TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2076 Chaitra

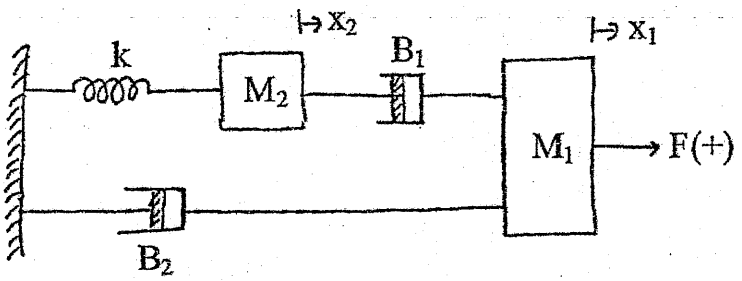
Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BME, BAM, BIE	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Control System *(EE 602)*

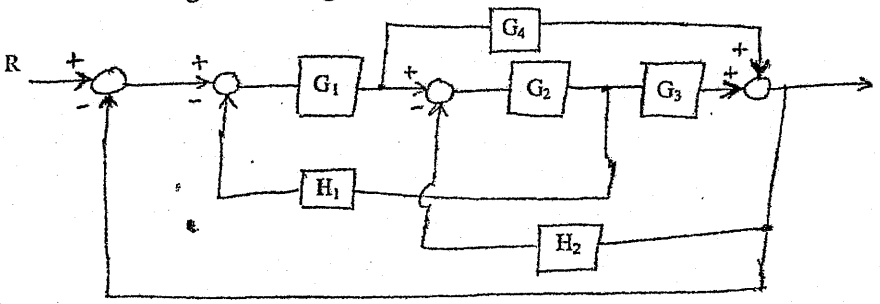
- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt <u>All</u> questions.*
- ✓ *The figures in the margin indicate <u>Full Marks</u>.*
- ✓ *Assume suitable data if necessary.*

1. a) Define control system. Why closed loop control system is more pronounced in modern complex systems rather than open loop control systems. Justify. [6]

   b) The given mechanical system has force, f(t) as input and x1 and x2 as displacement outputs. Draw equivalent f-v and f-I analogous electrical circuit and determine the transfer function with x_2 as output. [10]

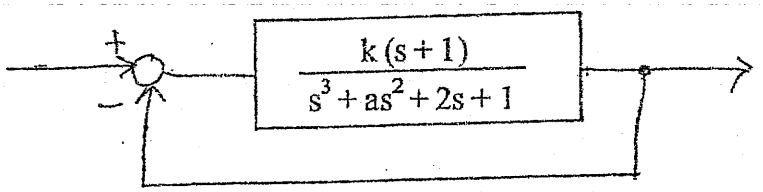


2. a) Reduce the following block diagram and find transfer function. [8]



   b) For a unity feedback system, the open loop transfer function is $G(S)=\frac{50}{s(s+2)}$. With unit step input find maximum overshoot and settling time. Also determine static error coefficients and steady state error if the input to the system is $r(t) = 2 + 4t + 6t^2, t \geq 0$. [8]

3. a) In the following system, determine K if the system just oscillates at a frequency 2 rad/sec. [6]



   b) Draw Bode plot for unity feedback system with open loop transfer function $G(S)=\frac{40(s+2)}{(2+s+25s^2)(1+2s)s}$. Find GM and comment on stability. [10]

4. a) Obtain the transfer function from the following system equations given by, [4]

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -K/M & -B/M \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1/M \end{bmatrix} u$$

$$y = [1 \quad 0] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

b) Sketch the Nyquist contour and plot of unity feedback system having open loop transfer function: $G(S)H(S) = \frac{s+10}{(S-3)(S+3)}$

(i) Comment on stability.
(ii) Determine gain margin. [5+1+2]

c) Discuss briefly about PD controller. [4]

5. a) How does the location of poles affect the stability in control system? [2]

b) For a unity feedback system with feed forward transfer function $G(s) = \frac{10}{s(s+1)}$, design a lead compensator such that the settling time of the system will become 2sec and maximum percent overshoot 5%. [12]

c) Describe angle criteria for a point in s-plane such that the root locus would cross through the point. [2]

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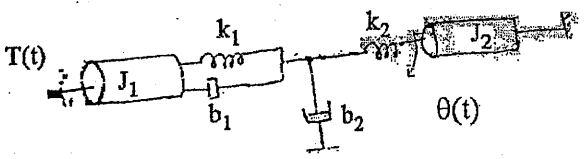
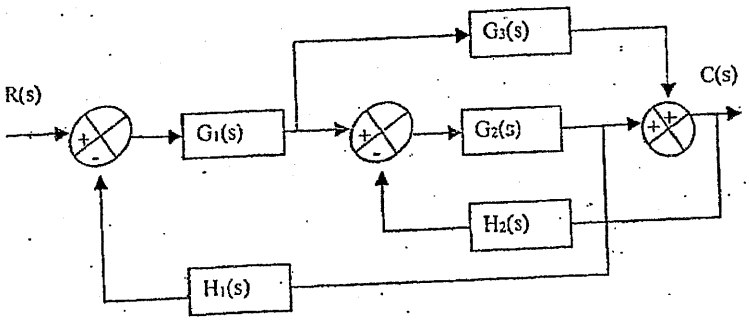
1. a) Which of the system is more sensitive to the disturbance and prove it how? Also discuss effect of gain on response of the system. [4+4]

   b) Find the transfer function $\frac{\theta(s)}{T(s)}$ for the mechanical system rotational system shown below: Also develop T-I analysis circuit. [8]



2. a) Using block diagram reduction technique, find the tr. Function $\frac{C(S)}{R(S)}$ of the figure given below. [8]



   b) A system has 40% overshoot and requires a settling time of 4 seconds when given a step input. Find peak time and rise time. [8]

3. a) Using R-H criteria fin the range of K for system having characteristics equation shown below, to be stable. [6]

$$S^4+2S^3+(4+K)S^2+9S+25=0$$

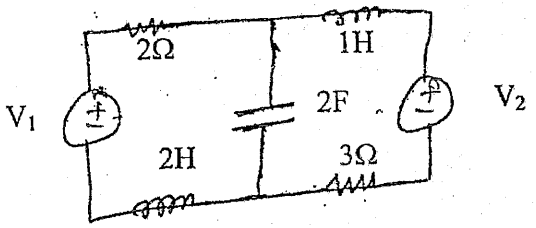
   b) Sketch Rout locus plot for the system with open loop transfer function. [6]

$$G(s)H(s)=\frac{k(s-1)}{s(s-1)}$$

   c) What sort of measures would you apply to track a reference from the actual output of the system? [4]

4. a) Using Nyquist criterion determine the stability of the feedback system whose open loop transfer function is given by $G(s)\,H(s)=\frac{1}{s(1+2s)(1+s)}$ and what is its gain margin? [10]

b) Develop state space model for circuit below. [6]



5. a) Consider a system shown below. The open loop transfer function is given by: $G(s)H(s)=\frac{2}{s(s+1)(s+2)}$. It is desired to compensate the system, so that the static velocity error constant K_v is 5 per second. The phase margin is at least 40° and gain margin is at least 10dB. Determine transfer function of appropriate lag compensator. [12]

b) Consider a point P in s-plane which actually indicate dominant closed loop pole of the system. How would you recognize that the root locus passes through the point P? [4]

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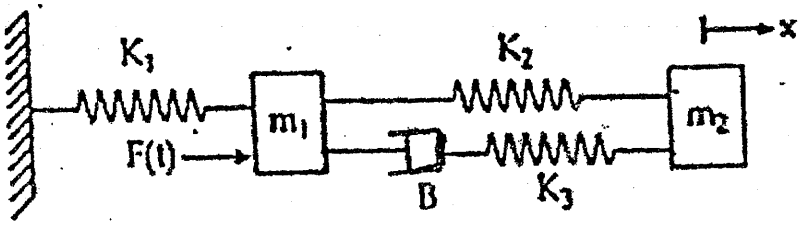
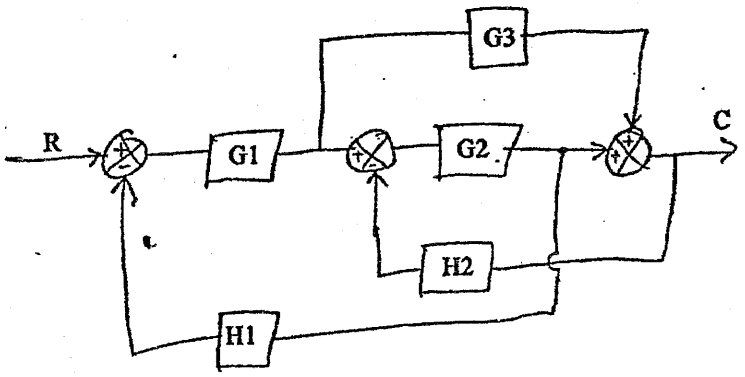
1. a) What is control system? Draw the block diagram of a closed loop control system and briefly explain the function of each block. [6]

   b) Find the transfer function. $\frac{X(S)}{F(S)}$, for the mechanical system of figure below. Also draw the F-V and F-I analogy circuit of the sy stem. [10]



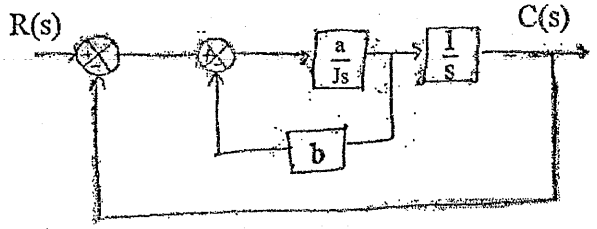
2. a) Develop Signal Flow graph for the block diagram model below and find transfer function using Mason's gain formula. [2+6]



   b) Check stability for the system with open loop transfer function $G(S)H(S)=\frac{2}{2s^5+3s^4+2s^3+s^2+2s}$ using R-H criterion. [4]

   c) What is derivative controller? How and why it can be useful? [4]

