Homework 2.1: Hodgkin-Huxley model - ion channel

Simplified HH model

1/1 point (graded)

In the Hodgkin-Huxley model, the potassium current obeys the equation:

$$I_K = \bar{g}_K n(t)^4 \left(u\left(t\right) - E_K\right)$$

where $\bar{g}_K$ is the maximal conductance, E_K the potassium reversal potential, and $n(t)^4$ is the proportion of channels that are open at time t. The quantity n obeys a first-order dynamics

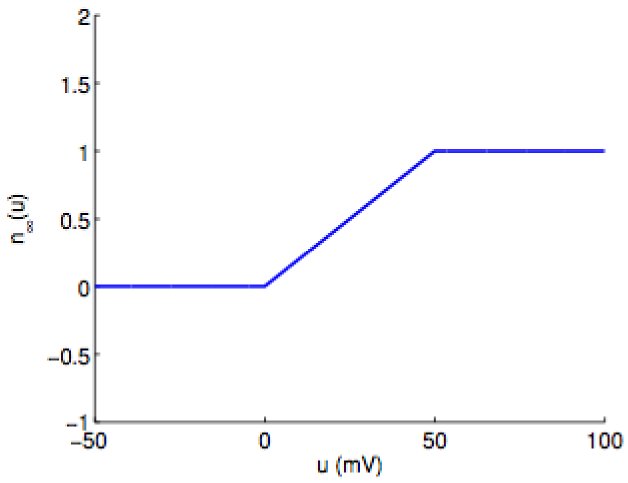
$$\frac{dn}{dt} = \frac{n_\infty(u) - n}{\tau_n(u)}$$

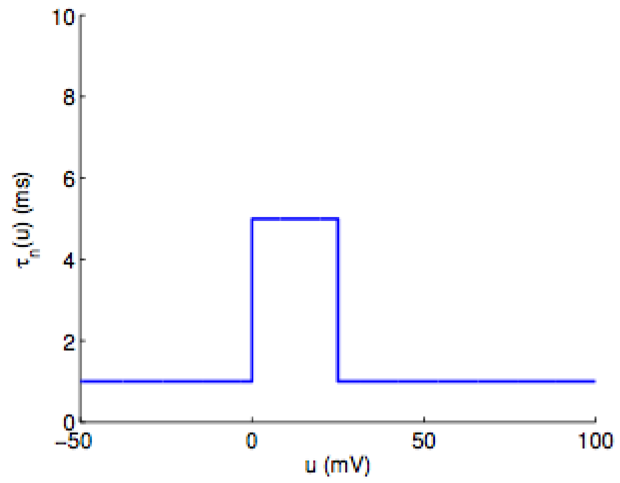
with voltage-dependent time constant τ_n and equilibrium value n_∞.

In order to determine τ_n and n_∞, Hodgkin and Huxley pharmacologically blocked the sodium current and measured the response of the potassium current to voltage jumps of various amplitudes. The goal of this exercise is to understand this key experiment by studying a simplified version of the Hodgkin-Huxley model. Suppose τ_n and n_∞ have the following form:

$$\tau_n\left(u\right) = \begin{cases} 1ms & \text{if u} <= 0 \text{ mV} \\ 5ms & \text{if } 0 < \text{u} <= 25 \text{ mV} \\ 1ms & \text{if u} > 25 \text{ mV} \end{cases}$$

$$n_\infty\left(u\right) = \begin{cases} 0 & \text{if u} <= 0 \text{ mV} \\ u/50 & \text{if } 0 < \text{u} <= 50 \text{ mV} \\ 1 & \text{if u} > 50 \text{ mV} \end{cases}$$





1. Calculate the response of $n\left(t\right)$ for $t >= 0$ to a voltage jump: $u\left(t\right) = \begin{cases} 0 & \text{if t} < 0 \\ u_0 & \text{if t} >= 0 \end{cases}$

