Code No: R22026 **R10** SET - 1

II B. Tech II Semester Supplementary Examinations January – 2014
CONTROL SYSTEMS
(Com. to EEE, ECE, EIE, ECC, AE)

Time: 3 hours Max. Marks: 75

Answer any **FIVE** Questions
All Questions carry **Equal** Marks
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1. a) Explain the concept of open loop and closed loop control systems. Also distinguish between them.

   b) Write the governing differential equations of the mechanical system shown in Fig. P1

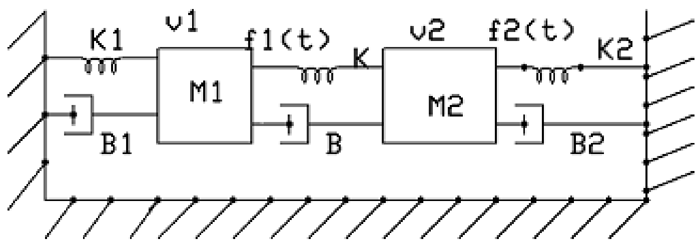

Fig.P1 Mechanical system

2. For the given block diagram shown in Fig. P2, find the transfer function and verify the same through signal flow graph.

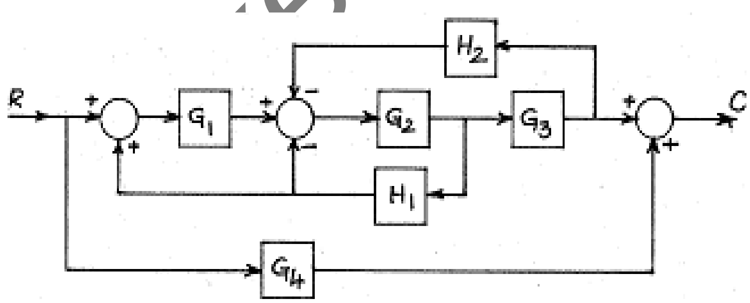

Fig. P2.

3. a) Measurements conducted on a Servomechanism show the system response to be $c(t)=1+0.2e^{-60t}-1.2e^{-10t}$, when subjected to a unit step. Obtain an expression for closed loop transfer function.

   b) A unity feedback control system has an open loop transfer function $G(s)=\dfrac{10}{s(s+2)}$. Find the percentage over shoot, peak time and settling time for 5% of tolerance.
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4. a) The open-loop transfer function of a unity feedback control system is given by $G(s) = \dfrac{K}{(s+2)(s+4)(s^2+6s+25)}$. Discuss the stability of the closed-loop system as a function of K. Determine the values of K, for which the system is stable.
   b) Explain the construction rules for root locus of linear control systems.

5. a) Explain the co-relation between time and frequency responses of second order systems.
   b) Determine the open loop transfer function for the Bode plot shown in Fig.P5.

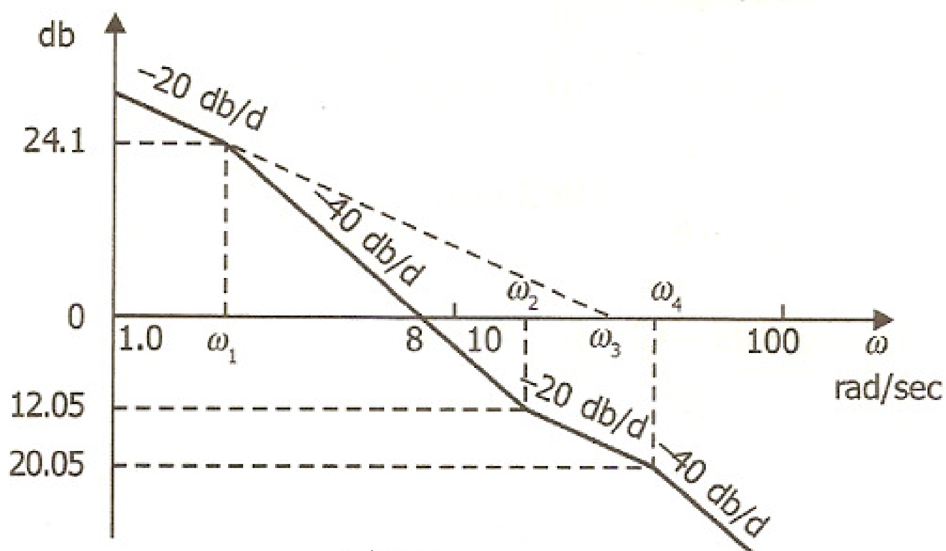

Fig. P5.