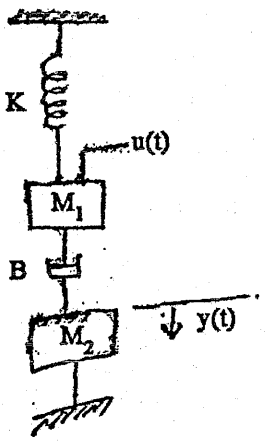
3. a) Determine values of a and b of the closed loop control system shown below, so that maximum overshoot for unit step input is 25% and the peak time is 2 sec. Assume that J=1 kg/m^3. [6]



b) Sketch Root locus plot for the system open loop transfer function $G(s)H(s) = \frac{k(s+2)}{s((s+1)(s^2+8s+64)}$. Discuss the region for stability, unstability and marginal stability. What is frequency of oscillation at the point of marginal stability? [10]

4. a) the open loop transfer function of closed loop system is $G(s)=\frac{2}{s(s+1)(2s+1)}$. Using Niquist Criterion, determine closed loop stability of this system. [8]

b) Consider a mechanical system shown in figure below. The external force u(t) is input to the system and displacement y(t) of the mass is the output. Obtain the state space representation of the system. [8]



5. Why lead compensator is required? Design a suitable lead compensating network for $G(S) = \frac{k}{s^2(1+0.25s)}$ to meet the following specification K_a=10 sec^{-1} P.M $\geq 35°$. [2+14]

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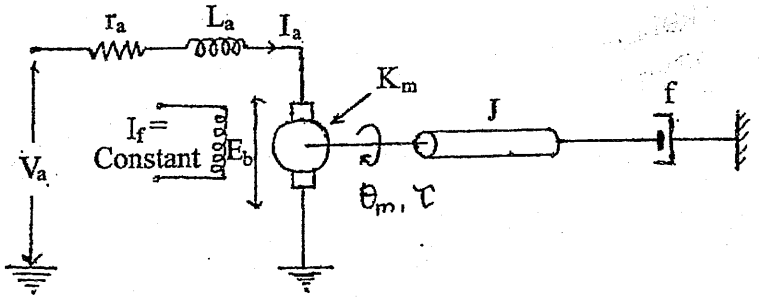
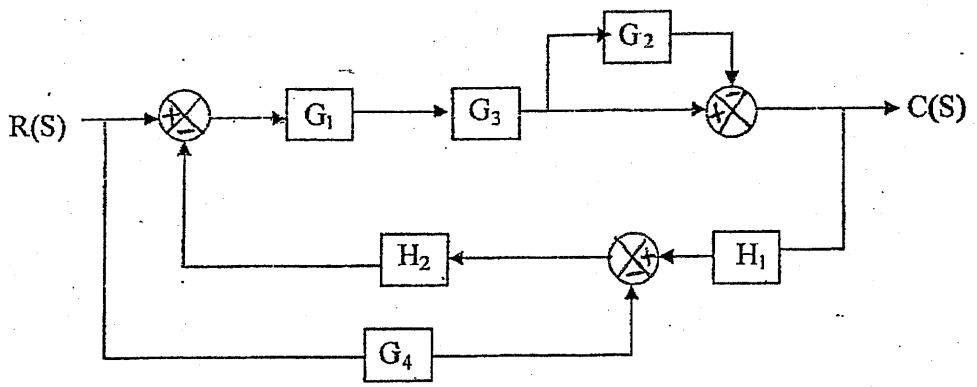
1. a) What is control system? Draw the block diagram of a closed loop control system and briefly explain the function of each block. [5]

   b) Show that the speed of response increases with the increase of the gain of the system. [3]

   c) Find the transfer function $\frac{\theta_m(S)}{V_a(S)}$ of the system below by constructing the block diagram. [8]



2. a) Determine the transfer function of the given system by reducing blocks. [8]



   b) Consider a unity feedback control system with the closed loop transfer function

$$\frac{C(S)}{R(S)} = \frac{Ks+b}{(s^2+as+b)}$$

   Determine the open loop transfer function. Show that the steady state error in the unit ramp input response is given by [5]

$$e_{ss} = \frac{a-k}{b}$$

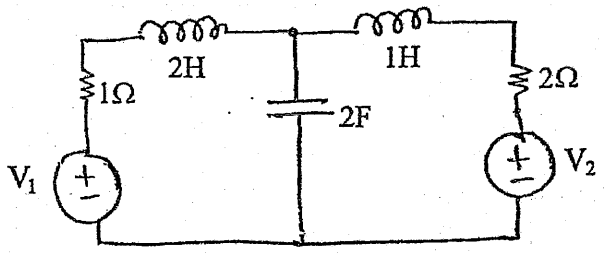
   c) How we can perform relative stability analysis using RH-Criteria? [3]

3. a) For a unity feedback system the open loop transfer function of a control system is given by [10]

$$G(S)=\frac{k}{s(s+4)(s^2+4s+20)}$$

Sketch the root locus for $0 \le K \le \infty$ and determine the breakaway point, the angle of departure from complex poles and the stability conditions.

b) Write the state equation for the circuit shown below. Also write output equation. [6]



4. a) Discuss working of PI controller. [4]

b) Suppose that the step response of a first order system is $C(t)=5(1-e^{-t/5})$. What are impulse and ramp responses? [4]

c) Sketch the Nyquist Plot of Unity feedback system having open loop transfer function and $G(S)H(S)=\frac{s+10}{(s-3)(s+3)}$. Comment on stability. What is gain margin? [8]

5. a) Discuss the purpose of lead and lag compensators. [4]

b) Design a suitable phase lag compensating network for $G(S)=\frac{k}{S(1+0.1s)(1+0.2s)}$ to meet the following specification [12]

$K_v = 30\ Sec^{-1}$

$P.M \ge 40°$

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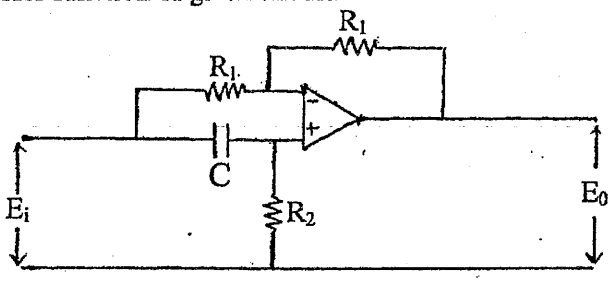
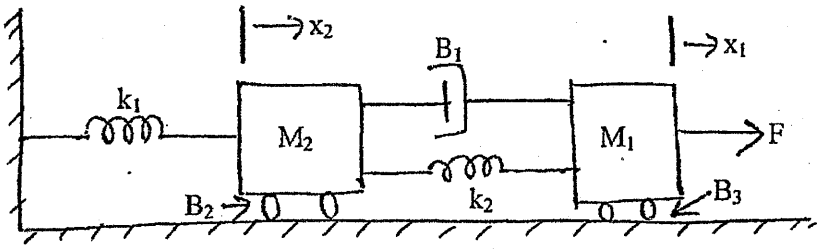
1. a) Inspite of cost and complicated design, closed loop control system are widely preffered over open loop control system. Justify the statement with some examples. [4]

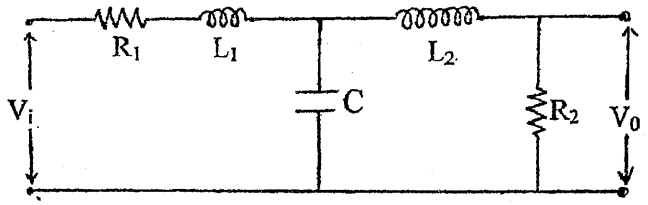
   b) Find the transfer function of given circuit. [4]



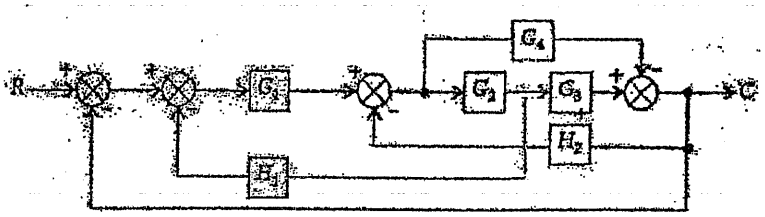
   c) For the mechanical system shown below find the transfer function $M_2(s)/F(s)$. Draw the force voltage analogy. [6+2]



2. a) Develop block diagram model for the circuit shown in figure below. [4]



   b) Using Masons gain formula, find the tr. Function $\frac{C(S)}{R(S)}$ of the fig given below. [8]



   c) Using R-H criteria, tell how many roots of polynomial is in right half s-plane. [4]
   $S^5 + 4S^4 + 2S^3 + 8S^2 + S + 4 = 0$

3. a) Fig (ii) is step response of system as in fig (i) find K and P. [6]

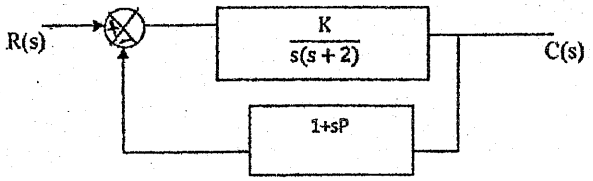


Fig. (i)

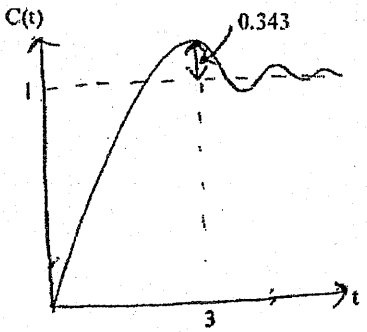


Fig. (ii)

b) Sketch the root locus for unity feedback the system having the forward path transfer function $G(S)=\frac{K}{(s^2+2s+2)(s^2+2s+5)}$ [10]

4. a) Using Nyquist criterion determine the stability of the feedback system whose open loop transfer function is given by

$$G(S)H(S)=\frac{(S+5)}{(S-2)(S+2)}$$

Also find GM. [8]

b) A system is characterized by the equation

$$\frac{Y(S)}{U(S)}=\frac{20(4s+2)}{s^3+5s^2+8s+2}$$

Find its state and output equation and express in matrix form. Then using your matrix, how do you get characteristic equation? [8]

