

UNIVERSITY OF GREATER MANCHESTER

**SCHOOL OF ENGINEERING AND BUILT
ENVIRONMENT**

BSC (HONS) MECHATRONICS (TOP-UP)

SEMESTER ONE EXAMINATION 2025/2026

ADVANCED MECHATRONIC SYSTEMS

MODULE NO: MEC6002

Date: Friday 16th January 2026

Time: 10am – 12 noon

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.

CANDIDATES REQUIRE:

Formula sheet (attached).

QUESTION 1

A separately excited DC motor is shown schematically in **Figure Q1**, representing the interaction between its electrical and mechanical components. The system operates such that the armature current (i) interacts with the magnetic field to produce rotational motion. The voltage source (V) supplies electrical energy to the armature circuit, while the armature resistance (R) and inductance (L) represent the electrical characteristics of the winding. The back electromotive force (e) is generated due to the motor's rotation and acts in opposition to the applied voltage. The developed torque (T) drives the motor shaft, whose motion is characterised by angular displacement (θ), moment of inertia (J), and damping coefficient (b), representing mechanical resistance due to friction and viscous effects.

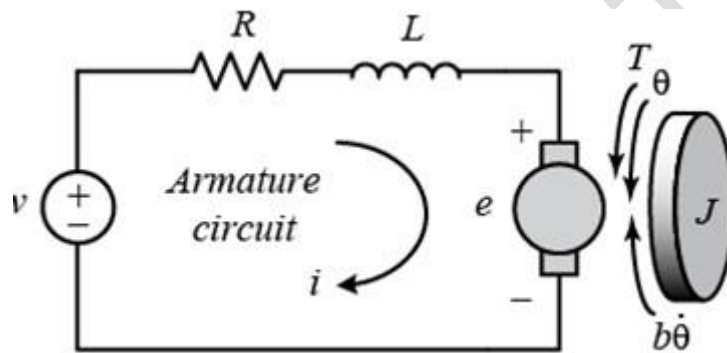


Figure Q1 Separately excited DC Motor

Table 2 Parameters are associated with the motor

Parameter	Symbol	Value	Unit
Armature Resistance	R	4	Ω
Armature Inductance	L	2.75×10^{-6}	H
Back EMF Constant	K_e	0.0274	V/(rad/s)
Torque Constant	K_t	0.0274	N·m/A
Moment of Inertia	J	3.2284×10^{-6}	kg·m ²
Damping Coefficient	b	3.5077×10^{-6}	N·m·s

Question 1 continued over page 3

PLEASE TURN THE PAGE

Question 1 continued

- a) Derive the differential equation representing the electrical dynamics of the DC motor, clearly relating voltage, current, inductance, resistance, and back EMF.
[10 marks]
- b) Derive the differential equation representing the mechanical dynamics of the DC motor, showing the relationship between torque, angular velocity, inertia, and damping.
[10 marks]
- c) Using the results from parts (a) and (b), obtain the overall transfer function of the system, expressing angular velocity (ω) as the output and applied voltage (V) as the input.
[5 marks]

[Total 25 marks]

PLEASE TURN THE PAGE

QUESTION 2

A two-dimensional drone platform is shown schematically in **Figure Q2**. The platform represents a simplified model of a quadrotor aircraft constrained to move and rotate in the y - z plane. The drone consists of a 600 mm frame weighing 500 g, fitted with four motors (each of mass 20 g) and four propellers (each weighing 7 g). The drone experiences gravitational force (mg) acting in the z -direction and is subject to aerodynamic thrust forces and moments generated by its motors. The system is influenced by two control inputs: A net thrust force (F) acting along the z -axis, and A pitching moment (M) acting about the drone's centre of mass. Assume the acceleration due to gravity, $g=9.81 \text{ m/s}^2$. Additional parameters may be assumed where necessary for model development.

