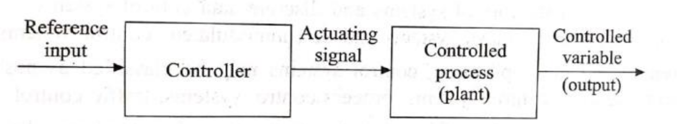
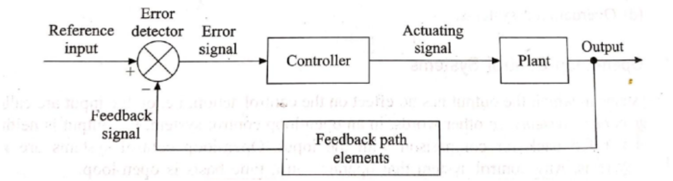
CMR
INSTITUTE OF
TECHNOLOGY

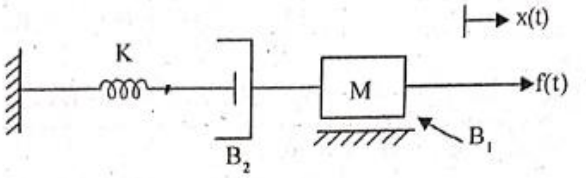
USN										

Internal Assessment Test - I

Sub:	**Control Systems**							Code:	**18EE61**
Date:	25.04.2023 8.30 – 10AM	Duration:	90 mins	Max Marks:	50	Sem:	VI	Branch:	EEE

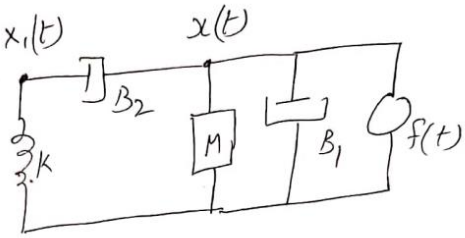
Answer Any FIVE FULL Questions

		Marks	OBE	
			CO	RBT
1	With the help of block diagram, define Open Loop and Closed Loop control systems. Write two examples for each systems Solution: 1. Open-Loop Control Systems:  Any physical system which does not automatically correct the variation in its output. ▸ It is not a feedback system ▸ It operates on a time basis Example: Washing machine, Electric Toaster, Traffic control. 2. Closed-Loop Control Systems:  ▸ Feedback control system. ▸ A system that maintains a prescribed relationship between the output and the reference input by comparing them and using the difference as a means of control. Example: Traffic control, Room heating system.	2 2 1 2 2 1	CO1	L1
2	For the mechanical system shown in Fig determine the transfer function X(s)/F(s)		CO1	L3



Solution

Mechanical Network :-



2

$$M\frac{d^2x}{dt^2} + B_1\frac{dx}{dt} + B_2\frac{d(x-x_1)}{dt} = f(t) \quad — (1)$$

2

$$K x_1(t) + B_2\frac{d(x_1-x)}{dt} = 0 \quad — (2)$$

Laplace Transform (1),

$$MS^2X(S) + B_1 S X(S) + B_2 S[X(S) - X_1(S)] = F(S)$$

$$X(S)\{MS^2 + S[B_1 + B_2]\} - B_2 S X_1(S) = F(S) \quad — (3)$$

L.T (2),

$$K X_1(S) + B_2 S[X_1(S) - X(S)] = 0$$

2

$$-B_2 S X(S) + X_1(S)[B_2 S + K] = 0 \quad — (4)$$

From (3) & (4).

$$\begin{bmatrix} MS^2 + S[B_1+B_2] & -B_2 S \\ -B_2 S & (B_2 S + K) \end{bmatrix} \begin{bmatrix} X(S) \\ X_1(S) \end{bmatrix} = \begin{bmatrix} F(S) \\ 0 \end{bmatrix}$$

2

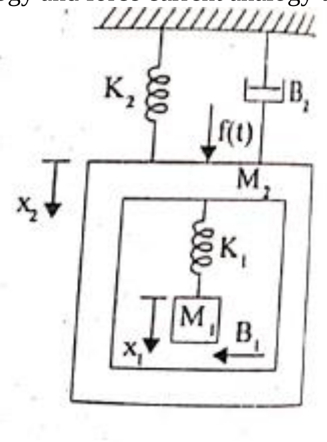
$$X(S) = \frac{\begin{vmatrix} F(S) & -B_2 S \\ 0 & (B_2 S + K) \end{vmatrix}}{\begin{vmatrix} MS^2 + S[B_1+B_2] & -B_2 S \\ -B_2 S & (B_2 S + K) \end{vmatrix}}$$

