CONTROL SYSTEMS
(ECEN 2211)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

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

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) If the gain of an open loop system is doubled, the gain margin
(a) is not affected (b) gets doubled
(c) becomes half (d) becomes $1/4^{th}$.

(ii) The transfer function of a plant is $T(s) = \frac{1}{s^3+0.2s+1)}$. The plant settling time for a step input when it settles to within 2% of its final value is
(a) 20 s (b) 40 s (c) 35 s (d) 45 s.

(iii) The type number of a system with transfer function $T(s) = \frac{10}{s^3(s+2)(s+4)}$, is
(a) one (b) two (c) three (d) four.

(iv) The characteristic equation of a system is $s^2 + 2s + 1 = 0$. The system is
(a) critically damped (b) under damped
(c) undamped (d) over damped.

(v) With use of PD controller, the rise time of the system
(a) decreases (b) increases
(c) remains same (d) none of these.

(vi) The characteristic equation of a unity feedback system is given by $s^4 + 2s^3 + 11s^2 + 18s + 18 = 0$. It will have closed loop poles such that
(a) all poles lie in the left half of the s plane
(b) all poles lie in the right half of the s plane
(c) two poles lie symmetrically on the imaginary axis of the s-plane
(d) no poles lie on the imaginary axis of the s-plane.

(vii) The steady error of a unity feedback control system subjected to unit ramp input is
(a) 2 (b) 1 (c) 0 (d) infinity.

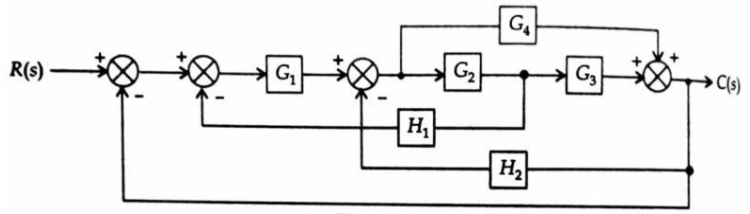
(viii) The function 1/(1+sT) has a slope of
(a) -6dB/ decade (b) 6 dB/decade
(c) -20 dB/decade (d) 20 db/decade.

(ix) A LTI system obeys
(a) principle of superposition (b) principle of homogeneity
(c) both (a) and (b) (d) none of these.

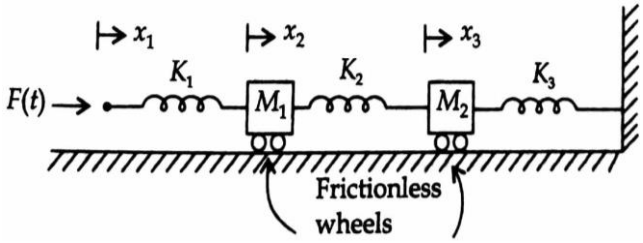
(x) A second order system has transfer function $G(s) = \frac{49}{s^2+16s+49}$ is subjected to a step input signal. The response of the system will exhibit a peak overshoot of
(a) 16 % (b) 9 % (c) 16 % (d) 0 %.

Group- B

2. (a) Evaluate the transfer function $\frac{C(s)}{R(s)}$ for the following figure using block diagram reduction technique. [(CO2)(Evaluate/HOCQ)]

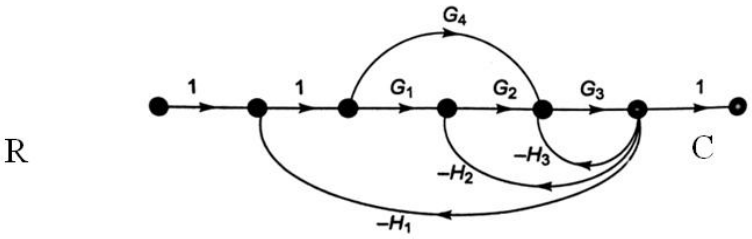


(b) Draw the mechanical equivalent network of the given figure and also Analyse the analogous electrical circuit using force –voltage analogy.



[(CO1)(Analyse/IOCQ)]
7 + 5 = 12

3. (a) Define Mason's Gain formula. Evaluate the overall transfer function C/R for the following signal flow graph.



[(CO2)(Remember/LOCQ, Evaluate/HOCQ)]

(b) Reflect on the advantages of a closed loop system over an open loop one? Define type and order of a system. [(CO1)(Understand/LOCQ)]
(2 + 6) + (2 + 2) = 12

Group - C

4. (a) Sketch the Root locus for the system which has the open-loop transfer G(s)H(s)= $\frac{K}{s(s+5)(s+6)}$. Evaluate the (i) Break-away point, (ii) value of K for marginal stability and (iii) imaginary axis cross over points for the plot.

[(CO3)(Evaluate/HOCQ)]

(b) 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)]

8 + 4 = 12

5. (a) List and define the time response specifications rise time, peak time, peak overshoot and settling time of a second order system step response.

[(CO3)(Remember/LOCQ)]

(b) Draw the root locus for the unity feedback system whose open loop transfer function is $G(s) = \frac{k}{s(s+3)(s+5)}$. Determine the value of k for marginal stability and the frequency of sustained oscillation. [(CO3)(Evaluate/HOCQ)]

4 + 8 = 12

Group - D

6. Draw the Bode plot of the system having open loop transfer function $G(s) = \frac{100(s+10)}{s(s+5)(s+20)}$.

[(CO4)(Analyze/IOCQ)]

12

7. (a) 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)]

(b) Define relative stability. [(CO4)(Remember/LOCQ)]

10 + 2 = 12

Group - E

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

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

Comment on controllability and observability of the system.

[(CO5)(Evaluate/HOCQ)]

(b) A system is described by the following matrices:

$A=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 0 & -2 & -3\end{bmatrix}$, $B=\begin{bmatrix}0\\0\\1\end{bmatrix}$, $C=[1 \quad 2 \quad 0]$. Determine the transfer function.

[(CO5)(Evaluate/HOCQ)]

6 + 6 = 12

9. Write short notes on any three: **(3 × 4) = 12**
   (i) Nyquist stability criterion
   (ii) Gain cross-over frequency and Phase cross-over frequency
   (iii) Error co-efficients
   (iv) PI and PD controller
   (v) Lead compensator. [CO6, Remember,Understand/LOCQ]

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	22.92	17.71	59.37

Course Outcome (CO):

After the completion of the course students will be able to

1. Students will be able to relate their pre-requisite knowledge from Mathematics and Signals & Systems.
2. They will develop the ability to understand mathematical model of physical systems and study their nature, configuration and relevant mapping into equivalent models.
3. The concept and classification of control systems, will be applied to identify, analyze and solve stability related issues in time response, error analysis and stability analysis in an advanced way.
4. Students will be able to evaluate, categorize and justify the margin of stability with respect to the system's nature using frequency domain analysis tools.
5. Students will be able to conceptualize different methods of evaluating system behavior with the help of models compatible to simulation.
6. Students will be able to design controllers according to desired performance specifications which can be applied for system design in higher semesters.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question