5. a) Discuss effect of addition of a zero to a system. [4]

b) The open loop transfer function of a system is given by:

$$G(S)=\frac{1}{S(S+1)(0.5S+1)}$$

Compensate the system, such that, $K_v = 5\ sec^{-1}$ and phase margin is at least 40° and the gain margin is at least 10 dB with a lag compensator. [12]

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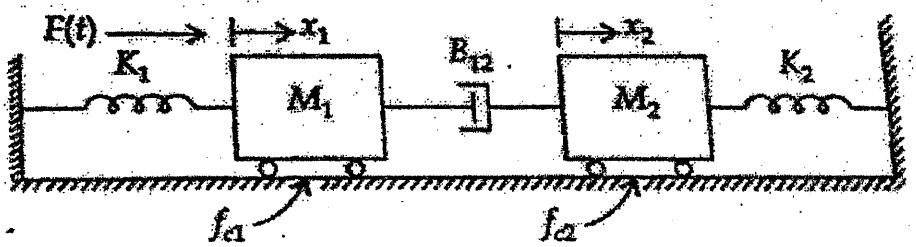
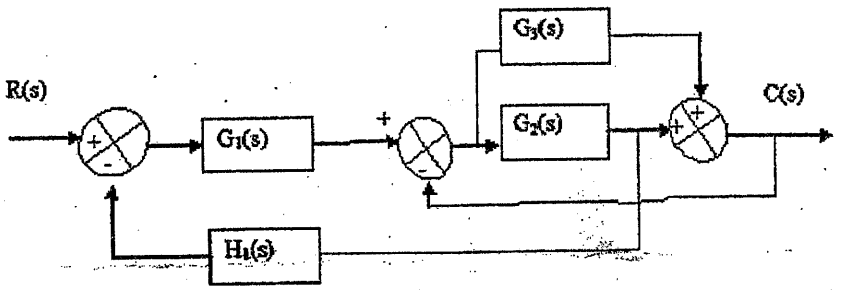
1. a) What is control system? Draw the block diagram of a closed loop control system and briefly explain the function of each block. Mention also the advantages of closed loop system over open loop system. [8]

   b) Construct the free body diagram and write the differential equations for the mechanical system given below and determine $X_2(s)/F(s)$. Also draw F-V analogy of the system below. [2+2+2+2]



2. a) Using Masons gain formula, find the tr, Function $\frac{C(S)}{R(S)}$ of the figure given below. [8]



   b) The system below in figure (a) when subjected to a unit step input, the output response is as shown in figure (b). Determine the value of K and T. [8]

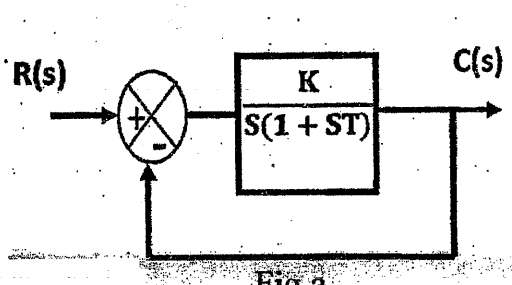


Fig a

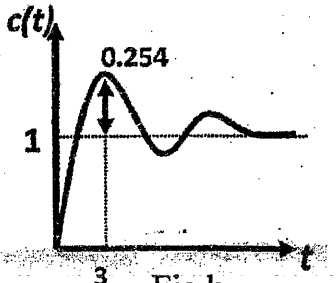


Fig b

3. a) Construct Routh array and determine the stability of the system whose characteristic equation is $s^6+2s^5+8s^4+12s^3+20s^2+16s+16=0$. Comment on the location of the roots of characteristic equation. [6]

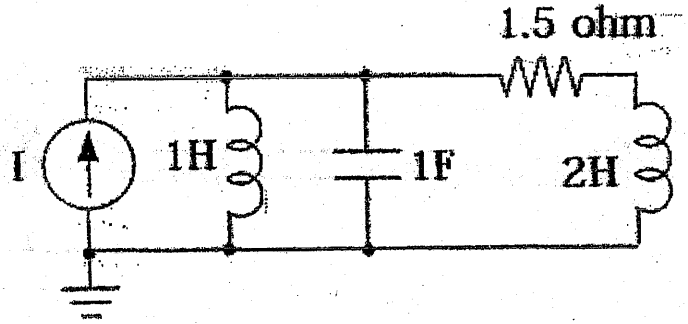
b) For a unity feedback system, the open loop transfer function of a control system is given by:

$$G(S)=\frac{K}{s(s+2)(s^2+6s+25)}$$

Sketch the root locus for $0 \le K \le \infty$ and determine the breakaway point, the angle of departure from complex poles and the stability conditions. [10]

4. a) Using Nyquist criterion, determine the stability of the feedback system whose open loop transfer functions is given by $G(s)\,H(s)=\frac{1}{s(1+2S)(1+S)}$ [8]

b) Develop state space equations for the following circuit considering voltage of 1F capacitor as output. "I" is input to the system. [8]



5. What would happen if zero is added to left half s-plane? Design a lead compensator for a unity feedback system with its feedforward transfer function as $G(s)=\frac{4}{s(s+2)}$ such that its settling time would be 2 sec but without change in maximum percent overshoot of its unit step response. Also velocity error constant should not be less than 2.5 per sec. [2+14]

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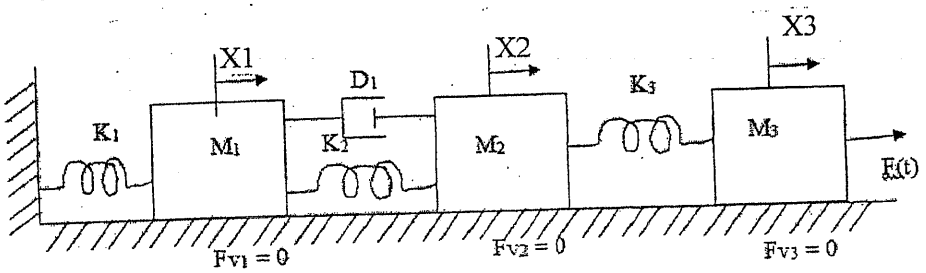
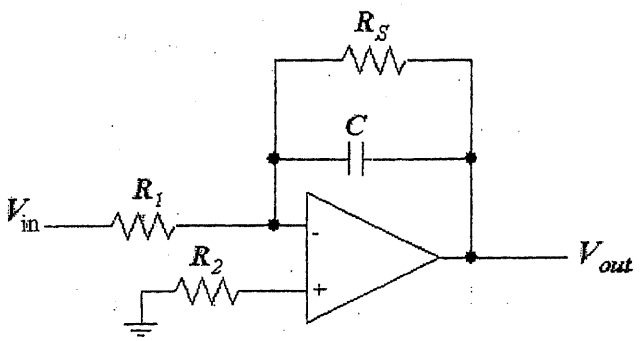
1. a) How would a closed loop system differ from open loop one on its steps response? Give analytical explanation. [6]

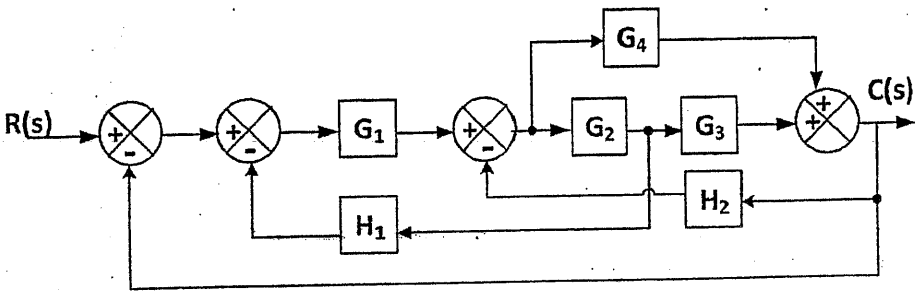
   b) Find the transfer function, $\frac{X2(S)}{F(S)}$, for the mechanical system of figure below. Also draw the F-V and F-I analogy circuit of the system. [6]



   c) Find transfer function of an op-amp model as below. [4]



2. a) Determine the overall transfer functions C(s)/R(s) of the given system by block diagram reduction technique. [8]



   b) Using R-H criteria, tell how many roots of polynomial given below is in right half s-plane, in left half s-plane and on jw axis. Comment on stability. [8]

$$s^6 + 3s^5 + 4s^4 + 6s^3 + 5s^2 + 3s + 2 = 0$$

3. a) The open loop transfer function of a control system is [8]

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

Using Nyquist criterion, determine the open loop and closed loop stability of this system.

b) The open loop transfer function of a unity feedback system is given by [8]

$$G(S)=\frac{108}{S^2(s+4)(s^2+3s+12)}$$

Find the static error coefficients and steady state error of the system when subjected to an input given by $r(t)=2+5t+8t^2$

4. a) Draw Bode Plot for the system with transfer function $G(s)=\frac{20s+200}{(s^2+4s+25)(s^2+40s)}$

Determine gain margin, phase margin and comment on stability of the system according to your plot. [8]

b) Given state equation and output equation, find transfer function $\frac{Y(S)}{U(S)}$ and determine the poles and zeros. [8]

$$X=\begin{bmatrix}0 & 1 & 0\\ -1 & -1 & 0\\ 1 & 0 & 0\end{bmatrix}X+\begin{bmatrix}0\\1\\0\end{bmatrix}u \quad \text{and} \quad y=\begin{bmatrix}0 & 0 & 1\end{bmatrix}X$$

5. a) State whether the statement "Derivative controllers are always used with other controllers" is true or false and justify your answer. [1+3]

b) Design a lead compensator for a system having open loop transfer function $G(s)H(s)=\frac{k}{s(1+0.1s)(1+0.001s)}$ so that the designed system should have PM $\geq 45°$, $K_v=1000\ \text{sec}^{-1}$ [12]

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21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2072 Chaitra

