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 open loop transfer function of a closed loop system is given by
(a) G(s)/H(s) (b) H(s)/G(s)
(c) G(s)/[1+G(s)H(s)] (d) G(s)H(s)

(ii) If the two transfer function blocks having transfer functions G_1 and G_2 are in series, then the overall transfer is
(a) $G_1 G_2$ (b) G_2 / G_1
(c) G_1 / G_2 (d) $G_1 + G_2$

(iii) A Torque T(t) is applied to a rotating shaft having moment of inertia J. A damper having damping coefficient B and a spring having spring constant K are attached to it. If the angular displacement of the body be Θ(t), then the differential equation representing the system is
(a) $T(t) = B\frac{d^2\Theta}{dt^2} + J\frac{d\Theta}{dt} + K\Theta$ (b) $T(t) = J\frac{d^2\Theta}{dt^2} + K\frac{d\Theta}{dt} - B\Theta$
(c) $T(t) = J\frac{d^2\Theta}{dt^2} + B\frac{d\Theta}{dt} + K\Theta$ (d) $T(t) + J\frac{d^2\Theta}{dt^2} + B\frac{d\Theta}{dt} + K\Theta = 0$

(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 all the first column terms of a Routh array are positive non zero, then the system is closed loop
(a) Unstable (b) Stable
(c) Marginally stable (d) None of these

(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 gain margin of a system is used to specify
(a) Relative stability (b) Absolute stability
(c) Time response (d) None of these

(viii) 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) 5
(c) 4 (d) 3

(ix) State space model is used for
(a) Only time invariant systems
(b) Both time variant and time invariant systems
(c) Only time variant systems
(d) None of these

(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) For unit step input, a unity feedback system having open loop transfer function $20/(s^2 + 2s + 5)$ has steady state error _____.

(xiii) A system has a closed loop pole at origin. The unit step response of it _____ linearly.

(xiv) The expression of gain margin 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)

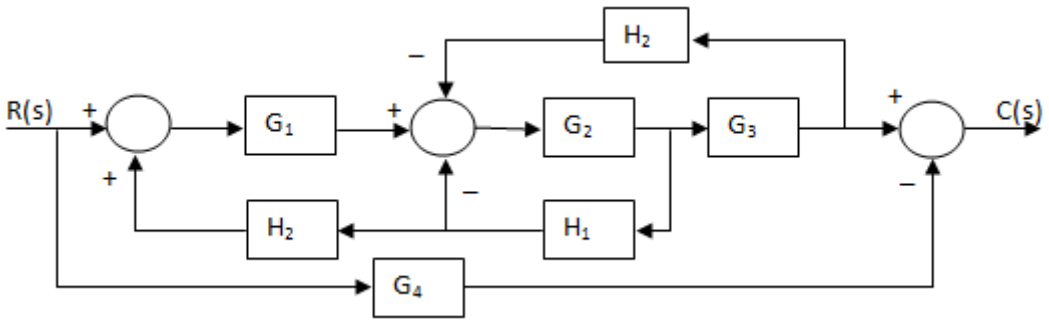

Fig. 1

Using block reduction technique, find the overall transfer function of the system represented by the block diagram in fig.1. *[(CO2)(Analyse/IOCQ)]*

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

5 + (3 + 4) = 12

3. (a)

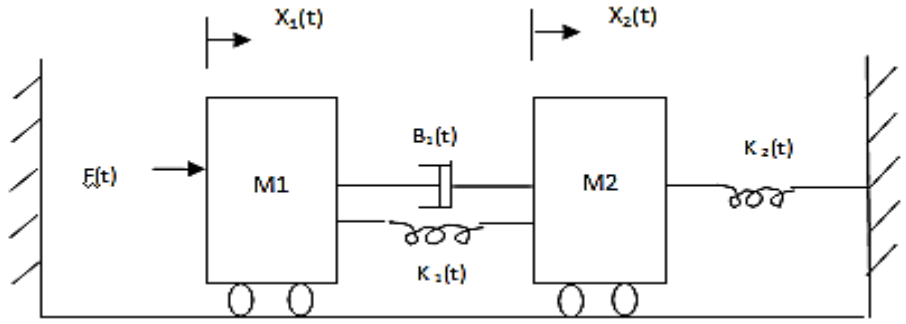

Fig. 2

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

(b) Hence represent the given mechanical system in terms of differential equation considering f_{c1} and f_{c2} as frictional coefficients for the mass M_1 and M_2. $X_1(t)$ and $X_2(t)$ are the displacement of M_1 and M_2 respectively and F(t) is the applied force. *[(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 system is k/s(s+8) and feedback path transfer function is 0.4. Find the value of k and w_n for the damping ratio 0.6. *[(CO3)(Evaluate/HOCQ)]*

(b) For the system given in (a), find the rise time, peak time, percentage peak overshoot and setting time. *[(CO3)(Evaluate/HOCQ)]*

(c) The forward path transfer function of a negative feedback system is $k/(s^3+ds^2+4s+2)$ and feedback path transfer function is (s+2). Find the values of 'd' and 'k' so that the given system oscillates at a frequency of 4 rad/sec. *[(CO2)(Evaluate/HOCQ)]*

3 + 4 + 5 = 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 $G(s) = 10^7 /[(s + 10)(s+1000)]$. *[(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 $G(s) = 3/ [s(3s -1)]$, 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 transfer function of a system is $Y(s)/ U(s) = 1/ (s^2 + 6s +8)$. Find the state equation and output equation of the system using state variable analysis. *[(CO6)(Analyse/IOCQ)]*

(b) Draw the state space block diagram of the system in (a). *[(CO6)(Analyse/IOCQ)]*

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

$$\begin{bmatrix} 0 & 2 & 1 \\ 0 & 4 & 3 \\ 1 & 5 & 2 \end{bmatrix}$$

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

6 + 3 + 3 = 12

9. (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)(Analyse/HOCQ)]*

(b) Draw the state space block diagram of the system in (a). *[(CO6)(Understand/LOCQ)]*

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

$$A = \begin{bmatrix} -1.2653 & -0.1025 \\ 2.5830 & -0.3056 \end{bmatrix}$$

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

6 + 3 + 3 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	19.79	41.66	38.54