Ref. No.: Ex/EE/T/314/2019

B.E. ELECTRICAL ENGINEERING
THIRD YEAR FIRST SEMESTER EXAM 2019

LINEAR CONTROL SYSTEM

Time: Three Hours   Full Marks: 100 (50 Marks for each Part)

Use Separate Answer script for each part

Part-I

Answer any *three* questions from this part.
Two marks reserved for neat and well-organized answer

1. a) Differentiate between static system and dynamic system. State an example of each. 4+4+
   b) Compare the characteristics of D.C. servomotor when used in armature controlled mode and in field controlled mode. (4+4)
   c) Given a unity feedback system with forward path transfer function

$$G(s)=\frac{10(1+0.5s)}{s(1+0.1s)(1+0.05s)}.$$

   (i) With the help of a neat asymptotic magnitude Bode plot, obtain the velocity error constant of the above system.
   (ii) Find the steady state error of the above system to a unit ramp input.

2. The block diagram of a servomechanism is shown in Fig 1 with appropriate parameters. 16

K_S=60 volts/radians
K_A=20 volt/volt
K_M=30*10^{-6} Nm/volt
J=161*10^{-6}Nm/rad/sec
a= Gear ratio=1:30
h= Gear ratio=1:20

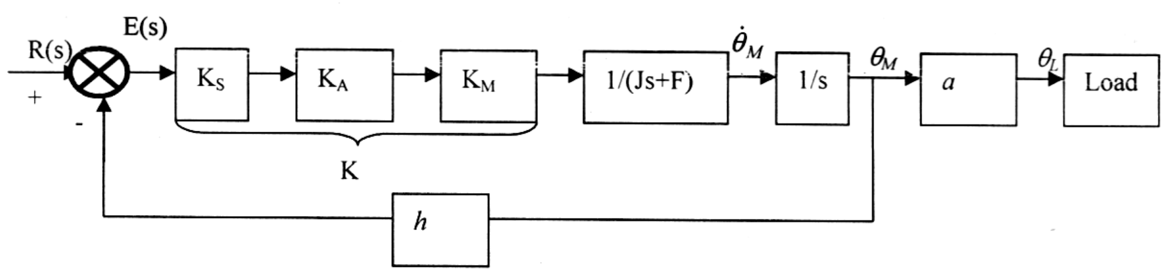

Fig.1

a) With the feedback loop open, calculate the steady state load speed corresponding to an input displacement of 1 degree.
b) Find the value of system (as shown in Fig 1) damping ratio.

[Turn over

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c) Determine the amount of total error rate damping needed to make the damping ratio 0.7 while meeting the specification that the steady state error as seen at the error detector is not to exceed 2 degree for an input velocity of 2 rad/sec.

d) Compute the natural frequency of the system.

3 a) What do you understand by the terms *angular resolution* and *voltage resolution* of a potentiometer? (2+2)+ 4+2+6

b) State *four* limitations of rotary potentiometers.

c) Explain clearly what is meant by the term *nonlinearity of a potentiometer*.

d) The open loop transfer function of a unity feedback control system is given as

$$G(s)=\frac{K}{s(\tau s+1)}$$

Determine the factor by which the gain K should be multiplied so that the overshoot of (closed loop) step response will be reduced from 75% to 25%.

4. a) A system is given by the following closed loop transfer function (3+3)+ 10

$$M(s)=\frac{1}{s^2+2s+1}$$

Briefly discuss the effect of addition of the following to the closed loop transfer function of the system.

(i) a non-minimum phase zero

(ii) a zero in the left-half of the s-plane.

b) Determine the values of K and k for the closed loop system shown in Fig. 2 so that the maximum overshoot in unit step response is 25% and the peak time is 2 sec.

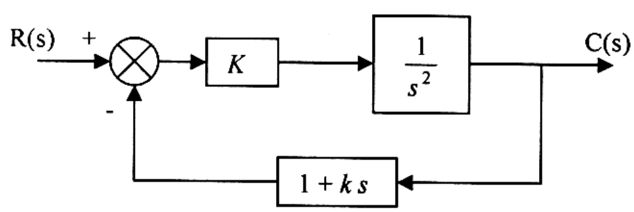

Fig. 2

5 The transfer function of a plant is given by 16

$$G(s)=\frac{K}{s(s+2)(s+5)}.$$

Design a suitable compensator to meet the following specifications:

a) Velocity constant $K_v \geq 10\ \text{sec}^{-1}$.

b) Phase margin $\phi_m \geq 35^{\circ}$.

