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ELEC436 Project-1
Coding of Below and Above Threshold Neuronal Model

1)

Read carefully the book pages of 133 - 140 to understand the algorithm for HH model and RC model.

2)

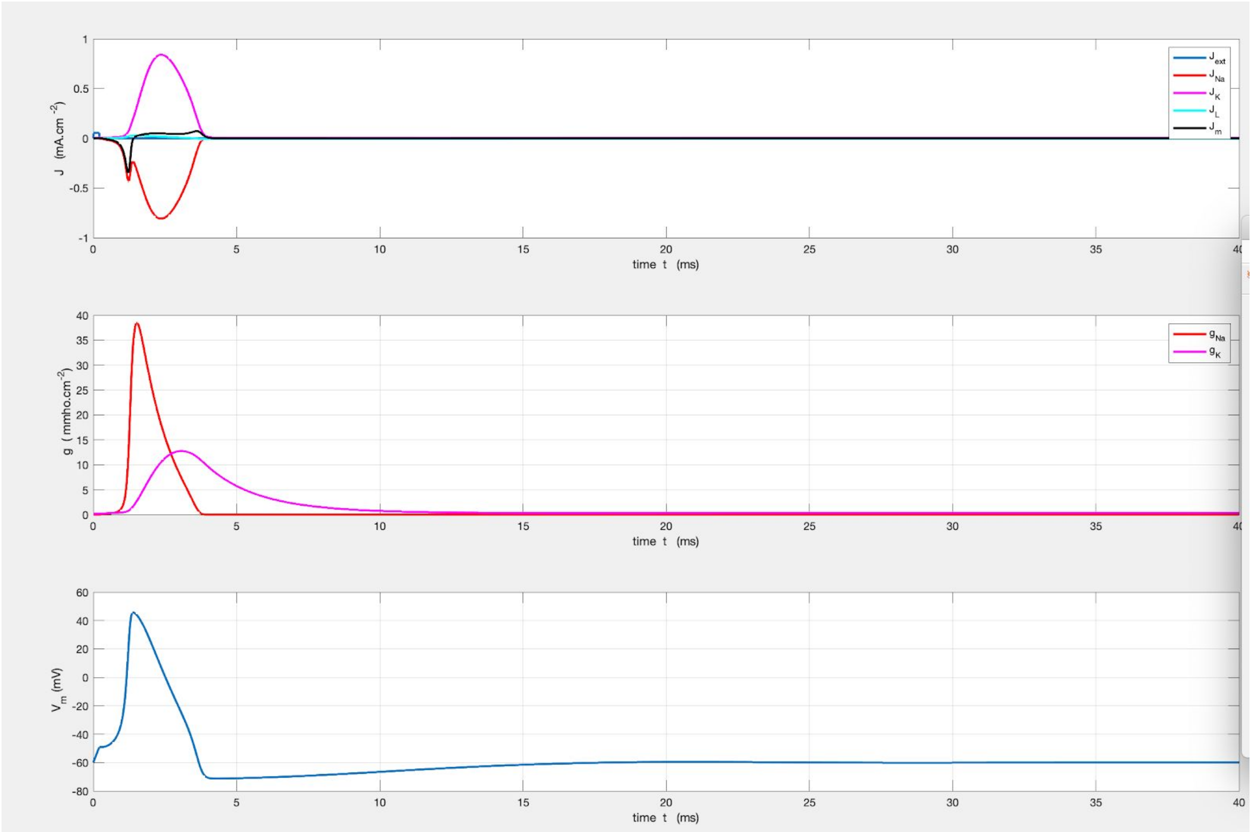
According to the directions provided in these pages write a MATLAB code to find memberane's voltage, ionic currents, probability particles of n, m, and h versus time (You can look at question 7 of CH5 of the book as well). Use the values provided in the table below as initial values. Note that for parts 1-5 use initial Vm = -60 mV.

Table 13.2. HH Membrane and Environmental Parameters

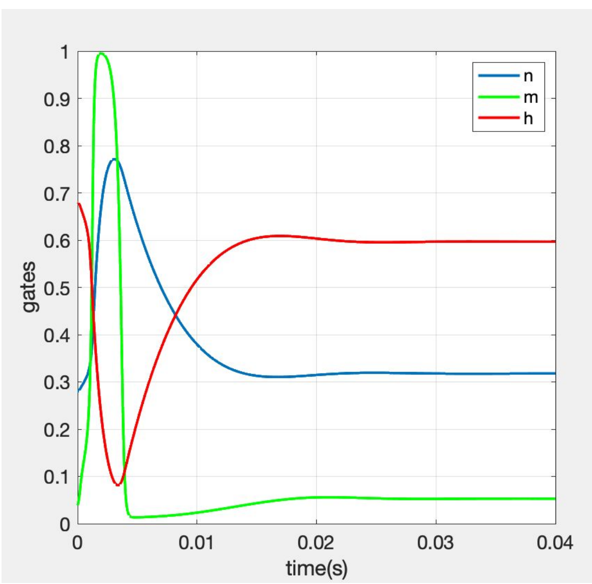
$\bar{g}_K$	36	mS/cm^2	maximum K^+conductivity
$\bar{g}_{Na}$	120	mS/cm^2	maximum Na^+ conductivity
g_L	0.3	mS/cm^2	leakage conductivity
C_m	1.0	μF/cm^2	membrane capacitance
E_K	-72.1	mV	K^+ Nernst potential
E_{Na}	52.4	mV	Na^+ Nernst potential
E_L	-49.2	mV	leakage Nernst potential
V_r	-60	mV	resting potential
I_s	0	μA/cm^2	stimulus current
I_m	0	μA/cm^2	total membrane current for patch if no stimulus

Parameter	Value
m_o	0.0393
h_o	0.6798
n_o	0.2803
Temperature	6.3 °C

Using the following parameters for HH and RC model.
R = 10 kOhm.cm2
C = 1 μF/cm2
Vrest = -60 mV, and a time step (dt) of 0.01 ms.
Generate a representative plot of the membrane voltage as a function of time for a step current density injection with I = 53 μA/cm2 for 0 <= t < 0.2 ms and I=0 otherwise. Add a threshold (Vthr) of a 15 mV (Vthr=-45 mV) to your code.