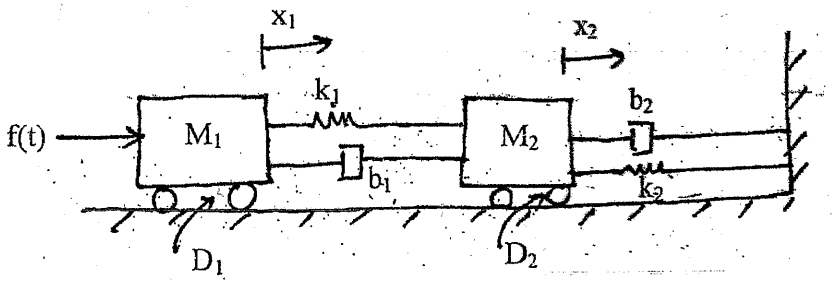
Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BME, BIE	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Control System *(EE602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

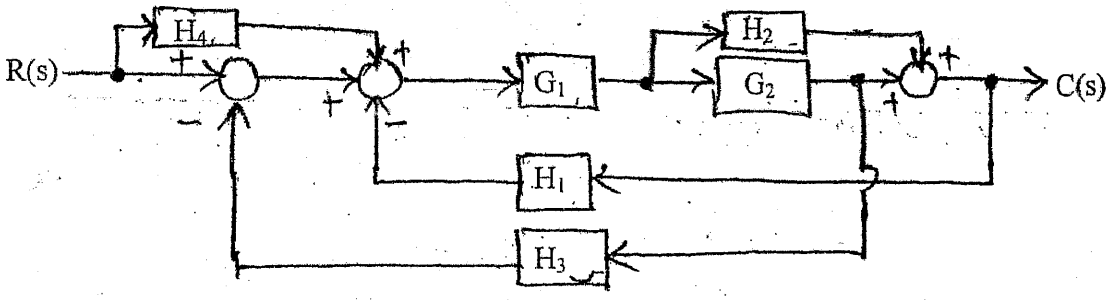
1. a) Define linear time invariant system. Justify the statement "modern complex systems are more pronounced with closed loop control system". [4]

   b) The given mechanical system has force f(t) as input and x_1 and x_2 as displacement outputs. Draw equivalent F-V analogous circuit and determine the transfer functions $X_1(S)/F(S)$ and $X_2(S)/F(S)$. [8]

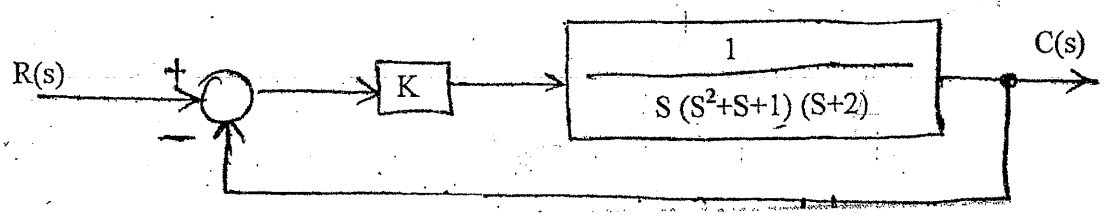


   c) Discuss, how a closed loop system has better disturbance rejection and command input tracking capabilities in comparision to an open loop system. [4]

2. a) Find Transfer function of the following system. [8]

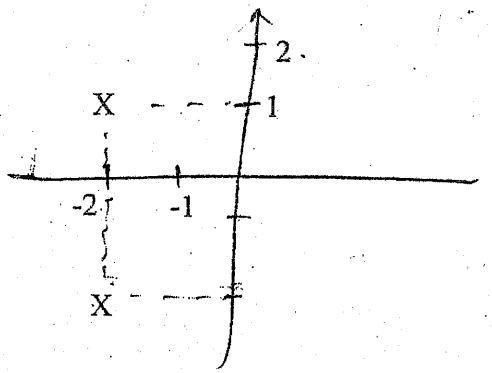


   b) Find the range of 'K' for stable operation using R-H criteria. [4]



   c) Explain how RH (Routh Hurwitz) method is used for determining relative stability. [4]

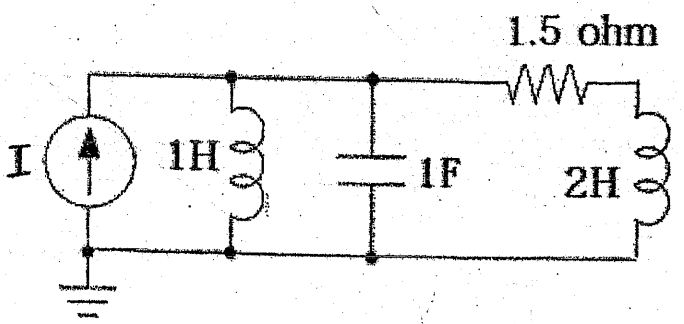
3. a) Open loop pole/zero plot of a unity feedback system are shown in figure below. Determine maximum overshoot and setting time for its step response. [6]



b) If desired damping ratio is '1' , which controller do you suggest, explain. [4]

c) Determine value of 'K' and 'b' so that the unity feedback system with open loop transfer function; $G(s)=\frac{K(s+1)}{s^3+bs^2+3s+1}$ [6]

4. a) Develop state space equations for the following circuit considering voltage of 2H inductor as output. I is input to the system. [6]



b) Draw Bode plot for the system with transfer function $G(s)=\frac{4s+40}{(s^2+4s+25)(s^2+50s)}$. Determine gain margin, phase margin and comment on stability of the system according to your plot. [10]

5. a) Compare the Lag and Lead compensator applications in control system. [4]

b) Design a suitable compensator for a unity feedback system with its feed forward transfer function as $G(s)=\frac{4}{s(s+2)}$ such that its maximum percent overshoot 16.3% and settling time 2 sec. for its step response. Also velocity error constant should not be less than 2 per sec. [12]

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22 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2073 Shrawan

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL, BEX, BME, BIE	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

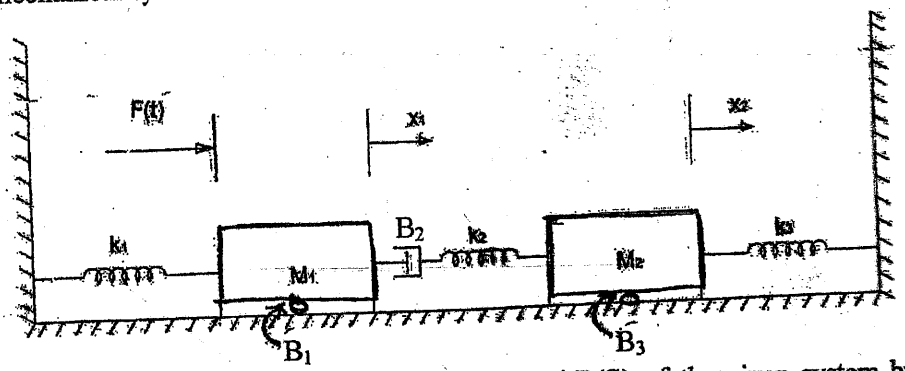
Subject: - Control System *(EE602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

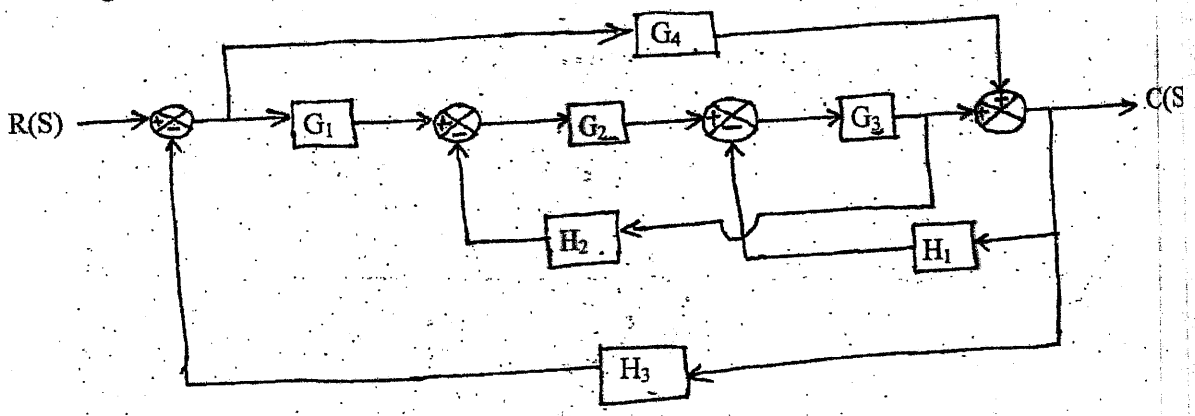
1. a) What kind of control system could have been in the following? Illustrate with necessary blocks and variables. [4×2]

   i) Governer system of Hydropower Station
   ii) Traffic light system of Kathmandu

   b) Find transfer function (consider displacement of mass M2 as output) for the given mechanical system. Also develop force-current analogous circuit. [8]



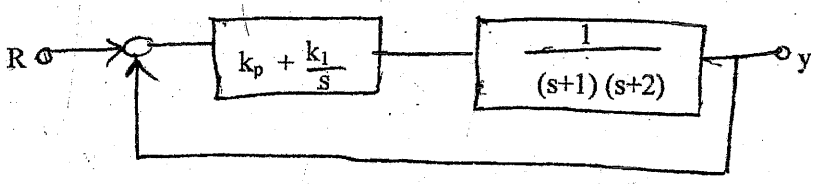
2. a) Determine the overall transfer functions C(S) / R(S) of the given system by block diagram reduction technique. [8]



   b) The system equations are given by: $\dot{x}(t) = \begin{bmatrix} 0 & 1 \\ -5 & -6 \end{bmatrix} x(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t)$; and

   $y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} x(t)$; Find transfer function of the system and also check stability. [8]

3. a) For a closed loop system presented by [4]



Determine the range of controller gain (K_p, K_I) so that the PI controller provides the stable output.

b) A unity feedback control system has an open loop transfer function $G(S) = \frac{K(S+9)}{S(S^2+4S+11)}$. Sketch the root locus and determine: [8]

