UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) IN BIOMEDICAL ENGINEERING

SEMESTER ONE EXAMINATION 2018/2019

BIOMECHATRONICS AND MEDICAL DEVICES

MODULE NO: BME5008

Date: Monday 14 January 2019 **Time: 10.00 morning – 12.00 noon**

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.

CANDIDATES REQUIRE:

Formula Sheet (attached)
Non-programmable calculator

SECTION A – answer ANY TWO questions from this section

Q1 a) A DC motor used for speed control on an artificial heart is a first order system, which has a time constant of 5 seconds:

(i) If the speed is suddenly increased from being at 25 rpm to 45 rpm, what will be the speed indicated by the speedometer after 10 seconds?

(5 marks)

(ii) If the maximum speed of the DC motor is 80 rpm, and is subjected to a unit step input, determine the time taken, "t" for the speed output to reach from 0 to 70% of its maximum speed.

(5 marks)

b) A second-order biomechatronic system has a natural angular frequency of 3.0 Hz and a damped frequency of 2.5 Hz. Find the following parameters for the system.

(i) The damping factor **(4 marks)**

(ii) The 100% rising time **(2 marks)**

(iii) The percentage maximum overshoot. **(2 marks)**

(iv) The peak time. **(2 marks)**

(v) The 2% settling time t_s. **(2 marks)**

(vi) Sketch this second order system and clearly identify characteristic features obtained from items (ii) to (v) above.

(3 marks)

[Total 25 marks]

Q2 The following are two biomechatronic systems:

- An artificial Foot
- A smart wheelchair

a) Identify THREE basic elements for both systems above.

(3 marks)

b) Specify four types of sensors that could be applied into above two biomechatronic systems, and describe the functions of these sensors applying into the systems.

(12 marks)

c) If closed loop control systems would be applied into these two systems, draw two control block diagrams for each of them. In the diagrams, you need clearly indicate the elements and their input and output signals for each block.

(6 marks)

d) Using block diagrams explain the differences between an open-loop control system and a closed-loop control system.

(4 marks)

Total 25 marks

Q3 Figure Q3 shows a block diagram of a prosthetic limb control system.

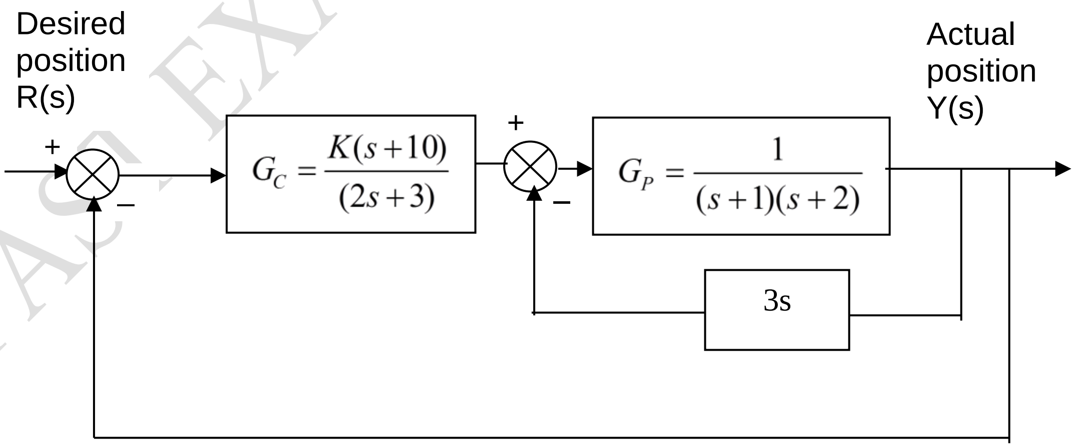

Figure Q3 A prosthetic Limb Control System

Q3 continues over the page……

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Q3 continued…..

a) Find the Output Y(s) for this control system if a unit step input is applied.
(8 marks)

b) What are the values of K which will achieve the steady state error $e_{ss} \leq 0.1$ for a unit step input F(s)? **(7 marks)**

c) Using the K obtained from (b) above, apply Routh-Array method to check the stability of the system.
(10 marks)