- ○ $n\left(t\right) = n_\infty\left(u_0\right)\left(1 - \frac{\tau_n(u_0)}{t+\tau_n(u_0)}\right)$
- ○ $n\left(t\right) = 1 - \frac{\tau_n(u_0)}{t+\tau_n(u_0)}$
- ● $n\left(t\right) = n_\infty\left(u_0\right)\left(1 - \exp\left(-\frac{t}{\tau_n(u_0)}\right)\right)$

$n(t) = 1 - \exp\left(-\frac{t}{\tau_n(u_0)}\right)$

$n(t) = n_\infty(u_0)\ln\left(\exp(1) + (1-\exp(1))\frac{\tau_n(u_0)}{t+\tau_n(u_0)}\right)$

$n(t) = \ln\left(\exp(1) + (1-\exp(1))\frac{\tau_n(u_0)}{t+\tau_n(u_0)}\right)$

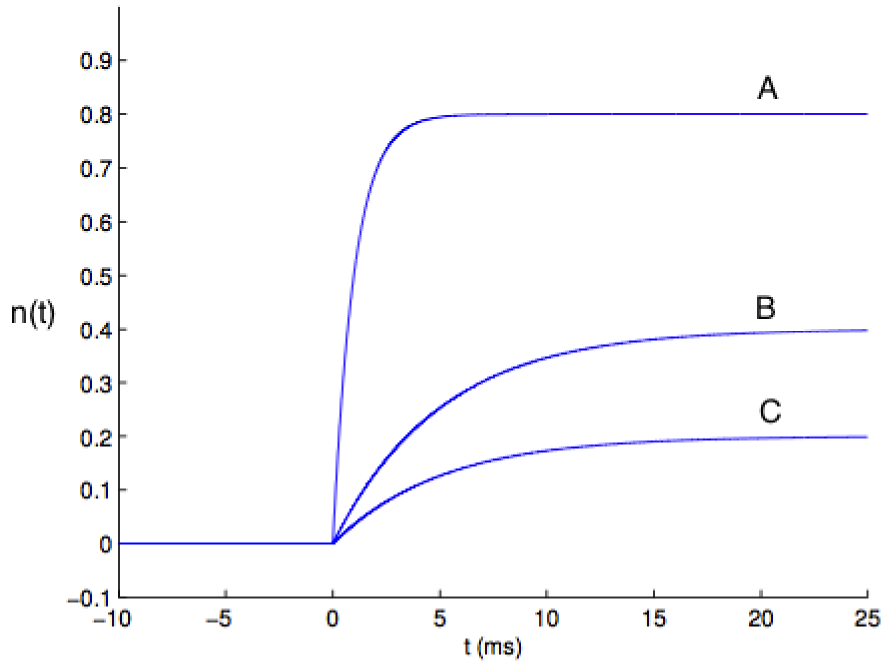
Submit You have used 1 of 1 attempt

Correct (1/1 point)

Evolution of membrane potential channels

3/3 points (graded)

2. $n(t)$ is sketched for $u_0 = 10, 20$ and $40mV$. Indicate the diagram belongs to each one:



$u_0 = 10$:

C

$u_0 = 20$:

B

$u_0 = 40$:

