BITS, PILANI - DUBAI CAMPUS

Knowledge Village, Dubai

Semester I 2005 - 2006

COMPREHENSIVE EXAMINATION (Closed Book)

BE (Hons) III Year (EEE/CS/EIE)

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

Date: January 2, 2006 **Time:** 3 Hours **M.M.** = 80 (40 %)

NOTE:

1. Answer **all questions from part A** and **any six questions from part B.**
2. If you are using Graph or semi graph sheets, first get it signed by the invigilator then only use it. **Graph sheets** used without **invigilator's signature** will not be accepted.
3. All the symbols carry their usual meanings unless otherwise indicated.
4. Any missing data can be assumed, but need to be mentioned.

PART - A **(2 x 10 = 20)**

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

(b) **The log magnitude asymptote of a control system is shown in figure (1). Determine the transfer function of the system.**

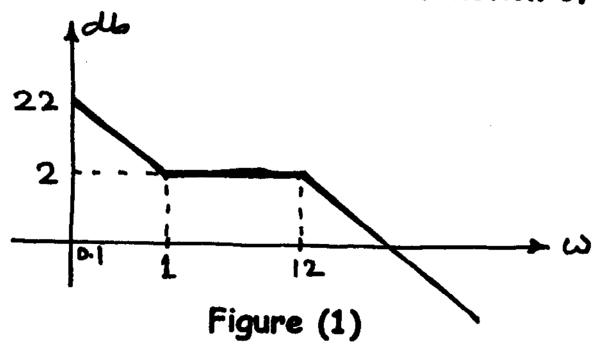

Figure (1)

(c) **Define gain cross over frequency and phase cross over frequency of a control system.**

(d) The overall transfer function $\frac{C(s)}{R(s)}$ of the block diagram shown in figure (2) will be .....

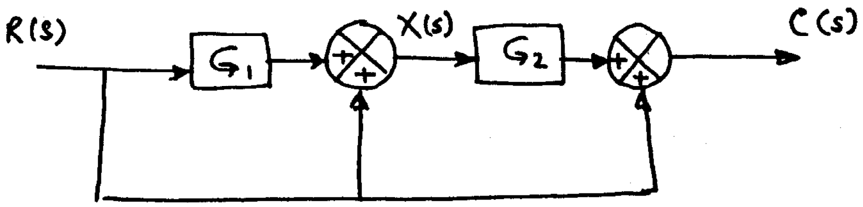

Figure (2)

(e) Transfer function $\frac{Y(s)}{U(s)}$ of the signal flow graph shown in figure (3) is

(i) $\frac{bc}{s-a}$ (ii) $\frac{s-a}{s}$ (iii) $\frac{bc}{s}$ (iv) $\frac{bc}{as}$

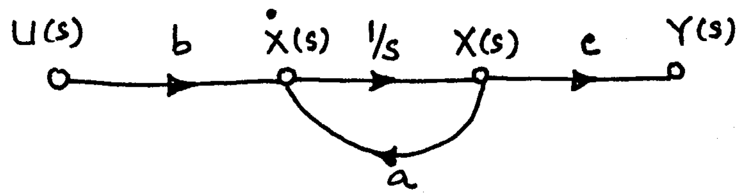

Figure (3)

(f) Find the Transfer function of a system if its impulse response is $e^{-3t}\sin 2t$.

(g) For a unity feedback system having $G(s)=\frac{35(s+4)}{s(s+2)(s+5)}$, find all error constants.

(h) A unity feedback system has $G(s)=\frac{180}{s(s+6)}$ and $r(t)=4t$, determine steady state error.

(i) Using Routh criterion, determine the stability of the system represented by the characteristic equation $s^4+8s^3+18s^2+16s+5=0$.

(j) A unity feedback system has a open loop transfer function of $G(s)=\frac{20(s+5)}{s(s+0.1)(s+3)}$. Determine steady state error for parabolic input.