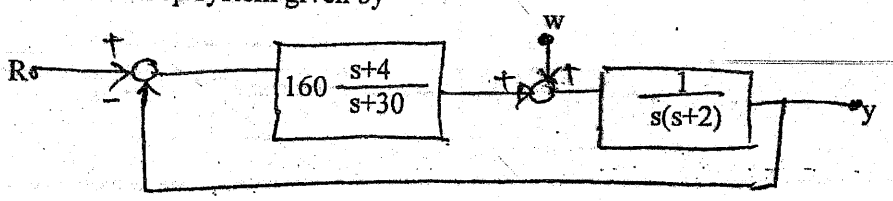
i) The range of 'K' for system to be stable
ii) Undamped natural frequency of oscillation

c) A closed loop servo is represented by the differential equation $\frac{d^2y}{dt^2} + 8\frac{dy}{dt} = 64z$ where 'y' is the displacement of the output shaft and 'u' is the displacement of the input shaft and z = u-y. Determine frequency of sustained oscillation, damping ratio and percentage maximum overshoot for unit step input. [4]

4. a) Draw the region in S-plane that satisfies following requirements. [4]

i) $S > 0.707$ (ii) $t_s < 2$ S

b) For a closed loop system given by [8]



i) Can the system track a step reference input 'r' with zero steady state error

ii) Can the system reject a step disturbance 'ω'with zero steady state error?

iii) Compute the sensitivity of closed loop transfer function to change in the plant pole at '-2'

c) How a controller with transfer function $G_c(S) = \frac{1+aTS}{1+TS}$ can be used as lead or lag compensator, explain. [4]

5. a) Design a suitable lead compensator for a system whose open loop transfer function is given by $G(S) = \frac{K}{s(1+0.2s)}$ [10]

The system should meet the following criteria

i) $K_v \geq 20\,\text{sec}^{-1}$
ii) P.M. $\geq 44°$

b) The differential equations related to a system are $\frac{dx_1}{dt} = -3x_1 + x_2$ and $\frac{dx_2}{dt} = -2x_1 + u$ for $t > 0$. Its output equation is given by $y = x_1$. Derive the transfer function of the system with these differential equation and output equation. [6]

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21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2072 Kartik

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL, BEX, BME, BIE	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Control System *(EE602)*

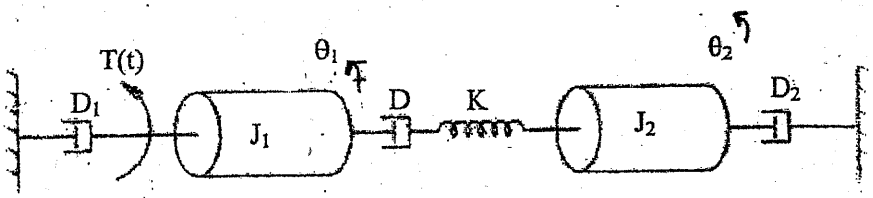
- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Necessary graph paper and semilog graph paper will be provided.*
- ✓ *Assume suitable data if necessary.*

1. a) What is control system? Mention its type and explain them with example and block diagram showing all necessary blocks and signals. [8]

   b) Explain the role of PD controller on transient and steady state performance specifications. [4]

   c) Explain why closed loop system has better disturbance rejection capability than open loop. [4]

2. a) Find transfer function of the system given below (take angular displacement of J_2 as output). Also develop Torque-Voltage analogy circuit. [8]



   b) What are the static error constants? Explain how they are applied in measuring steady state performance of given system. [4]

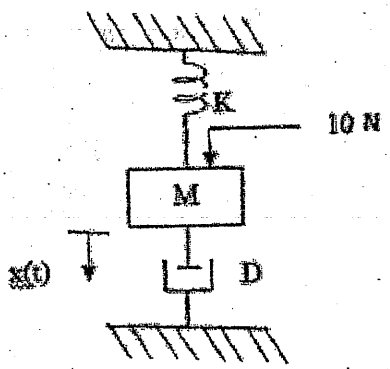
   c) Use RH criteria to find the position of roots of characteristic equation given by

   $C(s) = s^5 + 4s^4 + 2s^3 + 8s^2 + s + 4$; and hence determine the stability of the system. [4]

3. a) Construct the root locus for unity feedback system with OPTF $G(s) = \frac{k(s+2)}{s(s-1)}$ Hence show that the system is unstable for small value of gain and over damp at larger value of gain. [8]

   b) Discuss how the poles and zeros affect system dynamics. [4]

   c) Following figure shows a mechanical system and the response when 10 N of force is applied to the system. Determine the value of M, D and K. The displacement x is measured from the equilibrium position. [4]



4. a) Design a suitable compensator using root locus for a UFS with $G(s)=\frac{10}{s(s+1)(s+4)}$ to meet the specifications; damping ratio = 0.5 and undamped natural frequency = 2 rad/s. [12]

b) Define relative stability. Discuss how nyquist plot is used to determine the stability of a system. [4]

5. a) For a unity feedback system with $G(s)=\frac{250k}{s(s+50)(s+5)}$, select the value of 'k' so that the steady state error for a ramp input is 10%. At this value of 'k', construct the Bode plot. Hence determine approximate gain margin, phase margin, gain cross over frequency and phase cross over frequency. [8]

b) Given state equation and output equation, determine the poles and zeros of given system. [8]

$$X=\begin{bmatrix}0 & 1 & 0\\ -1 & -1 & 0\\ 1 & 0 & 0\end{bmatrix}X+\begin{bmatrix}0\\ 1\\ 0\end{bmatrix}u \text{ and } y=\begin{bmatrix}0 & 0 & 1\end{bmatrix}X$$

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22 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2071 Shawan

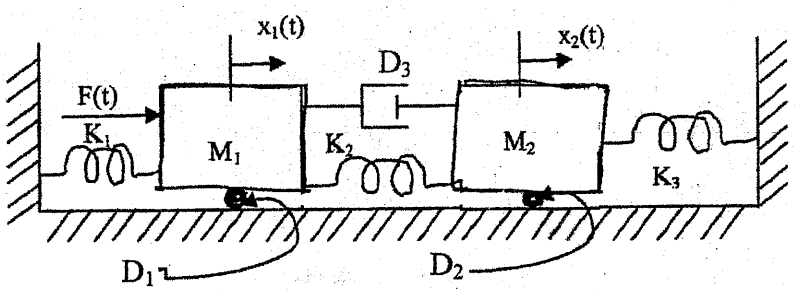
Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL, BEX, BME, BIE	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Control System *(EE602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) What is control system? Draw the block diagram of a closed loop control system and briefly explain the function of each block. Mention also advantages of closed loop system over open loop system. [8]

   b) Find the transfer function, $\frac{X2(S)}{F(S)}$, for the mechanical system of figure below. Also draw the F-V and F-I analogy circuit of the system. [8]



2. a) Discuss how the dynamic responses of control system are affected by a feed back. [6]

   b) For an open loop transfer function with unity feedback $G(S) = \frac{\omega_n^2}{s(s+2\xi\omega_n)}$ where $\xi < 1$, derive an expression for output when unit step input is applied. [4]

   c) Using R-H criteria, tell how many roots of polynomial is right half s-plane, in left half s-plane and on jw axis. [6]

   $S^6 + 2S^5 + 8S^4 + 12S^3 + 20S^2 + 16S + 16 = 0$

3. a) The open loop transfer function of a control system is given by

   $$G(S)H(S) = \frac{K}{s(s+6)(s^2+4s+13)}$$

   Sketch the root locus for $0 \le K \le \infty$ and determine the breakaway point, the angle of departure from complex poles and the stability conditions. [10]

   b) Discuss how a Bode plot can be used to determine transfer function of the system. Explain with an example. [6]

4. a) Construct the polar plot of unity feedback system with $G(S) = \frac{K}{S(S+1)(0.1S+1)}$.

   Then, upgrade the plot to make it. Nyquist plot. Hence find range of k for stable operation. [3+3+2]

   b) For given state equation and output equation, find transfer function $\frac{Y(S)}{U(S)}$ [8]

$$\dot{X} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -2 & -3 \end{bmatrix} X + \begin{bmatrix} 10 \\ 0 \\ 0 \end{bmatrix} u \quad \text{and} \quad y = [1 \quad 0 \quad 0]\, X$$

Design a suitable lead compensating network for $G(S) = \frac{k}{s^2(1+0.25s)}$ to meet the following specification $K_a = 10\ \text{sec}^{-1}$

$P.M \ge 35°$ [16]

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21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2071 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BME, BIE	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

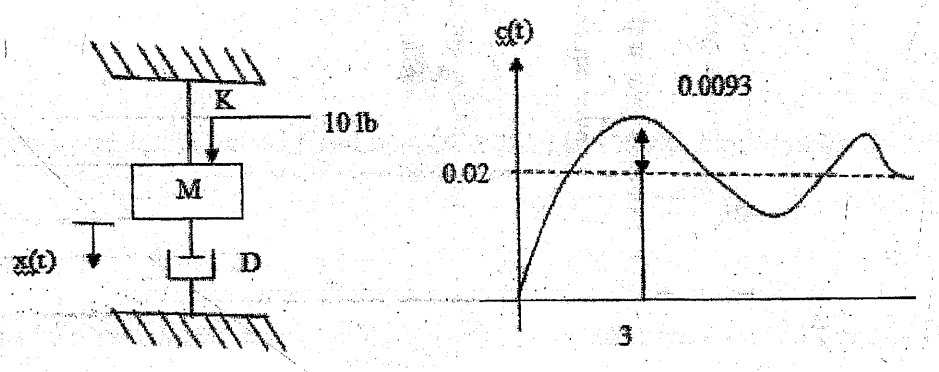
Subject: - Control System *(EE602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

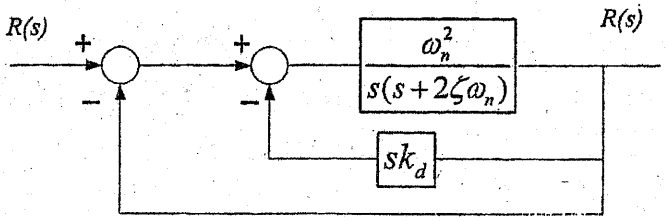
1. a) Construct a general block diagram of a control system showing the different blocks, variables and hence briefly point out their meaning. [4]

   b) Effect of disturbance in case of feedback control system can be suppressed by increasing the gain G(S) and / or H(S). [4]

