BITS, PILANI – DUBAI CAMPUS

Knowledge Village, Dubai

Year III – Semester I 2003 – 2004

COMPREHENSIVE EXAMINATION (Closed Book)

Course No.: **AAOC UC321** Course Title: **Control Systems**

Date: January 6, 2004 Time: 3 Hours Max. Marks = **80** (40 %)

(Answer all questions from Part A and any six from Part B)

PART – A

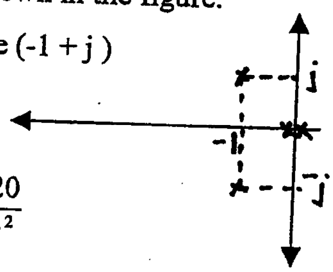
(2 x 10)

I. (a) The resonance peak of a second order system in terms of damping factor ξ is given by ......

(b) State the necessary condition for the Routh's stability criterion

(c) The steady state error for step input of the system whose transfer function is given by $(s+3) / [s(s+5)(s^2+5s+2)]$ will be ______________

(d) The pole zero locations of a open loop control system is shown in the figure. What will be the departure angle of the root locus at the pole (-1 + j)



(e) Draw the log magnitude asymptote of the function $G(s) = \frac{20}{s^2}$

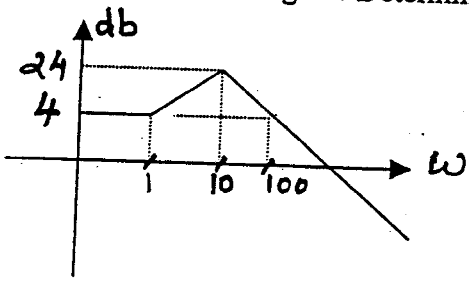
(f) Pick up a non-minimum phase transfer function

(i) $\frac{(s-1)}{(s+2)(s+3)(s+4)}$ (ii) $\frac{(s+1)}{(s+2)(s+3)}$

(iii) $\frac{10(s+1)}{s^2(s+2)}$ (iv) $\frac{(s+1)(s+3)}{s(s+2)(s+4)}$

(g) Define gain margin of a control system

(h) The log magnitude asymptote of a control system is shown in the figure. Determine the transfer function of the system.



(i) State Nyquist stability criterion.

(j) For the system having function $G(s)H(s) = \frac{100}{(s+2)^3}$, the number of encirclement of the (-1 + j0) point and stability will be respectively ....

PART – B

(10 x 6)

II. a) Derive the closed loop Transfer function of a control system (3)

b) Derive the transfer function of the network shown in figure 1. (7)

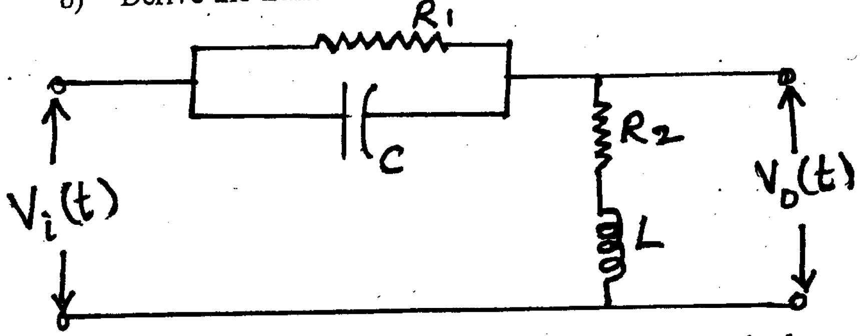


Fig.1

III. The block diagram of a feedback control system is shown in figure 2 below.

i) Draw the signal flow graph of the system. (4)

ii) Find the overall transfer function of the system Y(s) / R(s) by applying Mason's gain formulae. (6)