PART - B (6 x 10 = 60)

2. Write the differential equations governing the mechanical system (rotational) shown in figure (4). Draw the Torque-Current electrical analogous circuit and verify by writing node equations.

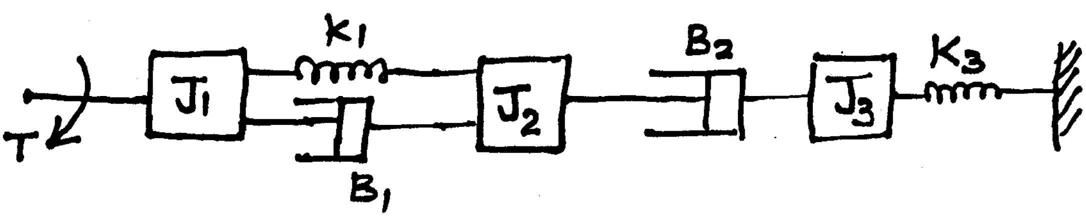

Figure (4)

3. For the system whose block diagram is drawn in figure (5), determine $\frac{C_1}{R_1}$ and $\frac{C_2}{R_1}$, (assuming $R_2 = 0$).

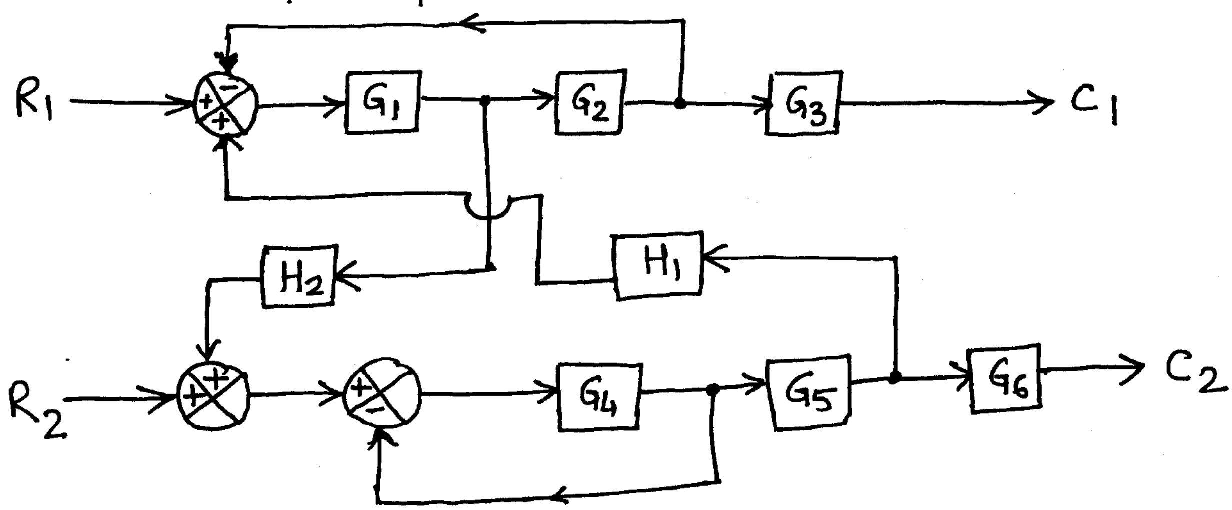

Figure (5)

4. **Consider the speed control system shown in figure (6), to control the angular speed (ω) of the load. The generator field time constant is negligible and it is driven at constant speed giving a voltage of K_g volts/field-amp. The generated emf is used to run the separately excited motor which has a back emf of K_b volts/rad/sec. The motor develops a torque of K_T N-m/amp. The motor and its load have a combined moment of inertia J $Kg\text{-}m^2$ and negligible friction. A tachometer is employed for speed feedback which develops a feedback voltage of K_t volts/rad/sec. The desired speed is set through a potentiometer. The difference between reference voltage (e_r) and the feedback voltage (e_t) is amplified using an amplifier which produces a field current of K_a amps/volt. Draw the Block diagram of the system and determine its Transfer Function.**