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Linear Control Systems

Part-II

Use separate Answer-script for each part

Time: Three Hours **Full Marks: 100**

Answer all the Questions.

Q6. Find the roots of the characteristic equation for system whose open loop transfer function is given below. Locate the roots in the s-plane and indicate the stability of the system. 4

$$G(s)H(s) = \frac{1}{(s+2)(s+4)}$$

OR

Q6. Differentiate between "Absolute Stability" and "Relative Stability". 4

Q7. Plot the Root-Locus for a unity feedback system whose forward path transfer function is as follows. 10

$$G(s) = \frac{K(s+1)}{s^2(s+2)}, K \geq 0$$

Also determine and indicate on the sketch i) number and angles of asymptotes, ii) the centroid, iii) the breakaway point/ points, if any, iv) intersection of the root locus and the asymptotes with the imaginary axis, if any v) the range of gain K for which the closed loop system remains stable, vi) any other value that has relevance to the plotting of root locus.

OR

Q7. For the system described by the following open loop transfer function, sketch the Nyquist plot and ascertain the stability of the closed loop system. 10

$$G(s)H(s) = \frac{K}{s^2(1+s)(1+2s)}$$

Q8. State Hurwitz's stability Criterion. Prove that from Hurwitz's stability criterion Routh's stability criterion can be established. 4+2

OR

Q8. By means of Routh's criterion, determine the stability of the system represented by the following characteristic equation. 6

$$q(s) = s^4 + 2s^3 + s^2 + 4s + 2 = 0$$

Q9a. The state model of a third-order system is given below. Find the state transition matrix for the unforced system. 10

$$\frac{d}{dt}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} -2 & 1 & 0 \\ 0 & -2 & 1 \\ 0 & 0 & -2 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

OR

Q9a. An LTI system is described by the following state model. Transform the state model into a canonical model. 10

$$\frac{d}{dt}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 2 \end{bmatrix}u \ldots\ldots y = [1 \quad 0 \quad 0]\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

Q9b. With the help of similarity transformation prove that the state model of an LTI system is not unique. 04

Q10a. State and explain Mason's Gain formula. 04

Q10b. Use the block diagram reduction technique and obtain the overall transfer function of the system given in Fig. P-10. 05

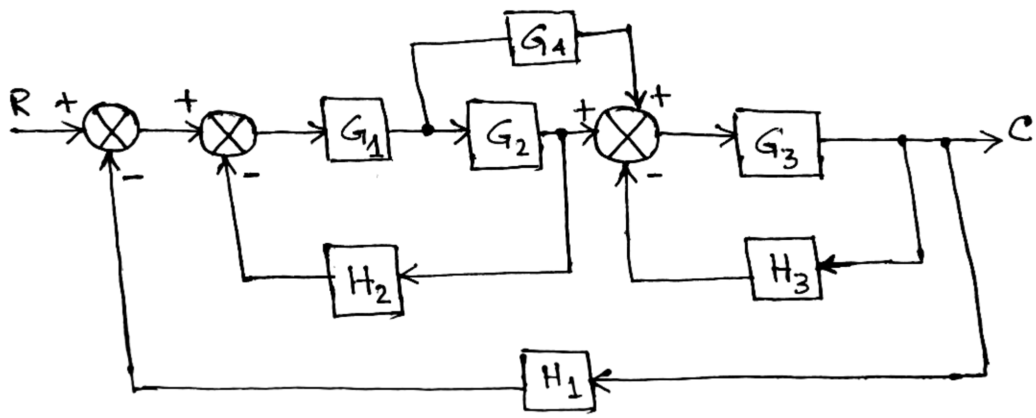

Fig. P-10

Q10c. Draw the signal flow graph for the system depicted in Fig. P-10. Use Mason's Gain Formula and find out the overall transfer function of the system. 07