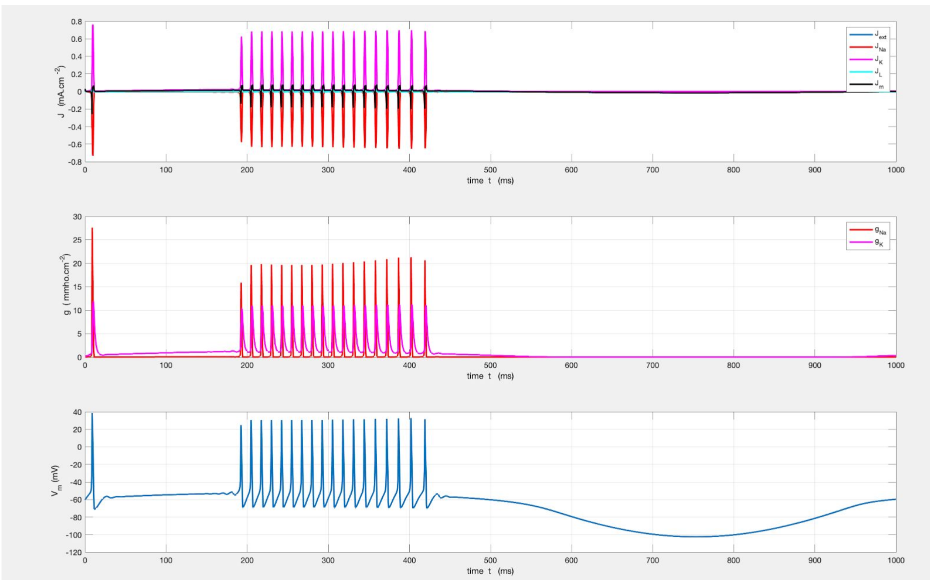
J (mA.cm -2)
time t (ms)
J_{ext}
J_{Na}
J_K
J_L
J_m
g (mmho.cm -2)
g_{Na}
g_K
V_m (mV)



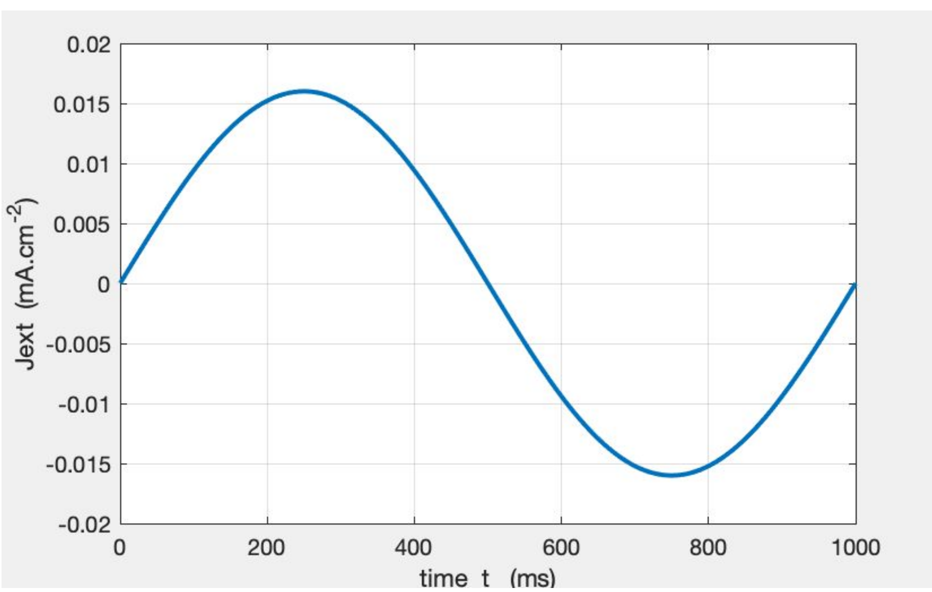
gates
time(s)
n
m
h

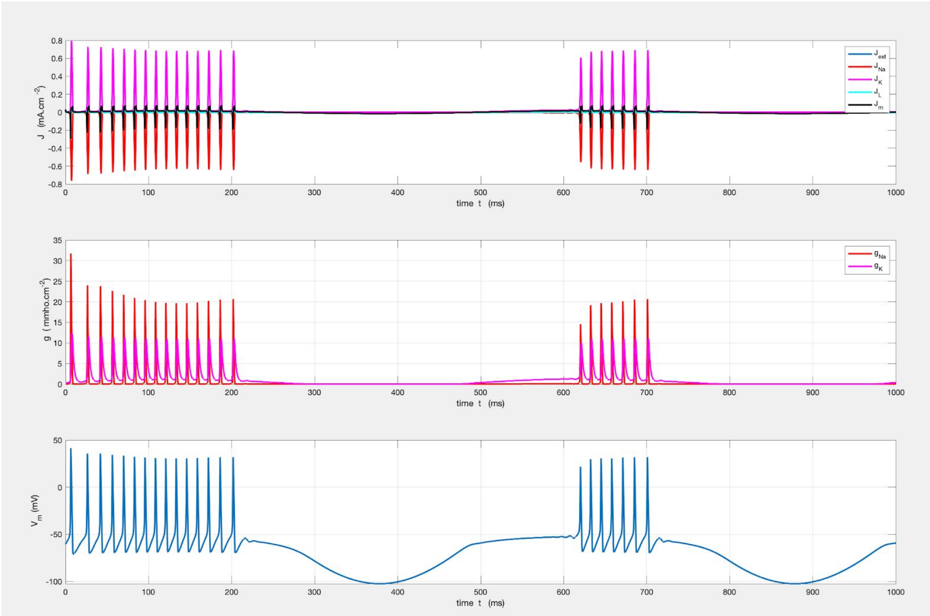
3)

Now examine the response of your model to sinusoidal stimulation. Use a sinusoidal current injection with a peak amplitude of 53 μA/cm2, R = 10 kOhm.cm2, C = 1 μF/cm2, Vrest = -60 mV, and a time step (dt) of 0.01 ms. Generate a plot of "spike count vs. stimulus frequency," where "spike count" is the total number of spikes generated during the 1 second stimulus interval (it would be sufficient to characterize the model for the following input frequencies: 1, 2, 5, 10, 20, 50, 100 Hertz. Remember to run the simulation for 1s. Show the input, the spiking pattern generated and the relationship between spike count vs. stimulus frequency).

