Question Paper

Exam Date & Time: 07-Dec-2023 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

VII SEMESTER B.TECH END SEMESTER EXAMINATIONS, NOV-DEC 2023

PHYSIOLOGICAL CONTROL SYSTEMS [BME 4069]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) A) Fig. 1 represents the signal flow graph of a control system. The following is given: $G_1 = G_2 = G_3 = G_4 = 2$; $H_1 = H_2 = H_3 = 0.5$. **Evaluate the given signal flow graph and compute the overall transfer function by applying Mason's gain formula**. (3)

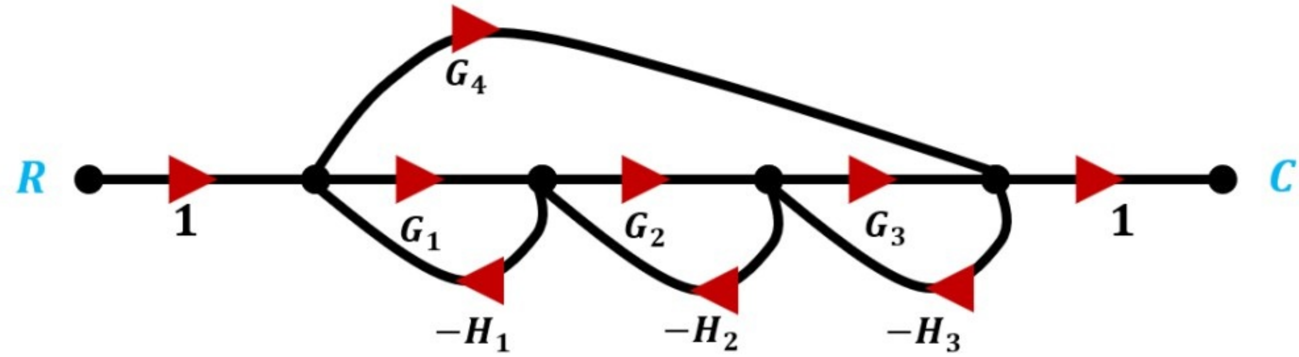


Fig. 1.

B) **Calculate the overall T.F. of the control system** represented by the given block diagram in Fig. 2 using block diagram reduction techniques. (4)

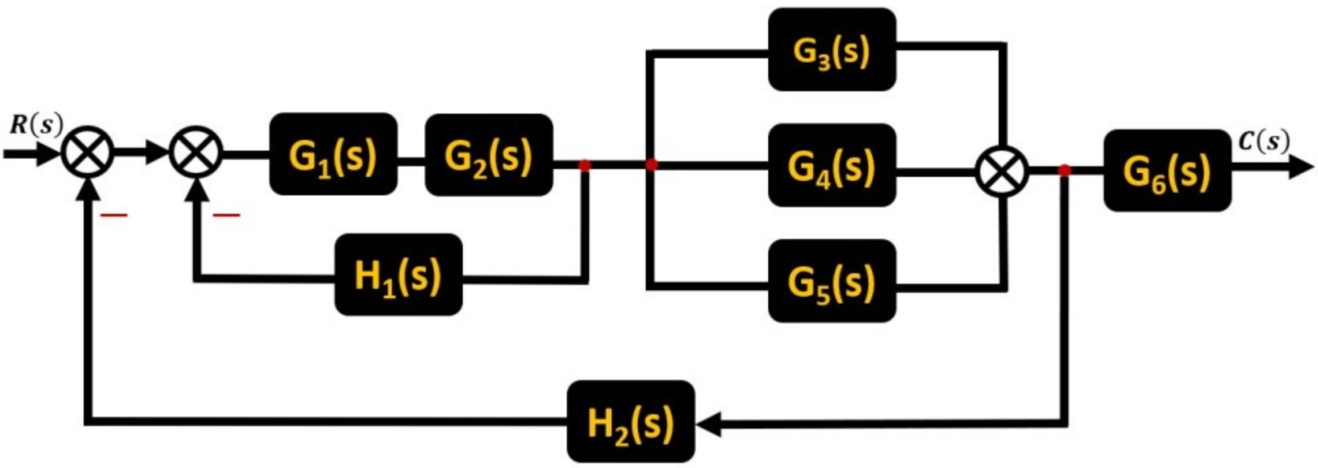


Fig. 2.