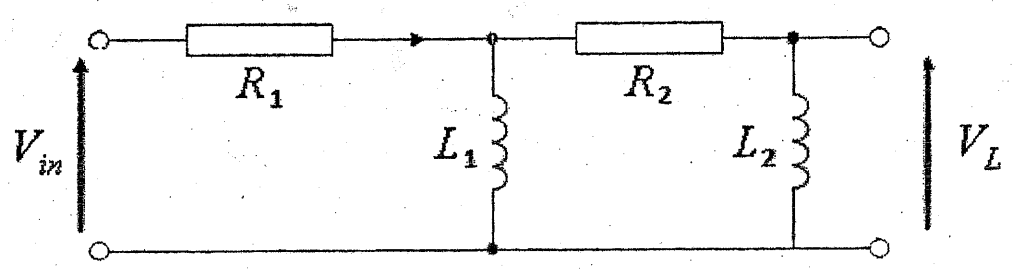
   c) Following figure shows a mechanical vibratory system and the response when 10 lb of force is applied to the system. Determine the transfer function and value of M, D and K. The displacement x is measured from the equilibrium position. [8]



2. a) Show that using the velocity feedback techniques shown figure below damping ratio and steady state error are both increased. [8]



   b) Develop block diagram model for the system below. [6]



c) Using R-H criteria, tell how many roots of polynomial is in right half s-plane, in left half s-plane and on jw axis and also comment on stability. [4]

$S^6+3S^5+4S^4+6S^3+5S^2+3S+2=0$

3. a) For the unity feedback system with open loop transfer function (OLTF) $G(s)=\frac{k}{(s+1)(s+3)}$, use angle criteria to check whether the root locus passes from point $s_d=-2+j3.5$. If yes, use magnitude criteria to select the appropriate value of gain parameter. [4]

b) For a system given by $\frac{d}{dt}\begin{bmatrix}x_1\\x_2\end{bmatrix}=\begin{bmatrix}-5 & -6\\1 & 0\end{bmatrix}\begin{bmatrix}x_1\\x_2\end{bmatrix}+\begin{bmatrix}1\\0\end{bmatrix}u;y=\begin{bmatrix}1 & 2\end{bmatrix}\begin{bmatrix}x_1\\x_2\end{bmatrix}$, determine the zeros and the poles of the system. [4]

c) The open loop transfer function of a control system is given by [8]

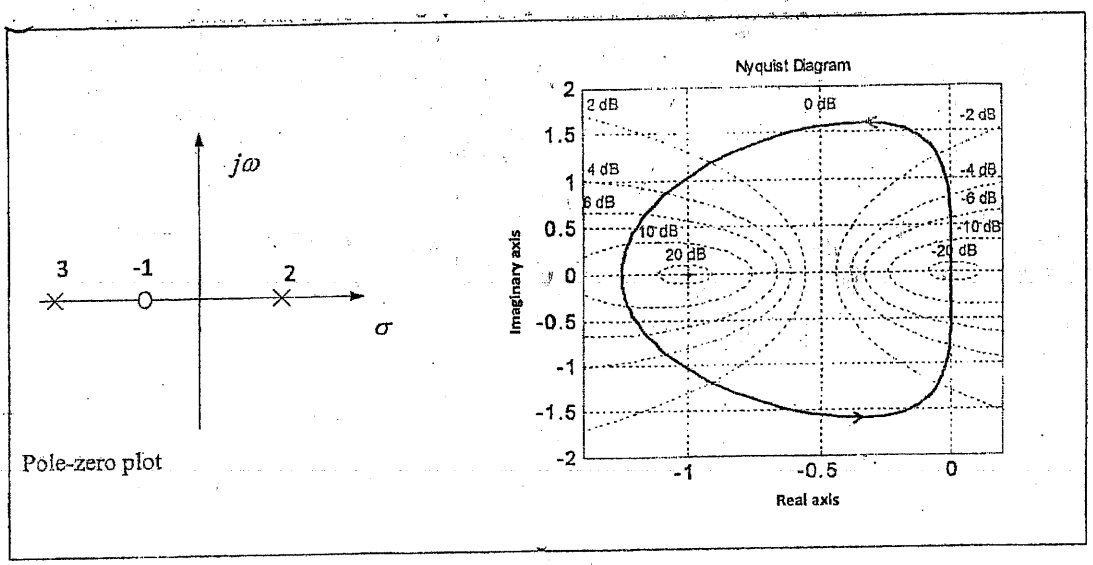
$$G(s)H(s)=K\frac{s^2-2s+5}{s^2+1.5s-1}$$

Sketch the root locus for $0\le K\le\infty$ and determine the breakaway point, the angle of departure from complex poles and the stability conditions. Also find value of K that gives poles at (-0.35±j0.6)

4. a) Design a suitable compensator for a unity feedback system with open loop transfer $G(s)=\frac{4}{s(s+2)}$ such that the settling time will become 2 seconds without change in overshoot and velocity time constant will be 2 s^{-1}. [12]

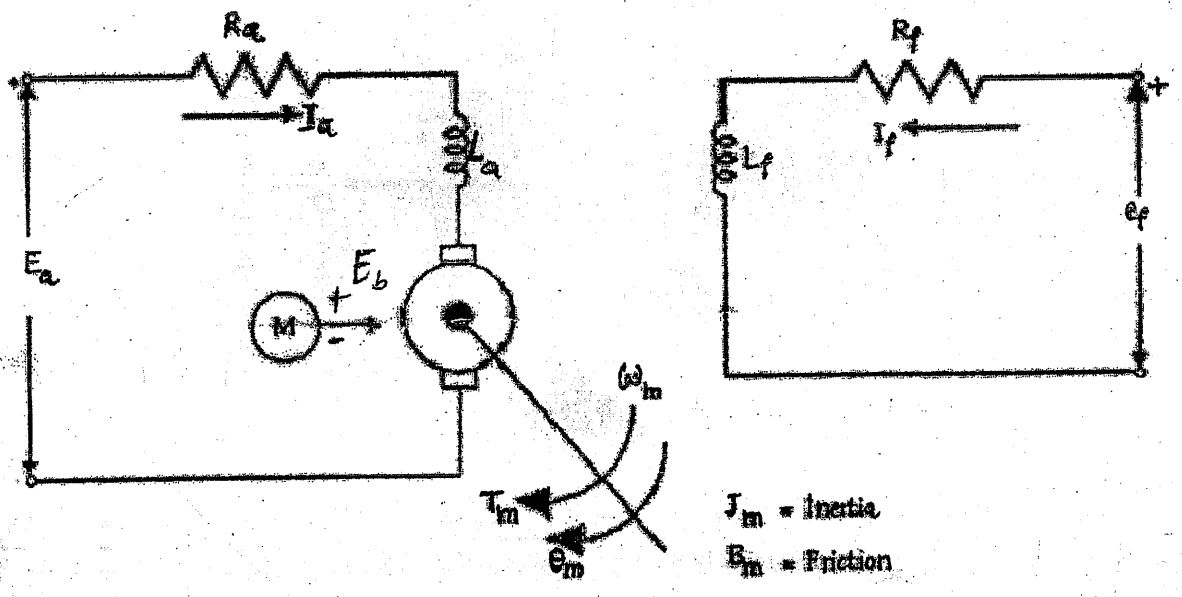
b) For a compensator transfer function given by $G_c(s)=\frac{s+\tau}{s+a\tau}$, give the condition of lead compensator. For the given value of 'a' what is the frequency that leads to maximum phase angle lead. [4]

5. a) State the Nyquist stability criteria for negative feedback control system. Using this concept determine whether the following system represented by figure below is stable. [4]



b) Discuss how bode plot can be used to determine transfer function of the system. [5]

c) Develop state equation for motor circuit at below. [5]



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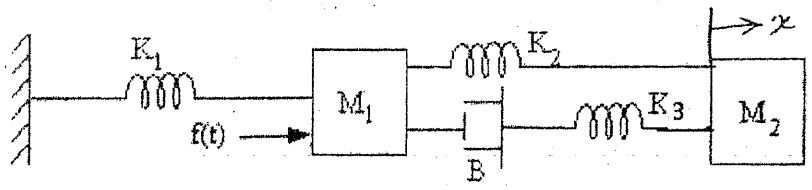
21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2070 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX,BME,BIE	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

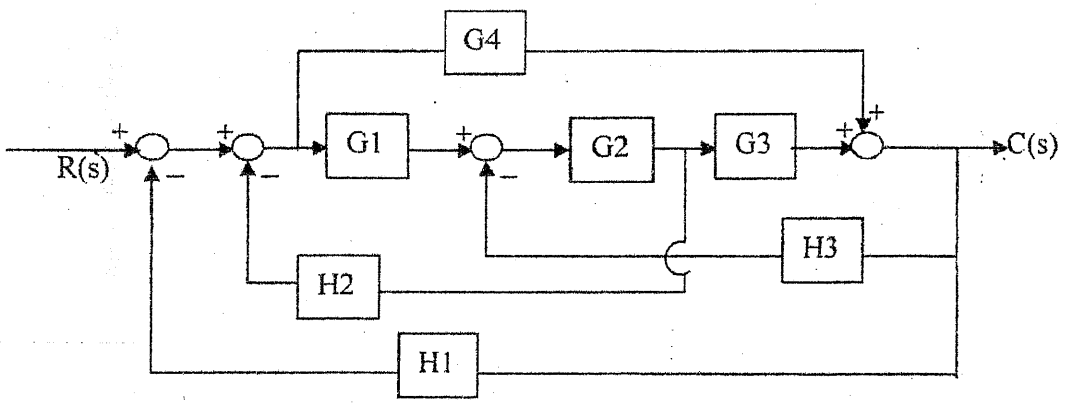
Subject: - Control System *(EE602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. (a) Find transfer function for the following mechanical system considering displacement of mass M_2 as output of the system. Also develop force current analogous circuit. [6]

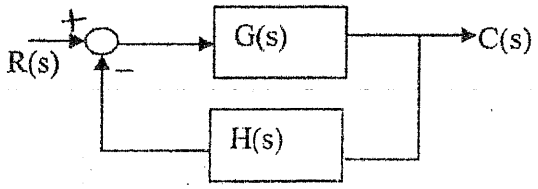


(b) Reduce the following block diagram model to obtain its overall transfer function. [6]



