



Prifysgol Cymru
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University of Wales
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LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 4

LEFEL 4

EXAMINATION PERIOD
MAY 2026

CYFNOD ARHOLIADAU
MAI 2026

HND ELECTRICAL AND ELECTRONIC ENGINEERING

MODULE CODE: GOEE4002

Dynamics Control and Instrumentation

TIME: 2 HOURS

ANSWER ALL FIVE QUESTIONS

Equipment or materials required – Calculators and a formulae booklet are allowed.

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Question One (20 marks)

An automated control system is being designed to maintain the water level in a storage tank. The system includes a water pump as the actuator, a water sensor for feedback, and a controller that adjusts the pump based on the water level measurements.

- a. The water level is initially designed as an open-loop system where the pump runs for a fixed time to fill the tank, without considering the actual water level in the tank. Using a simple block diagram, illustrate this open-loop system.

[4 marks]

- b. If an external disturbance such as unexpected water usage causes the water level to drop during filling, how will the open-loop system respond?

[1 mark]

- c. To improve performance, a closed-loop system is implemented, where the controller adjusts the pump operation based on real-time water level data from the sensor. Using a simple block diagram, illustrate the feedback control loop of this closed-loop system, identifying all key components.

[6 marks]

- d. The closed-loop system uses a proportional controller with gain, K_p . The sensor provides unity feedback, and the combined water pump and tank dynamics are modelled by the transfer function:

$$G(s) = \frac{5}{(s + 3)}$$

If the desired water level is changed via a step input of $L_{\text{set}} = 100\text{cm}$, answer the following:

- i. Derive the closed-loop transfer function.

[4 marks]

- ii. Determine steady-state water level L_{ss} for a step input of $L_{\text{set}} = 100\text{cm}$.

[5 marks]

Question Two (20 marks)

A crate of mass $m = 6\text{kg}$ is placed on a rough inclined ramp at an angle of $\theta = 20^\circ$ from the horizontal as shown in Figure 1. The coefficient of kinetic friction between the crate and the surface is $\mu = 0.25$. A motor applies a cable tension of force $F = 40\text{N}$ parallel to the ramp to pull the crate upward.

- a. Using Newton's second law, calculate the acceleration of the crate along the ramp. Assume that the applied force is greater than the downhill component of weight and friction.

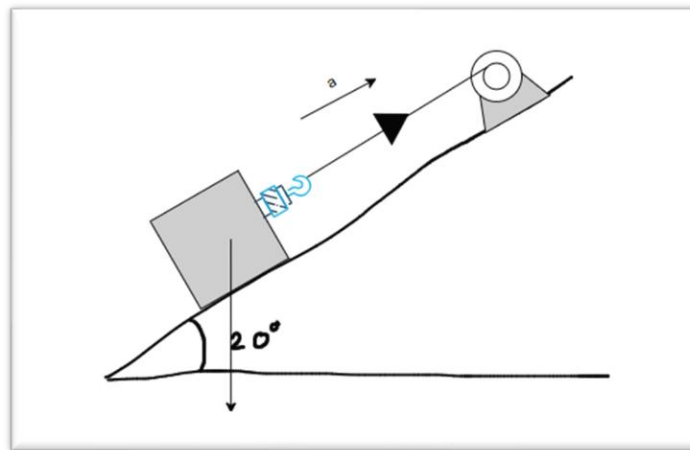


Figure 1

[4 marks]

- b. The crate is controlled by a PID controller that adjusts cable force F to maintain the crate's speed at a constant value of 1.5m/s as it moves up the ramp. The transfer function representing the system dynamics between applied force and crate velocity is given by:

$$G(s) = \frac{1}{ms + b}$$

- i. If the damping coefficient is $b = 0.4\text{Ns/m}$, use the transfer function to derive the steady-state applied force required to maintain the velocity at 1.5m/s in the presence of friction and gravitational force.

[4 marks]

- ii. Calculate $G(0)$ and explain its physical meaning in determining the steady state-applied force.

[4 marks]

- c. Now suppose the crate is attached by a rope that passes over a pulley to a hanging mass $m_2 = 10\text{kg}$. The system is designed to accelerate at a constant rate of 1.8m/s^2 up the ramp.

i. Write down the equations of motion for both masses.

[2 marks]

ii. Derive the required tension T in the rope using Newton's second law.

[3 marks]

- d. A position sensor is mounted on the ramp and measures the position of the crate, producing a voltage signal that is proportional to the position with a scaling factor of 0.02V/m . If the crate moves at a constant velocity of 1.5m/s , calculate the sensor output voltage after 6 seconds.

[3 marks]

Question Three (25 marks)

A unity feedback system has the following open-loop transfer function:

$$G(s) = \frac{(s + 3)}{(s + 4)(s^2 + 3s + 6)}$$

- a. Determine the locations of the poles and zeros of the open-loop system in the complex s-plane.

[4 marks]

- b. Plot the pole-zero diagram, clearly labelling all poles and zeros.

[4 marks]

- c. Comment briefly on the stability characteristics of the open-loop system.

[2 marks]

- d. Evaluate the magnitude of the transfer function $G(s)$ at the complex frequency point:

$$s = -1 + 2j.$$

Provide your answer in both rectangular and polar form showing all working.