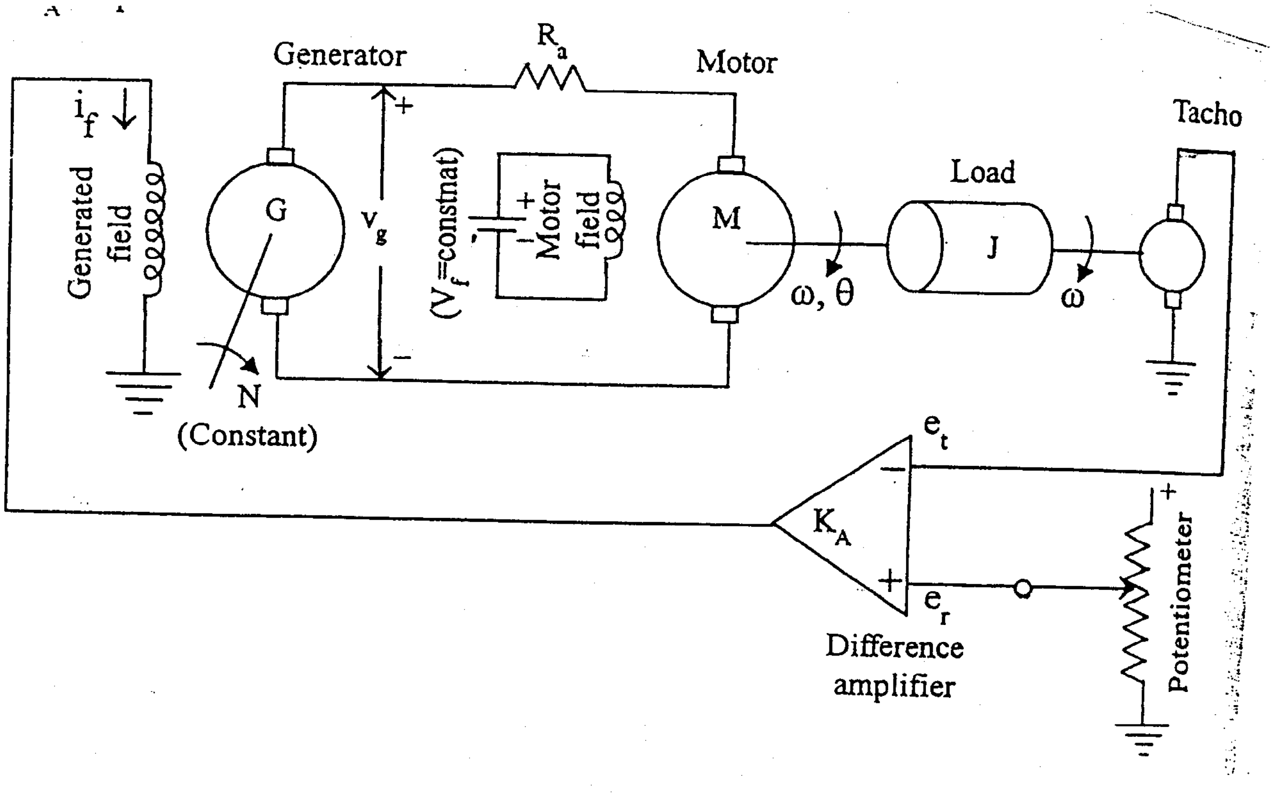

Figure (6)

5. The loop transfer function of a single loop feedback control system is given by

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

Taking K in the x-axis and T in the Y-axis, determine the region in the K-T plane in which the system is asymptotically stable and unstable. Indicate the boundary on which the system is limitedly stable.