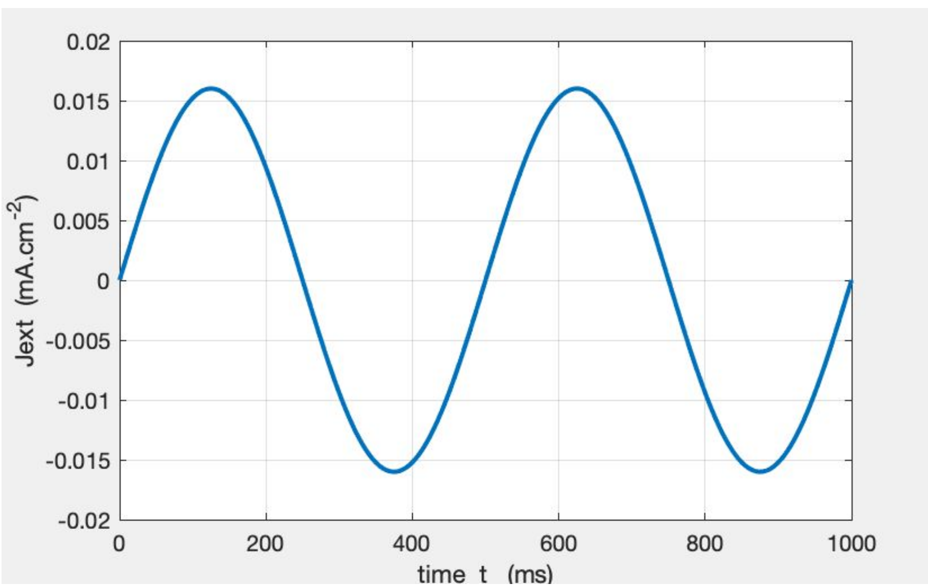


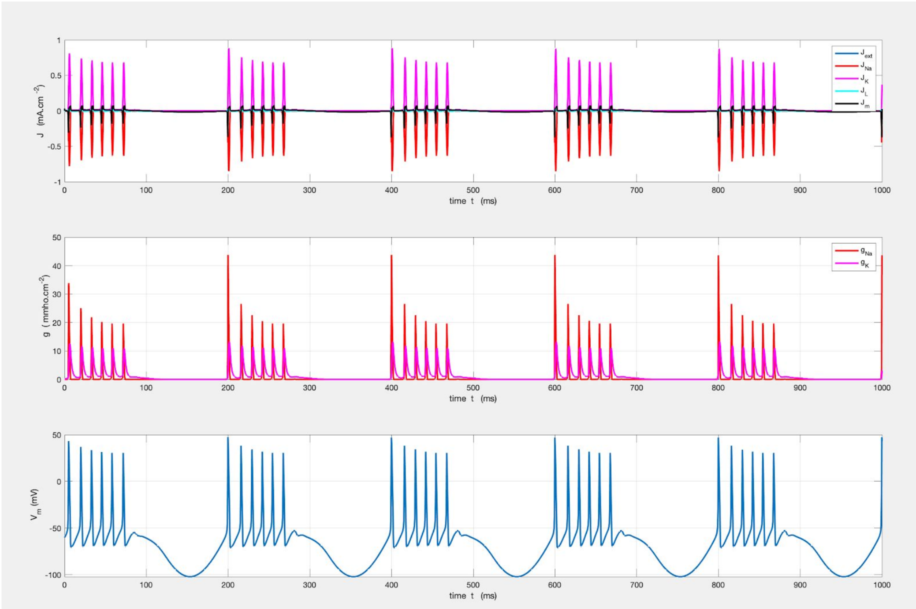
1Hz



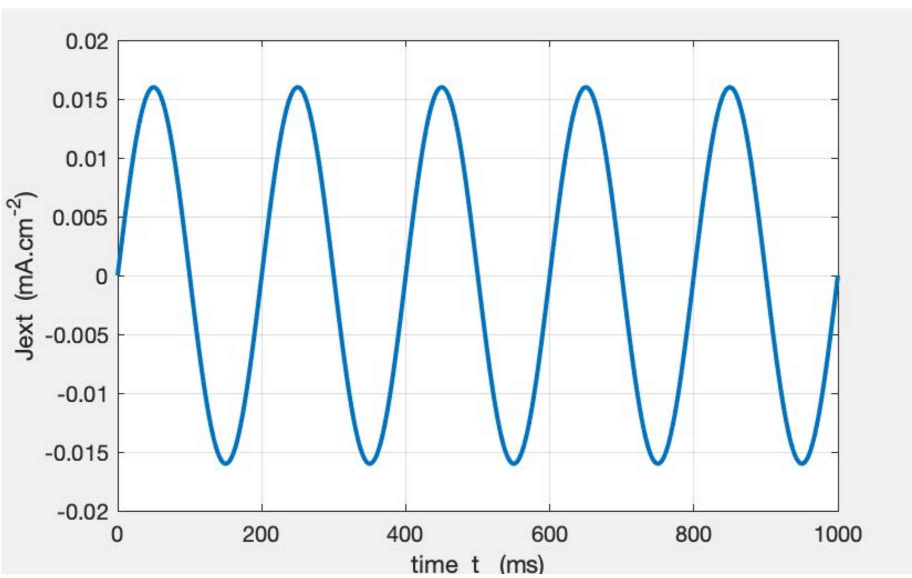

J (mA.cm^-2)
time t (ms)
J_ext
J_Na
J_K
J_L
J_m
g (mmho.cm^-2)
g_Na
g_K
V_m (mV)

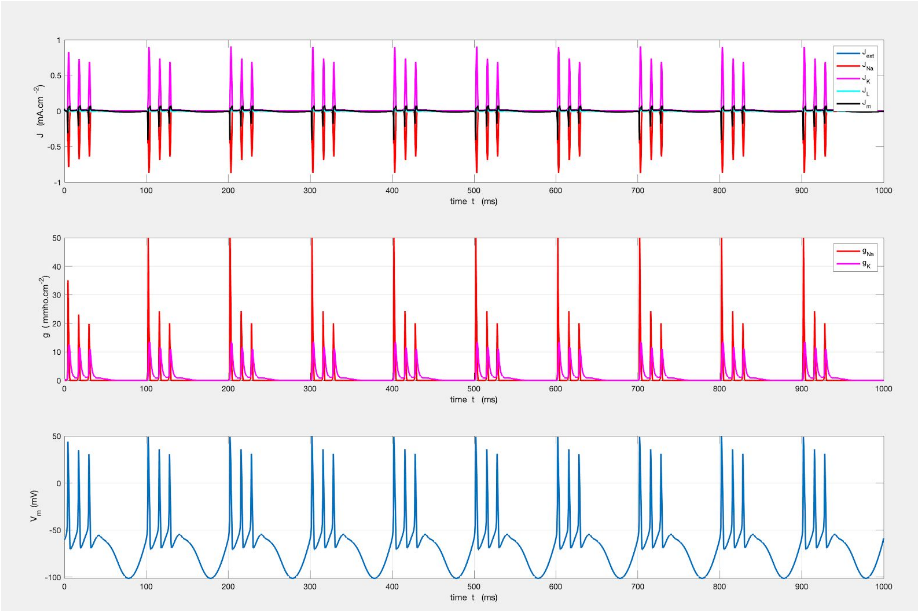
2Hz


Jext (mA.cm^-2)
time t (ms)


J (mA.cm^-2)
time t (ms)
J_ext
J_Na
J_K
J_L
J_m
g (mmho.cm^-2)
g_Na
g_K
V_m (mV)

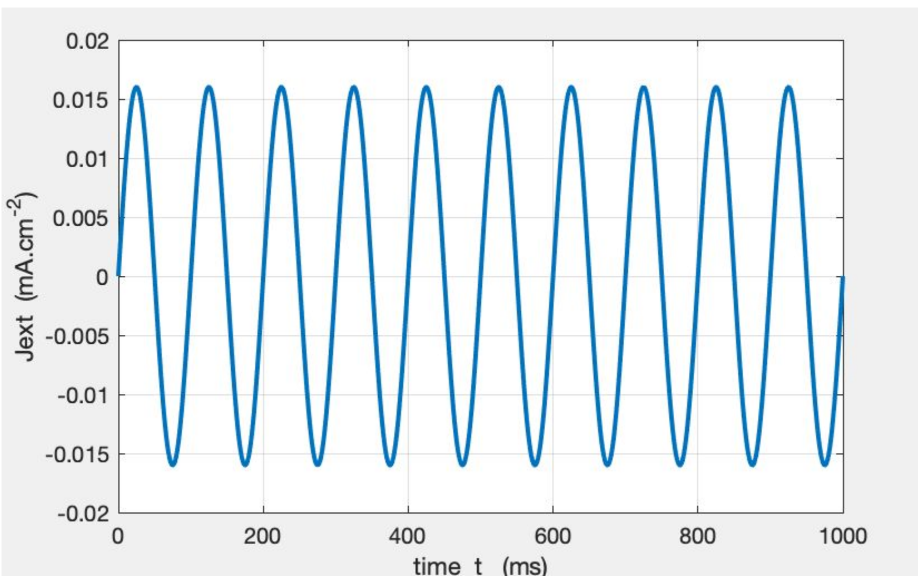
5Hz


Jext (mA.cm^-2)
time t (ms)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
0
200
400
600
800
1000