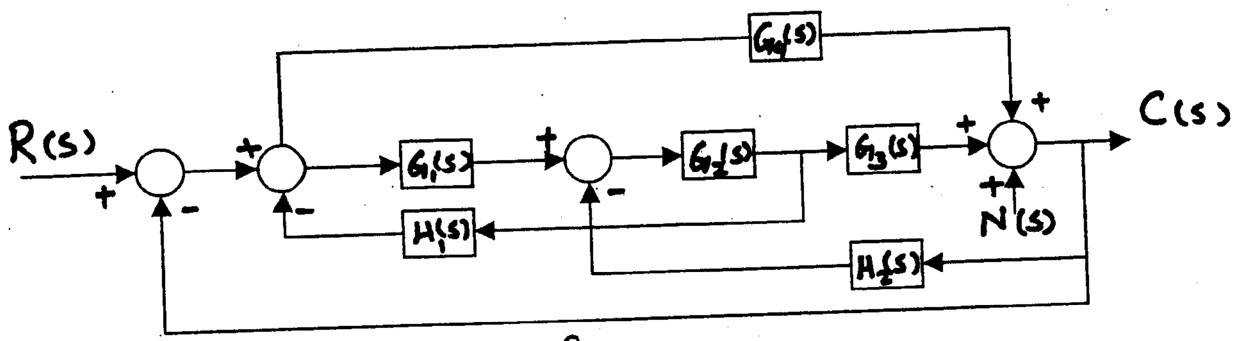


fig.2.

IV a) Explain the time domain specifications of a typical second order system (5)

b) Derive the expressions for the error coefficients of a unity feedback system (5)

V a) Explain the effect of feedback on system dynamics (3)

b) The figure 3 shown below is a mechanical vibratory system. When a force of 2 Nw (step input) is applied to the system the mass oscillates as shown in figure 4. Determine the system parameters M, B and K of the system for this response curve. The displacement 'x' is measured from the equilibrium position. (7)

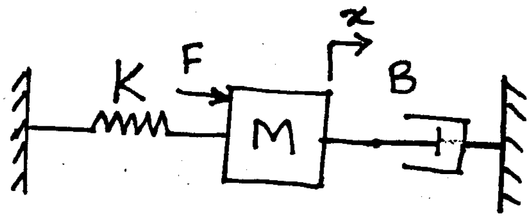


fig. 3

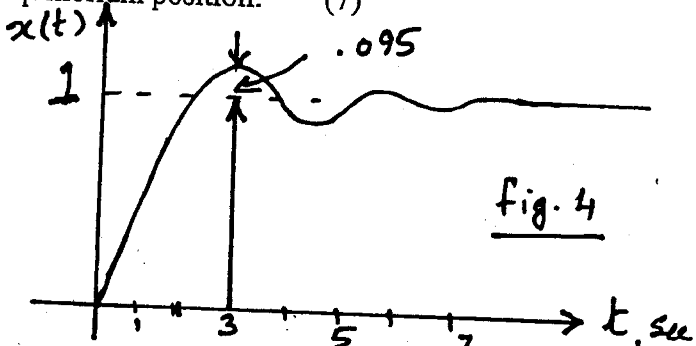


fig. 4

VI a) Sketch the root locus of the system shown in figure 5 below. (7)

b) From the root locus, find the closed loop poles of the system for which the closed loop system response will have 5% settling time of 2 seconds. (3)

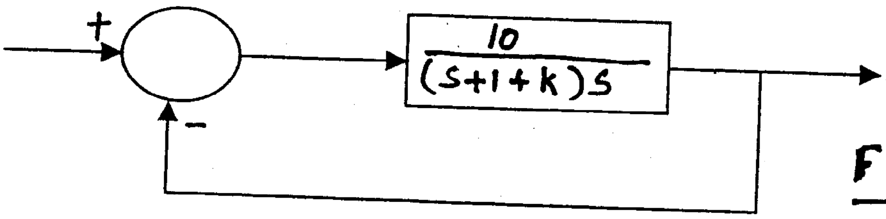


Fig. 5

VII. Draw the Bode plot for the following transfer function and obtain the values of gain margin and phase margin and thereby comment on the stability of the system.

$$G(s) = \frac{90(1+s)}{(1+4s)(s^2+6s+9)}$$

VIII Consider a unity feedback system with open loop transfer function

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

using Nyquist stability criteria determine the stability of the closed loop system.

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BITS, PILANI – DUBAI CAMPUS

Knowledge Village, Dubai

Year III – Semester I 2003 – 2004

TEST I (Closed Book)

Course No.: AAOC UC321 Course Title: Control Systems

Date: October 19, 2003 Time: 50 Minutes M.M. = 40 (20 %)

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1. - Each *part of this question carries 1 mark each.*

(a) A control system is said to be *linear*, if ....

(b) In case of mechanical rotational elements, the *through* variable is ...., whereas the *across* variable is ....

(c) The force of sliding friction between dry surfaces is known as ...., whereas the force required to initiate motion between two contacting surfaces is referred as ....

(d) Inertia and friction parameters are referred from one shaft of the gear train to the other in the direct ratio of ....

(e) Friction may be introduced internally in a system by use of ....

(f) The overall transfer function of the physical system consisting of more than one element can be obtained by multiplying the individual elements transfer function provided................