$$X(S) = \frac{F(S)[B_2 S + K]}{\{MS^2 + S[B_1+B_2]\}\{B_2 S + K\} - (B_2 S)^2}$$

2

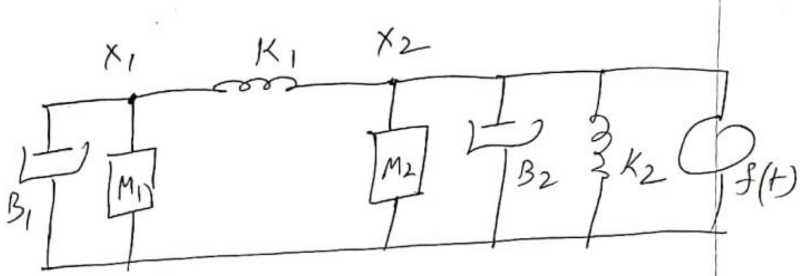
$$\therefore \frac{X(S)}{F(S)} = \frac{B_2 S + K}{[MS^2 + S(B_1+B_2)][B_2 S + K] - (B_2 S)^2}$$

3	Construct mathematical model for the mechanical system shown in Fig. Draw electrical equivalent network based on force voltage analogy and force current analogy and write its modelling equations.		CO1	L3



Solution

3) Mechanical network:-



1

$$M_1 \frac{d^2x_1}{dt^2} + B_1 \frac{dx_1}{dt} + K_1(x_1 - x_2) = 0 \quad \text{— (1)}$$

$$M_2 \frac{d^2x_2}{dt^2} + B_2 \frac{dx_2}{dt} + K_2 x_2 + K_1(x_2 - x_1) = f(t) \quad (2)$$

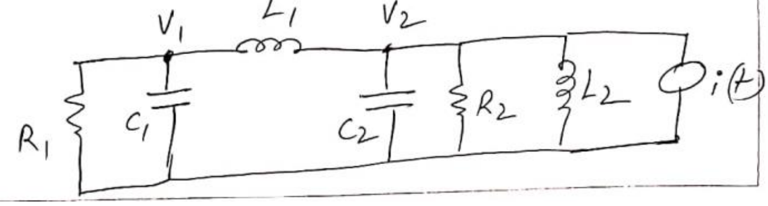
L.T (1) & (2).

$$M_1 s^2 X_1(s) + B_1 s X_1(s) + K_1[X_1(s) - X_2(s)] = 0$$

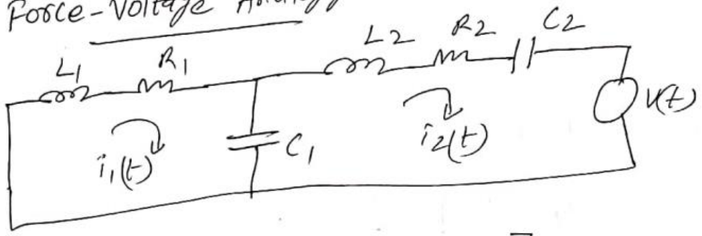
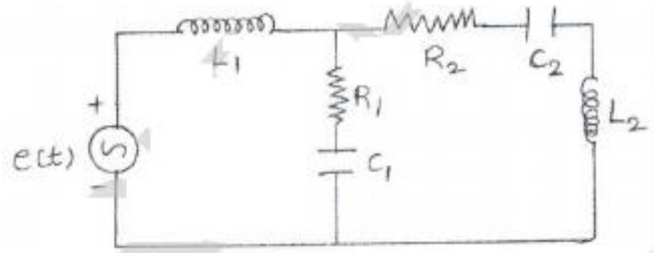
1

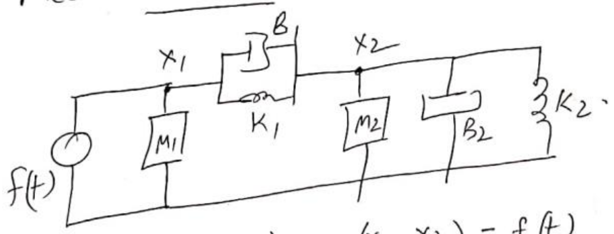
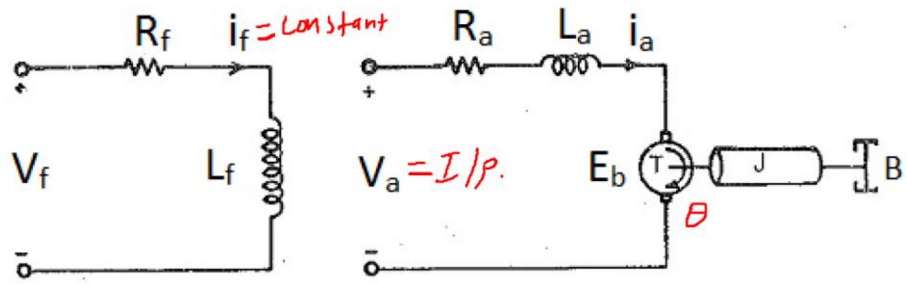
$$M_2 s^2 X_2(s) + B_2 s X_2(s) + K_2 X_2(s) + K_1[X_2(s) - X_1(s)] = F(s)$$

Force current analogy.



