CONTROL SYSTEMS
(ECE2202)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) For a second-order system with the transfer function $\boldsymbol{G(s)} = \frac{\mathbf{10}}{(s^2+4s+25)}$, what is the undamped natural frequency?
(a) 2 rad/s (b) 3 rad/s (c) 5 rad/s (d) 25 rad/s

(ii) In the time-domain analysis of a second-order system, what does the term 'damping ratio' (ζ) describe?
(a) The rate at which the system oscillates
(b) The relative speed of the system's response to a step input
(c) The ratio of the system's overshoot to its settling time
(d) The measure of the system's oscillatory nature and how quickly it returns to equilibrium

(iii) Consider a system with a characteristic equation $s^3+6s^2+11s+6=0$. How many roots of this equation lie in the left half of the s-plane?
(a) Zero (b) One (c) Two (d) Three

(iv) The entries in the first column of Routh array of a fourth order system are 5, 2, 1, - 2, 1. The number of poles in the right half plane are
(a) 1 (b) 2 (c) 3 (d) 4

(v) In a Bode plot, if the gain margin is negative, what can be inferred about the system?
(a) The system is stable (b) The system is marginally stable
(c) The system is unstable (d) The system is critically damped

(vi) What is the significance of the gain crossover frequency in a control system?
(a) It is the frequency at which the phase margin is maximized.
(b) It is the frequency at which the open-loop gain is unity (0 dB).
(c) It is the frequency at which the phase is 90 degrees
(d) It is the frequency at which the closed-loop system becomes unstable.

(vii) When the phase cross over frequency is equal to the gain cross over frequency, the system exhibits
(a) sustained oscillation (b) damped oscillatory response
(c) oscillations of increasing amplitude (d) over damped response

(viii) What does the state variable in state-space analysis represent?
(a) The physical output of the system
(b) The set of first-order differential equations describing the system
(c) The internal energy stored in the system
(d) The transfer function of the system

(ix) Which of the following matrices is responsible for defining how the input affects the state in a state-space model?
(a) Matrix A (b) Matrix B (c) Matrix C (d) Matrix D

(x) By the use of a PD control action to a second order system, the rise time
(a) Increases (b) Decreases (c) Remains same (d) Becomes half

Fill in the blanks with the correct word

(xi) The state-space model of a system is typically described by two equations: the state equation and the _____ equation.

(xii) The closed loop transfer function of a control system is $9/(s^2 + 3s + 9)$, then the type of the system is _____.

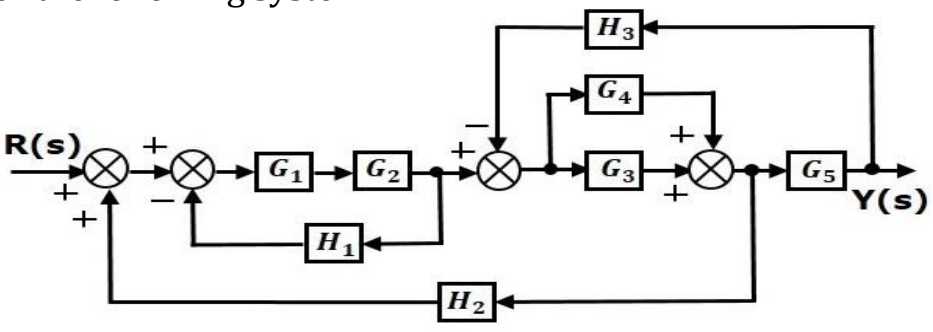
(xiii) For an _____ system, damping factor is less than unity.

(xiv) If all the roots of the characteristic equation lie on the left half of the s-plane, the system is _____.

(xv) With use of PD controller, the rise time of the system _____.

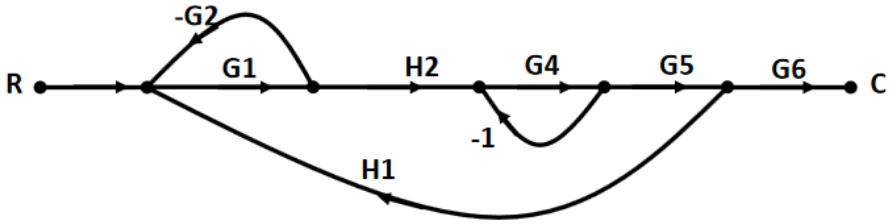
Group - B

2. (a) Use block diagram reduction technique to achieve the overall transfer functions for the following system.



[(CO1)(Apply/IOCQ)]

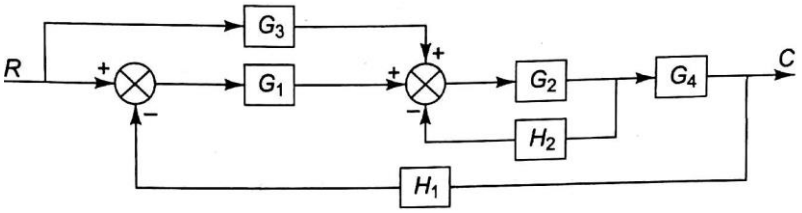
(b) Using Mason's gain formula obtain the overall transfer functions for the following system.