6. The open loop transfer function of a unity negative feedback system is given by

$$G(s) = \frac{K(s+9)}{s(s^2+4s+11)}$$

Sketch the root locus of the system.

7. Sketch Bode Plots for the following transfer function and determine the system gain K for the gain crossover frequency to be 5 rad/sec.

$$G(s) = \frac{Ks^2}{(1+0.2s)(1+0.2s))}$$

8. Construct the Nyquist plot for a system whose open loop transfer function is given by

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

Find the range of K for stability of the control system.

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Knowledge Village, Dubai

Semester I 2005 - 2006

III Year (EEE/CS/EIE)

TEST II (Open Book)

Course No.: AAOC UC321 Course Title: Control Systems

Date: November 13, 2005 Time: 50 Minutes M.M. = 20 (20 %)

NOTE: Only Text Book is allowed for answering questions.

1. A system is described by the following simultaneous equations, Draw its signal flow graph and use the Mason's gain formula to find the transfer function of the system. (05)

$$x_2 = x_1 - H_1 x_2$$
$$x_3 = G_1 x_2 - H_2 x_4$$
$$x_4 = G_2 x_3 - H_3 x_5$$
$$x_5 = G_3 x_4$$
$$x_6 = (G_4 + G_5) x_5 - H_4 x_6$$
$$x_7 = x_6$$

2. A unity feed back system has forward transfer function $G(s) = \frac{4}{s+1}$. Determine and compare the response of open loop and closed loop systems for unit step input. Suppose that due to parameter variation, G(s) is modified to $G'(s) = \frac{4}{(s+0.1)}$. What will be the effect on the open loop and closed loop unit step response of the system? Comment on the sensitivity of the two systems to parameter variations. (05)

3. For a given Plant transfer function, we can select the closed loop transfer function such that the given design specifications are met by a suitable controller design, by using different feedback structures. Which analysis will you perform to decide the better structure? Perform that analysis on the following data of a plant: (05)

P.T.O.

Plant Transfer function = $\frac{K}{s(s+1)}$ and the desired closed loop transfer function to satisfy the design specification = $\frac{100/4}{s^2+(1/0.2)s+(1/0.04)}$. Take K = 1 as nominal value and the frequency of interest is 5 rad/sec. What conclusion will you draw from the analysis?

4. The practical set up of a position control servomechanism is shown in Figure (1). Assume that the input and output of the system are the input shaft position and the output shaft position respectively. Obtain the closed loop transfer function after going through the individual block diagram of the system with following numerical values for the system constants. All the angular displacements are in rad. **(05)**

K_1, gain of the potentiometer	= 7.64 V/rad
K_p, Amplifier gain	= 10 V/V
K_b, back emf constant	= 0.055 V/rad
R_a, armature resistance	= 0.2 Ohm, and
La, armature inductance	= negligible
K, Motor torque constant	= 0.00006 N-m/V
J_m, inertia of the motor	= 0.00001 Kg-m^2, and
J_L, inertia of load	= 0.0044 kg-m^2, and
f_L is viscous friction of load	= 0.04 N-m/rad/s.
N, the gear ratio	= 0.1

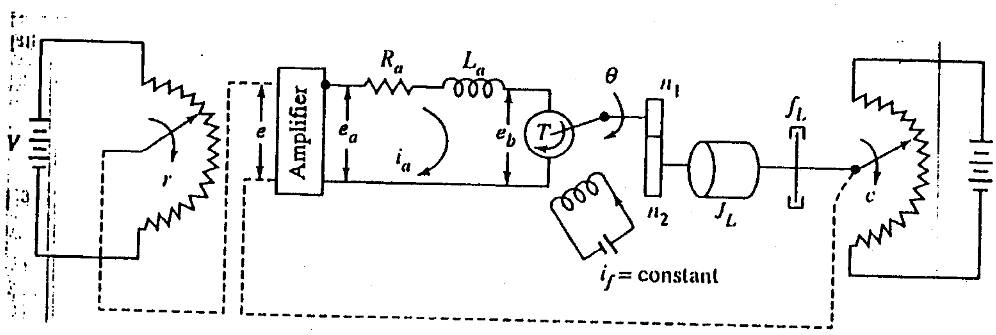

Figure (1)

Name: Id. No.