2

	$C_1 \frac{dV_1}{dt} + \frac{V_1}{R_1} + \frac{1}{L_1}\int (V_1 - V_2) = 0$ $C_1 s V_1(s) + \frac{V_1(s)}{R_1} + \frac{1}{L_1 s}[V_1(s) - V_2(s)] = 0.$ $C_2 \frac{dV_2}{dt} + \frac{V_2}{R_2} + \frac{1}{L_2}\int V_2(t) + \frac{1}{L_1}\int (V_2 - V_1)dt = i(t)$ $C_2 s V_2(s) + \frac{V_2(s)}{R_2} + \frac{1}{L_2 s} V_2(s) + \frac{1}{L_1 s}[V_2(s) - V_1(s)] = I(s)$	2		
	Force-Voltage Analogy. 	2		
	$L_1 \frac{di_1(t)}{dt} + R_1 i_1(t) + \frac{1}{C_1}\int[i_1(t) - i_2(t)] = 0.$ $L_1 s I_1(s) + R_1 I_1(s) + \frac{1}{C_1 s}[I_1(s) - I_2(s)] = 0.$ $L_2 \frac{di_2(t)}{dt} + R_2 i_2(t) + \frac{1}{C_2}\int i_2(t) + \frac{1}{C_1}\int[i_2(t) - i_1(t)] = v(t)$ $L_2 s I_2(s) + R_2 I_2(s) + \frac{1}{C_2 s} I_2(s) + \frac{1}{C_1 s}[I_2(s) - I_1(s)] = V(s)$	2		
4	Draw an equivalent mechanical network using force voltage analogy as shown in Fig. Determine the modelling equations  Solution		CO1	L3

	4) $L_1\frac{di_1}{dt} + R_1[i_1(t)-i_2(t)] + \frac{1}{C_1}\int[i_1(t)-i_2(t)] = e(t)$. $L_1 s I_1(s) + R_1[I_1(s)-I_2(s)] + \frac{1}{C_1 s}[I_1(s)-I_2(s)] = E(s)$ $L_2\frac{di_2}{dt} + \frac{1}{C_2}\int i_2(t)dt + R_2 i_2(t) + R_1[i_2(t)-i_1(t)] + \frac{1}{C_1}\int[i_2(t)-i_1(t)] = 0$. $L_2 s I_2(s) + \frac{1}{C_2 s} I_2(s) + R_2 I_2(s) + R_1[I_2(s)-I_1(s)] + \frac{1}{C_1 s}[I_2(s)-I_1(s)] = 0$. Mechanical network.  $M_1\frac{d^2x_1}{dt^2} + B_1\frac{d(x_1-x_2)}{dt} + K_1(x_1-x_2) = f(t)$ $M_1 s^2 X_1(s) + B_1 s[X_1(s)-X_2(s)] + K_1[X_1(s)-X_2(s)] = F(s)$. $M_2\frac{d^2x_2}{dt^2} + B_2\frac{dx_2}{dt} + K_2 x_2 + B_1\frac{d(x_2-x_1)}{dt} + K_1(x_2-x_1) = 0$ $M_2 s^2 X_2(s) + B_2 s X_2(s) + K_2 X_2(s) + B_1 s[X_2(s)-X_1(s)] + K_1[X_2(s)-X_1(s)] = 0$.	2 2 2 2 2		
5	With neat circuit diagram, Obtain the mathematical model for armature controlled dc motor and derive its transfer function Solution: 	2	CO1	L3

Derivation.

