CONTROL SYSTEMS
(AEI2203)

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) The closed loop transfer function of a system having forward path transfer function G(s) and negative feedback path transfer function H(s) is
(a) G(s)H(s)/[1+G(s)H(s)] (b) G(s)/[1+G(s)H(s)]
(c) G(s)/[1-G(s)H(s)] (d) G(s)H(s)/[1-G(s)H(s)]

(ii) A force F(t) is applied to a body of mass M. A damper having damping coefficient B and a spring having spring constant K are attached to it. If the displacement of the body be x(t), then the differential equation representing the system is
(a) $F(t) = M\frac{d^2x}{dt^2} + B\frac{dx}{dt} + Kx$ (b) $F(t) - M\frac{d^2x}{dt^2} + K\frac{dx}{dt} = Bx$
(c) $F(t) = B\frac{d^2x}{dt^2} + K\frac{dx}{dt} + Mx$ (d) $F(t) = M\frac{d^2x}{dt^2} - K\frac{dx}{dt} - Bx$

(iii) Mason's gain formula to find out the overall transmittance is given by,
(a) $T = \frac{\sum (P_k \Delta_k)}{\Delta + 1}$ (b) $T = \frac{\prod (P_k \Delta_k)}{\Delta + 1}$
(c) $T = \frac{\sum (P_k \Delta_k)}{\Delta \Delta_k}$ (d) $T = \frac{\sum (P_k \Delta_k)}{\Delta}$

(iv) If the characteristic equation of a system is $s^2+6s+4 = 0$, the system is
(a) Underdamped (b) Critically damped
(c) Overdamped (d) Undamped

(v) If the number 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) 2 (b) 0
(c) 3 (d) 5

(vi) 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 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) 1

(vii) The phase margin of a system is 25° and gain margin is 12 db. The system is
(a) Stable (b) Unstable
(c) Marginally stable (d) Cannot be predicted

(viii) A unity feedback system has open loop transfer function $G(s)=\frac{5}{s^2(s+3)}$. The polar plot of the system terminates with
(a) Magnitude 5, phase -180° (b) Magnitude 0, phase -180°
(c) Magnitude 0, phase -270° (d) Magnitude 5, phase -270°

(ix) In the state space model of a system having transfer function $T(s)= 1/(s^3+ 3s^2 + 7s + 8)$, the required summing point is
(a) 2 (b) 3
(c) 1 (d) 4

(x) A system is represented by, $\mathbf{y} = C\mathbf{x} + D\mathbf{u}$. Here C is the
(a) State matrix (b) Output vector
(c) Output matrix (d) Input vector

Fill in the blanks with the correct word

(xi) If a system has 2 negative real closed loop poles and one pair of closed loop poles on the jw axis, then on the basis of stability the system is ______________.

(xii) A system has a closed loop pole at s = - 5. The unit impulse response of it ____________ exponentially.

(xiii) A system has 4 open loop poles and 2 open loop zeroes. To draw the root locus of it, the number of asymptotic angles need to calculate is __________.

(xiv) If gain cross over frequency is greater than phase cross over frequency, then the system is _____________.

(xv) A unity feedback system with open loop transfer function G(s) = 4 /[s(s+p)] is critically damped. The value of p is __________.

Group - B

2. (a)