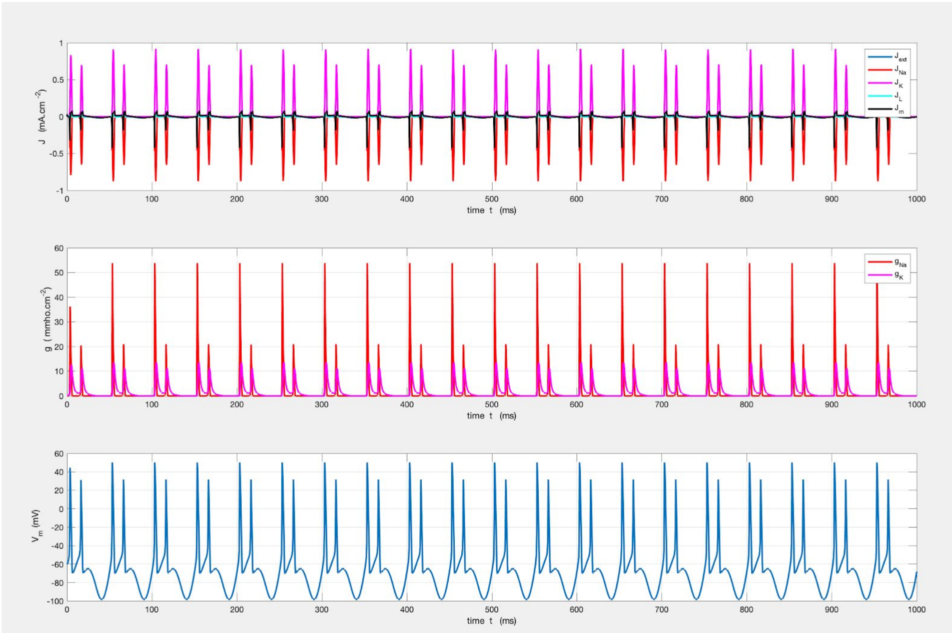


J (mA.cm^{-2})
time t (ms)
g (mmho.cm^{-2})
time t (ms)
V_m (mV)
time t (ms)

10Hz

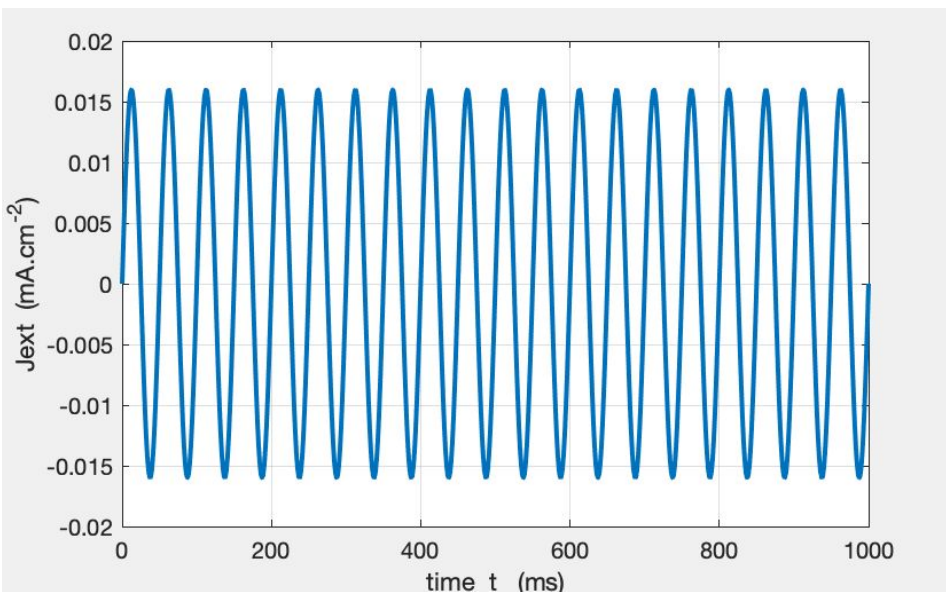


Jext (mA.cm^{-2})
time t (ms)

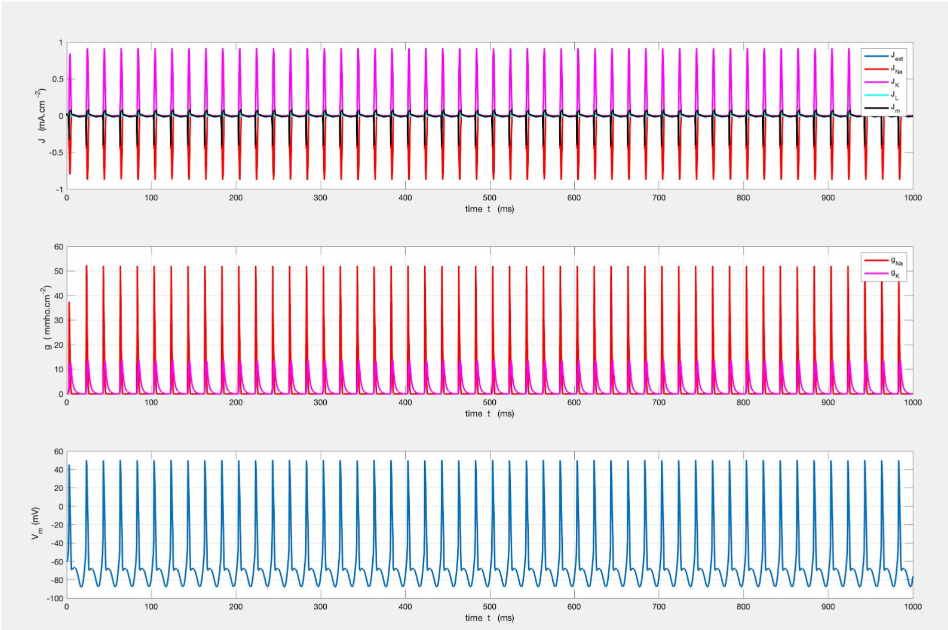


J_{ext}
J_{Na}
J_K
J_L
J_m
J (mA.cm^{-2})
time t (ms)
g_{Na}
g_K
g (mmho.cm^{-2})
time t (ms)
V_m (mV)
time t (ms)

