ENG36

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BEng(Hons) MECHATRONICS ENGINEERING

SEMESTER ONE EXAMINATION 2023/24

ADVANCED MECHATRONIC SYSTEMS

MODULE NO: MEC6002

Date: Monday 8th January 2024 **Time: 10:00 – 12:00**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions.

Answer ANY FOUR questions.

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.

School of Engineering
BEng(Hons) Mechatronics Engineering (Top-Up)
Semester One Examination 2023/24
Advance Mechatronic Systems
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QUESTION 1

Consider the vertical motion of the wing-tip fuel tanks system for a F-89 Scorpion aircraft as shown in Figure 1. The differential equation of motion governing this system is given as follows:

$$\ddot{y} + 6\dot{y} + 27y = 27x$$

The initial conditions for this system are modelled as follows:

$y(0) = y_0 = 0.5$ m
$\dot{y}(0) = \dot{y}_0 = 0.3$ m/sec

i. Determine the transfer function, angular frequency, damping ratio and damped angular frequency.

[12 Marks]

ii. Determine Peak time (t_p), Maximum overshoot (M_p), Settling time (t_s), and Rise time (t_r).

[13 Marks]

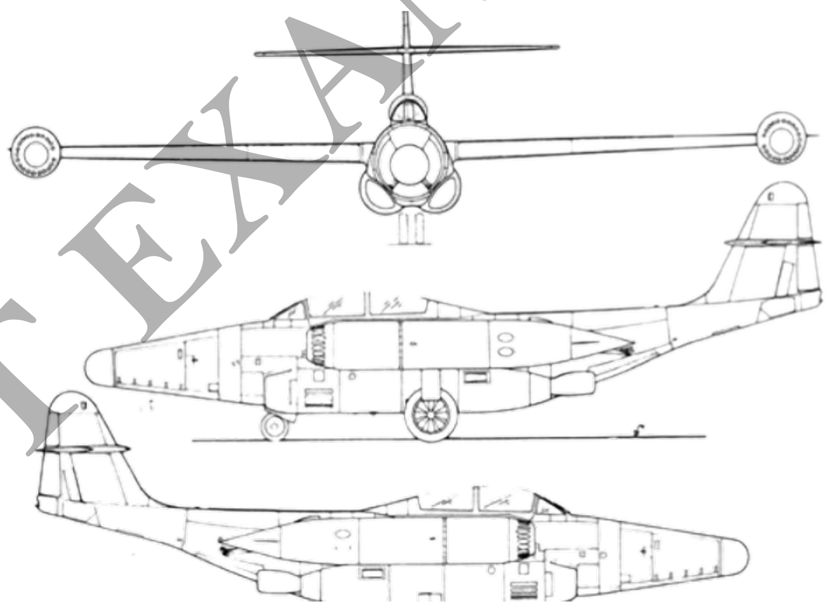

Figure 1 F-89 Scorpion Aircraft

Total 25 marks

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QUESTION 2

a) Determine the governing equation that describes the correlation between the input torque T and the angular displacement θ of a driveline with a locked wheel, as shown in Figure 2(a).

Using Laplace Transforms find the transfer function of the derived equations, assuming that the system receives a unit step input at an initial condition taken to be zero overall.

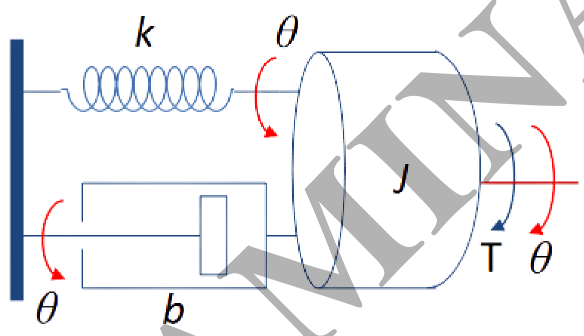

Figure 2(a) Schematical diagram of locked wheel

[18 Marks]

b) The response of a first-order mechatronic system to an impulse is represented by the following equation,

$$C(t) = 3e^{-0.5t}$$

Determine its time constant (τ), DC gain (K), transfer function (G_s), and step response.

[7 Marks]

Total 25 marks

QUESTION 3

a) A robot control system can be represented by the block diagram shown in Figure Q3(a). Using block diagram reduction techniques, find the θ_o for this control system if a unit step input is applied.

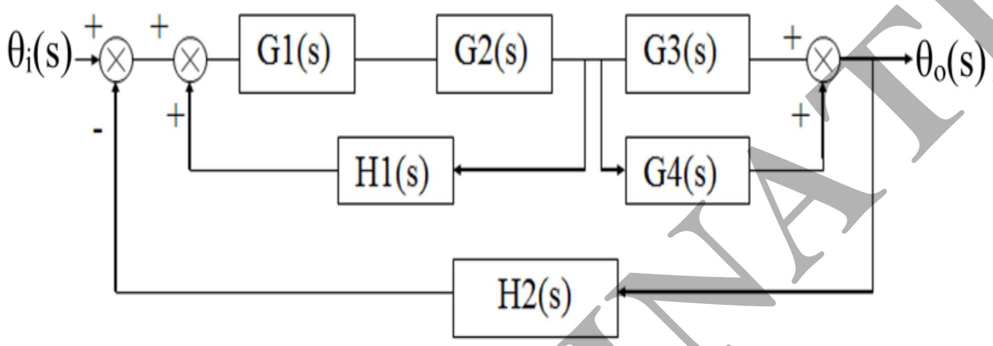

Figure Q3(a)

[9 Marks]

b) A mechatronic system has following transfer function:

$$G(s) = \frac{100}{25s + 10}$$

Determine and sketch the response of the system when ramp input is applied to the system.

