LINEAR CONTROL SYSTEMS AND APPLICATIONS
(AEIE 4122)

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

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and <u>any 5 (five)</u> from Group B to E, taking <u>at least one</u> 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 number of open loop poles and zeros of a system are 5 and 2 respectively, the number of root locus branches terminating at infinity is
(a) 5 (b) 3 (c) 4 (d) 0.

(ii) The steady state error for a type 2 system subjected to a unit ramp input is
(a) 2 (b) 0 (c) infinity (d) 1.

(iii) 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.

(iv) Which of the following can be used as an error detector in a control system?
(a) synchro (b) field controlled dc servomotor
(c) armature controlled dc servomotor (d) ac servomotor.

(v) The dominant poles of a system are located at $s = (-2 \pm j2)$. The damping ratio of the system is
(a) 1 (b) 0.8 (c) 0.7 (d) 0.6.

(vi) If the characteristic equation of a system is $s^2 + s + 4 = 0$, the time required to attain the 2nd overshoot of unit step response of the system is
(a) 2 sec (b) 5.55 sec (c) 4.86 sec (d) 3.65 sec.

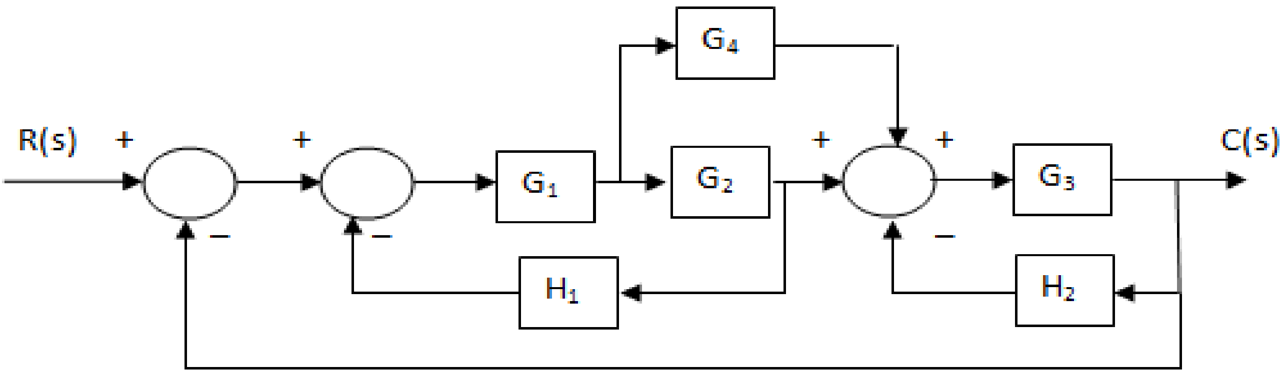
(vii) For a system Routh – Hurwitz criteria gives
(a) relative stability (b) absolute stability (c) both a and b (d) none of these.

(viii) The Bode plot of a system is used to specify
(a) absolute stability (b) relative stability
(c) time response (d) none of these can be predicted.

(ix) The damping ratio of the second order system $2d^2y/dt^2 + 4dy/dt + 8y = 8x$ is
(a) 0.1 (b) 0.25 (c) 1 (d) 0.5.

(x) The type of a transfer function denotes the number of
(a) zeros at origin (b) poles at infinity (c) poles at origin (d) none of these.

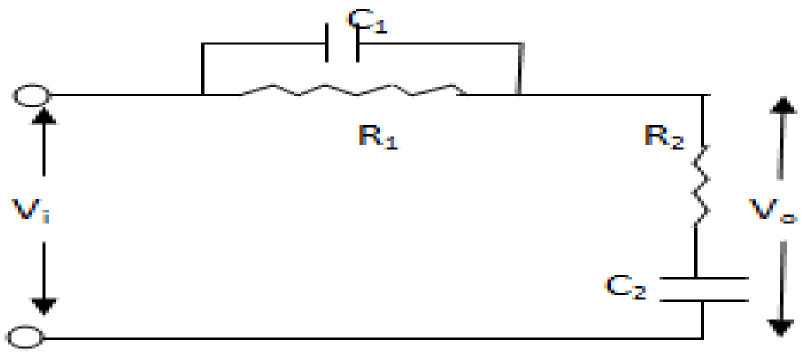
2. (a)



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

(b) For the same block diagram as mentioned in the previous question draw the signal flow graph and hence find the overall transmittance using Mason's gain formula. [(CO2)(Evaluate/HOCQ)]