(g) The transfer function of a linear time-invariant system is defined as ....

(h) If the forward path gain of a unity negative feedback control system is G(s), the closed loop transfer function of the system will be ....

(i) Define *output node* and *non-touching loops* with reference to signal flow graph.

(j) The feedback loop of a control system can drive the system to instability. True / False. ....

2. A vehicle towing a trailer through a spring-damper coupling hitch is shown in figure (1). The following parameters and variables are defined: M is the mass of the trailer, K_h the spring constant of the hitch, B_h the viscous-damping coefficient of the hitch, B_t the viscous-friction coefficient of the trailer, $y_1(t)$ the displacement of towing vehicle, $y_2(t)$ the displacement of the trailer, and f(t) the force of the towing vehicle. Write the differential equation of the system and obtain the transfer functions $\frac{Y_1(s)}{F(s)}$ and $\frac{Y_2(s)}{F(s)}$. [10]

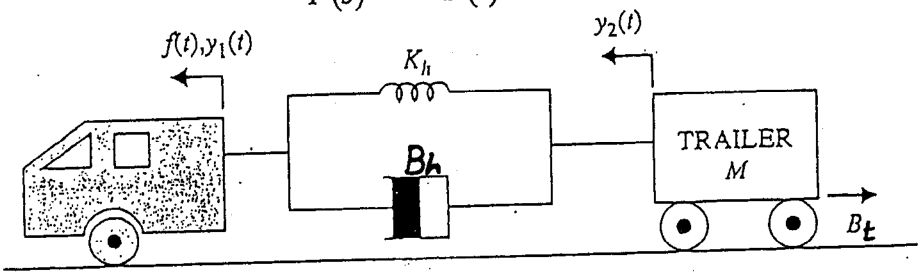


FIGURE (1)

3. Simplify the block diagram shown in figure (2) and obtain the closed-loop transfer function $C(s)/R(s)$. [10]

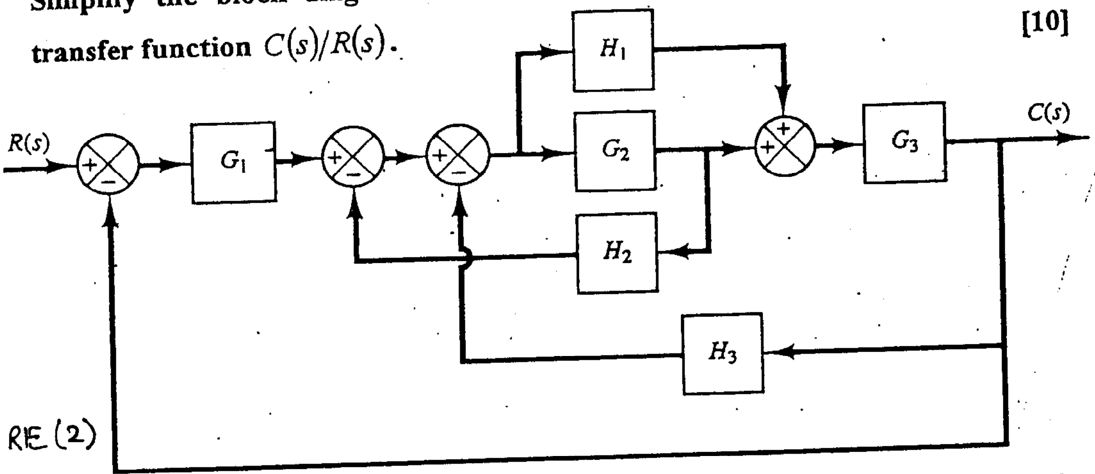


FIGURE (2)

4. Obtain the overall transfer function $Y(s)/R(s)$ of the signal flow graph given in figure (3), using Mason's gain formula. [10]

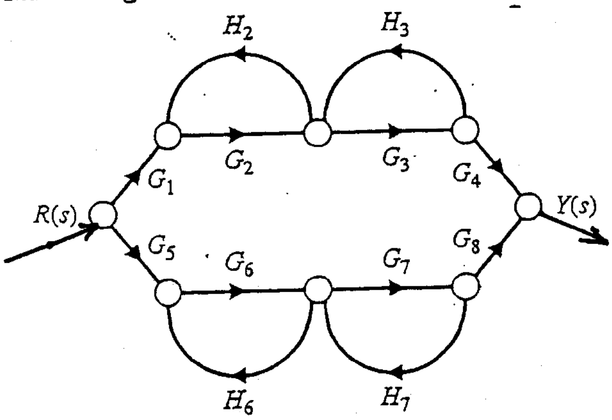


FIGURE (3)