Version - B

BITS, PILANI - DUBAI CAMPUS

Knowledge Village, Dubai

Semester I 2005 - 2006

QUIZ I (Closed Book)

BE (Hons) III Year (EEE/EIE/CS)

Course No.: AAOC UC321 Course Title: Control Systems

Date: October 13, 2003 Time:40 Minutes M.M. = 20 (10 %)

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1. Human system is

(a) an open loop control system

(b) a multi variable feedback control system

(c) a single variable control system

(d) a closed loop control system

2. Consider the following statements regarding a liner system y = f(x)

1. $f(x_1 + x_2) = f(x_1) + f(x_2)$
2. $f [x(t + T)] = f[x(t) + x)t)]$
3. $f (k x) = k.f(x)$

of these statements

(a) 1, 2 and 3 are correct.

(b) 1 and 2 are correct.

(c) 3 alone is correct

(d) 1 and 3 are correct.

3. The Transfer function of a system is used to study its

(a) Steady state behavior only

(b) Transient state behavior only

(c) Transient and Steady State

(d) Transient state and partly steady state

4. The output of a liner system for a unit step input is given by t^2e^{-t}. The transfer function is given by

(a) $s / (s+1)^3$

(b) $2s / (s+1)^3$

(c) $1 / s^2(s+1)$

(d) $2 / s(s+1)^2$

5. If torque T_1 is referred from a gear with N_1 teeth to a gear with N_2 teeth, the value of the torque received at the shaft of the second gear is

(a) $[N_1/N_2].T_1$

(b) $[N_2/N_1].T_1$

(c) N_1T_1

(d) $[N_2/N_1]^2. T_1$

6. Write the Transfer function of a system represented by the differential equation, $d^2y/dt^2 + 3. dy/dt + 4 y = 2. d^2x/dt^2 + 6 x$

7. Signal flow graph is

(a) Topological representation of a set of differential equations

(b) Bode Plot

(c) Nyquist plot

(d) Polar plot

8. A Position control system is a (an)

(a) Process Control system

(b) Servomechanism

(c) Automatic regulating system

(d) Stochastic control system

9. A temperature control system is known as

(a) Servomechanism

(b) Process control system

(c) Cascade control system

(d) Open loop control system

10. Construct the signal flow graph for the following set of equations

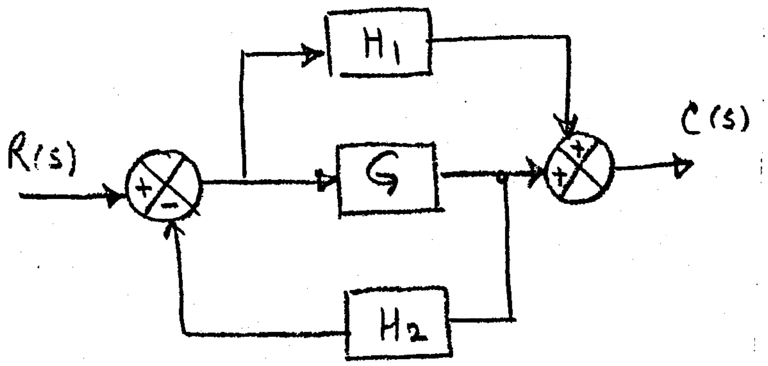
$$Y_2 = G_1Y_1 - G_2Y_4$$

$$Y_3 = G_3Y_2 + G_4Y_3$$

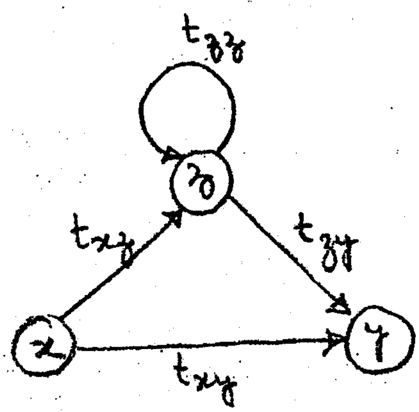
$$Y_4 = G_5Y_1 + G_6Y_3$$

where Y_1 is input and Y_4 is the output.