C) Q3. Apply the Routh Stability criterion to determine the stability of a control system with the following characteristic equation. (3) (3)

$$\Delta(s) = s^3 + 5s^2 + 6s + 30$$

2) A) An **incomplete schematic of the voltage clamp circuit is depicted below (Fig. 3).** What are the electronic components X and Y depicted in Fig. 3? Explain their role in the functioning of a voltage clamp circuit. Note: Supplement your answer with appropriate graphs. (4)

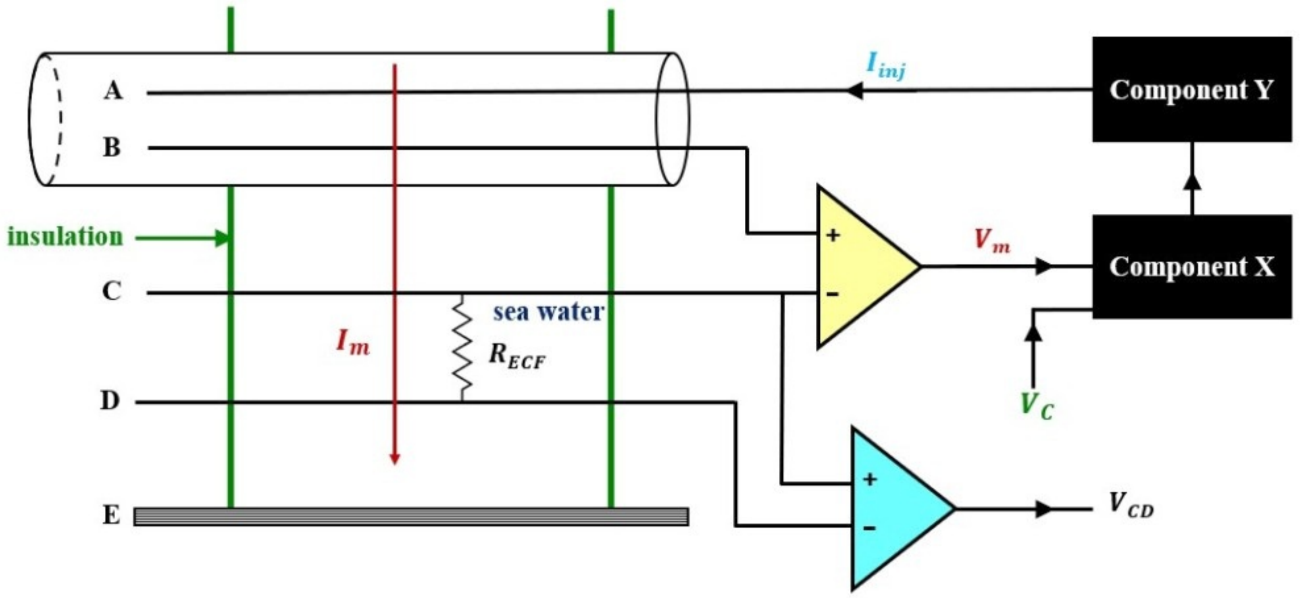


Fig. 3.