BITS, PILANI – DUBAI CAMPUS

Year III – Semester I 2003 – 2004

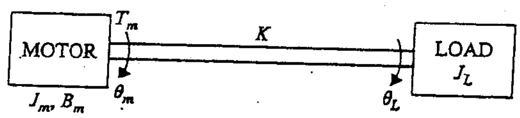
TEST I / Make up (Closed Book)

Course No.: AAOC UC321 Course Title: Control Systems

Date: November 02, 2003 **Time: 50 Minutes** **M.M. = 40 (20 %)**

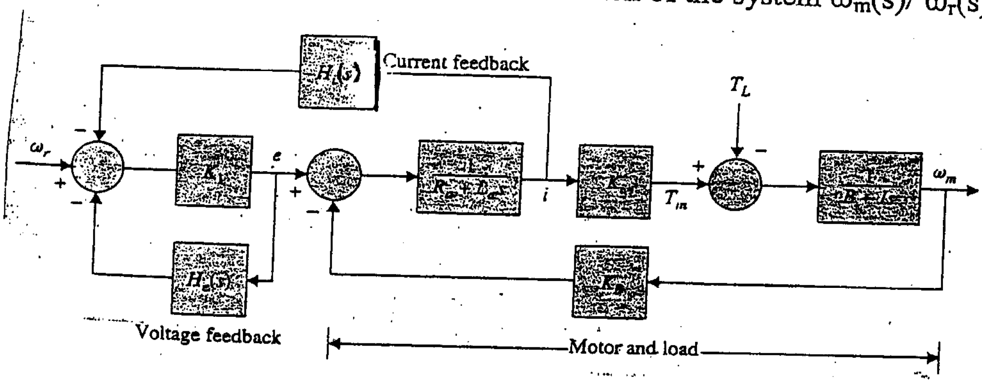
1. The figure 1 below shows a motor coupled to an inertial load through a shaft with a spring constant K. Write the mathematical model of the system. Also Find out the transfer functions of the system $\theta_L(s) / T_m(s)$ and $\theta_m(s) / T_m(s)$

(10)

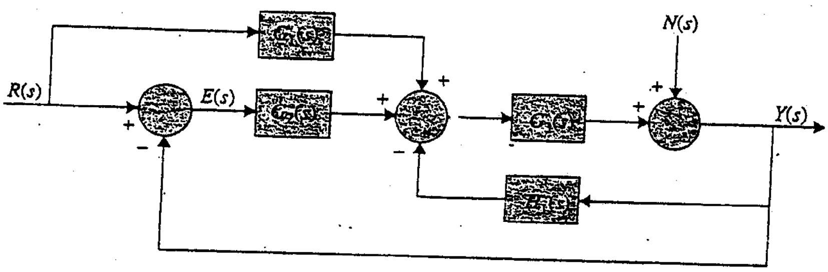


(a)

2. Given below is the block diagram representation of a dc servo system. Reduce the block diagram and find out the overall transfer function of the system $\omega_m(s)/ \omega_r(s)$ (10)



3. For the block diagram shown below, draw the equivalent signal flow graph and hence by applying Mason's gain formula, find out the over all system gain. Y(s) / R(s) (10)



4\. (a) Derive the formula for transfer function of a closed-loop system, having forward path transfer function as G(s) and transfer function of the feedback elements as H(s). (2)

(b) Draw the simplified diagram of a 'Mechanical Accelerometer' and obtain its transfer function. (3)

(c) Draw the general block diagram of an automatic control system and explain the functions of different elements used therein. (3)

(d) What do you mean by 'Disturbance input' in a control system? How one can eliminate the effect of it on the performance of control system? (2)

BITS, PILANI – DUBAI CAMPUS

Knowledge Village, Dubai

Year III – Semester I 2003 – 2004

QUIZ I (Closed Book)

Course No.: AAOC UC321 Course Title: Control Systems

Date: November 10, 2003 Time: 40 Minutes M.M. = 20 (10 %)

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1. By the use of feedback, the system gain is ...... (increased/decreased).

2. System sensitivity is defined as ....

3. The sensitivity of a closed-loop system with respect to variation in forward path gain (G) is reduced by a factor of .... As compared to that of an open-loop system.

4. Feedback in a control system ......(improves/reduces)..... the speed of its response when compared to the open loop system response.

5. If the transfer function of a system is given by:

$$G(s)=\frac{X(s)}{F(s)}=\frac{1}{Ms^2+fs+K}$$

the order of the system will be ....