[9 Marks]

c) Consider position control system used with machine has an amplifier in series with valve slider arrangement having transfer functions 27 mA/V and 12 mm/mA respectively. Also feedback displacement measurement arranged with transfer function 7mV/mm. Draw loop diagram and find the overall transfer function.

[7 Marks]

Total 25 marks

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QUESTION 4

a) Using Suitably labelled diagrams and explanations, differentiate between open and closed loop control systems.

[8 Marks]

b) State any four advantages of closed loop over open loop system.

[8 Marks]

c) Consider the system as shown in Figure 4(c), where V(t) is the input voltage, and i(t) is the output current. Determine the response i(t) of the system when V(t) is a unit-step input.

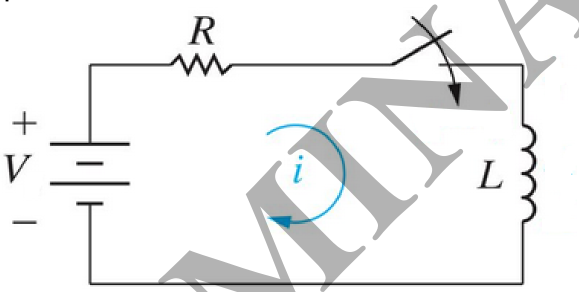

Figure 4(c) Linear system

[9 Marks]

Total 25 marks

QUESTION 5

a) Explain and identify following three actuation systems and their features. Specify applications in mechatronic systems from each of them:

i. Electrical actuation drive system

[5 Marks]

ii. Hydraulic actuation system

[5 Marks]

iii. Pneumatic actuation system

[5 Marks]

b) Figure 5(b) shows a control system employing hydraulic cylinders as the actuating elements. Clearly state the sequence of operations that will occur for the cylinders A and B when start button is pressed.

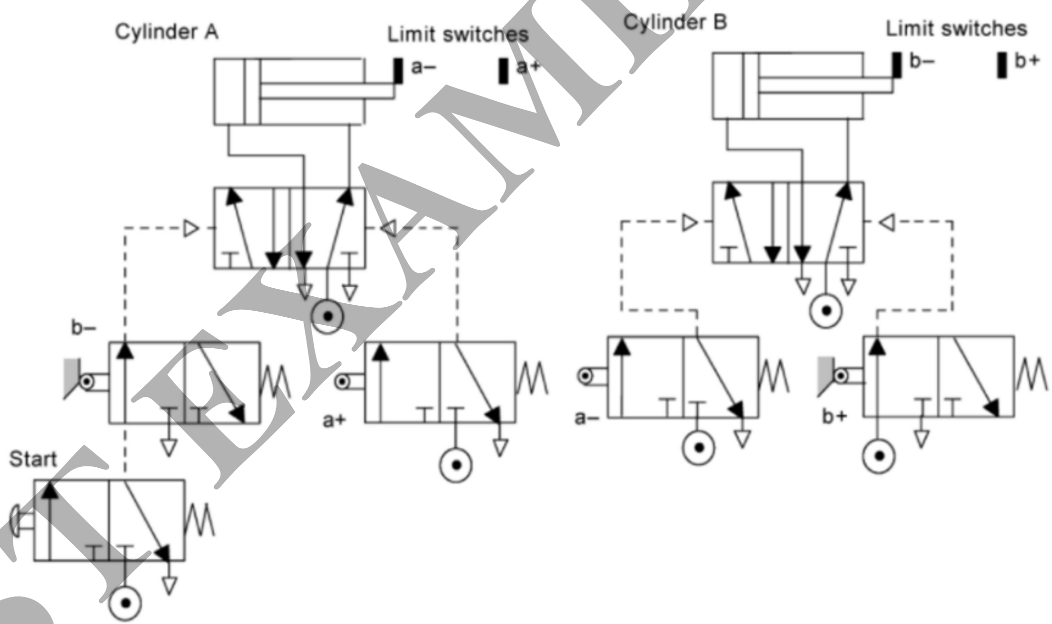

Figure 5(b) Two actuators sequential operation.

a-, a+, b-, and b+ are limit switches to detect when cylinders are fully retracted and fully extended.

[10 Marks]

Total 25 marks

END OF QUESTIONS

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Formula Sheet

$f'(t)$	$sF(s)-f(0)$
$f''(t)$	$s^2F(s)-sf(0)-f'(0)$

	$f(t)$	$F(s)$
1.	$\delta(t)$	1
2.	$u(t)$	$\frac{1}{s}$
3.	$t\,u(t)$	$\frac{1}{s^2}$
4.	$t^n\,u(t)$	$\frac{n!}{s^{n+1}}$
5.	$e^{-at}\,u(t)$	$\frac{1}{s+a}$
6.	$\sin\omega t\,u(t)$	$\frac{\omega}{s^2+\omega^2}$
7.	$\cos\omega t\,u(t)$	$\frac{s}{s^2+\omega^2}$

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

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

$\omega_d t_r = 1/2\pi$

$\omega_d t_p = \pi$

$M.O\,(\%) = \exp\left(\dfrac{-\zeta\pi}{\sqrt{(1-\zeta^2)}}\right)\times 100\%$

$t_s = \dfrac{4}{\zeta\omega_n}$

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

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$$\delta = \frac{c}{c_c}$$

$$c_c = \sqrt{4Mk}$$

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

$$\omega = \omega_n\sqrt{1 - \delta^2}$$

$$\tau\dot{y}(t) + y(t) = Ku(t)$$

$$G(s) = \frac{C(s)}{R(s)} = \frac{K}{\tau s + 1}$$

END OF PAPER