



Strathmore
UNIVERSITY

SCHOOL OF COMPUTING AND ENGINEERING SCIENCES
BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONICS ENGINEERING
2nd SEMESTER 2023 - UNIVERSITY EXAMINATION
BEE 3206: CONTROL SYSTEMS I

DATE: 13th December 2023

Time: 10:30-12:30 Hours

Instructions

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

Question 1 (30 Marks)

- (a) The following differential equation describes the open loop mechanical dynamics of a cart on wheels which models an electric car.

$$900 \frac{dv(t)}{dt} + 3v(t) = 120$$

- (i) Explain how the 900Kg car weight and the 120 Newton force can be calculated. 4 Marks
- (ii) Calculate the open loop steady state speed of the Cart. 4 Marks
- (iii) If the car is driven on open loop, calculate the rise time. 6 Marks
- (iv) If the car is driven on closed loop, calculate the rise time. 6 Marks

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

$$KG_p(s) = \frac{25}{s(s+2)}$$

- (i) Calculate the natural frequency of oscillation
- (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

Question 2 (15 Marks)

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

$$KG_p(s) = \frac{3}{s(0.2s+1)(0.25s+1)}$$

- (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 $r(t) = 6t$ 2 Marks

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

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

- (i) Determine the value of K that will cause sustained oscillations in the closed loop system. 4 Marks
- (ii) Plot the roots of the characteristic equation on the S plane for $K = 0$. 2 Marks
- (iii) Sketch the locus of each root as K varies from 0 to the value obtained in Q2(b) (i) above. 4 Marks

Question 3 (15 Marks)

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

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

- (i) Choose 5 suitable values of frequency in rad/sec and calculate the Bode dB magnitude and phase. 8 Marks
- (ii) Calculate the magnitude $|KG_p(j\omega)|$ for the range of frequencies in Q3(i) above. 2 Marks
- (iii) Plot the values $|KG_p(j\omega)|$ magnitude and angle $\angle KG_p(j\omega)$ and determine the phase and gain margin. 5Marks

Question 4 (15 Marks)

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

$$KG_p(s) = \frac{1.1}{s(2s+1)(0.2s+1)}$$

- (i) Choose 5 suitable values of 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

Student No.....