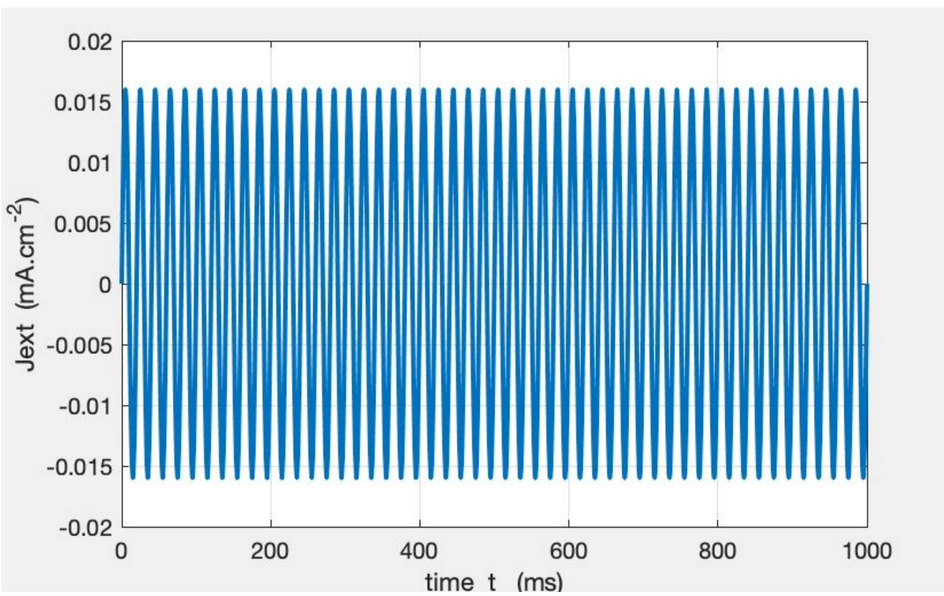
20Hz

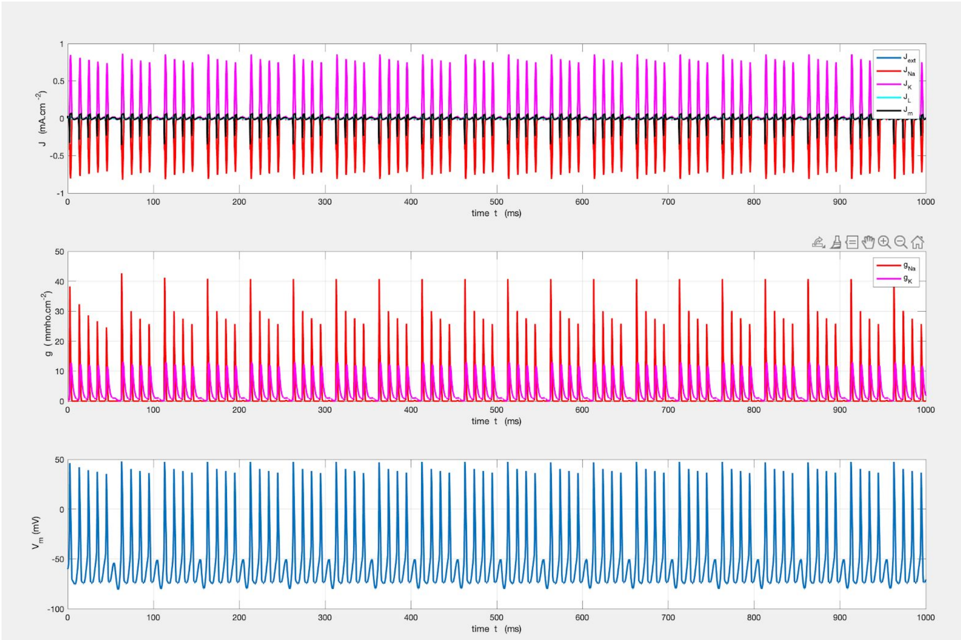


Jext (mA.cm^{-2})
time t (ms)


J (mA.cm^{-2})
time t (ms)
J_{ext}
J_{Na}
J_K
J_L
J_m
g (mmho.cm^{-2})
g_{Na}
g_K
V_m (mV)

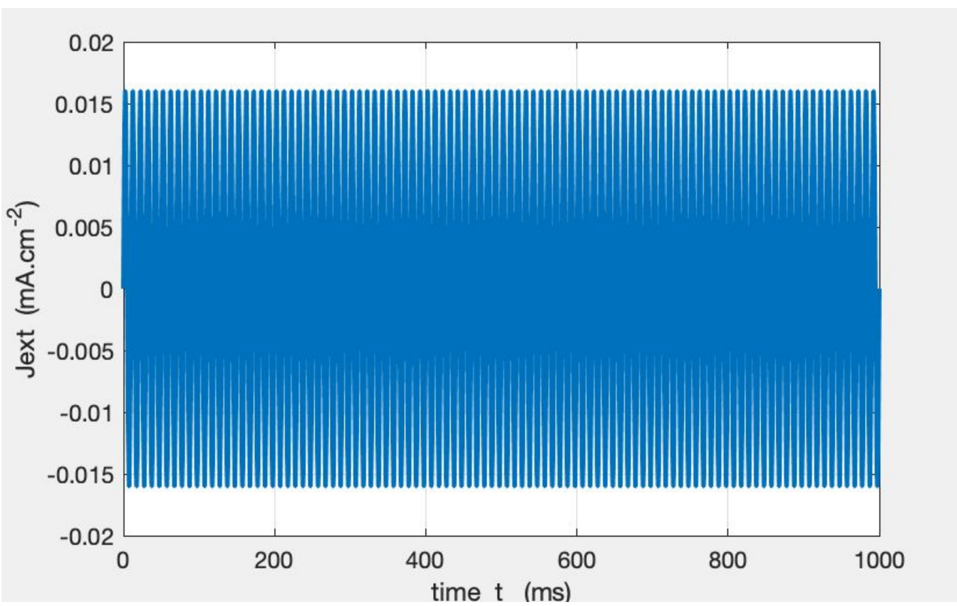
50Hz


Jext (mA.cm^{-2})
time t (ms)