6. Consider a feedback system having characteristic equation $1 + \dfrac{K}{(s+1)(s+1.5)(s+2)} = 0$
   It is desired that all the roots of the characteristic equation have real parts less than -1. Extend the Nyquist stability criterion to find the largest value of K, satisfying this condition.

7. A unity feedback system has an open loop transfer function $G(s) = \dfrac{K}{s(s+2)(s+60)}$. Design a Lead-Lag compensator to meet the following specifications: i) Phase Margin is at least 40º, ii) Steady state error for ramp input is 0.04 rad.

8. a) Explain the terms 'state' and 'state variable'. Prove that the state space representation is not unique.
   b) A linear time invariant system is described by the state equation.
   $\dot{X} = \begin{bmatrix} 0 & 6 \\ -1 & 5 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} [u]$ and Y = [1 0] X, $X(0) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$
   Obtain the output response y(t) , t ≥ 0 for a unit step input.

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1. a) Derive the relevant expressions to establish the effect of feedback on sensitivity, signal to noise ratio and rate of response.
   b) Derive an equivalent mathematical model in terms of the coordinate x, and another in terms of θ, for the system given below Fig. P1:

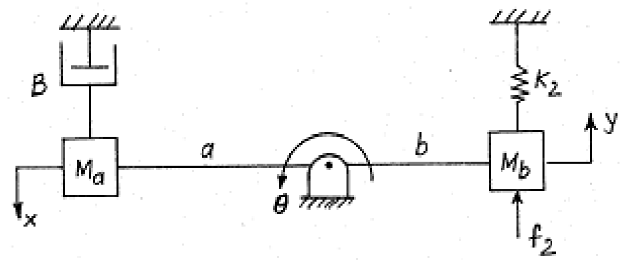

Fig. P1.

2. a) Derive the transfer function of the armature controlled DC servomotor and draw the block diagram.
   b) Using block diagram reduction techniques, find the closed loop transfer function of the system whose block diagram is given in Fig P2.

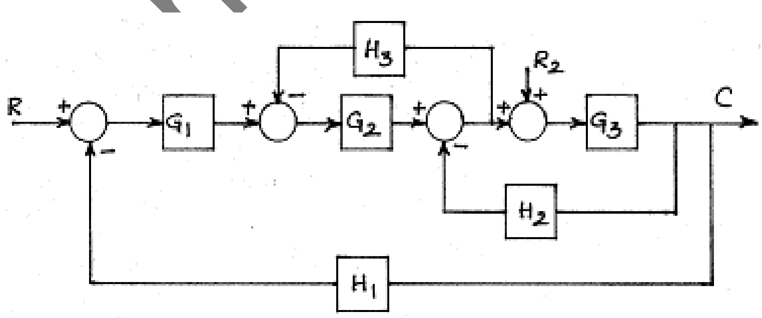

Fig P2.

3. A single loop unity feedback system is described by the equation $\frac{Jd^2\theta_0}{dt^2} + \frac{\mathrm{f}d\theta_0}{\mathrm{dt}} = \mathrm{Ke}$ $e = \theta_1 - \theta_0$, where K=335, J=1.5 and f=20. i) A step displacement of 20^0 is applied at the input terminals. Calculate the maximum overshoot time to reach the peak overshoot, settling time and steady state error of the system. ii) A step velocity input of 0.5rad/sec is applied at the input terminals. Calculate the maximum overshoot, time required to reach the peak overshoot and the time required for the error to stay within 5% of the steady state value.
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4. a) A unity feedback control system, has the open loop transfer function

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

Sketch the root loci and the complementary root loci for the characteristic equation Label all important points and information of loci.

b) The characteristic equation of a feedback control system is given by

$$s^3 + s^2 + (K+1)s + 3K = 0$$

Using RH criterion find the range of K for which the system is stable.

5. Construct the Bode diagram for the open-loop transfer function $G(s) = \dfrac{5}{s(1+0.6s)(1+0.1s)}$.

Determine the phase margin, gain margin and discuss the stability of the closed - loop system.

