BIBB 585-401—Homework 2

Jonathan Levine
jonlevi@sas.upenn.edu

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Problem 1

Give a short description of equation (5.25) including a description of the variables. Why do we use the form n4 and m3h?

The equation for the membrane current, i_m is equal to the sum of the currents for each ion. Given by Ohm's Law, this is

$$i_m = \sum_i g_i(V - E_i)$$

For the leakage current term, the conductance is constant, and thus the product is simply the product of the maximal conductance and the driving force

$$i_L = \overline{g}_L(V - E_L)$$

. For persistent, non-inactivating currents, the conductance is a function of voltage, and follows an activation function that depends on the probability of all subunits being in an open state simultaneously. Since there are roughly 4 subunits for the potassium channel, the probability is given as n^4, where n is the gating variable describing the voltage and time dependencies of the conductance. Therefore the potassium current in the equation is

$$i_K = \overline{g}_K n^4(V - E_K)$$

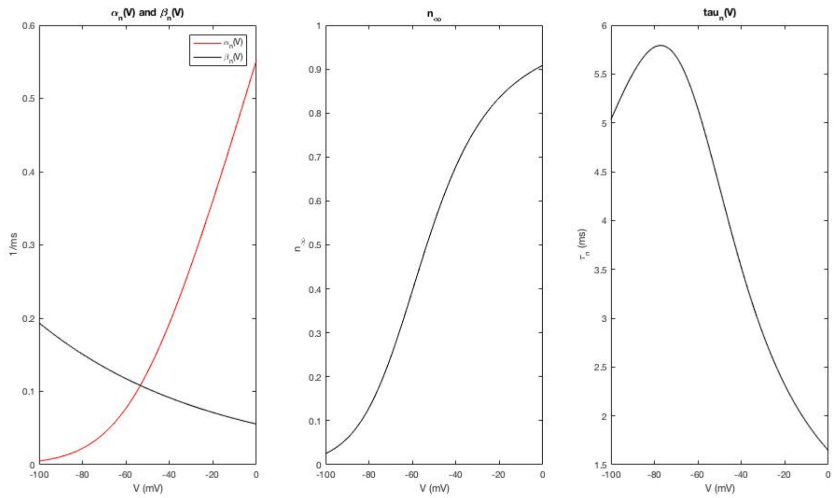
. For Inactivating, transient conductances, we also need to model the inactivation gate as an independent process from the activation. We can similarly define h as the de-inactivation variable, and together with m (similar to n but this time for Sodium), we can describe the dynamics of sodium conductance as a function of voltage and time by describing its activation and de-inactivation through the m and h functions. One could make a similar argument about the exponents on the m and h terms relating to the number of independent events required for a full opening. The exponents were also chosen because they fit the experimental data best. At any rate, the sodium conductance can be modelled by m^3h, and thus the sodium current becomes