(c) How can you characterize a control system in term of (i) Speed (ii) accuracy (iii) Stability explain. [4]

2. (a) For a second order system as below $G(s) = \frac{w_n^2}{s(s+2\xi w_n)}$ and H(s) =1, find expression for maximum overshoot on its unit step response where w_n is natural frequency of oscillation and ξ is damping ratio at underdamped situation. [7]



(b) Discuss how a feed back control system reject the disturbance input. [3]

(c) Find all static error constant for a unity feedback system with feedforward transfer function $G(s) = \frac{1000}{s(s+10)(s+100)}$. Evaluate steady state error if system is excited with r(t) = 2+t. [6]

3. (a) Obtain Nyquist plot and comment on stability using Nyquist Criterion for a unity feedback system with feedforward transfer function $(s) = \frac{(s+2)}{(s+1)(s-1)}$. [8]

(b) Discuss how Bode plot is used for determining relative stability. [4]

(c) Discuss the application of a PI controller with suitable example. [4]

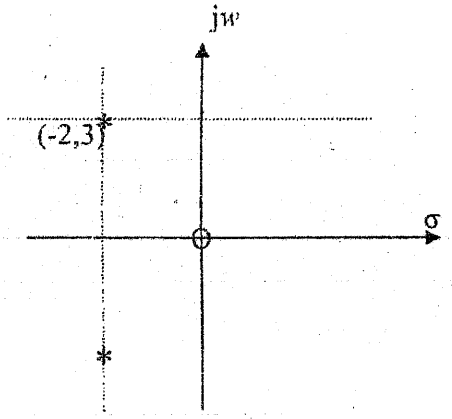
4. (a) Obtain characteristic equation for the system having given state model. [4]

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \end{bmatrix} = \begin{bmatrix} -5 & -1 \\ 3 & -1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 2 \\ 5 \end{bmatrix} u$$

$$Y = [1 \quad 2] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

(b) Design series lag compensator for the unity feedback system with feedforward transfer function $G(s) = \frac{K}{s(s+4)(s+80)}$. The velocity error constant is $30s^{-1}$ and phase margin at least 33^0. [12]

5. (a) Draw Root Locus for the system that has open-loop pole/zero plot in s-plane as below in figure. Also estimate the system gain at the point where the system exhibits critical damping. [8]



(b) The open loop transfer function of a closed loop system is $(s) = \frac{K(s+1)}{s(s+2)(s+3)}$, find maximum possible K for which the poles lie on left of point -0.5. [8]

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22 TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

Examination Control Division

2070 Ashad

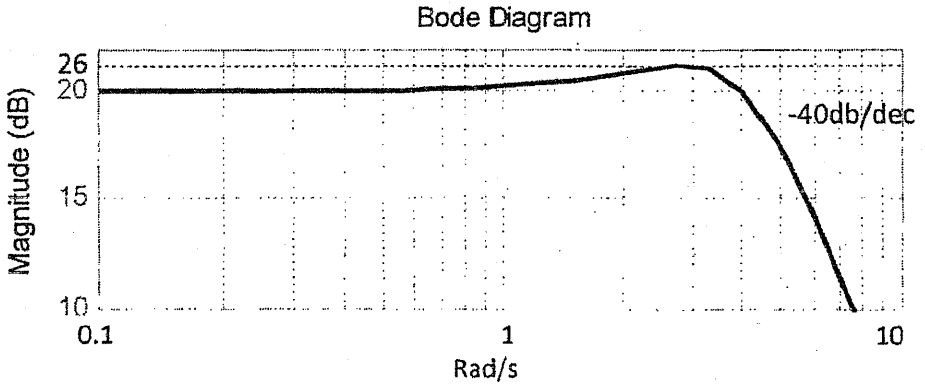
Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL, BEX, BME, BIE	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Control System *(EE 602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ ***Semi-log paper will be provided.***
- ✓ *Assume suitable data if necessary.*

1. (a) For a unity feedback system with open loop transfer function (OLTF) $G(s)=\frac{k}{(s+0.2)(s+1)(s+5)}$, generate *Nyquist plot* of the system to find the range of 'k' for stable operation At k = 10, what will be the value of phase cross over frequency and gain margin. [6]

(b) For an approximate *Bode Plot* of a close loop system as shown below, evaluate the following performance indices: (i) maximum overshoot. (ii) peak time. [4]



2.(a) Deduce the state space model of transfer function given by $G(s)=\frac{s^2+1}{s^3+5s^2-2s+1}$. [4]

(b) Evaluate the state transition matrix of system represented by $\frac{d}{dt}\begin{bmatrix}x_1\\x_2\end{bmatrix}=\begin{bmatrix}-5 & -6\\1 & 0\end{bmatrix}\begin{bmatrix}x_1\\x_2\end{bmatrix}+\begin{bmatrix}1\\0\end{bmatrix}u$ [4]

(c)For a unity feedback system with OLTF $G(s)=\frac{a}{s(s^2+s+1)(s+2)}$, find the range of 'a' for stable operation. At which of 'a', system become marginally stable; and also calculate undamped frequency of oscillation. [8]

3. (a) For the unity feedback system with OLTF $G(s)=\dfrac{k}{(s+1)(s+3)}$, use angle criteria to check whether the root locus passes from point $s_d=-2+j3.5$. If yes, use magnitude criteria to select the appropriate value of gain parameter. [4]

(b) For the unity feedback system with OLTF $G(s)=\dfrac{k(s+3)}{(s-1)(s^2+2s+4)}$, plot the root locus and find the range of gain parameter (k) for the system for: unstable, under-damped, over-damped conditions. [8]

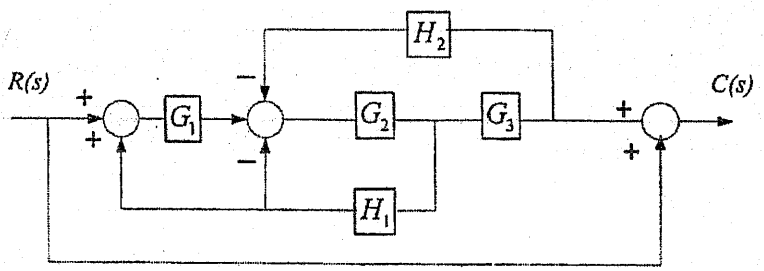
4

(b) Design a compensator using Bode plot for a unity feedback system with OLTF $G(s)=\dfrac{k}{s(s+2)(s+20)}$ to meet the specifications: $PM \geq 35^0$, $K_v \geq 20\ s^{-1}$, such that the bandwidth of the resultant system decreases. [12]

5. (a) How do you characterize control systems in term of their indices like speed, accuracy, stability and robustness? [4]

(b) What do you mean by force voltage analogy of a mechanical system? Explain with examples. [4]

(c) Convert the following block diagram into signal flow graph and hence use Mason Formula to get transfer function. [8]



6. (a) For a mechanical system with close loop transfer function, $\dfrac{\theta(s)}{T(s)}=\dfrac{1}{as^2+bs+c}$; where $\theta(s)$ the output of step input T(s)=10 Nm. Determine values of 'a', 'b', and 'c'; if maximum overshoot =6% peak time (t_p)=1 sec, and e_{ss} =0.5. [6]

(b) What are the performances indices of control system in time domain, explain with suitable diagram or graph. [4]

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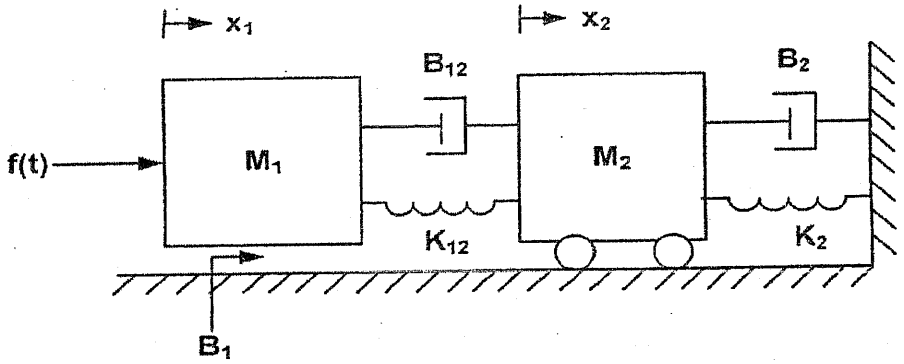
22 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2069 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BME, BIE	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Control System *(EE602)*

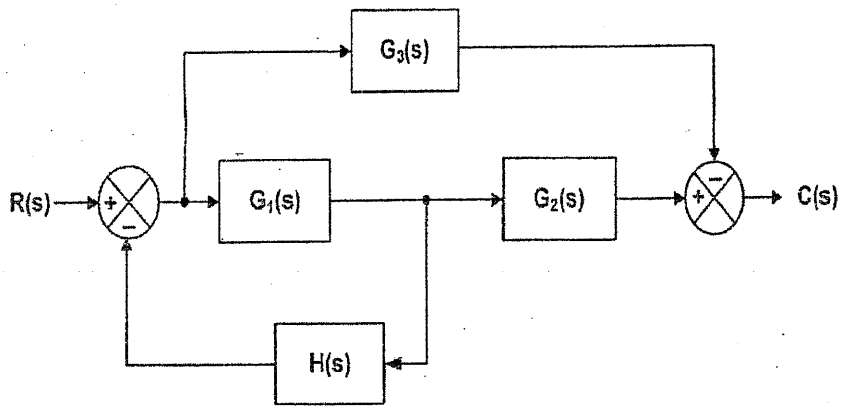
- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Bode plot and normal graph paper would be provided.*
- ✓ *Assume suitable data if necessary.*

1. Stating an example of a system that you see in everyday life, explain what do you understand by closed loop system and the importance of feedback in it. [4]
2. Write the differential equations governing the mechanical system shown in figure below and find $\frac{X_2(s)}{F(s)}$. [8+4]



Also tabulating the necessary analogies draw the Force-Current and Force-Voltage electrical analogous circuit.

