Ref. No.: Ex/FET/OE/ELE/T/203/2023(S)

BACHELOR OF ENGINEERING IN MECHANICAL ENGINEERING
4^{TH} YEAR 2^{ND} SEMESTER SUPPLEMENTARY EXAMINATION, 2023

Subject: BASIC LINEAR CONTROL SYSTEM ENGINEERING (OPEN ELECTIVE-II)

Time: 3 Hours **Full Marks: 100**

Question No.	Question 1 is compulsory Answer *Any Four* questions from the rest (4×20)	Marks
Q1	Answer ***Any Four*** of the following (4×5=20):	
	(a) Determine whether the system characterized by the differential equation $$y(t) = \dot{x} + x(t)$$ is time-invariant, linear, causal, and memoryless or not?	5
	(b) Derive state equations for the following system $$\ddot{y}(t) + 2\dot{y}(t) + 4y(t) = 2u(t).$$	5
	(c) Determine whether the system characterized by the differential equation $\ddot{y}(t) - \dot{y}(t) + 2y(t) = x(t)$ is stable or not? Assume zero initial conditions.	5
	(d) The unit impulse response of an LTI system is the unit step function $u(t)$. Find the response of the system to an excitation $e^{-at}u(t)$.	5
	(e) With the help of a schematic diagram indicate the different components and signals associated with a Closed-loop Control System.	5
	(f) Discuss "Direct acting" and "Reverse Acting" mode of Proportional control.	5
	(g) Why PID controller is called a "Gain-Reset-Preact Controller"?	5
Q2	(a) Define damping ratio (ξ) and undamped natural frequency (ω_n) for a second order system?	4
	(b) Show how second order systems are classified based on the values (or range of values) of the damping ratio of the system and draw the nature of the unit step responses for each type of systems.	8
	(c) Obtain the transfer function, $Y(s)/X(s)$, for the circuit shown in Figure Q2(c).	8

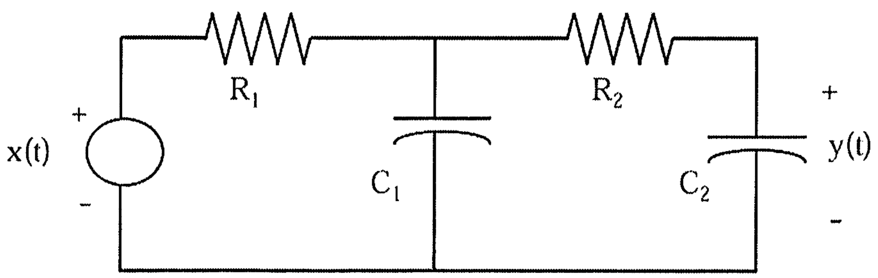

Figure Q2(c)

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Q3 (a) Consider the mechanical system shown in Figure Q3(a). Assume that the system is linear.

The external force $u(t)$ is the input to the system, and the displacement $y(t)$ of the mass is the output.

The displacement $y(t)$ is measured from the equilibrium position in the absence of the external force.

(i) Obtain a state-space representation of the system.

(ii) From state-space model obtain the transfer function.

(iii) Obtain the analogous electrical network based on *force-current* analogy. 4+4+4

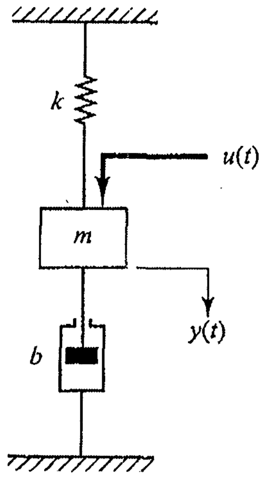

Figure Q3(a)

(b) Draw an asymptotic Bode magnitude plot for the system having a transfer function: 8

$$G(s) = \frac{10(s+3)}{s(s+2)}$$

Q4 (a) State and derive (i) Final Value Theorem and (ii) Initial Value Theorem for Laplace Transform. 4+4

(b) Find the transfer function of the system characterized by the following differential equation $\dot{y} + ay = x$. Assume zero initial condition. 4

(c) Solve the following differential equation using the Laplace Transform method 8

$$\ddot{y} + 4\dot{y} + 20y = 2\dot{x} - x, \text{ with, } x(t) = u(t) \text{ (unit step)}, y(0) = 0, \dot{y}(0) = 1$$

Q5 (a) Derive the differential equation for PID controller and briefly discuss the functions of each of the three components of a PID controller? 2+4

(b) Describe, stating the assumption, the Ziegler Nichols method of PID controller tuning based on unit step test. 6

(c) Consider a control system in which a PID controller is used to control the plant 8

$$G(s) = \frac{1}{s(s+1)(s+5)}$$

Determine the parameters of PID controller by Ziegler-Nichols tuning rule.

Q6 (a) Define state and output equation for an LTI system.

Indicate the order of the vectors and the matrices involved in State and Output equations for an n-th order LTI system with p inputs and m outputs. (2+2) +4

(b) Consider an LTI system given by the transfer function:

$$G(s) = \frac{s^2 + 9s + 15}{s^3 + 7s^2 + 16s + 4}$$ 8+4

Obtain the state-space model of the system in the phase variable canonical form. Draw the corresponding block diagram indicating the individual states.

Q7 (a) Show that the Root Locus would always start from open loop poles (for gain K=0) and terminate at the open loop zeros (as K tends to infinity). 4

(b) Consider a negative feedback system with unity feedback gain with the forward path transfer function given by

$$G(s) = \frac{K}{s(s+1)(s+2)}$$ 8

Draw the root loci of the system for positive values of the gain K.

(c) Define type of a system? For a unity feedback system define the following terms and find the expressions for steady-state error in response to Step, Ramp and Parabolic inputs in terms of these constants: 2+6

(i) Static position error constant

(ii) Static velocity error constant

(iii) Static acceleration error constant

Q8 (a) State and briefly explain the Routh's Stability Criterion. 4

(b) Consider the unity negative feedback system shown in Figure Q8(b). Determine the range of the values of the gain K for which the system remains stable. 8

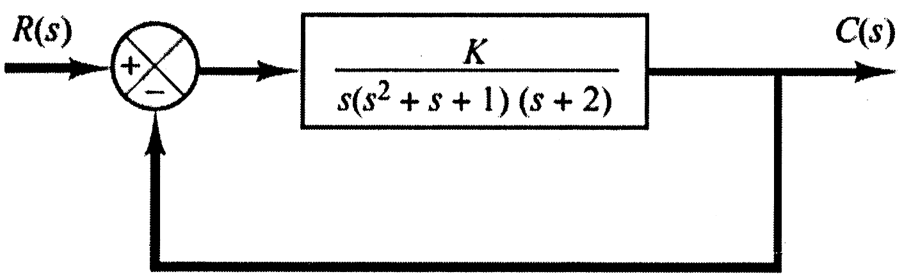

Figure Q8(b)

(c) What are "Analogous Systems"? Briefly discuss the *Force-Current* and *Force-Voltage* analogy between Mechanical and Electrical Systems. 2+6