6. In the following pick up the linear systems

(i) $\frac{d^2y(t)}{dt^2}+a_1\frac{dy(t)}{dt}+a_2y(t)=u(t)$ (ii) $y\frac{dy(t)}{dt}+a_1y(t)=a_2u(t)$

(iii) $2\frac{d^2y}{dt^2}+t\frac{dy}{dt}+t^2y(t)=5$

(a) (i) and (ii) (b) (i) only

(c) (i) and (iii) (d) (ii) and (iii)

7. **In a linear control system**

(a) the input signal follows the output

(b) the input signal linearly follows the output

(c) the input signal does not follow the output

(d) the output linearly follows the input

8. **In an open loop control system**

(a) external disturbance will be present

(b) stability is poor

(c) output is always constant

(d) for a constant input the output is constant

9. **In a closed loop control system**

(a) input signal controls the output

(b) error signal does not change

(c) feedback signal controls the output

(d) actuating signal controls the output

10. **The sensitivity in a closed loop control system with variation in G may be obtained using the relation**

(a) $\frac{G}{1+GH}$ **(b)** $\frac{G}{1-GH}$ **(c)** $\frac{1}{1-GH}$ **(d)** $\frac{1}{1+GH}$

11. **In a closed loop control system with variation in feedback the sensitivity may be calculated** using

(a) $\frac{H}{1+GH}$ **(b)** $\frac{GH}{1-GH}$ **(c)** $\frac{-H}{1-GH}$ **(d)** $\frac{-GH}{1+GH}$

12. **The application of feedback**

(a) has no effect on Signal to Noise ratio

(b) modifies the Signal to Noise ratio

(c) does not improve the Signal to Noise ratio

(d) modifies and improves the Signal to Noise ratio

13. **The superposition principle is applicable to**

(a) nonlinear systems **(b) linear and nonlinear systems**

(c) nonlinear discrete systems **(d) linear systems**

14. **A nonlinearity externally introduced in a control system**

(a) does not improve system performance

(b) increases unstable situation

(c) decreases system stability

(d) improves system performance

15. **In a discrete control system**

(a) the signal is continuously varying with time

(b) the signal is in the form of digital code

(c) the signal does not change

(d) the signal is in the form of pulses

16. **If the transfer function of an open loop system is G, then the forward path transfer function in the unity feedback control system is**

(a) $\frac{G}{1+G}$

(b) $\frac{1}{1+G}$

(c) $\frac{1}{1-G}$

(d) $\frac{G}{1-G}$

17. **Consider the torsional spring in a mechanical rotational system. Its analogous element in Force-Voltage analogy is**

(a) inductance

(b) Capacitance

(c) resistance

(d) 1/capacitance

18. **For a given capacitance, in Force-current analogy the analogous element in mechanical translational system is**

(a) Viscous friction **(b) Force** **(c) displacement** **(d) mass**

19. **In a series RLC circuit, the transfer function of the output voltage across the capacitor in terms of supply voltage is**

(a) $\frac{sC}{R+sL}$

(b) $\frac{sC}{s^2+sR+1}$

(c) $\frac{sC}{s^2+sR+\frac{1}{LC}}$

(d) $\frac{1}{s^2LC+sRC+1}$

20. **The transfer function between the actuating signal and the input signal with negative feedback is**

(a) $\frac{G(s)}{1+G(s)H(s)}$

(b) $\frac{G(s)H(s)}{1+G(s)H(s)}$

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

(d) $\frac{1}{1+G(s)H(s)}$

BITS, PILANI – DUBAI CAMPUS

Knowledge Village, Dubai

Year III – Semester I 2003 – 2004

QUIZ I (Closed Book)

Course No.: AAOC UC321 Course Title: Control Systems

Date: November 10, 2003 Time: 40 Minutes M.M. = 20 (10 %)

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1. By the use of feedback, the system gain is *decreased.*

2. System sensitivity is defined as $\frac{percentage \quad change \quad in \quad T(s)}{percentage \quad change \quad in \quad G(s)}$.

3. The sensitivity of a closed-loop system with respect to variation in forward path gain (G) is reduced by a factor of *(1 + GH)* As compared to that of an open-loop system.

4. Feedback in a control system *improves* the speed of its response compared to the response speed capability of the plant/components composing the system (forward path).

5. System is of 2^{nd} *order.*

6. *(c) (i) and (iii)* are the linear systems.