3. a) Convert the given block diagram to signal flow graph and determine the overall transfer function using Masson's Gain Formula. [6]



b) Consider a unity feedback system with a closed loop transfer function $\frac{C(s)}{R(S)} = \frac{Ks+b}{s^2+as+b}$ [6]

Determine the open loop transfer function G(S). Also compute the steady state error with unit ramp input.

4. The characteristics equation of a system is given by $S^6 + 3s^5 + 4s^4 + 6s^3 + 5s^2 + 3s + 2 = 0$. Comment on the stability. [6]

5. Plot the root loci for closed loop system with $G(S) = \frac{K}{S(S+1)(S^2+4S+5)}$, H(S) = 1. Also determine the dominant closed loop pole with $\xi = 0.5$. [12]

6. Draw the bode plot for transfer function $G(S) = \frac{48(1+s)}{(s^2)(1+3s)(1+0.5s)(2+02.s)}$, from the graph determine (i) Phase crossover frequency (ii) Gain crossover frequency (iii) P.M (iv) G.M (v) Stability of the system. [10]

7. Design a suitable cascade lag compensator network for the given system $G(s) = \frac{50K}{s(s+5)(s+10)}$ [16]

   Such that the requirement of velocity error constant of 30 sec^{-1} and phase margin of $\geq 45°$ are met.

8. A system has the transfer function $\frac{Y(s)}{U(s)} = \frac{2}{s^3+6s^2+11s+6}$ [8]

   Find the state and output equation in matrix form and test the controllability and observability of the system.

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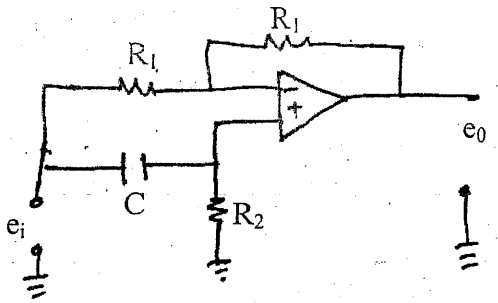
22 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2068 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BME, BIE	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Control System *(EE 602)*

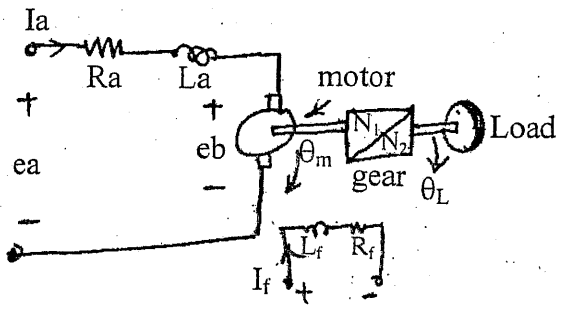
- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Find the transfer function $e_o(S)/e_i(s)$ of the given circuit. [6]

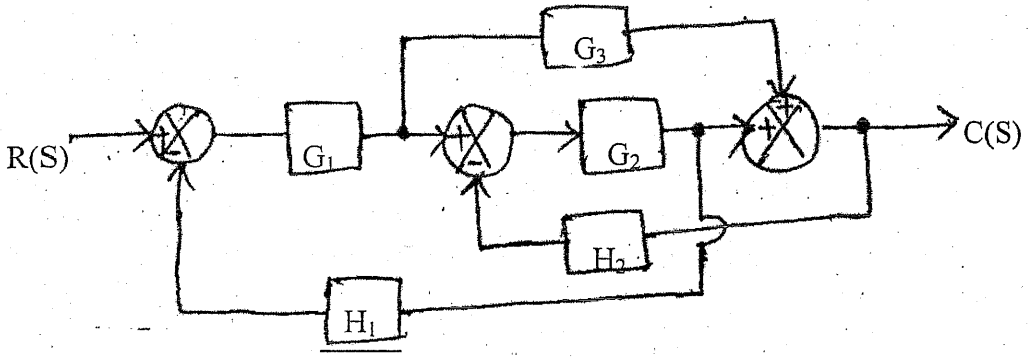


b) For an electromechanical system shown below, derive an expression for $V_L(S)$ considering it as armature controlled dc motor. [10]

Motor: i) Moment of intertia = J_m (ii) Frictional coefficient = D_m (iii) Torsional
Load: i) Moment of intertia = J_m (ii) Frictional coefficient = D_m (iii) Torsional



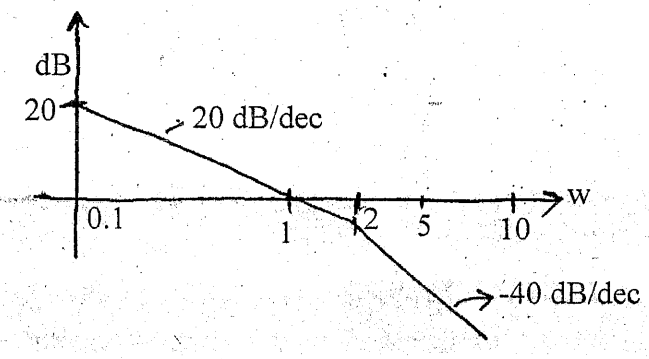
2. a) Determine overall transfer function $\frac{C(S)}{R(S)}$ by block diagram reduction technique. [8]



b) Apply RH criteria to determine the range of 'K' for a unity feedback system with $G(S)=\frac{K(S+13)}{S(S+3)(S+7)}$ will be stable. [8]

3. a) Sketch the root locus for the system having $G(S)=\frac{K(S+1)}{(S^2+2S+2)(S^2+2S+5)}$. [10]

b) Estimate transfer function with the help of following Bode plot. [6]



4. a) Write short notes on following: [4×2]

i) Gain margin and phase margin

ii) PD and PI controller

b) Determine TF for the system whose state space representation is given by: [8]

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix}=\begin{bmatrix}0 & -1\\ -2 & -3\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}1\\ 2\end{bmatrix}u$$

$$y=[1 \quad 0]\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

5. Design a suitable lead compensator for a system having open loop TF $G(S)=\frac{K}{S(1+0.1S)(1+0.001S)}$ such that the compensated system should have phase margin of at least 45° and static velocity error constant of at least 1000. [16]

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22 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2068 Baishakh

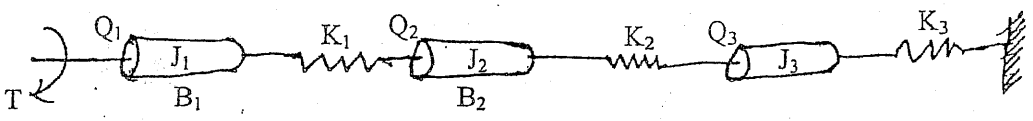
Exam.	Regular / Back		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Control System

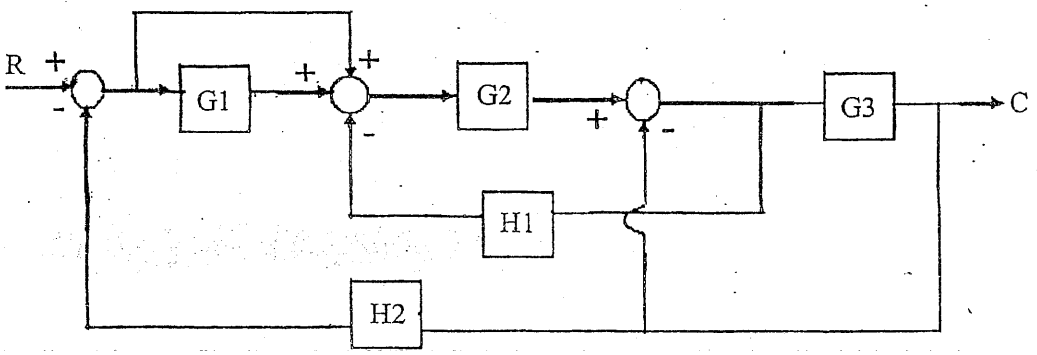
- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt <u>All</u> questions.*
- ✓ *The figures in the margin indicate <u>Full Marks</u>.*
- ✓ ***<u>Semilog graph paper will be provided.</u>***

1. State whether the following statements are true or false and justify them. [(1+3)×4]
   a) Introduction of feedback on the system makes the system response faster.
   b) Effect of disturbances can be reduced by increasing the gain of forward path TF.
   c) Proportional controller makes the steady state error zero.
   d) Derivative controllers are always used with other controllers.

2. a) Write differential equation and obtain transfer function of the mechanical system as shown below considering θ_3 as output. Also draw torque voltage analogy network. [6+2]



   b) Find overall transfer function of the system as shown below by block diagram reduction technique. [8]

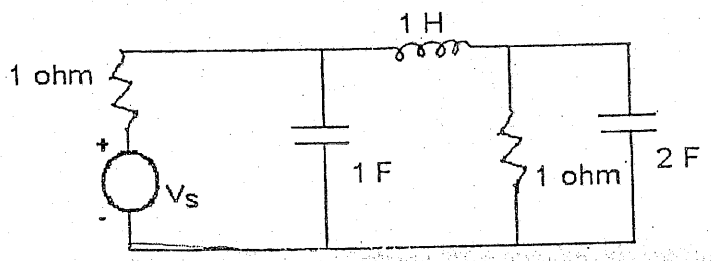


3. a) The open loop TF of a unity feedback control system is given as: [8]

$$G(s) = \frac{K}{(s+2)(s+4)(s^2+6s+25)}$$

Determine the range of gain K for the system to be stable. Also determine the value of K which will cause the sustained oscillation and corresponding oscillation frequency.

b) Write state equation for the system as below shown. Consider voltage across 2F capacitor as output. [8]



4. a) Sketch approximate polar plot for a unity feedback system with feed forward transfer function $G(s) = \frac{10}{s(s+1)^2}$ and obtain gain margin. [8]

b) Draw bode plot of a system having open loop transfer function, $G(s) = \frac{4(s+4)}{(s+2)(s^2+2s+4)}$. Also analyze the stability. [8]

5. Design a lead compensator for a system having open loop transfer function as $\frac{4}{s(s+2)}$, such that the designed system should have %Mp $\leq$ 16.3% and settling time (t_s) $\leq$ 2 sec. [16]

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