11. The overall transfer function $\frac{C(s)}{R(s)}$ of the following block diagram will be ....

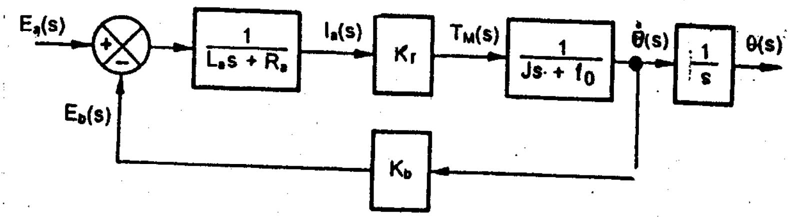


12. Compute the overall transmittance (gain) between the start and finish nodes of the following signal flow graph.



13. Write down the standard form of state variable representation of a SISO second order system.

14. Following is the block diagram representation of armature controlled d.c. motor. If one uses a tachometer for speed control scheme of this armature controlled d.c. motor, what will be the modifications in the given block diagram?



15. The relation between the pressure difference across a pipe of constant diameter and the volumetric flow rate of the liquid through it is linear only if

(a) Reynold number of the pipe flow is less than 2000 and fluid velocity is greater than 1500 m/s.

(b) Reynold number of the pipe flow is greater than 3000 and fluid velocity is greater than 1500 m/s.

(c) Reynold number of the pipe flow is less than 2000 and fluid velocity is much less than 1500 m/s.

(d) Reynold number of the pipe flow is more than 3000 and fluid velocity is much less than 1500 m/s.

16. In 'Thermal System', the condition of keeping uniform temperature in the liquid tank by perfect mixing with the help of a stirrer, is necessary so that system can be represented

(a) by a lumped parameter model

(b) by a model without any disturbance signal

(c) by a distributed parameter model

(d) Presence or absence of stirrer doesn't matter in modeling of system.

17. Relaxing the assumption of perfect heat insulation of tank in thermal system will result in heat flow through the tank walls to the ambient medium and heat storage in the tank walls which in turn modify the thermal system describing equation by affecting

(a) Thermal resistance and Thermal Capacitance respectively.

(b) Thermal Capacitance and Thermal resistance respectively.

(c) Thermal Capacitance only.

(d) Thermal resistance only.

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

19. The order of a system is determined by ……….

20. If the forward path transfer function of a system is G, then the transfer function of it with unity negative feedback will be

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

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

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

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

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BE (Hons) III Year (EEE/EIE/CS)

Semester I 2005 - 2006

TEST I (Closed Book)

Course No.: AAOC UC321 Course Title: Control Systems

Date: September 25, 2005 Time: 50 Minutes M.M. = 20 (20 %)

1.

(a) What is closed-loop instability (also known as hunting)? What is the cause of it? (1)

(b) For the block diagram shown in Figure (1), determine the output C(s), when only U(s) is present i.e. R(s) = 0. (2)

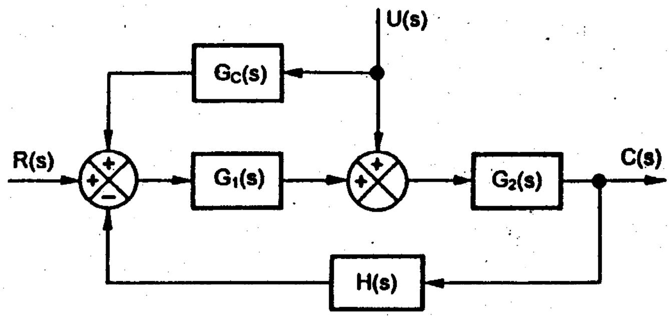

Figure (1)