$$i_{Na} = \overline{g}_{Na} m^3 h(V - E_{Na})$$

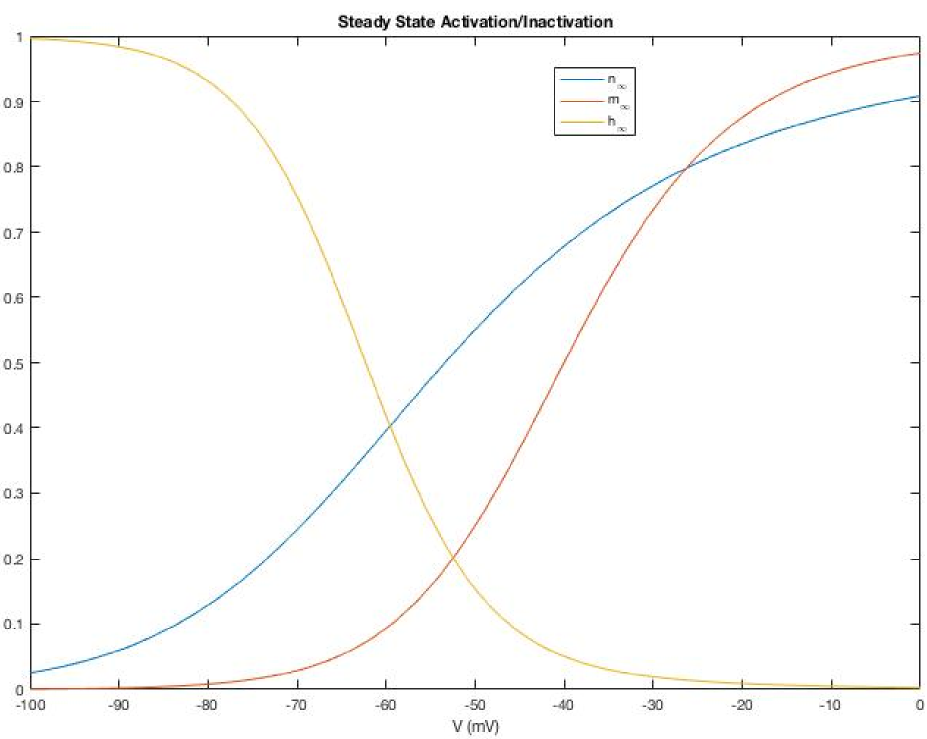
. Therefore we have

$$\begin{aligned} i_m &= \sum_i g_i(V - E_i) \\ &= i_L + i_K + i_{Na} \\ &= \overline{g}(V - E_L) + \overline{g}_K n^4(V - E_K) + \overline{g}_{Na} m^3 h(V - E_{Na}) \end{aligned}$$

