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Question Paper Code:R5B02

B.E./B.Tech. DEGREE EXAMINATION, NOV 2025

Fifth Semester

R21UBM502- BIO CONTROL SYSTEMS

Biomedical Engineering

(Regulations R2021)

Duration: Three hours Maximum: 100 Marks

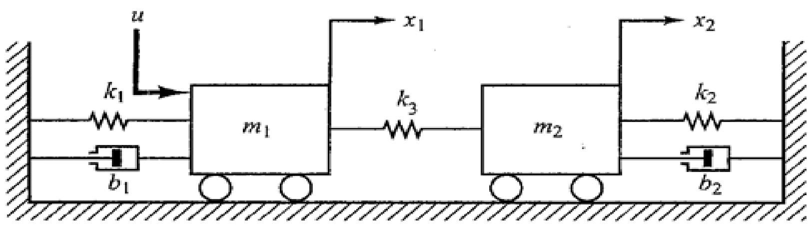
Answer ALL Questions

PART A - (10 x 2 = 20 Marks)

1.	Compare positive and negative feedbacks in a control system.	CO1 - U
2.	Write the force balance equation of an ideal mass element.	CO1 - U
3.	Find the type and order of the given system, whose open-loop transfer function $G(s)H(s) = \frac{s(s+5)}{s^2(s+2)(s+3)}$.	CO2 - App
4.	Give the expression for rise time of the step response for a second-order system.	CO1 - U
5.	A unity feedback system has the transfer function $G(s) = \frac{10}{s(s+6)}$. Determine the resonant peak and resonant frequency.	CO3 - App
6.	If a system is said to have a damping $\xi = 0.5532$ with the natural frequency $\omega_n = 2$ rad/sec, what will be the value of resonant frequency?	CO3 - App
7.	Draw the block diagram representation of state model.	CO1 - U
8.	List out the disadvantages of state space modeling using phase variable?	CO1 - U
9.	Give examples of positive and negative feedback physiological control system.	CO1 - U
10.	Explain why stability is essential for maintaining homeostasis in physiological systems.	CO1 - U

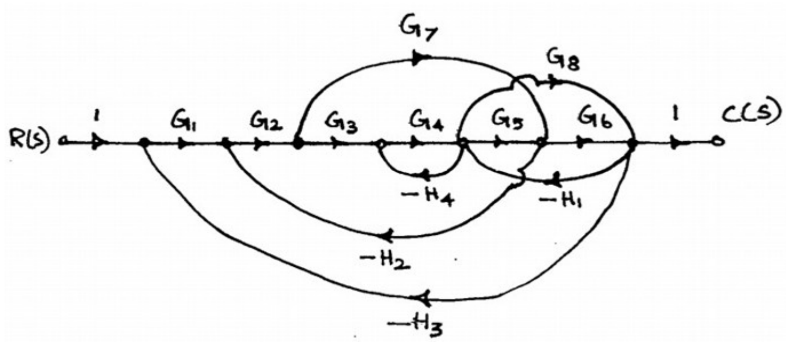
PART – B (5 x 16= 80 Marks)

11. (a) Obtain the transfer function X2(s)/U(s) of the following mechanical system as shown in Fig. Also draw the Force-Voltage and Force-Current electrical analogous circuits and verify the equations. CO2 -App (16)



Or

(b) Estimate the C(s)/R(s) for the Signal flow graph shown below using Mason's gain formula. CO2 -App (16)



12. (a) (i) The closed loop Transfer function of the system is $\frac{25K}{s^2+(5+500K_t)s+25K)}$. Find the value of K and K_t so that the maximum overshoot of the output is approximately 20 percent and the rise time is 0.05 sec. CO3 - App (8)

(ii) The open loop transfer function of a unity feedback system is given by $(s) = \frac{1}{s(1+s)}$. Determine the generalized error coefficients and steady state error of the system for the input $r(t) = 4 + 6t + 2t^3$. CO3 - App (8)