7. In a linear control system *(d) the output linearly follows the input*

8. In an open loop control system *(d) for a constant input the output is constant*

9. In a closed loop control system *(c) feedback signal controls the output*

10. The sensitivity in a closed loop control system with variation in G may be obtained using the relation *(d)* $\frac{1}{1+GH}$

11. **With variation in feedback the sensitivity may be calculated** ***(d)*** $\frac{-GH}{1+GH}$

12. **The application of feedback** ***(d) modifies and improves the Signal to Noise ratio***

13. **The superposition principle is applicable to** ***(d) linear systems***

14. **A nonlinearity externally introduced in a control system** ***(d) improves system performance***

15. **In a discrete control system** ***(d) the signal is in the form of pulses***

16. **If the transfer function of an open loop system is G, then the forward path transfer function in the unity feedback control system is (d)** $\frac{G}{1-G}$

17. **Consider the torsional spring in a mechanical rotational system. Its analogous element in Force-Voltage analogy is** ***(d) 1/capacitance***

18. **For a given capacitance, the analogous element in mechanical translational system is** ***(d) mass***

19. **In a series RLC circuit, the transfer function of the output voltage across the capacitor in terms of supply voltage is** ***(d)*** $\frac{1}{s^2LC+sRC+1}$

20. **The transfer function between the actuating signal and the input signal with negative feedback is** ***(d)*** $\frac{1}{1+G(s)H(s)}$

BITS, PILANI – DUBAI CAMPUS
Knowledge Village, Dubai
Year III – Semester I 2003 – 2004

COMPREHENSIVE EXAMINATION (Closed Book)

Course No.: **AAOC UC321** Course Title: **Control Systems**

Date: January 7, 2004 Time: 3 Hours Max. Marks = **80** (40 %)

(Answer all questions from Part A and any six from Part B)

PART – A

(2 x 10)

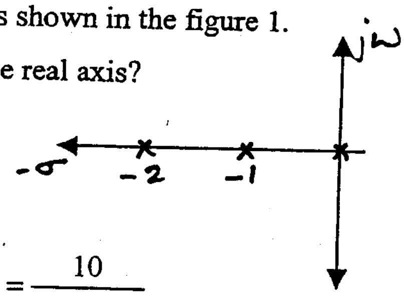
I. (a) What is regenerative feed back? Explain its merits and demerits

(b) Applying Routh's stability criterion, determine the limiting value of K so that the system described by the characteristic equation $s^3 + 3s^2 + 2s + K = 0$ is stable.

(c) The steady state error for ramp input of the system whose transfer function is given by $(s+8) / [s^2 (s+3)(s^2 + s + 2)]$ will be ____________

(d) The pole zero locations of a open loop control system is shown in the figure 1. What will be the breakaway point of the root locus on the real axis?

fig.1.



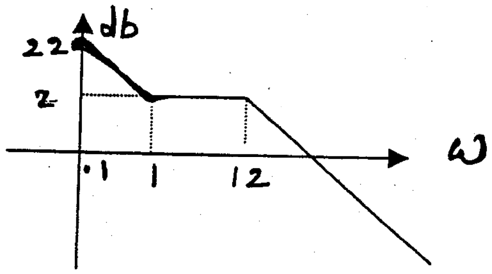
(e) Draw the log magnitude asymptote of the function $G(s) = \dfrac{10}{s(s+3)}$

(f) Define a minimum phase transfer function

(g) Define gain cross over frequency and phase cross over frequency of a control system

(h) The log magnitude asymptote of a control system is shown in the figure 2. Determine the transfer function of the system.

fig. 2.



(i) When a force is applied to a mass, dashpot and spring system, the opposing forces developed by them are respectively proportional to ....

(j) Explain how the roots of the characteristic equation determines the stability of the control system.

PART – B (10 x 6)

II. Derive the closed loop Transfer function $\theta(s) / E_a(s)$ of an armature controlled dc motor. Also Draw the block diagram of the system

III. The block diagram of a feedback control system is shown in figure 3 below.

i) Draw the signal flow graph of the system. (4)

ii) Find the overall transfer function of the system $Y(s) / R(s)$ by applying Mason's gain formulae. (6)

