[ESS36]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) IN BIOMEDICAL ENGINEERING

SEMESTER TWO EXAMINATION 2018/2019

MEDICAL EQUIPMENT TECHNOLOGY

MODULE NO: BME6001

Date: Monday 20th May 2019 **Time: 10:00 – 12:30**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

CANDIDATES REQUIRE :

Property tables provided
Formula Sheet (attached)
Non-programmable calculator

School of Engineering
BEng (Hons) Biomedical Engineering
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Medical Equipment Technology
Module No. BME6001

Answer ANY FOUR questions

Q1

(a) A metal microelectrode shown in figure Q1 has a tip that can be modelled as being cylindrical. The metal itself is 0.9 μm in diameter, and the tip region is 3.5 mm long. The metal has a resistivity of $1.4 \times 10^{-5}\,\Omega \cdot \mathrm{cm}$ and is coated over its circumference with an insulation material 0.25 μm thick. The insulation material has a relative dielectric constant of 1.56. Only the base of the cylinder is free of insulation.

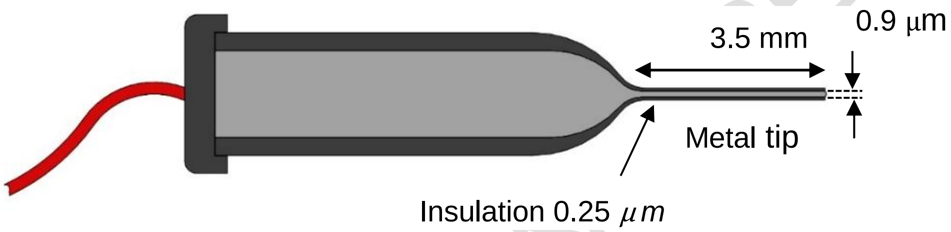

Figure Q1 A Metal Microelectrode

(i) What is the resistance associated with the tip of this microelectrode?
[2 marks]

(ii) What is the capacitance associated with the tip of the microelectrode when the capacitances at the interface of the electrode-electrolytic solution are neglected?
[4 marks]

(iii) At what frequency do you expect to see distortions when the electrode is connected to an amplifier having a purely resistive input impedance of 10MΩ? If the amplifier's input impedance is raised to 100MΩ, how does this effect the frequency response of the system?
[6 marks]

(b) Explain what are strain gauges, how they work and discuss some of the possible problems involved in elastic-resistance strain gauge sensors and their solutions.
[5 marks]

(c) A first-order low-pass filter instrument must measure hummingbird wing displacements (assumed to be sinusoidal) with frequency content up to 100 Hz and an amplitude inaccuracy of less than 5%. What is the maximum allowable time constant for the instrument? What is the phase angle at 60 Hz and estimate the frequency for a phase angle of -18.2°?
[8 marks]

Total 25 marks

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Q2

(a) The following unbalanced Wheatstone bridge figure Q2 is constructed as part of a medical equipment. Calculate the value of strain gauge required to balance the bridge circuit when R1=45*Ω*, R2=30*Ω*, R3= 15*Ω* and a 12 volt battery is used.

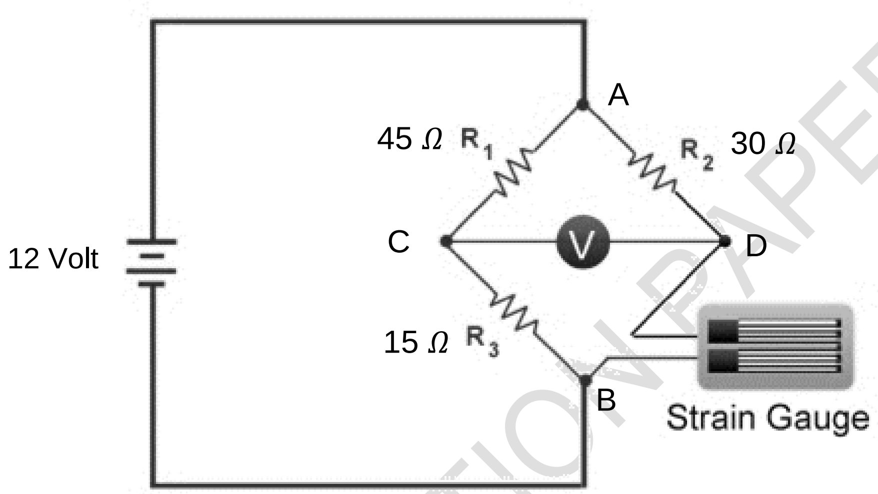

Figure Q2 Wheatstone bridge

[7 marks]