[Total 25 marks]

END OF SECTION A

SECTION B – answer <u>ANY 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.
(5 marks)

c) Plastics are divided into two types. Differentiate between the two types and discuss the methods for processing each type.
(7 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.
(5 marks)
[Total 25 marks]

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Q5

a) The properties that need to be considered when selecting the correct materials and fixation methods can depend on the mechanical properties of the joint being replaced. Discuss the properties of the following joints which would need to be considered when choosing the correct materials and suggest suitable fixation methods.

i. Knee replacement

ii. Shoulder replacement

(10 marks)

b) Cardiovascular disease is very common in the Western world. Demonstrate the use of angioplasty as treatment for treating blocked blood vessels. Explain how the device is introduced into the blocked vessel and the materials used to make the balloon and the stent. Explain how the stent is not rejected by the body.

(15 marks)
[Total 25 marks]

Q6

There are many imaging methods used in modern medicine to diagnose and treat patients.

a) One of the most commonly used devices is an endoscopy. Explain in detail how an endoscope works and how it can be used in three different ways to diagnose and treat patients

(10 marks)

b) Imaging machines use very different techniques to generate images. Both of the following techniques can produce a whole body scan if necessary. Describe the different ways data is collected and images generated in the following techniques

i. Computed Tomography (CT) scan

ii. Magnetic Resonance Imaging (MRI) scan

(15 marks)

[Total 25 marks]

END OF QUESTIONS

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Blocks with feedback loop

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

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

Steady-State Errors

$e_{ss} = \lim_{s \to 0}[s(1-G_O(s))\theta_i(s)]$ (for an open-loop system)

$e_{ss} = \lim_{s \to 0}[s\frac{1}{1+G_o(s)}\theta_i(s)]$ (for the closed-loop system with a unity feedback)

$e_{ss} = \lim_{s \to 0}[s\frac{1}{1+\frac{G_1(s)}{1+G_1(s)[H(s)-1]}}\theta_i(s)]$ (if the feedback H(s) ≠ 1)

$e_{ss} = \lim_{s \to 0}[-s \cdot \frac{G_2(s)}{1+G_2(G_1(s)+1)} \cdot \theta_d]$ (if the system subjects to a disturbance input)

Laplace Transforms

A unit impulse function	1
A unit step function	$\frac{1}{s}$
A unit ramp function	$\frac{1}{s^2}$

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First-order systems

$$G(s) = \frac{\theta_o}{\theta_i} = \frac{G_{ss}(s)}{\tau s + 1}$$

$$\tau\left(\frac{d\theta_o}{dt}\right) + \theta_o = G_{ss}\theta_i$$

$\theta_O = G_{ss}(1 - e^{-t/\tau})$ (for a unit step input)

$\theta_o(t) = G_{ss}[t - \tau(1 - e^{-(t/\tau)})]$ (for a ramp input)

$\theta_o(t) = G_{ss}(\frac{1}{\tau})e^{-(t/\tau)}$ (for an impulse input)

Second-order systems

$$\frac{d^2\theta_o}{dt^2} + 2\zeta\omega_n\frac{d\theta_o}{dt} + \omega_n^2\theta_o = b_o\omega_n^2\theta_i$$

$$G(s) = \frac{\theta_o(s)}{\theta_i(s)} = \frac{b_o\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$\omega_d t_r = 1/2\pi$ $\omega_d t_p = \pi$

Percentage overshoot (PO) = $\exp(\frac{-\zeta\pi}{\sqrt{(1-\zeta^2)}}) \times 100\%$

$t_s = \frac{4}{\zeta\omega_n}$ $\omega_d = \omega_n\sqrt{(1-\zeta^2)}$

subsidence ratio = $e^{(\frac{-2\zeta\pi}{\sqrt{1-\zeta^2}})}$

END OF FORMULAE SHEETS