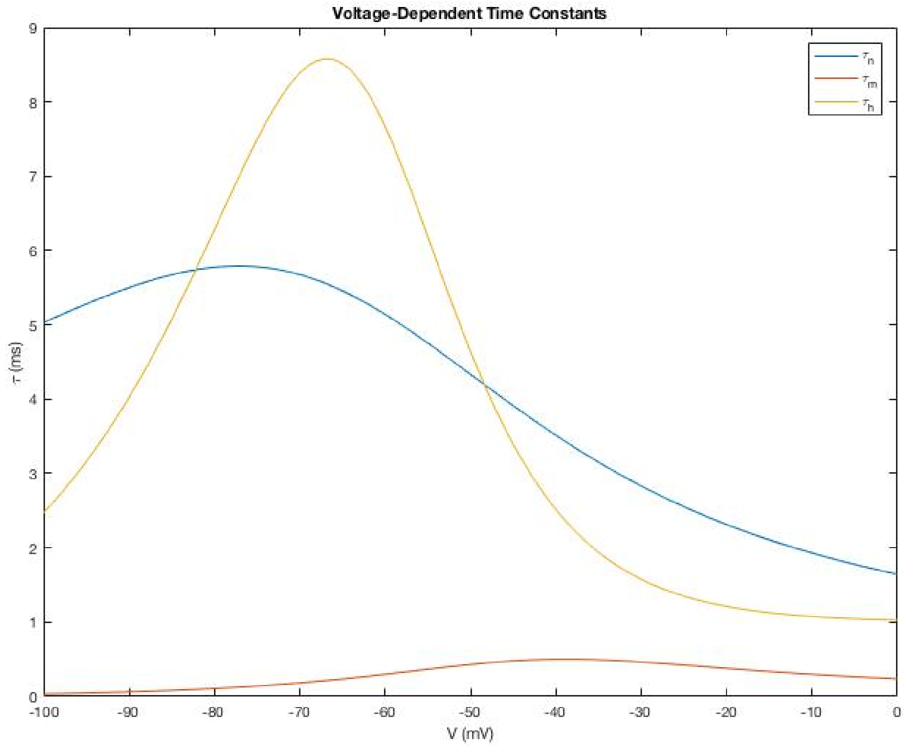
Problem 2



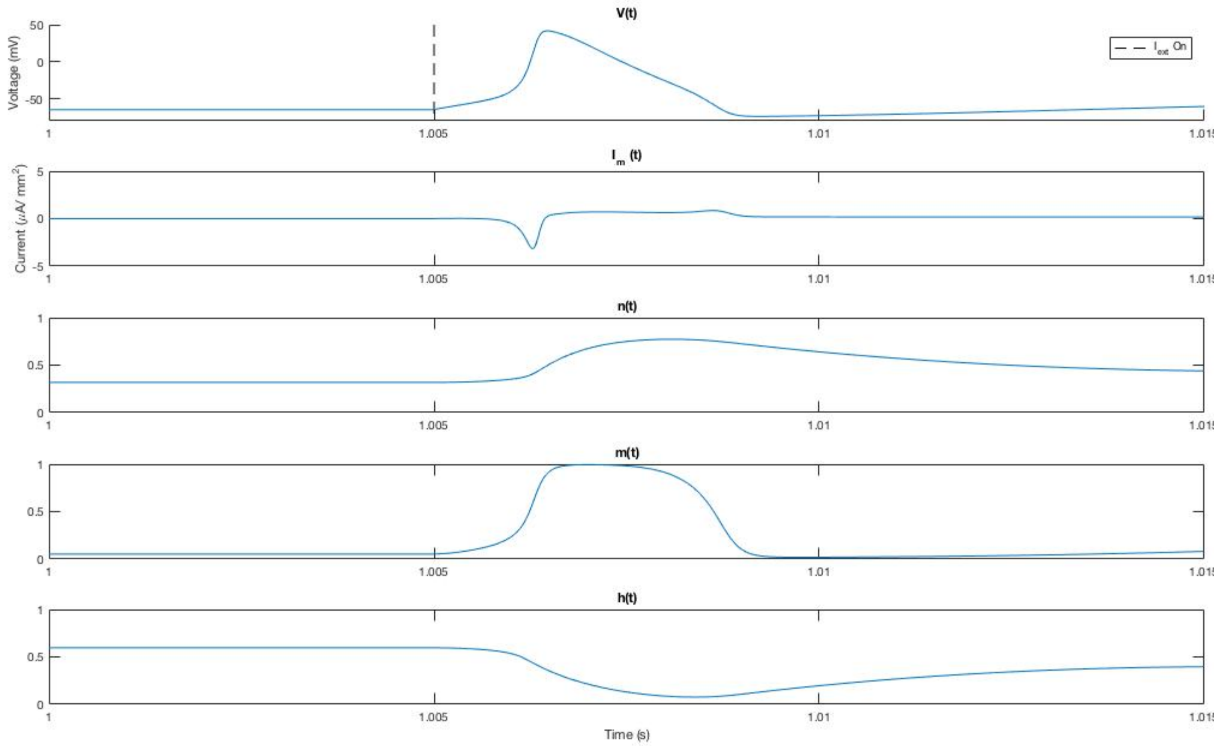
Problem 3



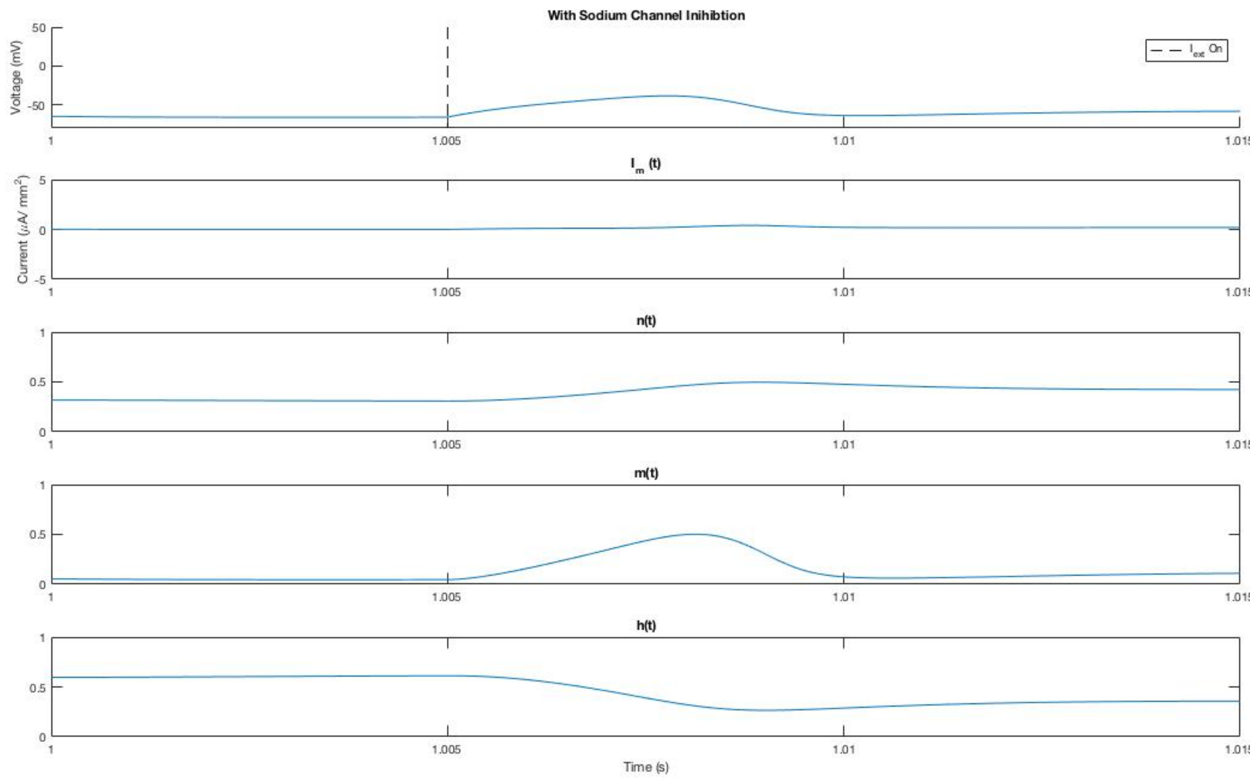
Problem 4

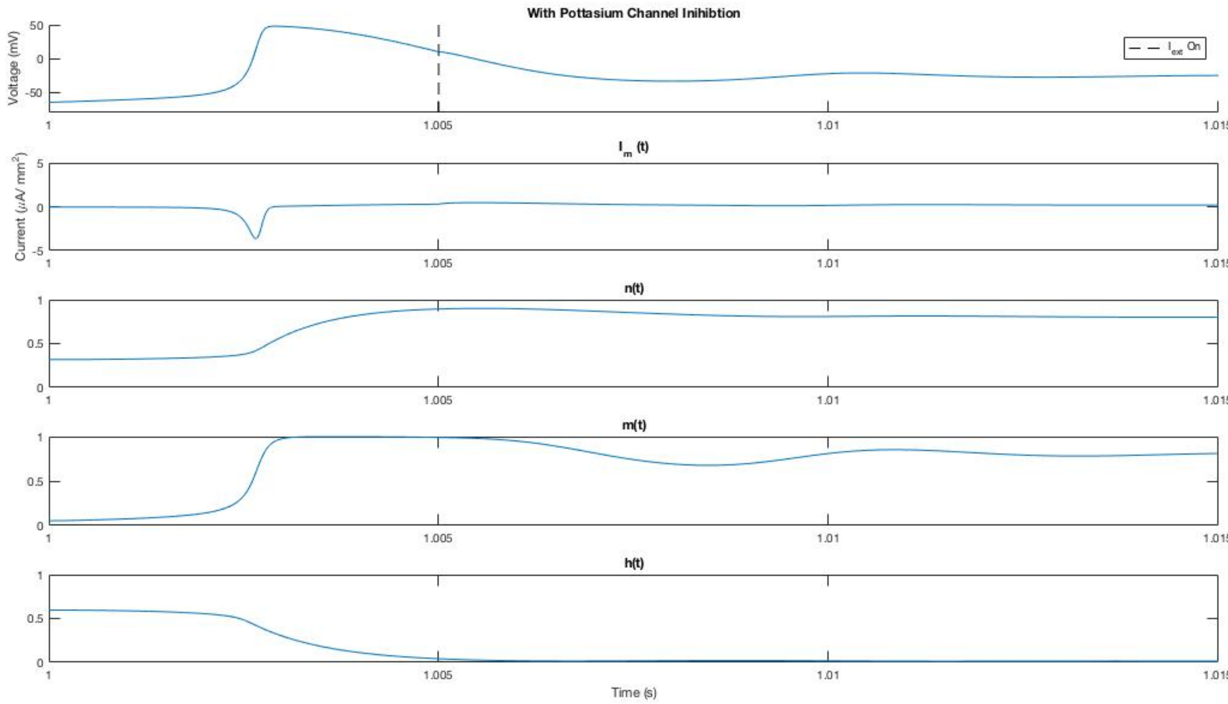

Voltage-Dependent Time Constants
τ (ms)
V (mV)
τn
τm
τh
9
8
7
6
5
4
3
2
1
0