B) Write down the relationship between the membrane current I_m and the output of component Y. (3)

C) If TEA is applied to a squid giant axon under a voltage clamp, using suitable illustrations (graphs), **sketch the membrane current recorded for the following two clamp levels: (i) 0 mV; (ii) +50 mV. Note:** The Nernst potential of the potassium ion is - 90 mV, and the Nernst potential for the sodium ion is +50 mV. The RMP of the squid axon is - 80 mV. (3)

3) Table 1 contains the steps for the algorithm required to simulate an Action Potential using the HH model. **However, steps 3 to 10 have been jumbled up in random order.** (4)

A) **Re-design / Re-arrange the jumbled-up algorithm (i.e., steps 3 to 10) and write down the sequentially correct algorithm to simulate an Action Potential**

Table 1: Algorithm to simulate an action potential

Step	**Statement**
	Initialize: V_m, E_{rest}, C_m, E_{Na}, E_K, E_{Leak}

1	Initialize t = 0, dt = 0.05 ms Initialize activation and inactivation parameters: n_0; m_0; h_0 Initialize the maximum values of conductances: G_K_bar, G_{Na}_bar, G_leak
2	A current pulse is used to initiate an action potential at t = 0 if (0<t<0.30 ms) I_s = 75 μA, else I_s = 0
3	Calculate the incremental change in membrane potential and update V_m : dV_m = **?** ; $\mathbf{V_m = V_m + dV_m}$
4	Calculate the incremental change in n, m, and h: dn = **?** ; dm = **?** ; dh = **?**
5	Calculate net change in membrane potential from the resting value: $\mathbf{v = V_m - E_{rest}}$
6	Calculate the voltage dependent rate constants (alpha and beta)
7	Calculate / Update the new values of n, m, h for current value of t: **n = ? ; m = m + dm ; h = h + dh**
8	Calculate ionic currents for current value of t: $\mathbf{I_K}$; $\mathbf{I_{Na}}$ = **?**
9	Calculate values of conductance's for current value of t: $\mathbf{g_K}$; $\mathbf{g_{Na}}$ = **?**
10	If t < 5 ms, increment t by dt, **repeat steps 2 to 9**
11	Output & plot the parameters: **n, m, h, g_{Na}, g_K, I_{Na}, I_K, V_m**
12	End

B) To **complete the design** of the simulation algorithm in Q3B, wherever there is a(?) indicated in Table 1, write down the appropriate equation for the parameter indicated. (3)

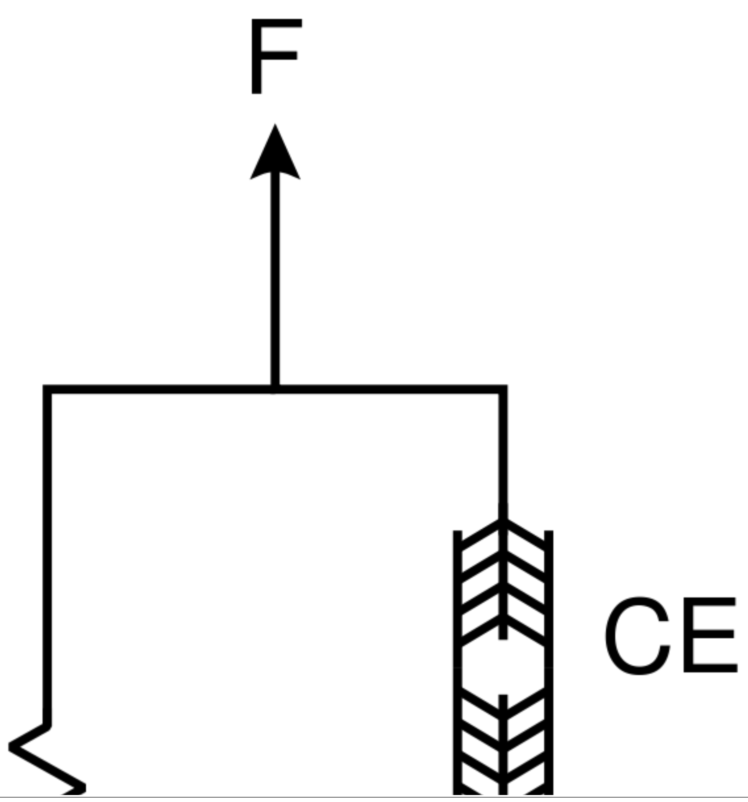
C) Discuss **how the model for a neuronal AP would differ from a model of a cardiac AP** *with the assumption* that the models incorporate all the physiological mechanisms which participate in the production of an AP in these cells. (3)