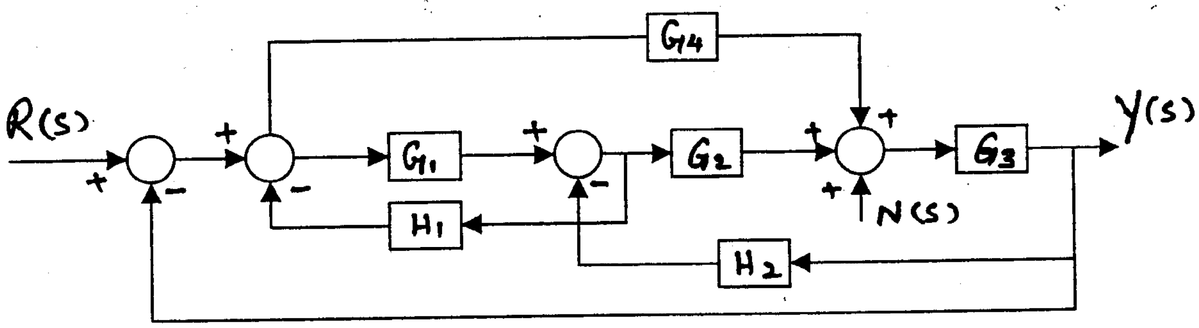


fig 3.

IV a) Derive the expressions for the step response of a typical second order system. Bring out the significance of damping factor on the step response of the system.

V a) Explain the effect of feedback on a control system (3)

b) Determine the values of K and k_1 of the closed loop system shown in figure 4 so that maximum overshoot in unit step response is 20 % and the peak time is 3 sec. Assume $J = 2$ Kg-m^2.

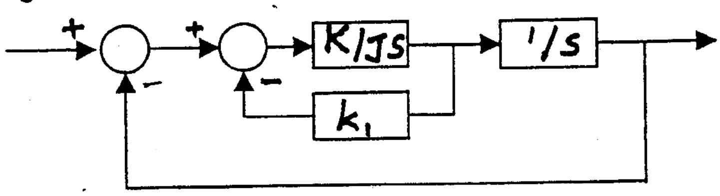


fig. 4

College of Engineering & Technology

Al Ghurair University - BITS, Pilani-Dubai

Year - III, First Semester 2002-2003

Comprehensive Exam : AAOC UC 321 / Control Systems

dt 06 - 01 - 03

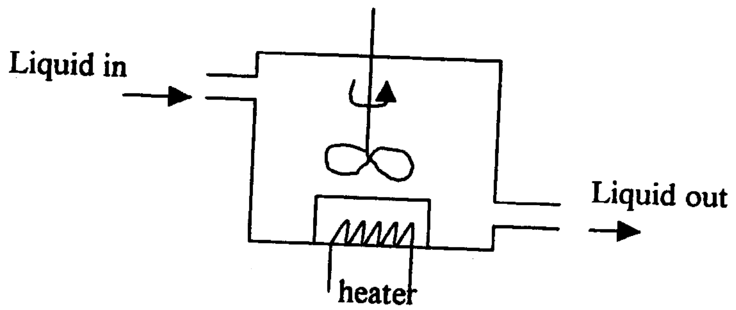
Duration : 3hrs

Max. Marks : 40

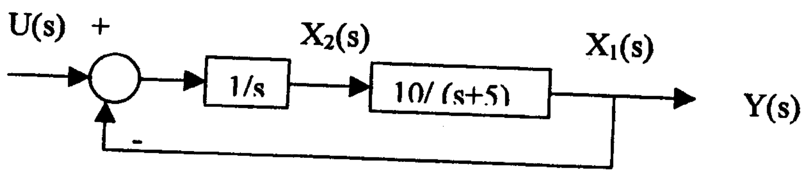
(Note : Answer all questions from part A and any four questions from part B.
Part A and Part B should be answered separately.
Each questions in part A carries 2 Marks and Part B carries 5 marks.
Only the first four answers from Part B will be Evaluated.)

Part A

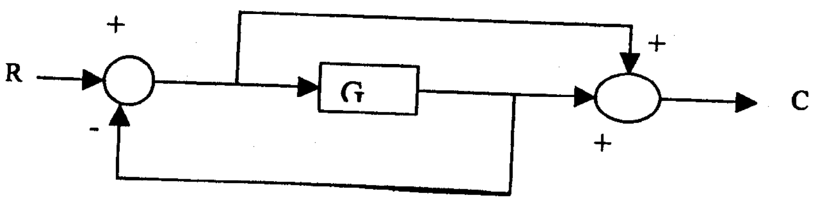
1. Consider the thermal system shown in the figure. Write the mathematical model of the system and Derive the transfer function $\Delta\theta(s) / \Delta H(s)$. Assume the temperature of the inflowing liquid is constant.