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0

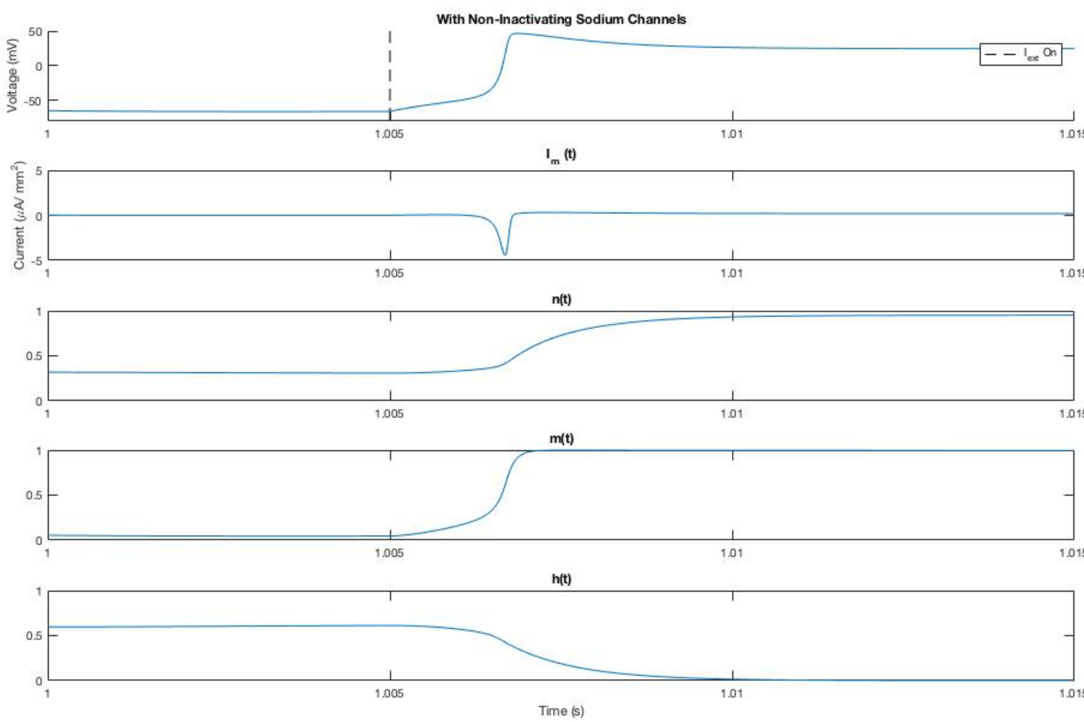
Problem 5


V(t)
Voltage (mV)
50
0
-50
I_ext On
I_m (t)
Current (μA/ mm²)
5
0
-5
n(t)
m(t)
h(t)
1
0.5
0
1
1.005
1.01
1.015
Time (s)

Problem 6


With Sodium Channel Inihibtion
Voltage (mV)
I_{ext} On
I_m (t)
Current (μA/ mm^2)
n(t)
m(t)
h(t)
Time (s)


With Pottasium Channel Inihibtion
Voltage (mV)
I_{ext} On
I_m (t)
Current (μA/ mm^2)
n(t)
m(t)
h(t)
Time (s)


With Non-Inactivating Sodium Channels
Voltage (mV)
I_{ext} On
I_m (t)
Current (μA/ mm^2)
n(t)
m(t)
h(t)
Time (s)