Ref. No.Ex/IEBE/T/226/2019

B.I.E.E. 2nd Yr. 2nd Semester Examination, 2019

SUBJECT: Linear Control Systems

Time: Three hours

Full Marks 100

All Modules are Compulsory.

Q.No.		Marks
	Module I	
1.	Draw the schematic diagram and derive the system equations for a) DC field controlled motor, b) Pneumatic system and c) Accelerometer.	6
	OR	
	Draw and describe a simple thermally insulated system with heater and stirrer. Identify system parameters and derive their mathematical model. Derive the 2 input single output unity feedback loop representation of the system considering temperature as output and inflow rate and inlet temperature as the inputs.	
2.	Derive the transfer function for the system in Fig.1 using block diagram reduction technique. Draw the equivalent signal flow graph and use Mason's Gain Formula to find the transfer function.	5+4+5

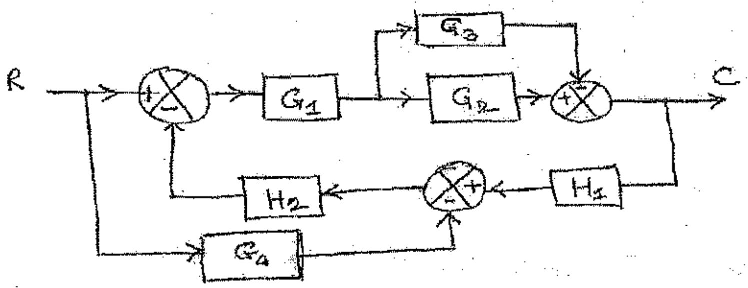
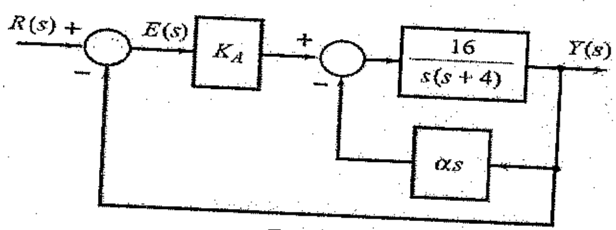


Fig.1

OR

	a) Draw and describe an AC position servo system and derive the control equation for the error signal. Draw the waveforms for carrier, reference and measured angular displacements, error and output signals stating assumptions and justifications.	6
	b) An armature controlled DC servomotor driving a system has the following components: i) Potentiometer: K_e=0.5V/deg, ii) Error amplifier: K_1=10.0V/V, iii) Motor: R_a=10.0Ω, L_a=0, Torque constant K_T=1Nm/A, J_m=2kgm^2, D_m=0 (including back emf effect), iv) Gear and Load: n=0.1, J_L=0.1kgm^2, D_L=0.2Nm/rad/s. Draw system block diagram and determine T.F. $\theta_o(s)/\theta_i(s)$.	8

Q.No.		Marks
	Module 2	
3.	Derive and draw the unit step response for a 2nd order underdamped system from first principles. Derive the initial value, the transient response, the envelopes and their start values, t_p, M_p, and t_s and show these in the diagram.	4+6
	OR	
	a) For a unity feedback system with $G(s)=25/s(s+6)$, determine the closed loop $T(s)$, ξ, ω_n, ω_d, t_r, t_s, t_p and M_p. For a unit ramp input, determine the steady state error.	6
	b) For $G(s)H(s)=K/s^2(s+1)(s+2)$, identify type of system. Find K such that the error is limited to 0.8 for an input $1+8t+5t^2$.	4
4.	A unity feedback control system has a forward path controller $G_c(s) = (s+a)/s$ preceding the process $G(s) = K\ (s+3)/(s^2-1)$. Find the steady state error to unit ramp input. Find conditions on a and K for system to be stable. Also find sensitivity of the system to parameter variations in (i) a, (ii) K and (iii) the unstable open loop pole location.	10
	OR	
	For the system in Fig.2, determine a) peak overshoot for unit step input in absence of rate feedback for $K_A=1$, b) steady state error for unit ramp input for $K_A=1$, c) value of α which reduces peak overshoot for unit step input to 1.5%, d) corresponding steady state error for unit ramp input, e) K_A for which peak overshoot is 1.5% while steady state error for unit ramp input is same as in b).	10
	 Fig.2	
	Module 3	
5.	Draw the root contours of the system with $GH(s)=K/s(s+1)(s+\alpha)$.	10
	OR	
	Draw the root locus of $GH(s)=Ks/(s^2+4)(s^2+16)$.	10
6.	a) For a unity feedback system with $GH(s)=K(s+2)/(s^2+2s+3)$, determine the open loop poles and show that the root loci from the poles are circular. What is the system gain and corresponding ω for which $\xi=0.7$?	6
	b) Draw the asymptotic Bode magnitude and phase plot for a simple pole $1/(1+j\omega T)$. Identify the critical frequency. Provide the derivation of the asymptotic segments and derive the values of errors at twice and ten times the critical frequency..	10
	c) Determine the breakaway points for the unity feedback system with $G(s)=K/s(s+4(s^2+4s+20)$.	4

Q.No.		Marks
6.	OR For the system having open loop TF GH(s) = $160(s+1)/s^2(s^2+4s+16)$, i. Identify Bode components and state magnitude and phase characteristics of the components, identify critical frequencies. ii. Draw the Bode magnitude and phase plots using asymptotes, iii. Provide table for calculated and graphically obtained gain and phase values at critical frequencies. iv. Identify gain margin, phase margin in the plots and compare graphical gain and phase margins with theoretical values. v. Comment on system stability.	4+8+4+3+1
7.	a) Draw the Nyquist contour and Nyquist plot of $G(s)=1/s(sT+1)$. What is the real intercept at $\omega=0$? b) State the expressions for GM and PM. Illustrate ω_p, ω_g, GM and PM in notional Bode magnitude and phase plots. Show how GM and PM are identified in a log magnitude vs. phase plot. c) How to determine the ω at which PM is +90° using N circles?	6+7+2
	OR a) Draw the Nyquist contour and Nyquist plot of $G(s) = 10(s+3)/s(s-1)$. b) Show and explain how GM and PM can be identified using a phase plot. c) Derive from first principles the relation for M circles in terms of the real and imaginary parts of $G(j\omega)$.	6+4+5
	Module 4	
8.	For a mass spring damper system subjected to 2N force, the steady state displacement of the mass required is 0.1m and the peak overshoot at 2s is required to be 0.0015m. Determine M, f and K of the system.	8
	OR a) Determine the value of controller gains K_p and K_I for a forward path PI controller ($K_p + K_I/s$) for a unity feedback system with $G(s) = 2/(s+4)$ so that its damping ratio and natural frequency of oscillation become 1 and 4 Hz resp.	4
	b) Determine the range of values of K of a unity feedback system with $G(s) = K/s(s+1)$ so that $e_{ss} < 0.004$ when $r(t) = 0.2t$.	4
9.	A unity feedback system with controller gain 5 and a velocity feedback loop, with plant TF $G(s)=K/s(s+1)$ and velocity feedback 4s, in the forward path. Draw the system block diagrams and determine closed loop TF and S^T_K. For a required T(s) of $25/(s^2+5s+25)$ at ω=5rad/s, determine the system gain K and the sensitivity to gain at the operating frequency.	7
	OR Design a lead compensator for a unity feedback system with an open loop transfer function $G(s) = 4K/\{s(s+2)\}$ for the specifications of $K_v=20s^{-1}$, phase margin $\varphi_m \geq 50°$ and gain margin at least 10dB.	7