(c) Draw the force-voltage electrical analogous circuit of the mechanical system shown in Figure (2). (2)

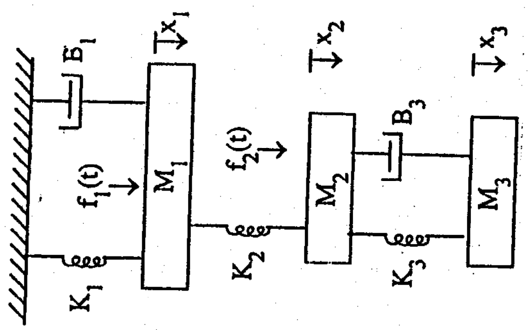

Figure (2)

2. **Obtain the torque equation of the gear train system shown in Figure (3), referred to (i) motor shaft and (ii) load shaft.** **(5)**

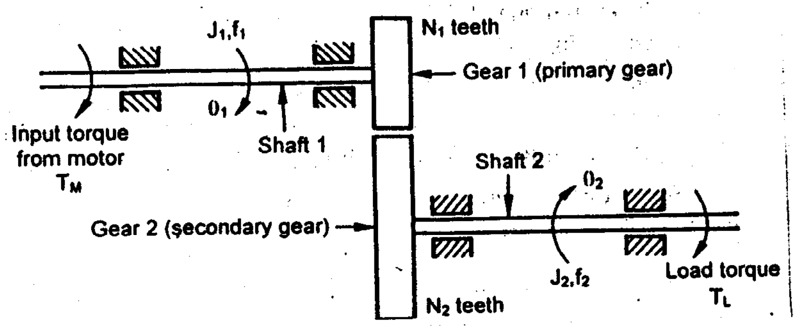

Figure (3)

3. **Obtain the describing equations from the free body diagrams of the mechanical rotational system shown in Figure (4) and determine its transfer function $\theta_2(s)/T(s)$. What is the order of the given system?** **(5)**

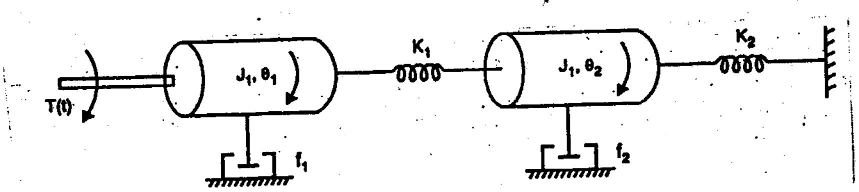

Figure (4)

4. **Evaluate the output of the system shown in Figure (5) when all the inputs are applied simultaneously, using block diagram reduction technique.** **(5)**

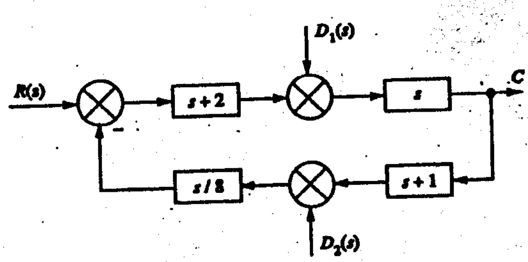

Figure (5)

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BE (Hons) III Year (EEE/EIE/CS)

Semester I 2005 - 2006

MAKEUP TEST I (Closed Book)

Course No.: AAOC UC321 Course Title: Control Systems

Date: Time: 50 Minutes M.M. = 20 (20 %)

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1. *- EACH PART OF THIS QUESTION CARRIES 1 MARK EACH.*

(a) List I gives component of mechanical system, List II gives there analog in force-voltage analogy of electrical circuit. Match them:

