UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG(HONS) BIOMEDICAL ENGINEERING

SEMESTER ONE EXAMINATIONS 2024/2025

BIOMECHATRONICS AND MEDICAL DEVICES

MODULE NO: BME5008

Date: Tuesday 7th January 2025 Time: 2:00pm – 4:00pm

INSTRUCTIONS TO CANDIDATES:

There are TWO sections (A and B) each containing THREE questions.

Answer TWO questions from each section.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of 100 marks.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

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SECTION A – ANSWER ANY <u>TWO</u> QUESTIONS FROM THIS SECTION

Q1

(a) A prosthetic limb control system can be represented by the block diagram. shown in Figure Q1(a). Using block diagram reduction techniques, find the transfer function for this control system. **(9 marks)**
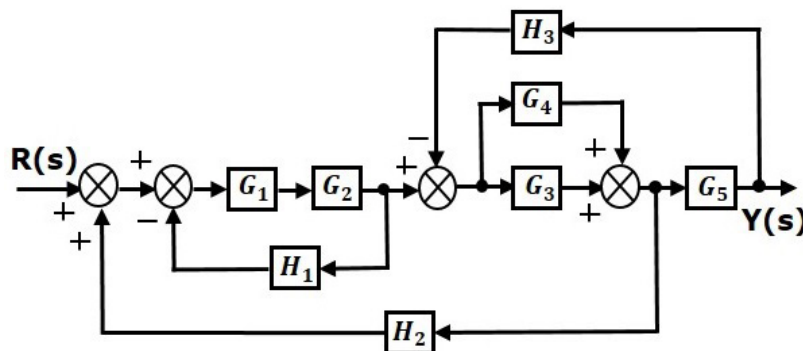

Figure 1a. Block diagram of a prosthetic limb control system.

(b) A capacitive sensor consists of two parallel plates of length 4 cm each and separated by an air gap of 2 mm. Calculate the the capacitance of the sensor and explain how would the capacitance of the capaictive sensor be affected when the separation distance between the plates is increased to 8 mm? Please elaborate on your answer with examples of Biomechatronics systems where capacitive sensors can be used.

(9 marks)

(c) A strainguage sensor changes its resistance from 100 Ω to 150 Ω as the temprature in a prosthetic arm increases. The strain in this case is calculated to be 0.004. Calcultate the gaugae factor in this case and quaote 2 examples of biomedical systems where a strainguage sensor would be employed.

(7 marks)

[Total 25 marks]

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Q2

A 2W Maxon motor designed to operate from 15 volts has a no- load speed of 7160 rpm (750 rad/s) and a stall torque of 5.53 mNm. The relationship among the torque, output power, and the rotational speed is given by the Figure Q2(a) and Table T1.

(a) Calculate the motor effciency 'η' and explain the relationship between mechanical power output of the motor and the electrical power supplied.

(8 marks)

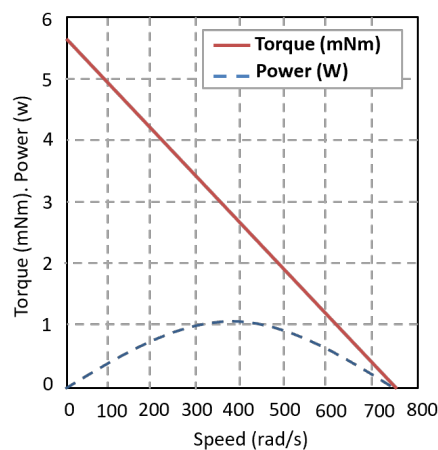(b) Calculate the maximum efficiency 'η_{max}' of the motor.   **(8 marks)**

Figure 2a. Relationship among the torque, output power, and the rotational speed

No-load speed @ 15V n_0 (rpm)	7160
No-load current I_0 (mA)	6
The starting current I_a (mA)	600
Terminal resistance R (Ω)	40
Torque constant Km (mNm/A)	50
Speed constant Ke (rpm/V)	150
Output power P_0 (W)	5

Table T1.