[15 marks]

Question Four (15 marks)

For the given system block diagram shown in Figure 2:

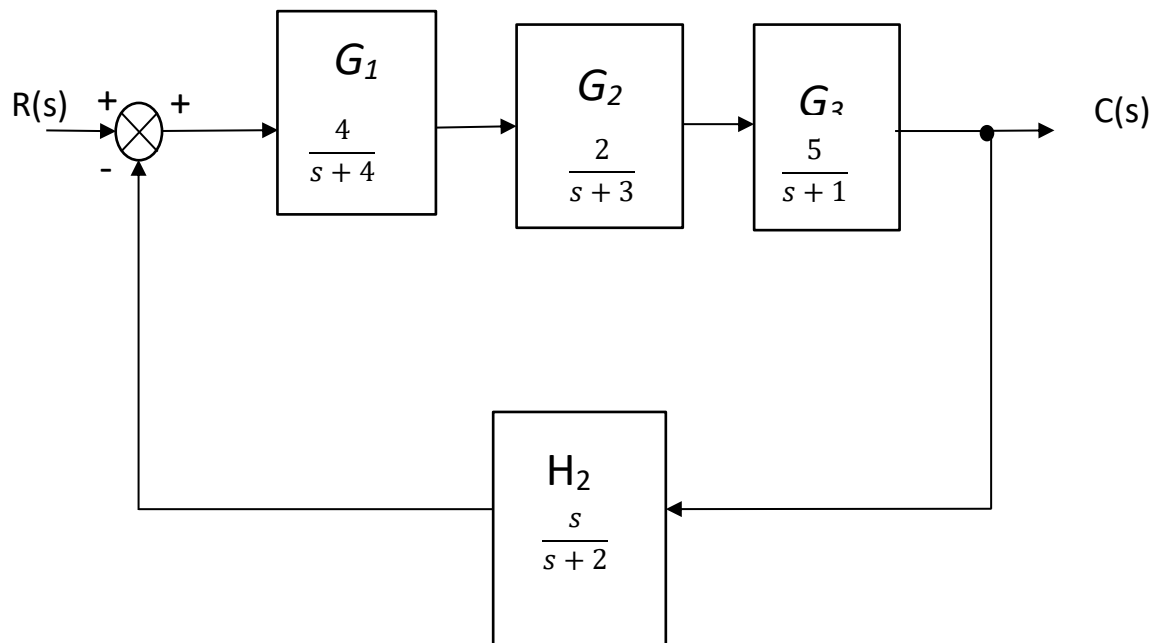


Figure 2

- Using block diagram reduction techniques, reduce the system to a single equivalent block and determine the closed-loop transfer function $\left(\frac{Y(s)}{R(s)}\right)$. All intermediate steps must clearly be shown.
[10 marks]
- Determine the order and type of the closed loop system and hence the steady state error for a unit step input.
[4 marks]
- Comment on the stability of the closed loop system, stating clearly the criterion used.
[1 mark]

Question Five (20 marks)

- a. An RC circuit consists of a resistor $R = 2k\Omega$ in series with a capacitor $C = 10\mu F$ as shown in Figure 3. The input voltage $v_{in}(t)$ is applied across the series combination, and the output voltage $v_o(t)$ is measured across the capacitor.

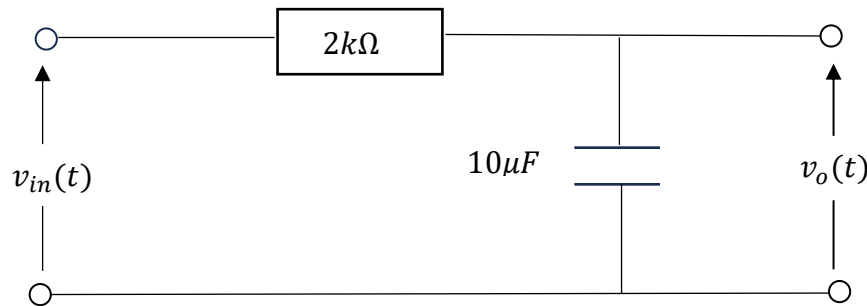


Figure 3.

- i. Derive the transfer function

$$H(s) = \frac{V_o(s)}{V_{in}(s)}$$

for the circuit.

[4 marks]

- ii. The input voltage is a step input $v_{in}(t) = V_0 u(t)$, where $V_0 = 5V$. Determine the time-domain expression for the output voltage $v_o(t)$

[6 marks]

- iii. State whether the circuit behaves as a low pass or high pass filter and briefly justify your answer.

[2 marks]

- b. An RLC circuit has resistance, $R = 150\Omega$ inductance, $L = 2H$, and capacitance, $C = 25\mu F$. The current in the circuit is given by:

$$\frac{d^2 i}{dt^2} + \frac{R}{L} \frac{di}{dt} + \frac{1}{LC} i = \frac{V}{CL}$$

- i. Determine the natural (undamped) angular frequency ω_0 and the damping factor α . Hence state whether the system is overdamped, critically damped, or underdamped?

[6 marks]

- iii. For a constant DC input voltage, state the steady-state current in the circuit and briefly explain your reasoning

[1 mark]

iv. If the applied voltage is

$$V(t) = V_0$$

where $V_0 = 10\text{V}$ is constant, find the steady- state current, i_{ss} of the circuit?

[1 mark]

Good luck

End of the exam