List I	List II
(i) Moment of Inertia	(I) Resistance
(ii) Dashpot	(II) Inductance
(iii) Linear Spring	(III) Voltage Transformer
(iv) Lever arrangement	(IV) Reciprocal of capacitance

(b) In mechanical rotational system, match list I with list II:

List I	List II
(i) Through variable	(I) Torque
(ii) Across variable	(II) Dash Pot
(iii) Power dissipating element	(III) Mass and spring
(iv) Energy storing element	(IV) Velocity

(c) AC servomotor differs from standard induction motor because its inertia and starting torque is respectively

(i) high, low (ii) high, high

(iii) low, low (iv) low, high

(d) **Match the equations:**

List I	List II
(i) Linear time invariant system	(I) $\frac{d^2x}{dt^2}+f\frac{dx}{dt}+Kx=F(t)$
(ii) Linear time varying system	(II) $\frac{d^2x}{dt^2}+f\frac{dx}{dt}+Kx^2=F(t)$
	(III) $\frac{d^2x}{dt^2}+f(t)\frac{dx}{dt}+K(t)x=F(t)$
	(IV) $\frac{d^2x}{dt^2}+f\frac{dx}{dt}+K\sin x=F(t)$

(e) **Can we apply the block diagram reduction technique to loading elements? Justify your answer.**

2. **Obtain the force balance equation of the levered system shown in Figure (1), referred to (i) a-end and (ii) b-end.** (5)

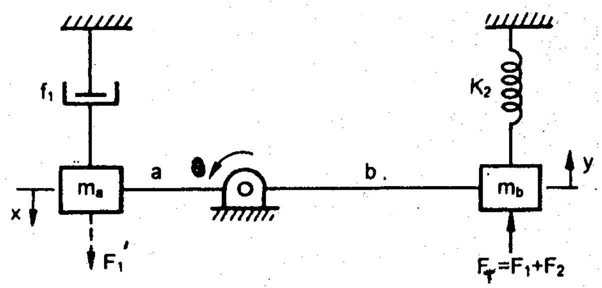

Figure (1)

3. **Obtain the describing equations from the free body diagrams of the electro-mechanical system shown in Figure (2) and determine its transfer function $X(s)/E(s)$.** (5)

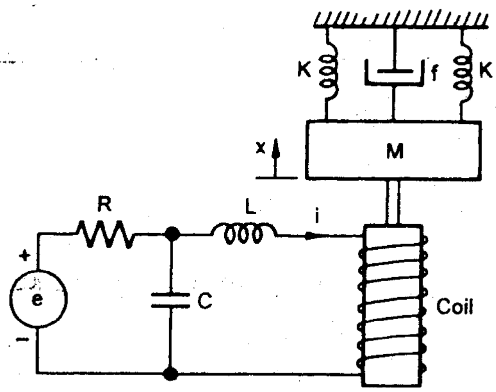

Figure (2)

4. Evaluate the output of the system shown in Figure (3) when all the inputs are applied simultaneously, using block diagram reduction technique.

(5)

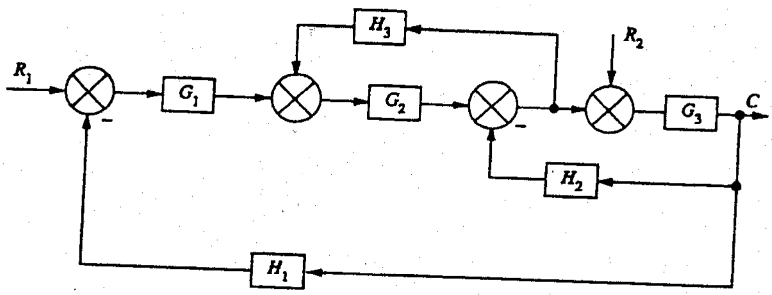

Figure (3)