CONTROL SYSTEMS
(AEIE 2204)

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

Figures out of the right margin indicate full marks.

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

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

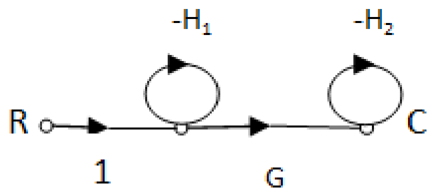
Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) The phase margin of a system is 30 degree and gain margin is 15 db. The system is
(a) marginally stable (b) stable (c) unstable (d) cannot be predicted.

(ii) If the characteristic equation of a system is $s^2 + s + 16 = 0$, the time required to attain the second overshoot of unit step response of the system is
(a) 3.65 (b) 486 (c) 3.17 (d) 2.

(iii)


The overall transmittance of the given system is
(a) $G/(1 + H_1 + H_2)$ (b) $G / (1+H_2)$ (c) G (d) $G / [(1+ H_1)(1+ H_2)]$

(iv) The Nyquist plot of a system encircles -1+j0 point twice in anticlockwise direction in GH plane. If the system has 3 open loop poles in the right side of the s plane, the number of roots of the characteristic equation of the system in the right side of s plane is
(a) 0 (b) 4 (c) 2 (d) 1.

(v) The slope of Bode plot for a transfer function having a pole at origin is
(a) +40db/dec (b) -40db/dec (c) -20db/dec (d) +20db/dec.

(vi) The transfer function of a system is given by $T(s) = 1/(s^4 +2s^3 +4s^2 +5s + 6)$. The number of integrators required to represent the system is
(a) 4 (b) 2 (c) 3 (d) 1.

(vii) If the numbers of open loop poles and zeros of a system are 4 and 1 respectively, the number of root locus branches terminating at infinity is
(a) 0 (b) 2 (c) 3 (d) 1.

(viii) The unit step response of a control system is $c(t) = 1 - e^{-2t}$. The transfer function of the system is

(a) (S-2)/(S+1) (b) (S-2)/(S+1) (c) 2 / [S(S+2)] (d) 2 / (S+2).

(ix) In the state space model of a system having transfer function $T(s) = 1/(s^3 + 4s^2 + 5s + 8)$, the required summing point is

(a) 2 (b) 3 (c) 1 (d) 4.

(x) The order of a system is the total number of

(a) Open loop poles (b) Open loop zeroes

(c) Closed loop zeroes (d) Closed loop poles.

Fill in the blanks with the correct word

(xi) The closed loop transfer function of a system having forward path transfer function G(s) and feedback path transfer function H(s) is _________.

(xii) The steady state error of a system having open loop transfer function $2/[s^2(s+3)]$ with step input is _________.

(xiii) The phase angle condition for root locus is _________.

(xiv) For the two blocks having transfer functions G1(s) and G2(s), the overall transfer function is _________.

(xv) The magnitude condition for root locus is _________.

Group - B

2. (a) Using block reduction technique find the overall transfer function of the system for the block diagram given in Fig.1. *[(CO2)(Analyse/IOCQ)]*

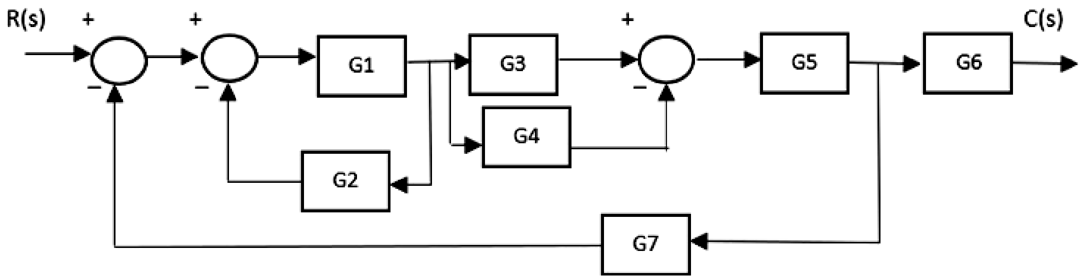


Fig. 1

(b) Draw the signal flow graph for the block diagram shown in Fig.1 and hence find the overall transmittance using Mason's gain formula. *[(CO2)(Analyse /IOCQ)]*

3 + (4 + 5) = 12

3. (a)

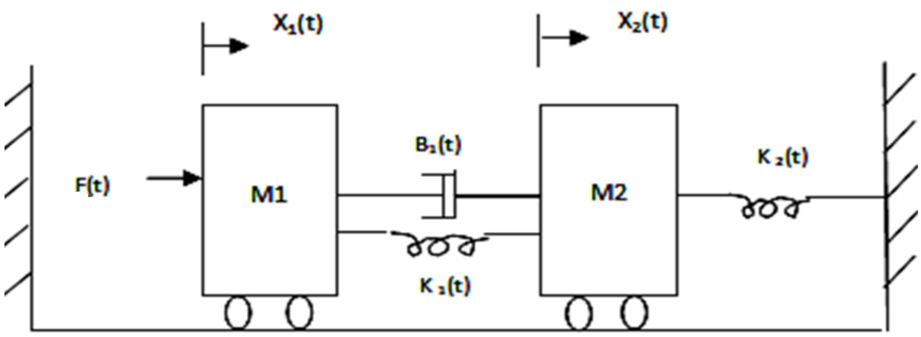


Fig. 2

Represent the given mechanical system shown in Fig. 2 in terms of differential equations considering fc_1 and fc_2 as frictional coefficients for the mass M1 and M2, where F(t) is the applied force and $X_2(t)$ is the displacement of mass M_2.