(b) Define the following terms:

(i) Absolute refractory period **[2 marks]**

(ii) Relative refractory period **[2 marks]**

(iii) Synapse **[2 marks]**

(iv) Reflex arc and its components **[5 marks]**

(c) A pair of biopotential electrodes is used to detect the electrocardiogram of an adult male. It has become necessary to determine the equivalent-source impedance of this electrode pair so that a particular experiment can be performed. Describe an experimental procedure that can be used to determine this quantity, using minimal testing equipment.

[7 marks]

Total 25 marks

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Q3

a) Explain in detail what inductive sensors are? What are the different types of inductive sensors? Describe their working principles? **[9 marks]**

b) A second-order instrument has a damping ratio of 0.7 and an undamped natural frequency of 90Hz. Sketch the step response, and give numerical values for the amplitude and time of the first two positive maxima. Assume that the input goes from 0 to 1 and that the static sensitivity is 12. **[7 marks]**

c) Relate EEG-wave actively recorded at the surface of the cortex to the underlying activity of cortical neurons. **[9 marks]**

Total 25 marks

Q4

(a) The output of a bio potential preamplifier that measures the electro-oculogram has an undesired dc voltage of +6V due to the electrode half-cell potentials, with a desired signal of ±0.8V superimposed.

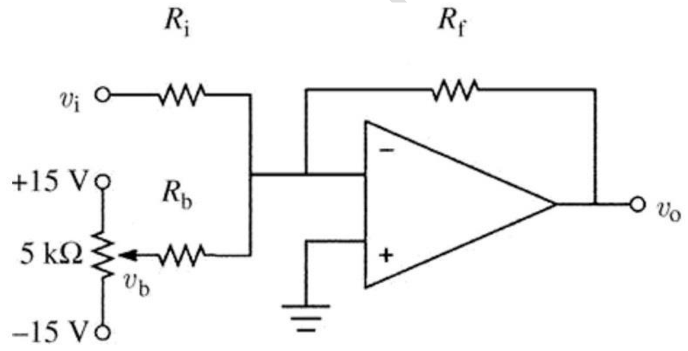

Figure Q4-1 Op amp designed circuit.

(i) Calculate the value for resisters R_b and R_f in designed circuit that will balance the dc voltage to zero and provide a gain of -10 for the desired signal without saturating the op amp when $R_i = 15k\Omega$.

[6 marks]

(ii) Use the circuit shown in Figure Q4-1 to design a dc-coupled single op-amp circuit that will amplify the $\pm 120\mu V\ EOG$ to have the maximum gain possible without exceeding the typical guaranteed linear output range. Include a control that can balance (remove) series electrode offset potentials up to ±450 mV. Give all numerical values.

[6 marks]

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Question 4 continued ……

(b) An AgCl surface is grown on an Ag electrode by the electrolytic process. The current passing through the cell is measured and recorded during the growth of the AgCl layer and is found to be represented by the following equation:

$$I = 100mA\, e^{-t/10}$$

(i) If the reaction is allowed to run for a long period of time, so that the current at the end of this period is essentially zero; how much charge is removed from the battery during this reaction? **[3 marks]**

(ii) How many grams of AgCl are deposited on the Ag electrode's surface by this reaction? **[5 marks]**

(iii) The chloride electrode is then placed into a beaker containing 1 litre of 0.9 molar NaCl solution. How much AgCl will be dissolved? **[5 marks]**

Total 25 marks

Q5

a) Explain in detail what Piezoelectric sensors are, the principal of how they work, their modes of operation and discuss some of the available piezoelectric material and their properties. **[7 marks]**

b) In block-diagram form, show the elements required for an automatic indirect system for measuring blood pressure. **[8 marks]**

c) Draw a typical lead II electrocardiogram and label all waves (P, QRS, and T) and intervals. Explain what is happening electrically within the heart during each wave or interval. **[10 marks]**

Total 25 marks

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Q6

a) What is the type of microcontroller that is used on the Arduino Uno Board?
[3 marks]

b) Illustrate and explain with the aid of a diagram the von-Neumann architecture.
[12 marks]

c) By applying state machines design techniques, design a state diagram illustrating how a blood pressure monitor system works. The system has the following requirements:

- Blood pressure arm cuff is attached to the system.
- Beeping sound when detecting blood pressure.
- Display detected blood pressure reading.