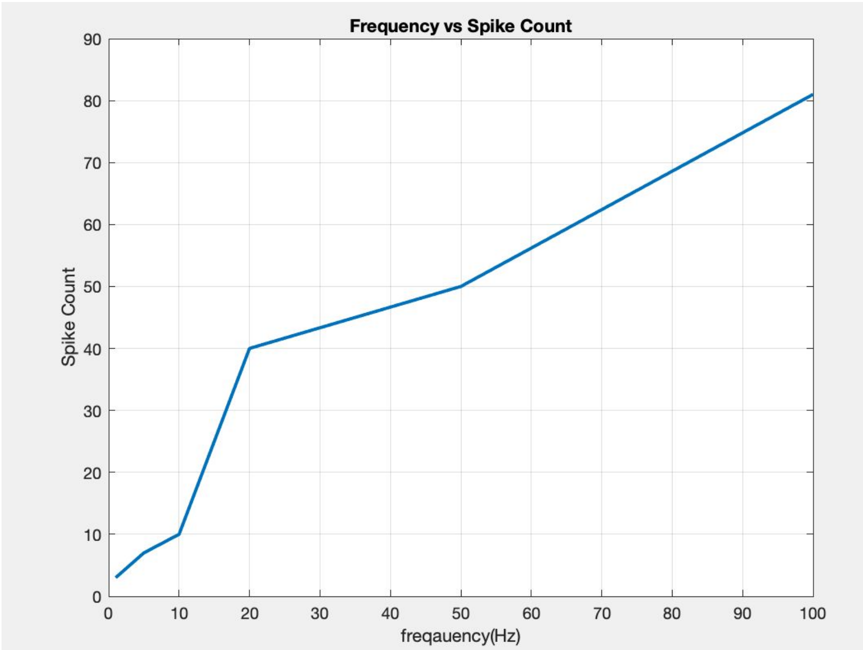


J (mA.cm^{-2})
J_{ext}
J_{Na}
J_K
J_L
J_m
time t (ms)
g (mmho.cm^{-2})
g_{Na}
g_K
time t (ms)
V_m (mV)
time t (ms)

100Hz



Jext (mA.cm^{-2})
time t (ms)



When the frequency of external stimulus increases from 1Hz to 100 Hz, the number of spike counts increases because sufficient positive current is applied when the membrane repolarizes new stimulus applied.
When the frequency of external stimulus goes high than 100 Hz there is not sufficient electric charge to depolarize the membrane before the current polarity reverses which then acts to repolarize the membrane. From a circuit analysis point of view, there is not sufficient time for the capacitor to charge and hence only a small voltage drop across it can develop. At higher frequency, the impedance of the capacitor is low thus the voltage across it is also low.

4)

How long is the time interval from the start of the stimulus to the peak of the subsequent action potential? The stimulus duration is 0.15 ms and amplitude, in μA/cm2, is

A) 50

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Time interval from start of stimulus to the peak of subsequent action
potential length for stimulus current with amplitude 50 uA: 1.8980ms
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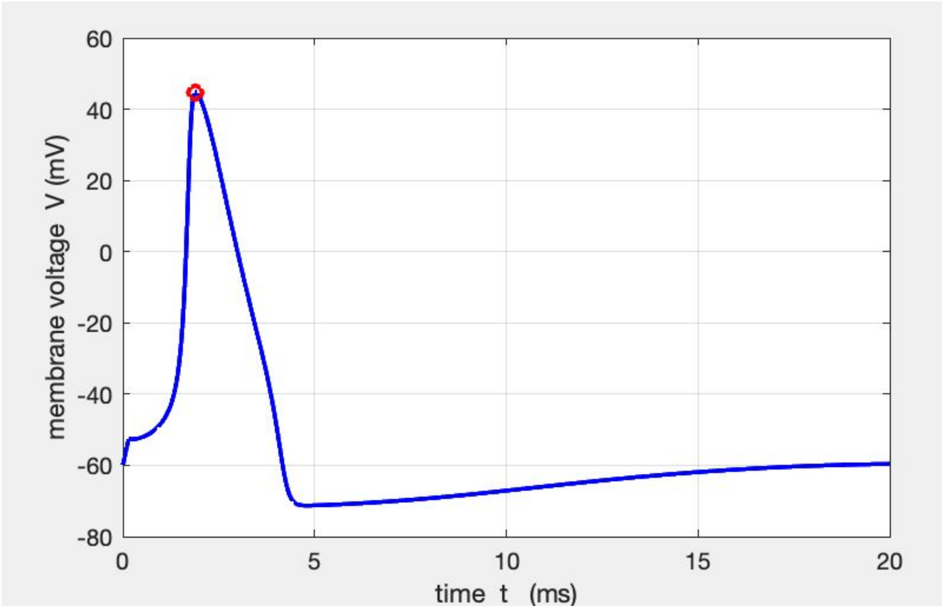
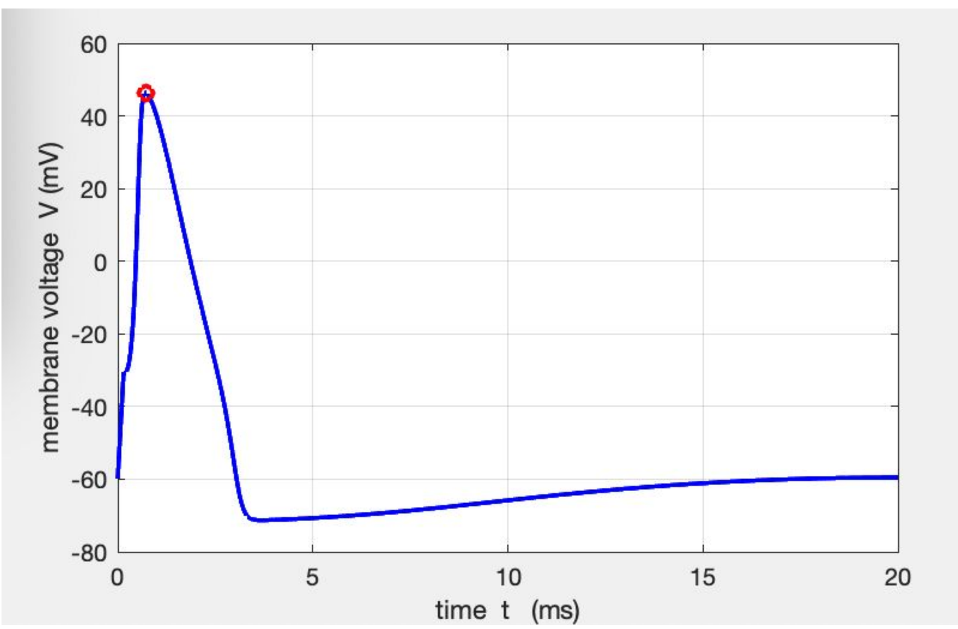


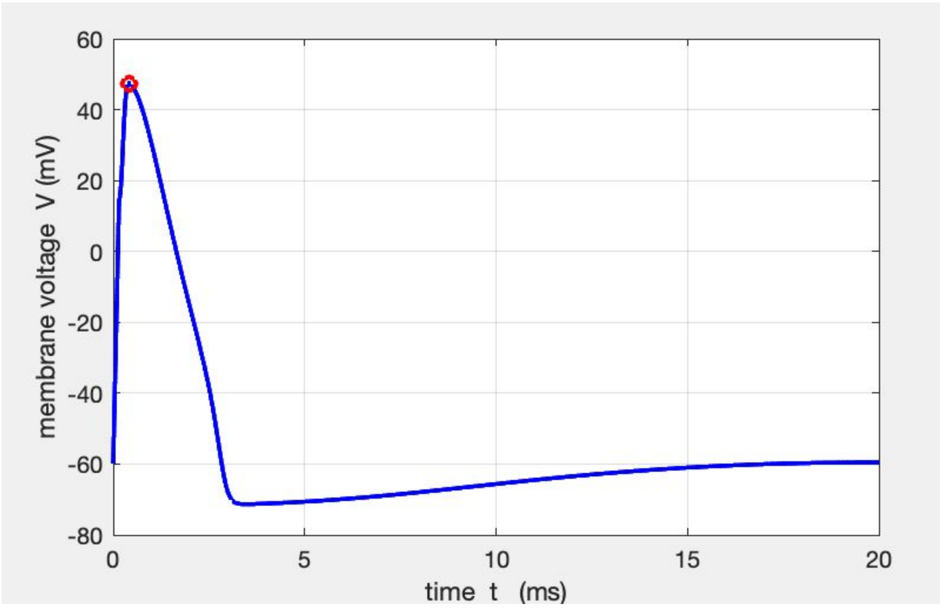
B) 200

Time interval from start of stimulus to the peak of subsequent action potential length for stimulus current with amplitude 200 uA: 0.7100ms