6. Sketch the Nyquist plot for the loop transfer function: $G(s)H(s) = \dfrac{100}{s(s^2+s+1)(s+1)}$

From the Nyquist plots determine the stability of the closed loop system and also obtain the gain margin and phase margin.

7. Consider a unity feedback system whose open-loop transfer function is G(S) = $\dfrac{K}{s(s+1)s+4)}$ Design a lag-lead compensator such that the static velocity error constant is 10 sec^{-1}, the phase margin is 45^0, and the gain margin is 10 dB or more.

8. a) A feed back system has a closed loop transfer function. $\dfrac{Y(s)}{R(s)} = \dfrac{10}{s(s+1)(s+4)}$.

Construct a state variable model for the system.

b) Consider the homogeneous system given by $\dot{X}$ (t) = $\begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$ X(t)

Find the response X(t) when X(0) = $\begin{bmatrix} 1 \\ 1 \end{bmatrix}$

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1. a) What is the impulse response? Also explain its significance.
   b) Explain merits and demerits of closed loop systems.
   c) For the given lever system shown in Fig. P1, determine the equation relating f and x.

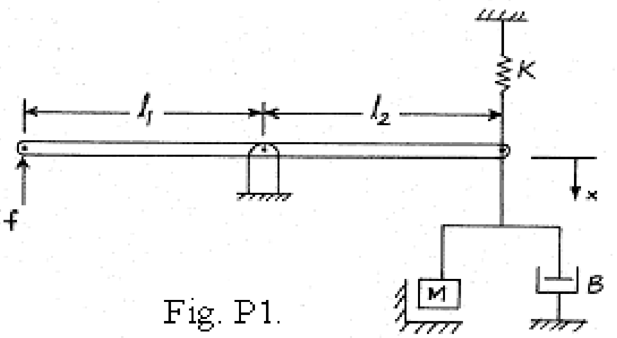

Fig. P1.

2. a) Derive from fundamentals, the transfer function of AC Servo Motor.
   b) Find the transfer function of the system shown in Fig. P2:

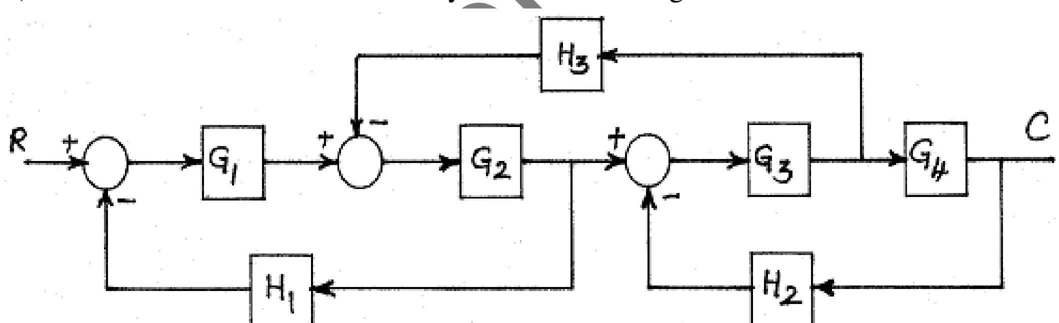

Fig. P2

3. For a unity feedback system $G(s) = \dfrac{36}{s(s+0.72)}$. Determine the characteristic equation of the system. Calculate the undamped frequency of oscillations, damped frequency of oscillations, damping ratio, peak overshoot, time required to reach the peak output and settling time when a unit step input is applied to the system.
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4. a) A feedback system has an open-loop transfer function of $G(s)H(s) = \frac{K}{s(s^2+5s+9)}$.

   Determine the maximum value of K for the closed-loop system to be stable.

   b) Sketch the root locus plot for the control system with a forward transfer function

   G(s) = $\frac{K(s+2)}{s^2+2s+3}$ and H(s) = 1.

5. a) Explain the frequency domain specifications for standard type-1 and second order system.

   b) Plot a Bode diagram for the transfer function $G(s) = \frac{75(1+0.2s)}{s(s^2+16s+100)}$ and find the gain crossover frequency.

6. For the given unity feedback system with open loop transfer function

   $G(s)H(s) = \frac{10}{s^2(0.2s+1)(0.5s+1)}$, sketch the Nyquist plot that correspond to the entire Nyquist path. Determine the values of poles, zeros and number of encirclements with respect to the -1 and determine its relative stability.

