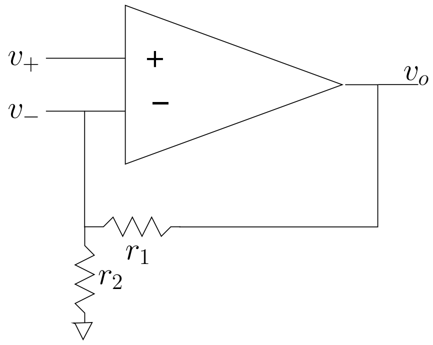
1 Problems NS3

Topic of this homework: Neuron and synapse terminology; Postulates of systems; Analysis of a diffusion transmission line.

Problem *# 1: Analyize the circuit of the OpAmp with feedback.*

– *1.1: Set up the equations and solve for various properties of the OpAmp.*



1. In qualitative terms, what is the ratio of the input to output impedance.
2. Describe the purpose and setup for the *space-clamp* circuit.
3. Find the formula for the transfer function $H = V_o/V_+$.

Problem *# 2: Analyize a Δ long patch of membrane.*

– *2.1: Set up the equations to estimate the properties of a mylinated nerve fiber.*

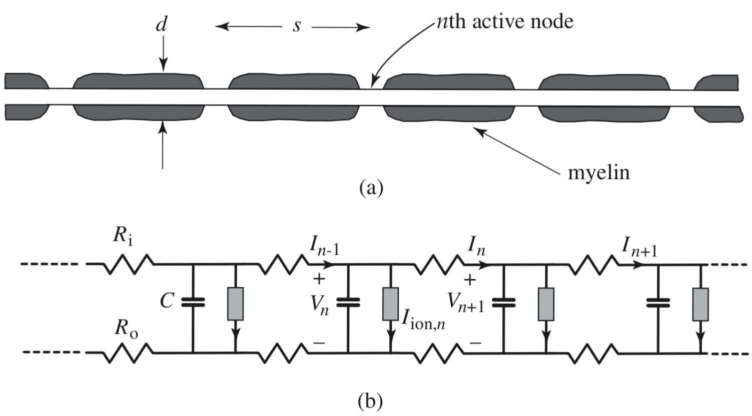


Figure 1: *Diagram of the Frog axon showing the physical and electrical circuit (Scott, p. 142).*

Standard frog axon

Distance between nodes $(s) = 2$ mm.

Outside fiber diameter $(d) = 14\ \mu$m.

Internal resistance/length $(r_{\mathrm{i}}) = 140$–145 megohm/cm.

External resistance/length $(r_{\mathrm{o}}) \ll r_{\mathrm{i}}$.

Capacity of myelin/length $(c_{\mathrm{m}}) = 10$–16 pF/cm.

Capacity of active node $(C_{\mathrm{n}}) = 0.6$–1.5 pF.

Experimental impulse speed $v_{\mathrm{e}} = 23$ m/s.

Figure 2: *Parameters measured for the Frog axon (Scott, p. 143)*

1. Assume the following

$$\begin{aligned} \lambda_o f_{\max} &= v_e = 23 \text{ [m/s]} \\ &= \lambda_o/2 \text{ [mm]} \end{aligned}$$

From a previous homework we assumed that $\Delta = \lambda/2$ and $\tau = RC$. Here $\Delta = s$ is taken to be the distance between nodes.

Find $f_{\max}$.

2. Find the time constant ($\tau = RC$) and the cutoff frequency $f_c = 1/2\pi\tau$. Compare f_c to $f_{\max}$.

Problem *# 3: Thermodynamics of the cell membrane*

– 3.1: Set up the equations to estimate the equilibrium sodium and potassium concentrations.

1. Define the three membrane currents that re the most important to action potentials (spikes).

$$\begin{aligned} J_{\texttt{disp}} &= C_o \frac{d}{dt} v(t) \\ J_c(s) &= q\mu_{\texttt{Na}}[\texttt{Na}^+]E = q\mu_{\texttt{Na}}[\texttt{Na}^+]\frac{dV}{dx} \\ J_d &= -qD_{\texttt{Na}}\frac{d}{dx}[\texttt{Na}^+] \end{aligned}$$

2. What is the relation between the conduction and diffusion currents under equilibrium conditions?

3. Derive the relation between the voltage and $[\texttt{Na}^+]$ when the system is in the equilibrium condition?

4. Integrate the differential equation and derive the relation between the $\texttt{Na}^+$ concentrations on the two sides of the membrane and the voltage across the membrane $V = V_o - V_i$. Hint: see pp. 57-59.

History

Problem *# 4: Relevant historical questions*

– *4.1: Provide a brief definition of the following properties:*

1. Albert Einstein.
2. Hodgkin and Huxley.
3. Hermann Helmholtz.