



SCHOOL OF COMPUTING AND ENGINEERING SCIENCES
BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONICS ENGINEERING
2nd SEMESTER 2024/2025 - UNIVERSITY EXAMINATION
BEE 3206: CONTROL SYSTEMS I

DATE: 20th March 2025

Time: 11:00-13:00 Hours

Instructions

1. This examination consists of **FOUR** questions.
2. Answer **QUESTION ONE** and any other **TWO QUESTIONS**.

QUESTION ONE (30 Marks)

Q1(a) A Linear Time Invariant control system dynamics can be described using linear differential equations.

- (i) Write down the linear differential equation that is used to model the input/output relationship.
2 Marks
- (ii) Assuming zero initial conditions, derive the transfer function for the system described by the linear differential equation.
2 Marks

Q1(b) The following differential equation models the open loop dynamics of a Cart on wheels where $v(t)$ is the speed.

$$\frac{dv(t)}{dt} + 0.5v(t) = 1$$

- (i) If the system loop is closed with unity feedback, derive the transfer function
2 Marks
- (ii) For the unity feedback closed-loop system, derive an expression for the output $v(t)$ when the input is a unit step.
4 Marks
- (iii) Determine the open-loop steady state speed V_{ss_ol} and the closed-loop steady state speed V_{ss_cl} when the input is a unit step.
2 Marks
- (iv) Sketch the output $v_{ol}(t)$ and $v_{cl}(t)$ versus time when the input is a unit step.
4 Marks

Q1(c) The open loop transfer function of a servo system with unity feedback is given as;

$$G_p(s) = \frac{K}{s(0.5s+1)}$$

If the desired natural frequency of oscillation of the closed loop system $\omega_n = 5$ rad/sec calculate;

- (i) The value of K
 - (ii) The damping ratio
 - (iii) The damped natural frequency
 - (iv) The dominant time constant τ_c
 - (v) Sketch the system time response when the input is a unit step for $0 < t < 5\tau_c$
- 10 Marks

Q1(d) Determine the range of K for which the unity feedback control system described by the following open loop transfer function is stable;

$$G_p(s) = \frac{K(s+13)}{s(s+3)(s+7)}$$

4 Marks

QUESTION TWO (15 Marks)

Q2(a) The open loop transfer function of a unity feedback control system is given as;

$$G_p(s) = \frac{50}{s(s+5)(s+4)}$$

- (i) Calculate the position error constant K_p , velocity error constant K_v and acceleration error constant K_a 3 Marks
- (ii) Find the steady state error if the input is $r(t) = 5t$ 1 Mark

Q2(b) The open loop transfer function of a unity feedback control system is given as;

$$G_p(s) = \frac{K}{(s+2)(s^2+6s+25)}$$

- (i) Determine the value of K that will cause sustained oscillations in the closed-loop system. 2 Marks
- (ii) Calculate the roots of the characteristic equation for $K = 0$. 2 Marks
- (iii) For the closed-loop system, calculate the roots of the Characteristic Equation for the following values of K

K	50	150
Roots		

4 Marks

- (iv) Plot the root locus on the graph paper provided 3 Marks

QUESTION THREE (15 Marks)

Q3 For the open-loop transfer function of a control system with unity feedback is given as;

$$G_p(s) = \frac{1.15}{s(1+2s)(1+0.2s)}$$

- (i) Choose suitable values frequency in rad/sec and calculate the Bode db magnitude and phase. 8 Marks
- (ii) Plot the open loop Bode magnitude and phase on a log-linear graph and determine the approximate Gain Margin and Phase Margin. 4 Marks
- (iii) Plot the open loop Bode db magnitude and phase on a Nichols Chart and determine the approximate value of the db magnitude resonant peak and the frequency at which it occurs. 3 Marks

QUESTION FOUR (15 Marks)

Q4 The open loop transfer function of a unity feedback control system is given as;

$$G_p(s) = \frac{200}{s(s+5)(s+10)}$$

- (i) Choose suitable values of frequency in rad/sec and calculate the Bode db magnitude and phase. 8 Marks
- (ii) Calculate the magnitude $|G_p(j\omega)|$ for the range of frequencies in Q4(i) above. 2 Marks
- (iii) Plot the values $|G_p(j\omega)|$ magnitude and $G_p(j\omega)$ phase and determine the phase and gain margin. 5 Marks

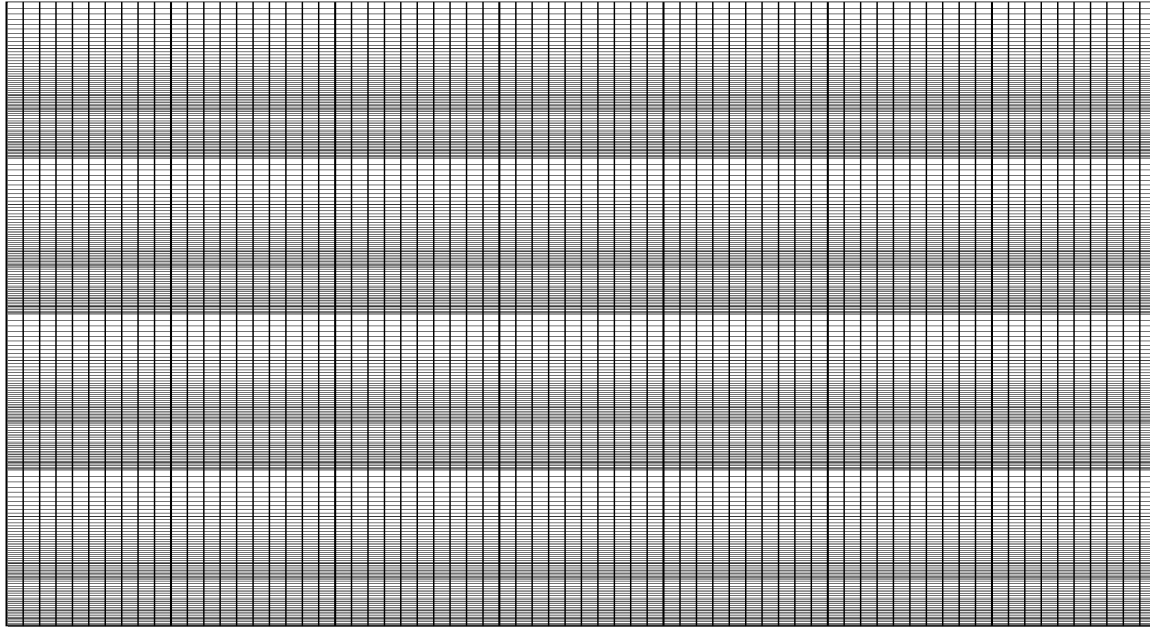
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