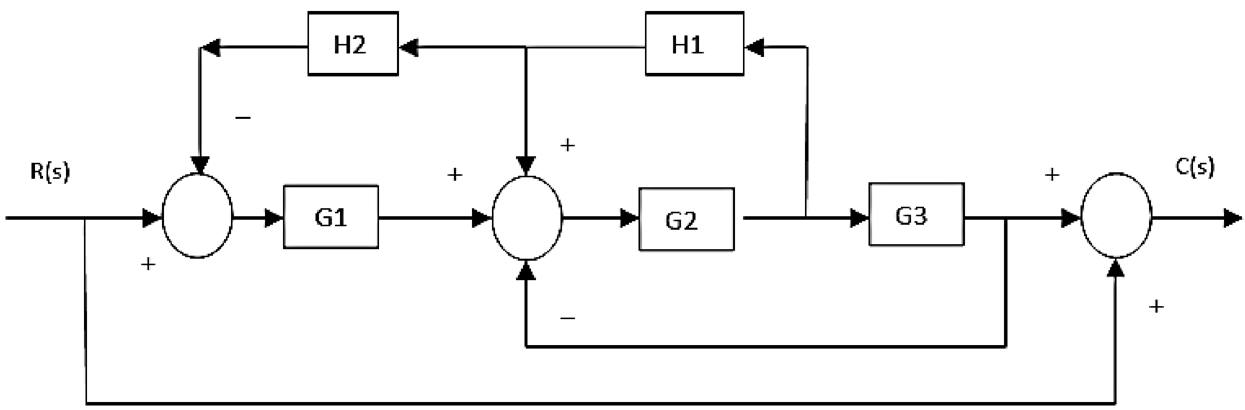

Fig. 1

Draw the signal flow graph of the block diagram given in Fig. 1. Find the overall transmittance of it using Mason's gain formula. *[(CO2)(Analyse/IOCQ)]*

(b) Find the overall transfer function of the system given in Fig. 2 using block reduction techniques. *[(CO2)(Analyse /IOCQ)]*

(3 + 4) + 5 = 12

3. (a)

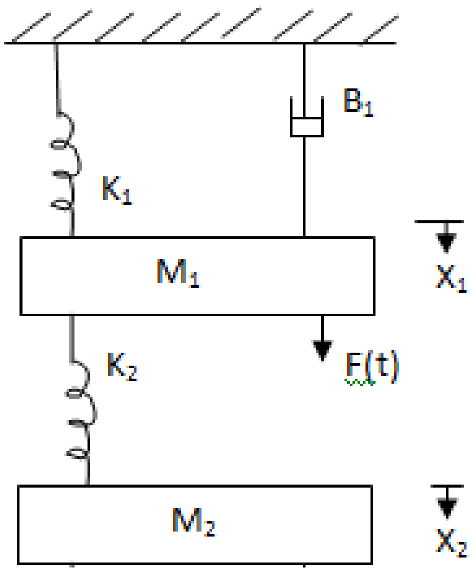

Fig. 2

Draw the free body diagrams of mass M_1 and M_2 in the given mechanical system in Fig. 2. *[(CO1)(Understand/IOCQ)]*

(b) Find the differential equations to represent the given mechanical system and take the Laplace transform of them. *[(CO1)(Analyse/IOCQ)]*

(c) Find the transfer function $X_2(s) / F(s)$. *[(CO1)(Analyse /IOCQ)]*

3 + 5 + 4 = 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. *[(CO3)(Analyse/IOCQ)]*

(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)(Understand/LOCQ)]*

4 + 5 + 3 = 12

5. (a) The open loop transfer function of a system is given by $G(s) = k/[s(s^2 + 4s + 9)]$. Find the number of root locus branches, number of asymptotes, asymptotic angles, centroid and breakaway point (if any). *[(CO4)(Understand/LOCQ)]*

(b) For the system in (a), find the angle of departure or angle of arrival and the intersecting points of root locus with the jw axis. *[(CO4)(Analyse/IOCQ)]*

(c) Plot the root locus and hence comment on the closed loop stability of the system. *[(CO4)(Analyse/IOCQ)]*

5 + 4 + 3 = 12

Group - D

6. (a) Construct the Bode plot for a unity feedback control system having open loop transfer function $G(s) = 1/[s(1 + 0.02s)(1+0.04s)]$. *[(CO5)(Evaluate/HOCQ)]*

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

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

7 + 4 + 1 = 12

7. (a) For a unity feedback system having open loop transfer function $G(s) = k/[s(4s + 1)]$, draw the relevant Nyquist contour in s-plane. Hence map this contour in GH plane by showing necessary calculations and draw the Nyquist plot in GH plane. *[(CO5)(Evaluate/HOCQ)]*

   (b) Using principle of argument find the stability of the system from the Nyquist plot thus obtained. *[(CO5)(Remember/LOCQ)]*

(1 + 5 + 3) + 3 = 12

Group - E

8. (a) The state equation of an LTI system is given by,

$$\dot{X} = \begin{bmatrix} 0 & 1 \\ -2 & -1 \end{bmatrix} X + \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} U$$

   Find the Eigen values of the system. Hence comment on the stability of the system. *[(CO6)(Evaluate/HOCQ)]*

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

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

   Find the transfer function of the system. *[(CO6)(Analyse/IOCQ)]*

(4 + 2) + 6 = 12

9. (a) Write the working equations of a field controlled dc servo motor, represent the system in block diagram and find the overall transfer function of the system. *[(CO6)(Analyse/IOCQ)]*

   (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)(Analyse/IOCQ)]*

(2 + 2 + 2) + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	17.70	54.17	28.13