Neurodynamics

Computer Lab Week 1

(1) Linear and nonlinear current

Current density carried by single ionic species *S*

$$J_S = z_S^2 \, P_S \, V_m \, \frac{[S]_i - [S]_o \, e^{-z_S V_m / V_t}}{1 - e^{-z_S V_m / V_t}}$$

Current density carried by single ionic species *S*

intracellular concentration

extracellular concentration

$$J_S = z_S^2 \, P_S \, V_m \, \frac{[S]_i - [S]_o \, e^{-z_S V_m / V_t}}{1 - e^{-z_S V_m / V_t}}$$

current

valence

permeability

voltage across the membrane

thermal voltage

$$V_t = \frac{kT}{q} = \frac{RT}{F}$$

For potassium (K+), the current becomes:

$$J_K = P_K\, V_m\, \frac{[K]_i - [K]_o\, e^{-V_m/V_t}}{1 - e^{-V_m/V_t}}$$

because valence (ionic charge) of $z_K = +1$

For potassium (K+) current, given constants are

$$J_K = P_K\, V_m\, \frac{\boxed{[K]_i} - \boxed{[K]_o}\, e^{-V_m/\boxed{V_t}}}{1 - e^{-V_m/\boxed{V_t}}}$$

For potassium (K+) current, membrane voltage

$$J_K = P_K \boxed{V_m} \frac{[K]_i - [K]_o \, e^{-\boxed{V_m}/V_t}}{1 - e^{-\boxed{V_m}/V_t}}$$

ranges between -150 mV and +150 mV (Q1)

For potassium (K+) current,

$$J_K = \boxed{P_K} V_m \frac{[K]_i - [K]_o \, e^{-V_m/V_t}}{1 - e^{-V_m/V_t}}$$

What is the permeability, P?

Next, do the linear approximation...

$$J'_K = g_K \left(V_m - E_K\right)$$

Constants given:

$$J'_K = \boxed{g_K}\,(V_m - E_K)$$

$$E_K = \boxed{V_t}\ \ln \frac{\boxed{[K]_o}}{\boxed{[K]_i}}$$

and Vm ranges between -150 mV and +150 mV (Q1)

(2) The resting potential

At equilibrium...

$$0 = J_{Na}(V_r) + J_K(V_r) + J_{Cl}(V_r)$$

where Vr is the resting membrane potential

What are the currents (J) for each ion as a function of voltage?

Simplify and solve for Vr

(3) GHK membrane dynamics

$$C_m \frac{dV_m}{dt} = -J_{Na} - J_K - J_{Cl}$$

$$J_K = P_K \, V_m \, \frac{[K]_i - [K]_o \, e^{-V_m/V_t}}{1 - e^{-V_m/V_t}}$$

$$J'_K = g_K \, (V_m - E_K)$$

where each ion current, J, can be written with GHK or as a linear approximation of GHK

Each ion conductance g_{ion} has a specific behavior

$$g_{Na^+}(t) = \begin{cases} 13mS/cm^2 & 0 < t \leq 500ms \\ 0mS/cm^2 & 500 < t \leq 1000ms \end{cases}$$

$$g_{K^+}(t) = \begin{cases} 5mS/cm^2 & 0 < t \leq 250ms \\ 0mS/cm^2 & 250 < t \leq 500ms \\ 5mS/cm^2 & 500 < t \leq 1000ms \end{cases}$$

$$g_{Cl^-}(t) = \begin{cases} 0.15mS/cm^2 & 0 < t \leq 250ms \\ 0mS/cm^2 & 250 < t \leq 500ms \\ 0.15mS/cm^2 & 500 < t \leq 1000ms \end{cases}$$

** Use built-in ODE solver function