CONTROL SYSTEMS
(AEIE 2204)

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) A unity feedback system has open loop transfer function $G(s) = k / s(s^2 + 4)$. The open loop gain k at s= -2 which lies on the root locus branch is
(a) 16 (b) 2
(c) 4 (d) 8.

(ii) A system has a pole at s= 0. The unit impulse response of it
(a) linearly increases with time (b) exponentially increases with time
(c) exponentially decreases with time (d) constant with time.

(iii) The unit step response of a control system is $c(t) = 1 – e^{-10t}$. The transfer function of the system is
(a) 10 / (S+10) (b) (S-10)/(S+1)
(c) (1-S)/(S+10) (d) 10 / [S(S+10)].

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

(v) If the characteristic equation of a system is $s^2 + s + 9 = 0$, the time required to attain the 1st undershoot of unit step response of the system is
(a) 2 sec (b) 2.13 sec
(c) 4.86 sec (d) 3.65 sec.

(vi) For a system Routh-Hurwitz criteria is used to specify
(a) frequency response (b) relative stability
(c) absolute stability (d) time response.

(vii) If the system transfer function is $T(s) = 1/ (s^3+6s^2+3s+7)$, the number of integrators required to represent the system is
(a) 2 (b) 4
(c) 5 (d) 3.

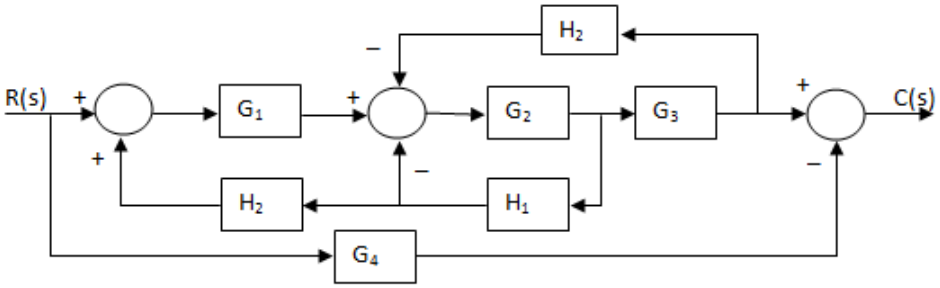
(viii) The gain margin of a system is used to specify
(a) frequency response (b) relative stability
(c) absolute stability (d) time response.

(ix) The Nyquist plot of a system encircles -1+j0 point twice in clockwise direction in GH plane. If the system has no 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) 2 (b) 4 (c) 0 (d) 3.

(x) A system has 4 open loop poles and 1 open loop zero. The asymptotic angles to draw the root locus are
(a) 90°, 270° (b) 45°, 135°, 225°, 315°
(c) 60°, 180°, 300° (d) no asymptotic angles.

Group – B

2. (a)

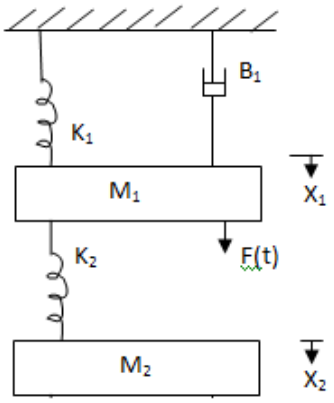


Find the overall transfer function of the system for the given block diagram using block reduction technique. *[(CO2) (Analyse/IOCQ)]*

(b) Draw the signal flow graph for the same block diagram as mentioned in the previous question and hence find the overall transmittance using Mason's gain formula. *[(CO2) (Analyse/IOCQ)]*

6 + (3 + 3) = 12

3. (a)



Draw the free body diagram of the given mechanical system and write the differential equations of the system. *[(CO1) (Understand /LOCQ)]*

(b) Find the transfer function $X_2(s)/ F(s)$ of the above system. *[(CO1) (Understand/LOCQ)]*

(c) Establish the working equations of an armature controlled dc servo motor. Represent the system by block diagram, and derive the transfer function considering angular velocity as the output. *[(CO2) (Analyse/IOCQ)]*

4 + 2 + 6 = 12

Group - C

4. (a) The forward path transfer function of a unity feedback system is given by 1/(2s). Show how the output of the system varies with time when unit step input is applied to the system. Also find the steady state error of this. *[(CO3) (Analyze/LOCQ)]*

   (b) The overall transfer function of a system is given by, $T(s) = (s^2 +5s -6) / (s^4 + 4s^3 + 8s^2 +20s +15)$. Find the number of poles on RHP, LHP and on jw axis using Routh-Hurwitz criteria. Hence comment on the stability of the system. *[(CO4) (Evaluate/HOCQ)]*

   (c) A unity feedback system has open loop transfer $G(s) = k(s+5) / s^2 (s^2 + 6s +4)$. Find the steady state error if unit step input is applied to the system. *[(CO3) (Evaluate/HOCQ)]*

4 + 5 + 3 = 12

5. (a) For a unity feedback system having open loop transfer function $G(s) = k/[s(s^2 + 4s +9)]$, find the angle of asymptotes, centroid and break away point (if any). *[(CO4) (Evaluate /HOCQ)]*

   (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) (Evaluate /HOCQ)]*

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

5 + 4 + 3 = 12

Group - D

6. (a) For a unity feedback system having open loop transfer function $G(s) = 4/ [s(1-4s)]$, draw the Nyquist contour in s-plane and map each of the segments in GH plane by necessary calculations. *[(CO5) (Evaluate /HOCQ)]*

   (b) Draw the Nyquist plot in GH plane from the above calculations. *[(CO5) (Analyze/IOCQ)]*

   (c) Write the Principle of Argument, and find out all the parameters of it from the above Nyquist plot. Hence comment on the closed loop stability of the system. *[(CO5) (Remember/LOCQ)]*

6 + 3 + 3 = 12

7. (a) Construct the Bode plot for a unity feedback control system having open loop transfer function $G(s) = 10 /[s (1 + 0.5s)(1+0.1s)]$. *[(CO5) (Understand/LOCQ)]*

   (b) From the above plot find the gain margin, phase margin, gain cross-over frequency and phase cross-over frequency. *[(CO5) (Evaluate/HOCQ)]*

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

7 + 4 + 1 = 12

Group - E

8. (a) The transfer function of a system is $Y(s)/ U(s) = 1/ (s^2 +4 s +5)$. Find the state equation and output equation of the system using state variable analysis. *[(CO6) (Understand /LOCQ)]*

(b) Hence draw the state block diagram of the system. *[(CO6) (Understand/LOCQ)]*

(c) The state matrix of a system is given by,

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -2 & -3 \end{bmatrix}$$

Derive the roots of the characteristic equation. *[(CO6) (Evaluate/HOCQ)]*

5 + 3 + 4 = 12

9. (a) What are controllability and observability of a system? *[(CO6) (Remember/LOCQ)]*

(b) The state matrix, input matrix and output matrix are given by,

$$A = \begin{bmatrix} 2 & 3 \\ 0 & -4 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad C = \begin{bmatrix} 1 & 0 \end{bmatrix} \quad D = 0$$

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

(c) What are the differences between the state variable approach and transfer function approach for system modelling? *[(CO6) (Remember/LOCQ)]*

2 + 6 + 4 = 12

Cognition Level	*LOCQ*	*IOCQ*	*HOCQ*
Percentage distribution	*32.29*	*29.16*	*38.54*

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.*