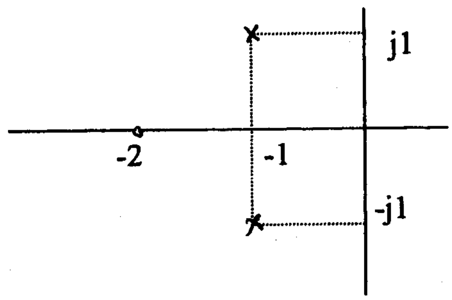
2. Obtain a state space model of the system shown in figure below.



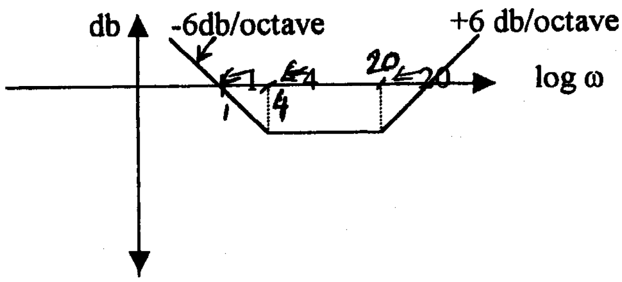
3. The block diagram of a system is shown below. Draw the signal flow graph of the system and reduce the block diagram to find out the over all transfer function



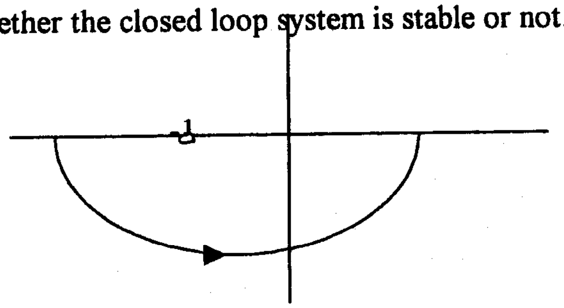
4. Explain the effect of feedback on dynamic response of an open loop system with gain K and a pole at −a.
5. Explain the working principle of a variable reluctance stepper motor
6. The open-loop transfer function of an unity feed back system is 100 / [s(s+8)]. Calculate the peak time and the peak over shoot of unit step response of the system.
7. The characteristics equation of a system is given by $s^5 + s^4 + 3s^3 + 3s^2 + 2s + 2 = 0$. Apply Routh's criterion and comment on the stability of the system.
8. Given the pole zero locations as in the figure below. Determine the angle of departure of the root locus from the open loop pole at −1+j1



9. A log magnitude asymptote is given below. find the transfer function.



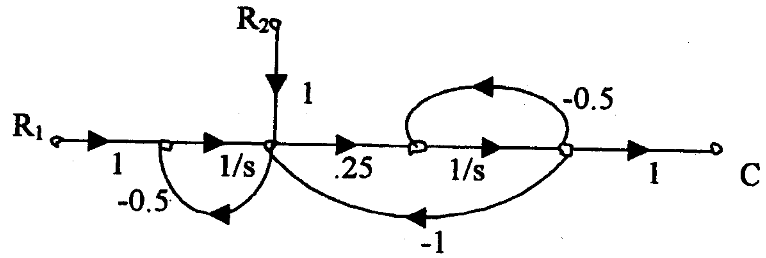
10. The polar plot of a system with one open loop pole on the right hand s-plane is given below. Determine whether the closed loop system is stable or not. Write the transfer function of the system.



Part B

1. Explain the working principle of a synchro. Also explain how is it used as a synchro error detector?

2. For the system with signal flow graph shown in the figure below, find the steady state response of the system when both the inputs R1 and R2 are unit step signals.



3. Plot the root locus (on a graph sheet with scale 1cm = 1 unit) for the closed loop control system with $G(s) = \frac{K\ (s+9)}{s(s^2+4s+11)}$; H (s) = 1
Locate the closed loop poles on the root loci such that the dominant closed loop poles have a damping ratio 0.5 . Determine the corresponding value of gain K.

4. Draw the bode diagram of the following two transfer functions:
   a) $G(s) = (sT_1 + 1) / (s\ T_2+1)$ where $T_1 > T_2 > 0$
   b) $G(s) = (-sT_1 + 1) / (s\ T_2+1)$ where $T_1 > T_2 > 0$

5. When do you use a lead compensator ? Give the detailed analysis of a lead compensator. Explain the design procedures of a lead compensator to improve the phase margin of a type I system.

6. Investigate the stability of a closed loop system with the following open–loop transfer function

$$G(s) = \frac{K\ (s+3)}{s(s-1)} \quad ; \quad K > 1 \qquad \text{: use Nyquist criterion}$$