4) Between the biceps and the triceps, which forms the agonist muscle and which forms the antagonist muscle? Explain the advantages of the biceps and triceps working together. (3)

A)

B) With the help of a flowchart, explain the key steps underlying the mechanism of excitation-contraction coupling in a muscle fiber. (3)

C) Fig. 4. presents a diagrammatic representation of the Hill's Model. Write down what each component of Hill's model represents and explain the force-velocity equation for the element represented by CE. (4)



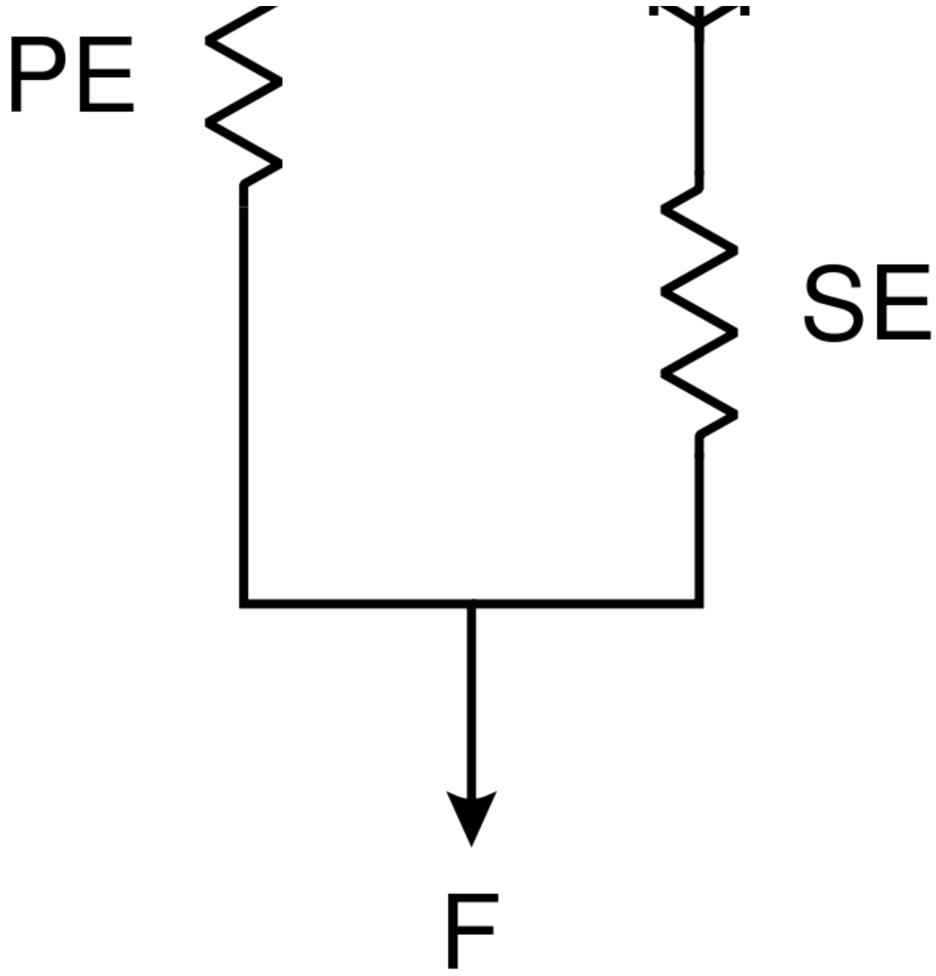


Fig. 4.

5) With the cardiac cycle in context, write down the key events in relation to the systemic circulation. (3)

A)

B) What do R and C represent in the Windkessel model? Explain, with the help of an equation, how the rate of change of pressure is computed in the Windkessel Model. (3)

C) Design a protocol to estimate the resistance of the Windkessel using invasive or direct measurements. (4)

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