[(CO2)(Apply/IOCQ)]

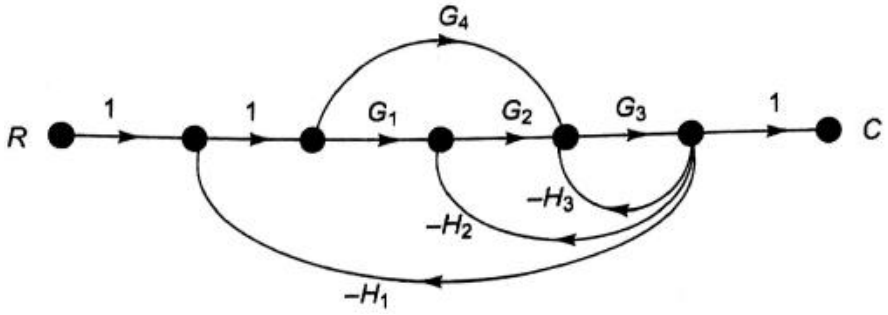
6 + 6 = 12

3. (a) Find out the overall transfer function of the system using block diagram reduction technique.



[(CO2)(Apply/IOCQ)]

(c) Find out the overall transfer function using Mason's Gain formula.



[(CO2)(Apply/IOCQ)]

6 + 6 = 12

Group - C

4. (a) A unity feedback system has $G(s) = \frac{K}{s(s+6)}$, and input r(t)=4t. Determine:

(i) Steady state error for k=180.

(ii) The value of k to reduce error by 6%. *[(CO3)(Evaluate/HOCQ)]*

(b) Explain the effect of adding a pole on the unit step response of a second order system having following transfer function. Here w_n and ζ have their usual meanings.

$$\frac{w_n^2}{s^2 + 2\zeta w_n s + w_n^2}$$

[(CO3)(Remember/LOCQ)]

(c) Using Routh-Hurwitz Criterion, comment on the stability of a system having the characteristic equation $s^5 + 6s^4 + 3s^3 + 2s^2 + s + 1 = 0$. Identify how many poles are lying on the right-hand side if the system is unstable.

[(CO3)(Evaluate/HOCQ)]

4 + 4 + 4 = 12

5. (a) The open loop transfer function of a unity feedback system is given by:

$$G(s) = \frac{K}{s(1+sT)}$$

where K and T are positive constants. By what factor should the amplifier gain be reduced so that the peak overshoot of unit step response of the system is reduced from 75% to 25%? *[(CO3)(Evaluate/HOCQ)]*

(b) The characteristic equation of a system is given by, $s^4 + 20Ks^3 + 5s^2 + 10s + 15 = 0$ Find the range of K, for which the system is stable. *[(CO3)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - D

6. The transfer function of a system is:

$$\frac{200}{(s+1)(s+10)}$$

(i) Construct the Bode plot for the given system.
(ii) Find the frequency at which the phase is -180°.
(iii) Determine the stability of the system based on the phase and gain margins.

[(CO4)(Analyse/IOCQ)]

12

7. The open loop transfer function of a unity feedback system is given by $G(s) = \frac{5}{s(s+1)(s+2)}$. Draw the Nyquist plot and hence comment on its stability. *[(CO4)(Evaluate/HOCQ)]*

12

Group - E

8. (a) A single input single output system is given by

$$\dot{x}(t)=\begin{bmatrix}-3 & 1\\ 0 & -1\end{bmatrix} x(t) + \begin{bmatrix}1\\1\end{bmatrix} u(t);\ y=[1 \quad 1\ ]x(t)$$

Comment on controllability and observability of the system. Also obtain the transfer function of the system. *[(CO5)(Evaluate/HOCQ)]*

(b) Write down the properties of state transition matrix? *[(CO5)(Remember,/LOCQ)]*

9 + 3 = 12

9. (a) A single input single output system is given by

$$\dot{x}(t)=\begin{bmatrix}-0.5 & 0\\ 0 & 3-2\end{bmatrix} x(t) + \begin{bmatrix}0\\1\end{bmatrix} u(t);\ y=[0 \quad 1\ ]x(t)$$

Comment on controllability and observability of the system. *[(CO5)(Evaluate/HOCQ)]*

(b) Obtain the transfer function for the following system with the following state equations

$$\dot{x}(t)=\begin{bmatrix}0 & 1\\ -2 & -3\end{bmatrix} x(t) + \begin{bmatrix}0\\1\end{bmatrix} u(t),\ y=[0 \quad 1\ ]x(t)$$ *[(CO5)(Evaluate/HOCQ)]*

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	7.29	37.50	55.21