7. Consider the unity feedback system whose open loop transfer function is $G(s) = \frac{K}{s(s+3)(s+6)}$.

   Design a lag-lead compensator to meet the following specifications:

   i) Velocity error constant, $K_v = 80$, ii) Phase Margin = 35º.

8. Explain the properties of state transition matrix. A linear time invariant system is described by the state equation:

   $$\dot{X} = \begin{bmatrix} 0 & 6 \\ -1 & 5 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u \text{ and } y = [1 \quad 0]\, X, \qquad X(0) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

   Obtain the state transition matrix, hence obtain the output response y(t) , t ≥ 0 for a unit step input.

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1. a) Explain the feedback characteristics and also explain their effects.
   b) Consider the mechanical system shown in *Figure P1*. Suppose that the system is at rest initially $[x(0)=0, \dot{x}(0)=0]$, and at t=0 it is set into motion by a unit-impulse force. Obtain a mathematical model for the system.

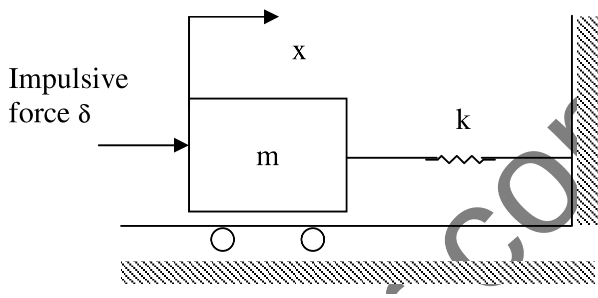

Figure P1

2. a) Find the transfer function of a field controlled DC Servo Motor.
   b) Find the closed loop transfer function of the system whose block diagram is given in Fig.P2

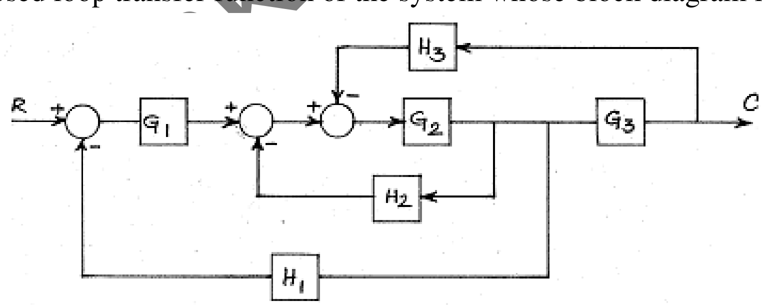

Fig P2.

3. a) Explain the time – response specifications of a standard second order system.
   b) A unity-feedback system in characterized by the open-loop transfer function $G(s)=\dfrac{1}{s(0.5s+1)(0.2s+1)}$. Determine the steady-state error for unit-step, unit-ramp and unit-acceleration input.
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4. a) The characteristic equation of a feedback control system is $s^3 + (K+0.5)s^2 + 4Ks + 50 = 0$. Using R-H criterion determine the value of K for which the system is stable.
   b) Determine i) the number of root loci ii) number of asymptotes iii) root loci on the real axis (if any) for the following transfer function: $GH(s) = \dfrac{K(s+1)}{s^3(s+2)(s+3)}$.

5. The closed loop transfer function of a feedback control systems is given by

$$M(s) = \frac{C(s)}{R(s)} = \frac{1}{(0.01s+1)(0.01s^2+0.05s+1)}$$

   a) Plot the frequency response curve for the closed – loop system.
   b) Determine the peak resonance peak M_P and the resonant frequency ω_p of the system.

6. State and explain Nyquist stability criterion. Draw the Nyquist plot for the open loop transfer function $G(s) = \dfrac{1}{s(1+0.1s)(1+s)}$ and discuss the stability of the closed loop system and determine its relative stability.

7. A unity feedback control system has an open loop transfer function of $G(s) = \dfrac{4}{s(2s+1)}$. It is desired to obtain a phase margin of 45^0 without sacrificing system K_v of the system. Design a suitable lag-network and compute the value of network components assuming any suitable impedance level.

8. a) Derive the relation for complete solution of non-autonomous state space equation.
   b) Construct the state model for a system characterized by the differential equation:

$$\frac{d^3y}{dt^3} + 6\frac{d^2y}{dt^2} + 11\frac{d\ y}{dt} + 6y = u$$

   Draw the block diagram representation of state model.