[(CO1)(Understand/LOCQ)]

(b) Derive the transfer function $X_2(s)/F(s)$ from Fig.2. *[(CO1)(Analyse/IOCQ)]*

(c) Find out the overall transfer function and draw the block diagram of armature controlled dc servomotor considering angular velocity of the shaft as output and applied voltage to the filed winding as input. *[(CO1)(Analyse/IOCQ)]*

4 + 3 + 5 = 12

Group - C

4. (a) If unit step, unit ramp and unit parabolic inputs are applied to a type 1 system, then show which inputs are acceptable for the type 1 system and why?

[(CO3)(Analyse/LOCQ)]

(b) A control system with negative feedback has forward path transfer function G(s) = $k/[s^3+4s^2+s+8]$ and feedback path transfer function H(s) = [1 + 2s]. Using Routh-Hurwitz criteria determine the required value of k and the frequency of sustained oscillation to make the system marginally stable. *[(CO4)(Evaluate/HOCQ)]*

(c) The unit step response of a unity feedback system is $c(t) = e^{-0.3t} - 0.5te^{-0.3t}$. Find the open loop transfer function of the system. *[(CO3)(Evaluate/HOCQ)]*

4 + 5 + 3 = 12

5. (a) For a unity feedback system having open loop transfer function $G(s) = k/[s(s^2 + 2s + 16)]$, find the angle of asymptotes, centroid and break away point (if any).

[(CO4)(Understand/LOCQ)]

(b) For the above system find the angle of departure or angle of arrival and the intersecting point of root locus with the jw axis. *[(CO4)(Understand/LOCQ)]*

(c) Draw the root locus plot and make useful remark on the stability of the system from the plot. *[(CO4)(Analyse/IOCQ)]*

4 + 4 + 4 = 12

Group - D

6. (a) For a unity feedback system having open loop transfer function $G(s) = 3/[s(3s - 1)]$, draw the Nyquist contour in s-plane and map each of the segments in GH plane by necessary calculations. *[(CO5)(Evaluate/HOCQ)]*

(b) Hence draw the Nyquist plot in GH plane. *[(CO5)(Analyse/IOCQ)]*

(c) Write the Principle of Argument and find out all the parameters of it from the Nyquist plot thus obtained. Hence comment on the closed loop stability of the system. *[(CO5)(Apply/HOCQ)]*

6 + 3 + 3 = 12

7. (a) Construct the Bode plot for a unity feedback control system having open loop transfer function $G(s) = 10^7 /[(s + 10)(s+1000)]$. *[(CO5)(Evaluate /HOCQ)]*

(b) From the Bode plot thus obtained, find gain margin, phase margin, gain cross-over frequency and phase cross-over frequency. *[(CO5)(Analyse /IOCQ)]*

(c) Hence comment on the stability of the system. *[(CO5)(Understand /LOCQ)]*

7 + 4 + 1 = 12

Group - E

8. (a) In the state variable model of a linear time invariant system, matrices are given by,

$$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad C = \begin{bmatrix} 1 & 0 \end{bmatrix} \quad D = 0$$

Check the controllability and observability of the system. *[(CO6)(Evaluate/HOCQ)]*

(b) In the state space model of a system, matrix A is given by,

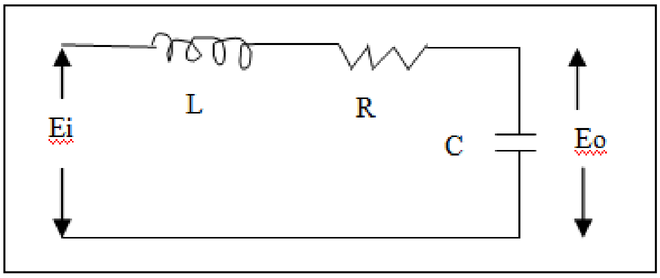
$$A = \begin{bmatrix} -1.1680 & -0.0886 \\ 2.0030 & -0.2443 \end{bmatrix}$$

Find the stability of the system. *[(CO6)(Evaluate/HOCQ)]*

(c) Write the differences between the transfer function representation and state variable representation of a system. *[(CO6)(Remember/LOCQ)]*

6 + 2 + 4 = 12

9. (a)



Find the state equation and output equation of the given system using state variable analysis. Hence draw the state block diagram of the system.

[(CO6)(Analyse/IOCQ)]

(b) What are the advantages of state variable approach of system modelling?

[(CO6)(Remember/LOCQ)]

(6 + 3) + 3 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	25	41.66	33.34

Course Outcome (CO):

After the completion of the course students will be able to
1. Develop mathematical model of physical systems in forms of differential equation and transfer function.
2. Represent the systems using block diagram and signal flow graph models.
3. Investigate the time response of systems and calculate performance indices.
4. Apply the concept of stability in s-domain by using Routh stability criterion and root locus technique.
5. Analyze frequency response and stability of linear systems using different stability criterion.
6. Understand the concept of state variable analysis and compensation techniques for design.

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