is present in the signal with a SNR of 72 dB. At what sampling rate should the signal be digitised, and how many quantisation levels should be used?

[3 marks]

Define what are meant by a linear time invariant (LTI) system, and the properties of causality and bounded-input, bounded output (BIBO) stability. An LTI system has an impulse response $h[n]$ and a frequency response $H(\omega)$. Show that, in response to an input sequence $x[n] = \exp(i\omega n)$ for $-\infty < n < \infty$, the output sequence is given by $y[n] = H(\omega)\exp(i\omega n)$, and comment on the result.

[11 marks]

Give a block diagram of a general feedback loop, and define what is meant by the gain of the system box, and the open loop gain. What effect does the presence of feedback have on the steady-state error?

[5 marks]

3. Consider a simple two-compartment model for a renal dialysis system. Treat all the body fluid (including blood) as one compartment, with the dialysis fluid as the second. Make reasonable assumptions to obtain an expression for the time-dependence of the concentration of solute in the blood. What do your results tell you about the design of a dialysis system?

[12 marks]

An attempt is made to assess the resistivity of a cell membrane by measuring the decay of the leakage current across it. Use a simple model to express the resistivity in terms of the data recorded in the experiment. Be specific about what other measurements might need to be made on the membrane to obtain a numerical value for the resistivity.

[10 marks]

Assume that the electrical action of the heart is represented by a single activity vector of strictly dipole character. Show how a suitable arrangement of ECG leads may be used to measure the time-dependence of the spatial orientation of the activity vector.

[8 marks]

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4. Describe the type of experiment a bio-engineer might perform on muscle tissue in order to measure its visco-elastic properties.

[4 marks]

Experiments indicate that the muscle tissue behaves as a simple Maxwell solid. Write down a possible constitutive equation relating pressure and density changes in the tissue. Use this, together with Newton's second law and the continuity equation, to derive a one-dimensional equation describing the (linear) propagation of pressure waves in the muscle. You may assume that the tissue is uniform and isotropic.

[14 marks]

Demonstrate how the above results can be used to establish the visco-elastic parameters from measurements of the propagation velocity and attenuation of pressure waves in the muscle.

[12 marks]

**5.** Describe the physical principles involved in using an electromagnetic sensor for blood flow measurement. Discuss the technical limitations of such a sensor and give a rough sketch of a typical device.

[10 marks]

Describe, analytically, the signal processing procedures used in the (ultrasound) colour-flow-mapping technique for displaying the spatial dependence of the mean velocity of blood in an artery.

[20 marks]