C) 500

Time interval from start of stimulus to the peak of subsequent action potential length for stimulus current with amplitude 500 uA: 0.4190ms



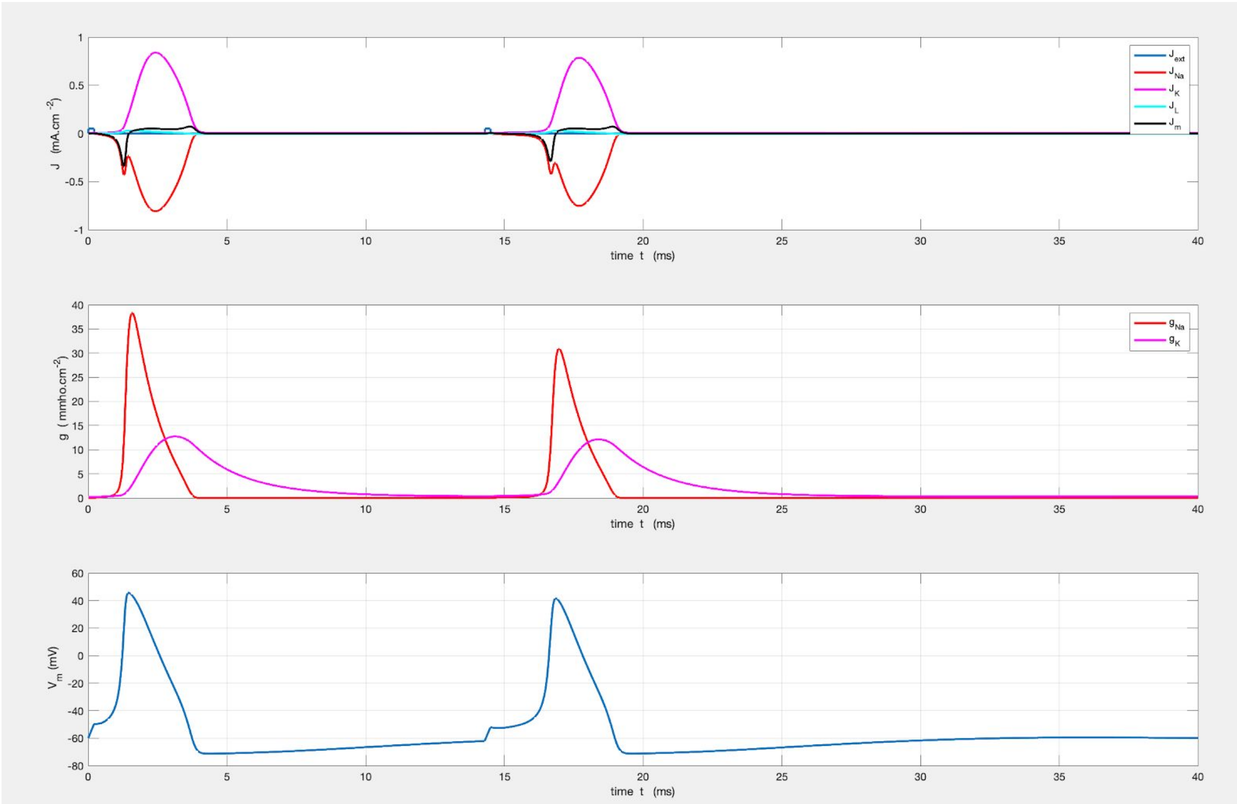
This part shows that when the amplitude of stimulus increasing the time to peak voltage is decreasing.

5)

How long must one wait after an initial stimulus to give a second stimulus that leads to an action potential? Evaluate with the HH model. What is the earliest time that a 2nd stimulus can be given, and produce a 2nd action potential, if the stimulus duration is 0.15 ms amplitude, in μA/cm2, is

A) 50,

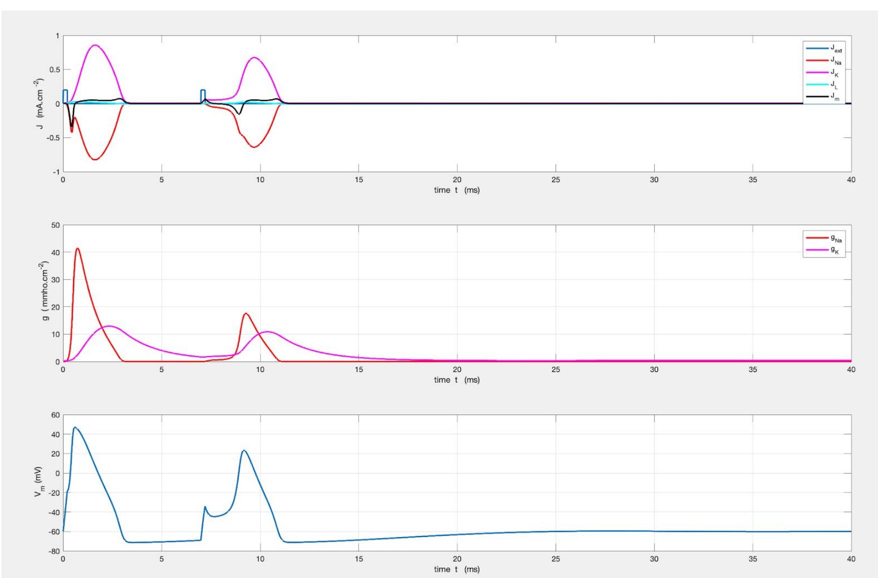
Time interval from start of stimulus to the peak of subsequent action potential length for stimulus current with amplitude 50 uA: 14.294000000000 ms for(V>Vthr)



