LINEAR CONTROL SYSTEMS AND APPLICATIONS
(AEIE 4122)

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**

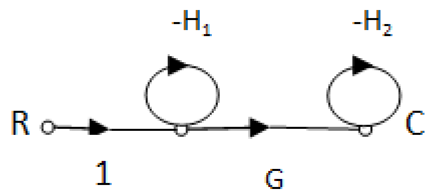
Choose the correct alternative for the following

(i) 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) 4 (b) 16 (c) 2 (d) 8

(ii) Type of a system means
(a) Number of open loop poles at origin
(b) Number of open loop zeroes at origin
(c) Number of open loop complex poles
(d) Number of open loop complex zeroes.

(iii) For the ramp input the steady state error of the system is given by,
(a) $1/K_v$ (b) $1/K_a$ (c) $1/(1+K_p)$ (d) (K_a+1)

(iv)



(a) $G/(1+H_2)$ (b) G (c) $G/[(1+H_1)(1+H_2)]$ (d) $G/(1+H_1+H_2)$

(v) The closed loop transfer function of a negative feedback system having forward path transfer function G(s) and feedback path transfer function H(s) is given by
(a) $\frac{G(s)H(s)}{1+G(s)H(s)}$ (b) G(s)H(s) (c) $\frac{G(s)H(s)}{1-G(s)H(s)}$ (d) $\frac{G(s)}{1+G(s)H(s)}$

(vi) A system having transfer function $G(S) = \frac{1}{2(s+0.5)}$ is subjected to a unit step input, the steady state value of the output is
(a) 1 (b) 2 (c) ½ (d) 1/10

(vii) Using Routh – Hurwitz criteria we can find out
(a) Relative stability of the system
(b) Time response of the system
(c) State matrix of the system
(d) Absolute stability of the system.

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

(ix) If the sign of all the 1st column terms of Routh Array are positive, the system is
(a) Unstable (b) Marginally stable (c) Stable (d) Cannot be predicted.

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

Fill in the blanks with the correct word

(xi) If a closed loop system has 2 complex roots with negative real part and two complex roots lying on the jw axis, then the system is _________.

(xii) The order of the system having closed loop transfer function $2s/s^2(s+1)$ is _________.

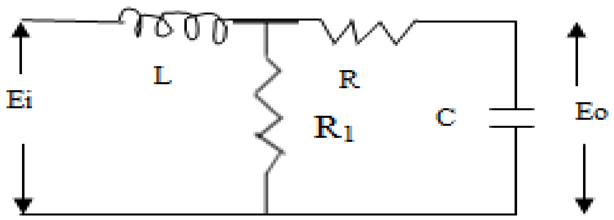
(xiii) If the number of open loop poles and zeroes of a system are 4 and 3 respectively, the number of asymptotic angle is _________.

(xiv) Among the 4 closed loop poles of a system, 3 are negative real and 1 is positive real, then the system is _________.

(xv) The Laplace transform of unit impulse response is _________.

Group - B

2. (a) Establish the differential equations for the given system and take Laplace Transform of them. *[(CO1)(Analyze/IOCQ)]*

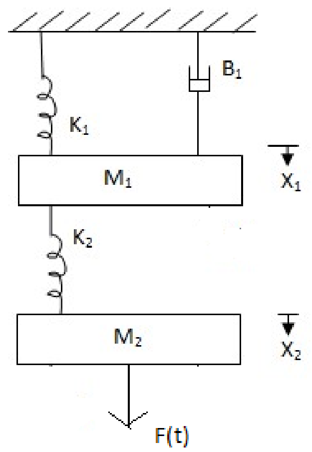


(b) Using the above set of equations draw the block diagram of the system. *[(CO2)(Analyse/IOCQ)]*

(c) Draw the signal flow graph from the above block diagram and caculate theoverall transmittance using Mason's gain formula. *[(CO2)(Analyse/IOCQ)]*

3 + 3 + 6 = 12

3. (a) Draw the free body diagram of the given system and represent the system in terms of differential equations. *[(CO1)(Analyze/IOCQ)]*



(b) Hence find the transfer function $X_1(s)/F(s)$ where F(t) is the applied force and $X_1(t)$ and $X_2(t)$ are the displacement of mass M_1 and M_2 respectively.

[(CO1)(Evaluate/HOCQ)]

6 + 6 = 12

Group - C

4. (a) The open loop transfer function of a unity feedback system is $G(s) = k / [s(Ts+1)]$ .Find the natural frequency of oscillation and damping ratio of the system in terms of k and T. *[(CO3)(Evaluate/HOCQ)]*

(b) For the above system by what factor the gains should be multiplied so that the damping ratio is increased from 0.3 to 0.9. *[(CO3)(Evaluate/HOCQ)]*

(c) Consider the characteristics equation of a control system given by $s^5+3s^4+10s^3+30s^2+169s+507=0$, show that the following three conditions are satisfied:

i. The system has three poles in the left half of the s plane.

ii. The system has four symmetric poles.

iii. The system has two poles in the right half of the s plane. *[(CO4)(Apply/IOCQ)]*

4 + 2 + 6 = 12

5. (a) A control system with negative feedback has forward path transfer function $G(s) = 5 / [s(s+1)+5]$ and feedback path transfer function $H(s) = (s+4)$. Find the natural frequency of oscillation and damping ratio of the system. Also find the rise time, peak time, percentage peak overshoot and settling time for the unit step response of the system. *[(CO3)(Evaluate/HOCQ)]*

(b) The forward path transfer function of a negative feedback system is $G(s) = k / (s^3+ds^2+4s+2)$ 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 4rad/sec.

[(CO3)(Analyze/IOCQ)]

7 + 5 = 12

Group - D

6. (a) Construct the Bode plot for a unity feedback control system having open loop transfer function $G(s) = \frac{200(s+10)}{s(s+5)(s+20)}$. *[(CO5)(Analyze/IOCQ)]*

(b) From the above plot find the gain margin, phase margin, gain cross-over frequency and phase cross-over frequency. *[(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 $G(s) = k/[s(s+4)(s^2+4s+20)]$ 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)(Evaluate/HOCQ)]*

(c) Sketch the root locus plot on the graph paper and remark on the stability of the system. *[(CO4)(Understand/LOCQ)]*

4 + 4 + 4 = 12

Group - E

8. (a) The overall transfer function of a control system is given by $C(s)/R(s) = 16/[s^2 + 1.6s + 16]$. Find out the derivative rate feedback constant K_t for the given system having damping ratio 0.8 if derivative feedback is included in the system.

[(CO6)(Evaluate/HOCQ)]

(b) For the above system find out rise time, peak time, maximum peak overshoot with derivative feedback control. *[(CO6)(Analyze/IOCQ)]*

(c) Also find out rise time, peak time, maximum peak overshoot without derivative feedback control. *[(CO6)(Analyze/IOCQ)]*

3 + 6 + 3 = 12

9. (a) Draw the block diagram of PID controller 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 field controlled dc motor. Hence draw the block diagram to represent the system. *[(CO2)(Understand/LOCQ)]*

3 + 3 + (4 + 2) = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	21.87	46.88	31.25

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.*