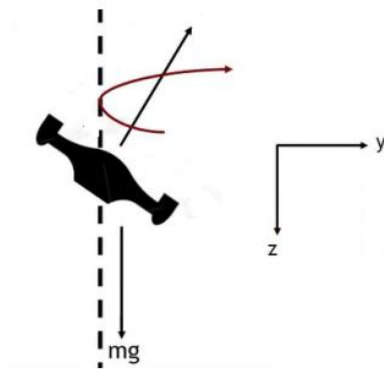


Figure Q2 Two-dimensional drone platform model illustrating rotation and vertical motion

- Develop the differential equations of motion governing the drone's translation in the y and z coordinates.

[10 marks]
- Derive the rotational dynamics equation using the appropriate Euler angle (θ) representing the drone's pitch motion.

[10 marks]
- Clearly state all assumptions, coordinate frames, and sign conventions used in your derivation.

[5 marks]

[Total 25 marks]

PLEASE TURN THE PAGE

School of Engineering and Built Environment
BSc (Hons) Mechatronics (top-up)
Semester One Examination 2025/2026
Advanced Mechatronic Systems
Module No: MEC6002

QUESTION 3

- a) Explain the difference between step, impulse, ramp, and sinusoidal input signals. Discuss the purpose and typical applications of each signal type in the context of control systems analysis and testing.

[8 marks]

- b) Explain the difference between underdamped, overdamped, and critically damped systems in terms of their transient response characteristics. Provide suitable examples from real-world control applications (such as robotic actuators, vehicle suspension systems, or servo mechanisms) to illustrate each damping behaviour.

[9 marks]

- c) Differentiate clearly between an open-loop control system and a closed-loop control system. Use block diagrams to illustrate both types of systems. Explain the advantages and disadvantages of each configuration in relation to accuracy, stability, complexity, and response to disturbances.

[8 marks]

[Total 25 marks]

PLEASE TURN THE PAGE

QUESTION 4

A prosthetic elbow joint uses a brushless DC motor for smooth and precise movement as shown in **Figure Q4**. The motor joint system is governed by the following equation. $V(t)$ is the input control voltage from the neural interface, $\theta(t)$ is the angular position of the elbow joint.

$$\ddot{\theta} + 4\dot{\theta} + 173\theta = 170V$$



Figure Q4 Prosthetic Arm Joint Control

- a) Determine the transfer function, angular frequency, damping ratio and damped angular frequency.

[12 Marks]

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

[13 Marks]

[Total 25 marks]

PLEASE TURN THE PAGE

QUESTION 5

- 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 5**.

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.

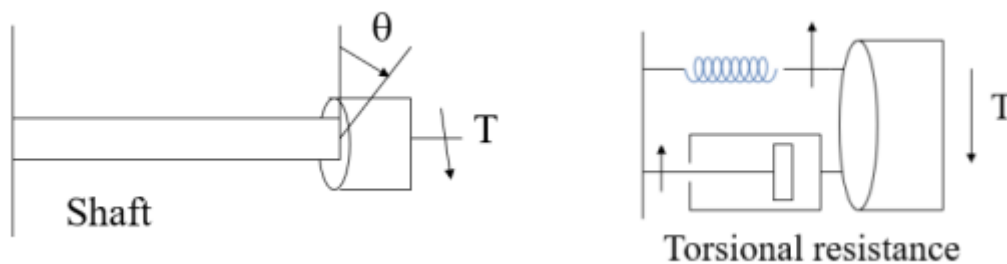


Figure 5 Schematic diagram of locked wheel

[18 Marks]

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

$$C(t) = 4e^{-0.6t}$$

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

[7 Marks]

[Total 25 marks]

END OF QUESTIONS

PLEASE TURN THE PAGE FOR FORMULA SHEET

School of Engineering and Built Environment
 BSc (Hons) Mechatronics (top-up)
 Semester One Examination 2025/2026
 Advanced Mechatronic Systems
 Module No: MEC6002

Formula Sheet

$$\begin{array}{l} f'(t) \\ f''(t) \end{array} \quad \begin{array}{l} sF(s) - f(0) \\ s^2F(s) - sf(0) - f'(0) \end{array}$$

	$f(t)$	$F(s)$
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.	$\cos \omega t u(t)$	$\frac{s}{s^2 + \omega^2}$

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

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

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

$$\omega_d t_p = \pi$$

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

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

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

PLEASE TURN THE PAGE

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

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

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

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

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

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

END OF PAPER