B) 200

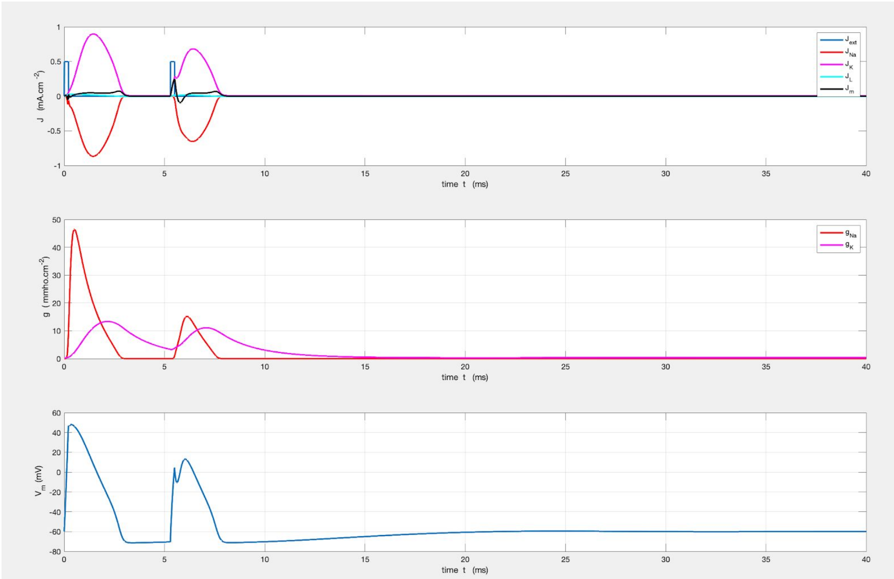
Time interval from start of stimulus to the peak of subsequent action potential length for stimulus current with amplitude 200 uA: 6.128 ms for(V>Vthr)

6.998ms for V>0



C) 500

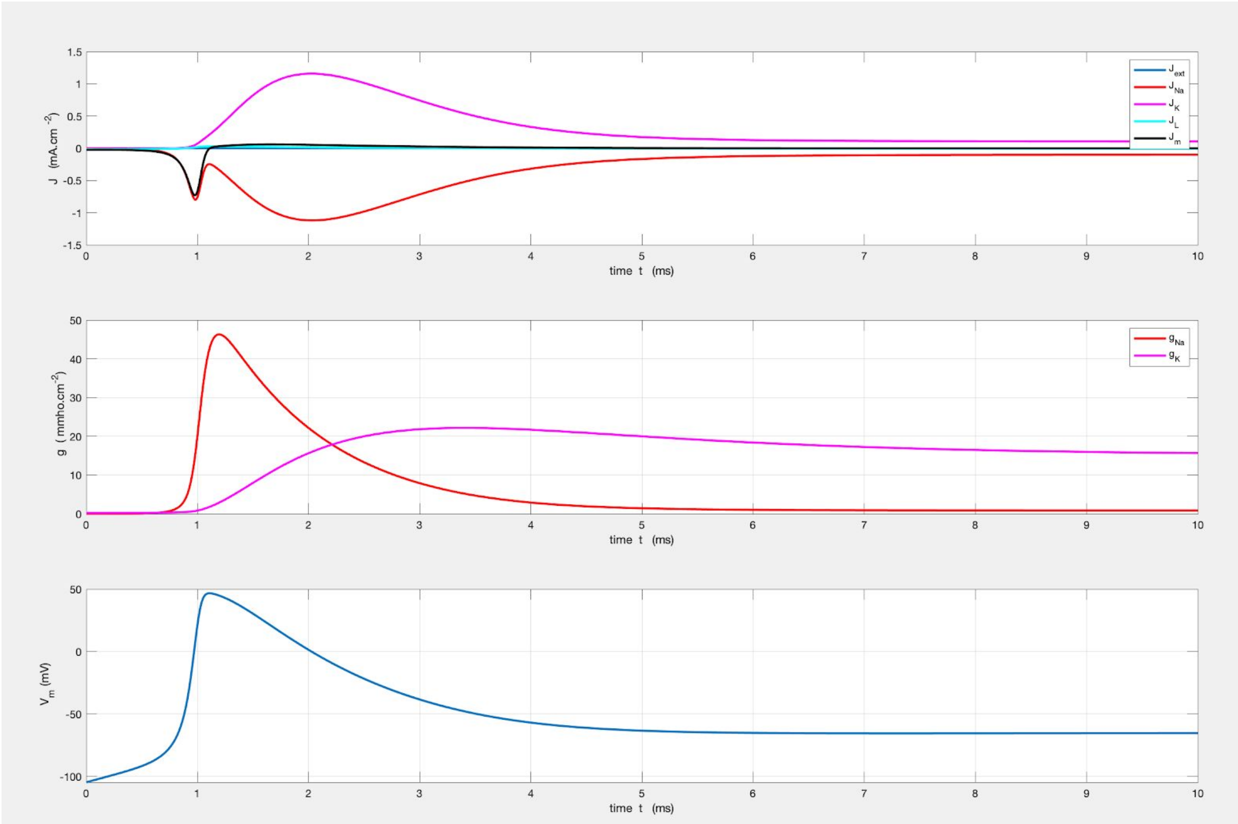
Time interval from start of stimulus to the peak of subsequent action potential length for stimulus current with amplitude 200 uA: 5.295 ms for(V>Vthr)



If an action potential is elicited, then a period ensues during which the membrane cannot be re-excited, the so-called absolute refractory state.After an interval it becomes possible to elicit an action potential, but it requires an abnormally high stimulus.Refractoriness can be understood mainly by the behavior of the inactivating parameter h. Some time must elapse for h to recover to normal or near-normal values. Time also is needed to permit n to decrease, because excitation requires bringing about the condition that INa > IK. Increasing Vm initiates the regenerative process that characterizes the rising phase of the action potential. In part 4, we also examine that when the amplitude of stimulus current increasing the peak time of membrane voltage decreasing. Considering the above explanation I find the times where h value becomes normal for given stimulus current. Combining the results of part4, the decreasing time trend is expected.

6)

Anode break excitation. Change the initial membrane potential to − 105 mV.
A) Simulate what happens during the first 10 msec. This phenomenon is called “anode-break excitation” because excitation occurs after shutting off a hyperpolarizing (anodal) pulse of current if the amount of hyperpolarization is sufficiently large.



B) Study the membrane conductance and describe why this excitation occurs.

--Reason for exctation occurred in part A.

The excitation in part A happened because the resting potential of the membrane is actually -60 but we applied initial voltage -105 instead of -60. Thus, now membrane with initial gating values does not satisfy resting conditions and tries to reach Vmembrane -60V. While membrane potential is reaching -60V, it exceeds threshold value and membrane excited. Therefore, we see the graphic as part A.

--General explanation of anode-break excitation:

The basis of the anode break excitation is that anodal polarization decreases the potassium conductance and removes inactivation. These effects persist for an appreciable time so that the membrane potential reaches its resting value with a reduced outward potassium current and an increased inward sodium current. The total ionic current is therefore inward at V =0 and the membrane undergoes a depolarization which rapidly becomes regenerative.

Just prior to release of the hyperpolarization, the value of h is elevated while m and n are reduced. However, m rapidly regains its normal value following restoration of normal Vm, since τm is relatively short.

The result, based on τm << τn, τh, is that there is a depressed n, normal m, and elevated h. All three combine to promote INa > IK. The consequence can be the initiation of excitation.