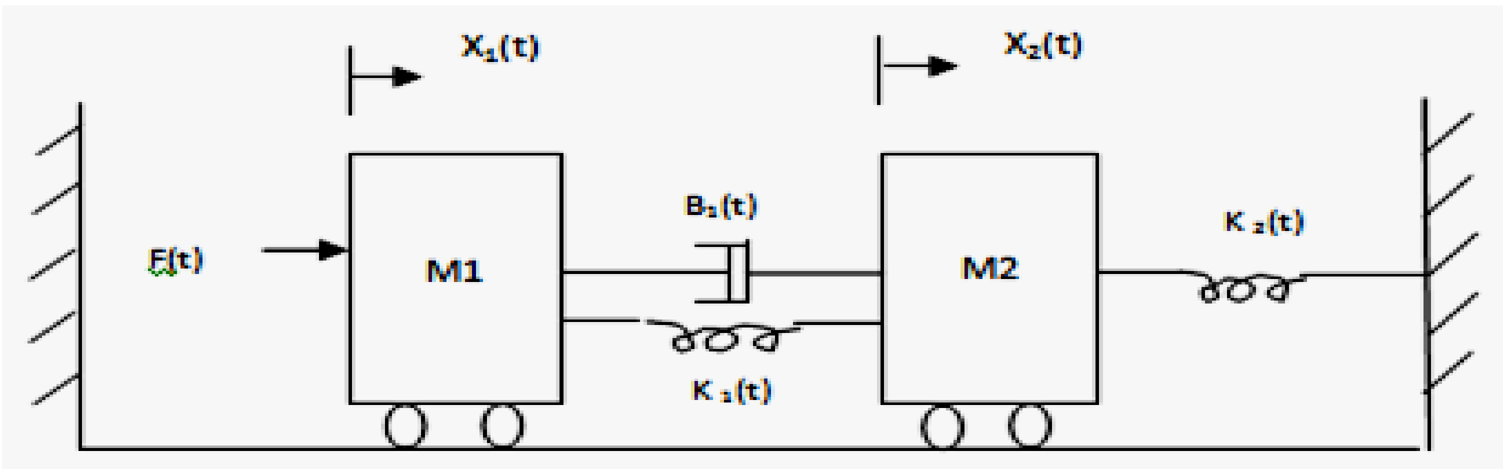
(c) Find the transfer function of the system given below.



[(CO1)(Analyze/IOCQ)]

6 + 4 + 2 = 12

3. (a)



Draw the free body diagram of the masses in the given system and represent the system 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)(Analyse/IOCQ)]

(b) Hence find the transfer function $X_2(s)/F(s)$. [(CO1)(Evaluate/HOCQ)]

(c) What are the advantages of negative feedback? [(CO2)(Understand/LOCQ)]

6 + 4 + 2 = 12

Group - C

4. (a) The forward path transfer function of a unity feedback system is given by 1/(sT). 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)(Evaluate/HOCQ)]

(b) If unit step, unit ramp and unit parabolic inputs are applied to a type 0 system, then show which inputs are acceptable for the given system and why? [(CO3)(Analyse/IOCQ)]

(c) A unity feedback system has open loop transfer $G(s) = k(s+3) / s^2 (s^2 + 4s + 8)$. Find the steady state error if unit ramp input is applied to the system.
[(CO3) (Evaluate/HOCQ)]
(5 + 1) + 4 + 2 = 12

5. (a) A feedback system has forward path transfer function $25 / s(s+1)$ and feedback path transfer function $(2+bs)$. For the unit step input of the system find the value of 'b' such that damping ratio is 0.25. Also find the rise time, peak time, percentage peak overshoot and settling time of the system. [(CO3)(Evaluate/HOCQ)]
(b) The transfer function of a system is given by $T(s) = k / (s^3 + 5s^2 + 7s + k)$. Find the value of k for the system to be oscillatory and hence find the frequency of oscillation.
[(CO4)(Evaluate/HOCQ)]
(3 + 4) + 5 = 12

Group - D

6. (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)(Analyse/IOCQ)]
(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)(Understand/LOCQ)]
7 + 4 + 1 = 12

7. (a) For a unity feedback system having open loop transfer function $G(s)=k/[s(s^2 + 8s + 32)]$, find the centroid of asymptotes, asymptotic angles and breakaway points.
[(CO4)(Evaluate/HOCQ)]
(b) For the above system find out the angle of departure or arrival and intersecting points of root locus with the imaginary axis. [(CO4)(Analyze/IOCQ)]
(c) Hence sketch the root locus plot on the graph paper and comment on the stability of the system. [(CO4)(Understand/LOCQ)]
4 + 4 + 4 = 12

Group - E

8. A unity feedback system has open loop transfer function $G(s) = 9 / s(s+9)$.
(i) Calculate the natural frequency of oscillation, damped frequency of oscillations, damping factor, damping ratio of a unit step input. [(CO6)(Evaluate/HOCQ)]
(ii) If the damping ratio is to be made 0.7 by introduction of a derivative controller, then determine the derivative time constant and find the rise time, peak time, maximum overshoot without derivative control and with derivative control.
[(CO6)(Evaluate/HOCQ)]
(4 + 8) = 12

9. (a) Draw the block diagram of PID control and find out the transfer function of it.
[(CO6)(Understand/LOCQ)]
(b) Design a PID controller with the help of electronic circuit and explain each stage.
[(CO6)(Understand/LOCQ)]

(c) Find the transfer function of a field controlled dc motor. Hence draw the block diagram to represent the system. [(CO6)(Understand/LOCQ)]

3 + 3 + (4 + 2) = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	19.79	30.20	50

Course Outcome (CO):

After the completion of the course students will be able to

1. Derive mathematical model of physical and simulated systems.
2. Execute block diagram reduction and signal flow graph to calculate overall system gain.
3. Investigate the time response of systems and calculate performance indices.
4. Analyze the stability of linear systems using Routh stability criterion and root locus method.
5. Explain frequency response of a process and determine stability using Bode plot.
6. Understand the concept and utility of control actions and its usages.

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