Let i_f = constant.

$$R_a i_a + L_a \frac{di_a}{dt} + e_b = V_a.$$

$$R_a i_a + L_a \frac{di_a}{dt} = V_a - e_b \quad \text{— (1)}.$$

$$T \propto i_a \Rightarrow T = K_a i_a \quad \text{— (2)}$$

$$J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt} = T \quad \text{— (3)}$$

$$e_b \propto \frac{d\theta}{dt} \Rightarrow e_b = K_b \frac{d\theta}{dt} \quad \text{— (4)}$$

L.T (1), $R_a I_a(s) + L_a s\, I_a(s) = V_a(s) - E_b(s)$

$$I_a(s)\left[R_a + L_a s\right] = V_a(s) - E_b(s)$$

$$I_a(s) = \frac{V_a(s) - E_b(s)}{R_a + L_a s} \quad \text{— (5)}$$

3

L.T (2), $T(s) = K_a I_a(s)$ — (6)

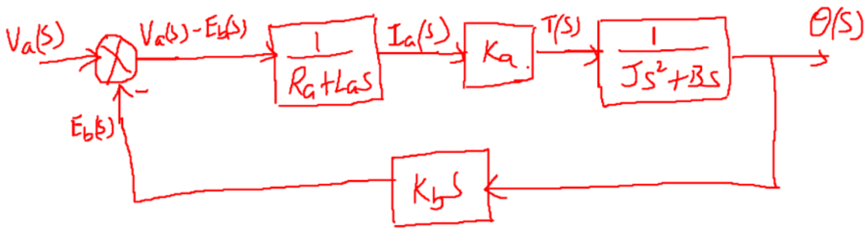
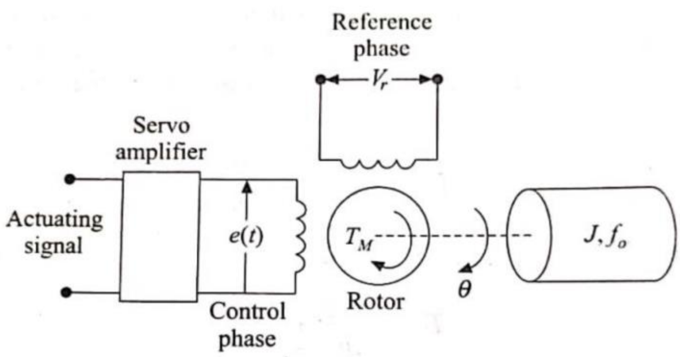
L.T (3), $\theta(s)\left[Js^2 + Bs\right] = T(s)$ — (7)

L.T (4), $E_b(s) = K_b s\, \theta(s)$ — (8)

2

From (5), (6), (8)

$$T(s) = K_a\left[\frac{V_a(s) - K_b s\, \theta(s)}{R_a + L_a s}\right] \quad \text{— (9)}$$

	(9) in (7), $$\theta(s)[Js^2+Bs] = \frac{K_a V_a(s) - K_a K_b s\,\theta(s)}{R_a+L_a s}$$ $$\theta(s)\{[Js^2+Bs][R_a+L_a s]\} = K_a V_a(s) - K_a K_b s\,\theta(s)$$ $$\theta(s)\{(Js^2+Bs)(R_a+L_a s)\} + K_a K_b s\,\theta(s) = K_a V_a(s)$$ $$\theta(s)[(Js^2+Bs)(R_a+L_a s)+K_a K_b s] = K_a V_a(s)$$ $$\therefore \frac{\theta(s)}{V_a(s)} = \frac{K_a}{(Js^2+Bs)(R_a+L_a s)+K_a K_b s}$$ Block Diagram representation. From (5),(6),(7)(8).  	2 1		
6	With neat circuit diagram of AC servomotor, derive the transfer function and find the expression for Motor Gain and Motor time constant Solution - An ac servomotor is basically a two-phase induction motor except for certain special design features.  	2	CO1	L3

	Mechanical Load,  $J\frac{d^2\theta}{dt^2} + f\frac{d\theta}{dt} = T_M$ — (1)			
	Motor Torque: $T_M = K_1 e_c - K_2\frac{d\theta}{dt}$. — (2)			
	(2) in (1), $J\frac{d^2\theta}{dt^2} + f\frac{d\theta}{dt} = K_1 e_c - K_2\frac{d\theta}{dt}$ — (3)	3		
	L.T (3), $Js^2\theta(s) + fs\theta(s) = K_1E_c(S) - K_2 s\,\theta(s)$			
	$Js^2\theta(s) + fs\,\theta(s) + K_2 s\,\theta(s) = K_1E_c(S)$	1		
	$\theta(s)\left[Js^2 + s(f+K_2)\right] = K_1E_c(s)$.			
	$\therefore \frac{\theta(s)}{E_c(s)} = \frac{K_1}{s\left[Js+(f+K_2)\right]} = \frac{K_1}{s(f+K_2)\left(\frac{Js}{f+K_2}+1\right)}$			
	$= \frac{K_1/(f+K_2)}{s\left[\frac{Js}{f+K_2}+1\right]} = \frac{K_m}{s[\tau_m s+1]}$	2		
	where $K_m = \frac{K_1}{f+K_2}$, $\tau_m = \frac{J}{f+K_2}$	2		
	↳ Motor Gain ↳ Motor Time			