A

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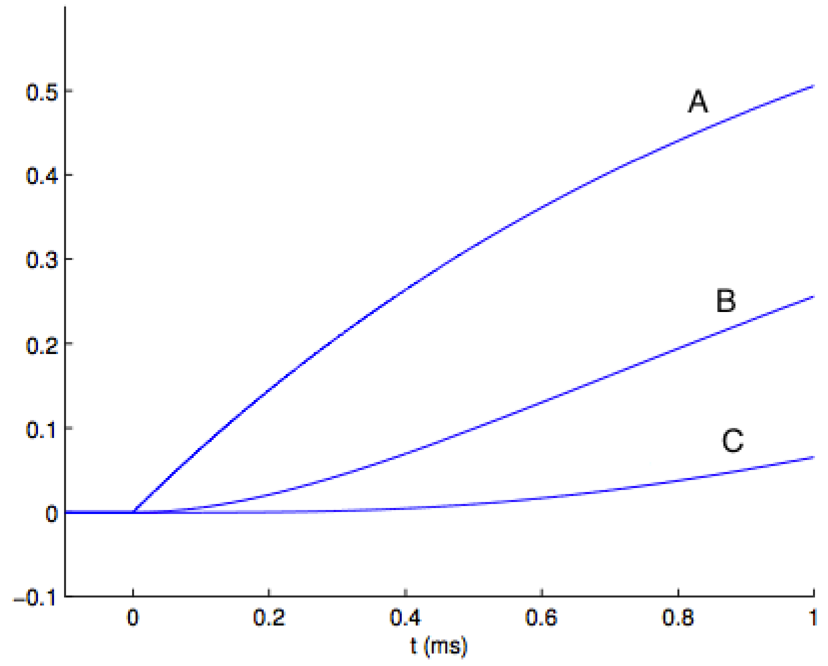
Correct (3/3 points)

Evolution of the fraction of open channels

3/3 points (graded)

3. For $u_0 = 40mV$ the behaviour of $n(t)$, $n^2(t)$ and $n^4(t)$ is sketched (assuming $t \ll \tau_n$). Indicate the diagram belongs to each one:



$n\,(t)$:

A ▼ ✔

$n^2\,(t)$:

B ▼ ✔

$n^4\,(t)$:

C ▼ ✔

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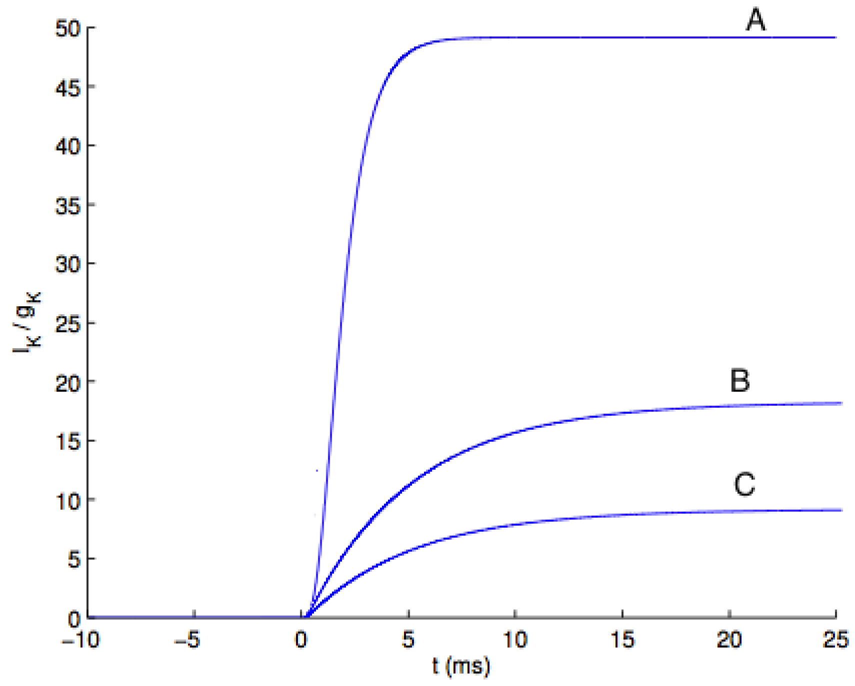
✔ Correct (3/3 points)

Potassium current curve

1/1 point (graded)

4. Indicate the current $I_K\,(t)(\,u_0\;=40mV,\,E_K\;=-80mV)$:



A ▼ ✔

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✔ Correct (1/1 point)

Parameter estimation

0 points possible (ungraded)

5. If we measure $I_K\left(t\right)=\bar{g}_K n(t)^p\left(u\left(t\right)-E_K\right)$ for voltage steps of various amplitudes, how can we determine $p, \tau_n\left(u\right)$, and $n_\infty\left(u\right)$? (no point for this question)

Submit You have used 1 of 1 attempt

Discussion

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