[10 marks]

Total 25 marks

END OF QUESTIONS

Formula Sheets

First order Instruments

$$a_1 \frac{dy(t)}{dt} + a_0 \mathrm{y(t)} = b_0 x(t)$$

$$\frac{\mathrm{y(D)}}{\mathrm{x(D)}} = \frac{K}{\tau D + 1}$$

$$f = \frac{\omega}{2\pi}$$

$$\emptyset = \tan^{-1}\left(\frac{-\omega\tau}{1}\right)$$

Second- order Instruments

$$x(t) - B\frac{d_y(t)}{dt} - K_s y(t) = M\frac{d^2y(t)}{dt^2}$$

$$y(t) = -\frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} K \sin\left(\sqrt{1-\zeta^2}\,\omega_n t + \phi\right) + K \quad when\ \zeta < 1$$

$$\phi = arcsin\sqrt{1-\zeta^2}$$

$$t_n = \frac{3\pi/2 - \phi}{\omega_n\sqrt{1-\zeta^2}} \quad and \quad t_n = \frac{7\pi/2 - \phi}{\omega_n\sqrt{1-\zeta^2}}$$

Chemical equations:

$$q = \int_0^\infty i dt$$

Avogadro's number = 6.03×10^{23}
Molecular weight of AgCl =143.2

Further equations:

$$C = \varepsilon_0 \varepsilon_r \frac{A}{x}$$

$$f = \frac{1}{2\pi RC}$$

$$\nu_o = -RC\frac{d\nu_i}{dt}$$

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$$\frac{V_o(jw)}{V_i(jw)} = -\frac{R_f}{R_i}\frac{1}{1 + jw\tau} \quad low\ pass\ filter$$

$$\frac{V_o(jw)}{V_i(jw)} = -\frac{R_f}{R_i}\frac{jw\tau}{1 + jw\tau} \quad high\ pass\ filter$$

$$R = \rho\frac{L}{A}$$

$$C_d = \frac{2\pi\epsilon_r\epsilon_0 L}{\ln(D/d)}$$

$$f_n = \frac{r}{2}(\frac{1}{\pi\rho L}\frac{\Delta P}{\Delta V})^{1/2}$$

$$\zeta = \frac{4\eta}{r^3}(\frac{L(\Delta L/\Delta P)}{\pi\rho})^{1/2}$$

$$C_t = C_d + C_b$$

$$f_{n,bubble} = f_{n,no\ bubble}\,(\frac{\Delta P \Delta V_{total}}{\Delta P/\Delta V_{no\ bubble}})^{1/2}$$

$$\zeta_{bubble} = \zeta_{no\ bubble}\,(\frac{\Delta V/\Delta P_{total}}{\Delta V/\Delta P_{no\ bubble}})^{1/2}$$

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Mechanical Characteristics of Fluids

Parameter	Substance	Temperature	Value
η	Water	20 °C	0.001 Pa·s
η	Water	37 °C	0.0007 Pa·s
η	Air	20 °C	0.000018 Pa·s
ρ	Air	20 °C	1.21 kg/m^3
$\Delta V/\Delta P$	Water	20 °C	0.53×10^{-15} m^5/N per ml volume
η	Blood	All	$\cong 4 \times \eta$ for water

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Physical Constants

$g = 9.8$ m/s^2	Acceleration due to gravity
$c = 3 \times 10^8$ m/s	Velocity of light
$\sigma = 5.67 \times 10^{-12}$ W/(cm$^2 \cdot$K^4)	Stefan-Boltzmann constant
$k = 1.38 \times 10^{-23}$ J/K	Boltzmann's constant
$h = 6.63 \times 10^{-34}$ J·s	Planck's constant
$R = 8.31$ J/(mol·K)	Gas constant
$F = 96{,}500$ C/equivalent	Faraday's constant (equivalent =mole/valence)
$q = -1.602 \times 10^{-19}$ C	Charge on the electron
$\epsilon_0 = 8.8 \times 10^{-12}$ F/m	Dielectric constant of free space
$N = 6.02 \times 10^{23}$ molecules/mol	Avogadro's number

END OF FORMULAE SHEETS