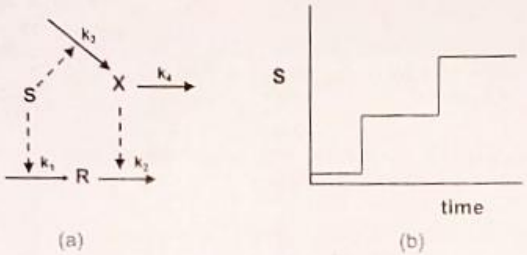
Systems thinking – Monsoon 2022
End Semester Examination

Max. Time: 3.0 hrs **Max. Marks: 50**

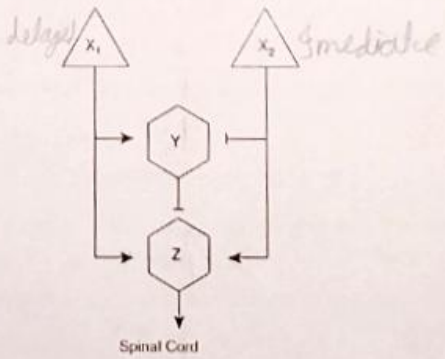
1. The input to the circuit given below is S and output is the accumulation of protein R. k represents kinetic constant. [CO-4, CO-5, CO-6]



(a) (b)

(a) Identify the regulation in (a). [1 mark]
(b) Show that the steady state of R is independent of signal S. [2 marks]
(c) Show that the circuit is incapable of fold detection. [2 marks]
(d) Draw the dynamics of X and R for the input S profile given in figure (b). [2 marks]
(e) What is the emergent characteristic of the circuit? Give a biological example. [2 marks]

2. Multi-input circuit occurs in the neurons for human pain sensation (X1, X2, Y, Z are neurons). Identify the circuit. This circuit explains why there are two types of pain (say after an insect bite). Explain how the pain works based on the circuit. [4 marks] [CO-4, CO-5]



3. Consider a two-node positive feedback loop in which each node is also positively autoregulated (PAR). [CO-6]

   a. Write equations for this system. Assume that autoregulation and cross-activation are multiplicative (resembling an AND gate). [1 mark]
   b. Draw the nullclines. Show that the circuit can show bistability. [2 marks]
   c. Draw the signal-response plot by considering that the signal can activate any one node directly independent of other interactions. [2 marks]

4. Show that the model given below exhibit periodic behaviour.

$$\frac{dU}{dt} = U(1 - V)$$

$$\frac{dV}{dt} = \alpha V(U - 1)$$

α is a kinetic parameter. [4 marks] [CO-5]

5. Draw a circuit that can give rise to relaxation oscillation. Draw the phase plane and sketch the oscillations. Show that this circuit is also capable of fold detection.
[4 marks] [CO-5, CO-6]

6. Both coherent FFLs and positive feedback loops can provide delays and memory. Explain the statement (use equations and drawings to explain). [4 marks] [CO-5, CO-6]

7. Draw the phase-plane of excitable system. Explain the mechanism behind the firing of neurons. [3 marks] [CO-5, CO-6]

8. What is Weber's law? How is this connected to fold change detection? [3 marks] [CO-6]

9. Analyse the coherent FFL with OR logic at the Z promoter. What is the length of the delay following ON and OFF steps of Sx? [3 marks] [CO-6]

10. A dynamic system is represented by the differential equation [3 marks] [CO-5, CO-6]

$$\tau \frac{dy(t)}{dt} + y(t) = r(t)$$

The system is given the sinusoidal input r(t) = sinωt. The value of ω at which magnitude of the output y(t) is $1/\sqrt{2}$ at steady state, is given by (in terms of τ)

11. A biochemical reaction involves binding of a substrate (S) to enzyme (E) forming modified substrate (Sp). [2 marks] [CO-5, CO-6]

$$E + S \rightleftharpoons ES \longrightarrow E + Sp$$

Write the rate expression for modified substrate formation in terms of Michaelis-Menten constant. Draw and depict the significance of kinetic parameters.

12. Explain the circuit that can help to maintain glucose homeostasis despite variation in insulin sensitivity among people. [2 marks] [CO-5, CO-6]

13. How cells read the genome to control the function/response? [2 marks] [CO-4]

14. Give two examples of biological signal and response. [2 marks] [CO-4]