Or

(b) (i) Using the Routh criterion, check whether the system represented by the following characteristic equation is stable or not. Comment on the location of the roots. Determine the frequency of sustained oscillations if any. CO3 - App (8)

$$s^5 + s^4 + 2s^3 + 3s^2 + 3s + 5 = 0$$

(ii) A unity feedback system is characterized by the open-loop transfer function, $G(s) = \frac{K(s+13)}{s(s+3)(s+7)}$ using the Routh-stability criterion method; calculate the range of values of K for the system to be stable. Determine the values of K, which cause sustained oscillations in the closed-loop system. What are the corresponding oscillating frequencies? CO3 - App (8)

13. (a) A drug delivery system uses a control loop whose open-loop transfer function is modeled as: CO4 - Ana (16)

$$G(s)H(s) = \frac{40}{s(s+2)(s+5)}$$

Sketch the Bode log-magnitude and phase plots of this system. From the plots, evaluate:

(i) Gain crossover frequency
(ii) Phase crossover frequency
(iii) Gain margin
(iv) Phase margin

Analyze the system's stability and comment on whether it is suitable for accurate and stable control in automated drug infusion.

Or

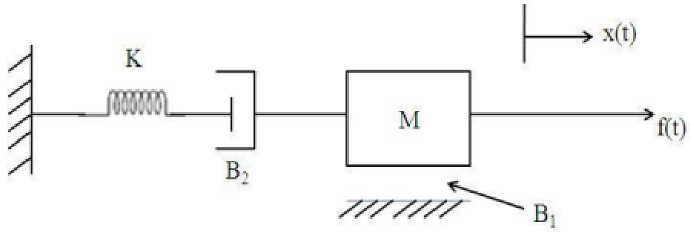
(b) A simplified model of a respiratory feedback control system is represented by the open-loop transfer function: CO4 - Ana (16)

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

where K denotes the neural gain of the respiratory control loop. Using the Nyquist stability criterion,

(i) Determine the range of values of K for which the closed-loop system remains stable.
(ii) Comment on the biological significance: explain how an excessively high value of K could lead to oscillatory or unstable breathing patterns, while too low a value of K could result in sluggish or inadequate response to changes in blood gas levels.

14. (a) (i) Obtain the state model of the mechanical system shown below. CO2 - App (8)

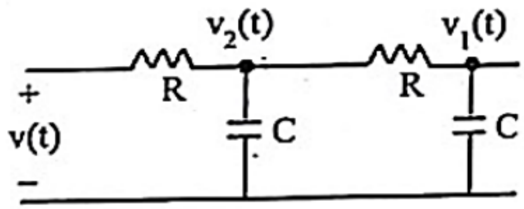


(ii) Obtain the transfer function of the system defined by the following state space model. CO2 - App (8)

$$\begin{bmatrix}\dot{x_1}\\ \dot{x_2}\\ \dot{x_3}\end{bmatrix} = \begin{bmatrix}-2 & 1 & 0\\ 0 & -3 & 1\\ -3 & -4 & -5\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix} + \begin{bmatrix}0\\ 0\\ 1\end{bmatrix} u\ ; y = \begin{bmatrix}0 & 1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}$$

Or

(b) (i) Obtain the state model of the given electrical network by choosing $V_1(t)$ and $V_2(t)$ as state variables. CO2 - App (8)



(ii) Deduce the canonical state model for the given transfer function. CO2 - App (8)

$$\frac{Y(s)}{U(s)} = \frac{10(s+4)}{s(s+1)(s+3)}$$

15. (a) Assess the advantages and limitations of using Nyquist analysis in the study of the pupillary light reflex stability compared to other stability analysis techniques. How does Nyquist analysis provide insights into the dynamic behavior of the reflex, and in what contexts might it be particularly valuable? CO5 - An (16)

Or

(b) Analyze the role of the autonomic nervous system in shaping the frequency response of the circulatory control model. How do sympathetic and parasympathetic inputs interact in the frequency domain, and how does this interaction affect heart rate variability and blood pressure regulation? CO5 - An (16)