Q2 continues over the page

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Q2 continued..

(c) W&Z is a small biomechatronic company. Recently the senior management team intends to introduce a new type of prosthetic griper. Since this griper will have two fingers to execute relatively simple movements, the management thought that a brushed DC motor or a Brushless DC (BLDC) motor could meet the requirement.

You are asked by the management to investigate these two types of motors and provide the following information to them:

Comparison between a DC motor and a BLDC motor, with reasons, in the features of

• Commutation

• Speed/Torque

• Cost   **(9 marks)**

[Total 25 marks]

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Q3

(a) Explain and identify following three actuation systems and their features. Specify three applications in biomechatronic systems from each of them:
1. Mechanical actuation system
2. Hydraulic actuation system
3. Pneumatic actuation system

(9 marks)

(b) An open loop system consisting of a water tank and flow control valve is being operated at your home. Draw a block diagram representing such a system and identify the disturbances that can affect such a system? Does this control system have appropriate mechanism to deal with disturbances?

(8 marks)

(c) A closed loop system consisting of 'adaptive cruise control' is installed in your car. Draw a block diagram representing this control system and identify the disturbances that can affect such a system? Does this control system have appropriate mechanism to deal with disturbances?   **(8 marks)**

[Total 25 marks]

END OF SECTION A

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SECTION B – ANSWER ANY <u>TWO</u> QUESTIONS FROM THIS SECTION

Q4

Engineering materials fall into the following four main categories:
  Metals and alloys
  Plastics (polymers)
  Ceramics and glasses
  Composite materials
(a) Identify two of the major properties for each of the categories.

(8 marks)

(b) Summarise why composite materials are often used as a substitute for other materials.

(8 marks)

(c) Plastics are divided into two types. Differentiate between the two types and discuss the methods for processing each type.

(5 marks)

(d) Metals are used in a large variety of medical devices, some within the human body. Demonstrate two uses for metals in the body and where they would most likely be used.

(4 marks)

[Total 25 marks]

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Q5

Over 97,000 Percutaneous Coronary Interventions (previously called angioplasty) are carried out every year in the UK. It is a common procedure used to open and widen blocked or narrowed coronary arteries. A stent is usually inserted and left in place.

a) Discuss the materials can be used to make stent and explain how the stent is inserted into the body. **(10 marks)**

b) Cardiac pacemakers are often used to regulate the heart. Summarise what a pacemaker is and describe how it works. **(10 marks)**

c) Explain why biomedical devices need coating? **(5 marks)**

[Total 25 marks]

Q6

Bioimaging has transformed diagnostic medicine over the past century and made medical diagnosis more accurate Discuss how information is collected and the images produced in the following machines. Give the advantages of each technique and also any disadvantages.

a) X ray/CT scan

(7 marks)

b) Ultrasound

(7 marks)

c) Nuclear medicine

(5 marks)

d) MRI

(6 marks)

[Total 25 marks]

END OF SECTION B

END OF QUESTIONS

PLEASE TURN PAGE FOR FORMULA SHEET

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Formula Sheet:

Blocks with feedback loop

$G(s) = \dfrac{Go(s)}{1 + Go(s)H(s)}$ (for a negative feedback)

$G(s) = \dfrac{Go(s)}{1 - Go(s)H(s)}$ (for a positive feedback)

Capacitance:

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

A = L *W

Strain gauge:

$\Delta R/R_0 = G\,\varepsilon$

Motor Selection and Efficiency:

$\omega = 2\pi f$

1 RPM = 0.016 Hz

$\text{Power}_{req} = T\omega$

$I = (T/K_m) + I_0$

$N_{motor@load} = N_{20/no\ load} - IRK_e$

Efficiency = $\dfrac{Pout}{Pout + Pdis}$

$\eta = T\omega/IV$

$$\eta_{max} = \left(1 - \sqrt{\frac{I_0}{I_a}}\right)^2$$

END OF PAPER