BT6270: Computational Neuroscience
Assignment 1

Shreya Nema (BS17B033)

Hodgkin Huxley model

The Hodgkin-Huxley model explains how the dynamics of ion channels (Na+, K+) contribute to the generation of an Action Potential in a neuron. An Action Potential is a sharp voltage spike elicited by stimulating a neuron with a current that exceeds a certain threshold value. The model is a set of nonlinear differential equations that exhibits the electrical characteristics of neuronal cells. The current amplitude is increased gradually, at a threshold amplitude, the voltage response does not increase proportionally but it shows a sharp, disproportionate increase. Once the membrane voltage reaches a threshold value, it increases further rapidly to maximum value and drops again rapidly to a value that is less than resting value, before returning to the baseline value.

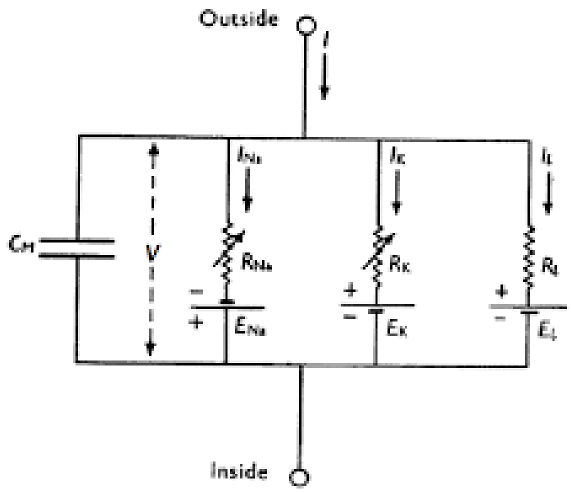


Fig: Basic components of Hodgkin-Huxley Model

1. Threshold values for the external applied currents I_1, I_2, and I_3 in which shift of dynamical behavior from one to another is seen, such as no AP, finite number of AP's, Continuous firing and then followed by distortion resulting in no more APs.

   The voltage vs time plot behaves differently for different applied current. At small values of current no spikes were observed assuming that a peak height is greater than 10mV. Beyond some particular value (0.0223 µA) even a small change in the system dynamics causes sudden change in action potential. Beyond 0.0622 µA a sudden burst in the number of spikes was observed followed by a steady increase in spikes count. At value of 0.457 µA, a sudden decrement in the number of spikes was observed and no action potentials were obtained.

Hodgkin–Huxley model undergoes a Hopf bifurcation when external current is used as bifurcation parameter. Increasing the injected current will increase the firing rate of the neuron. Threshold values for the external applied currents I_1, I_2, and I_3 obtained from the code that used 0.003 µA current jump value starting from 0.01 µA.

I1: 0.0221
I2: 0.0622
I3: 0.4577
These current values divide the graph into four regions:

I < I1 :

Fig: Plot of Voltage vs Time for I=0.02 µA (<I1), V<0

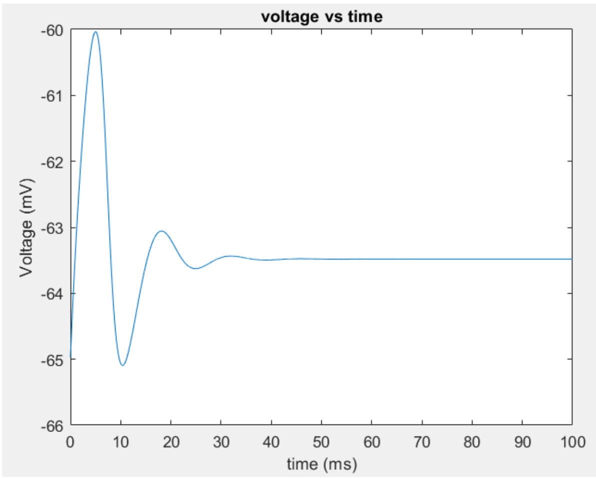


Fig: Plot of gating variables for I=0.02 µA

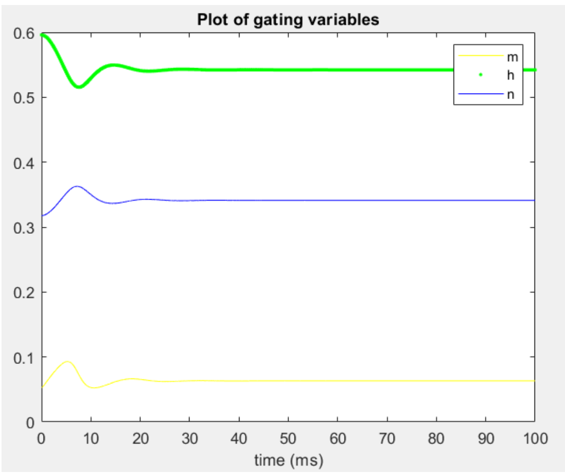
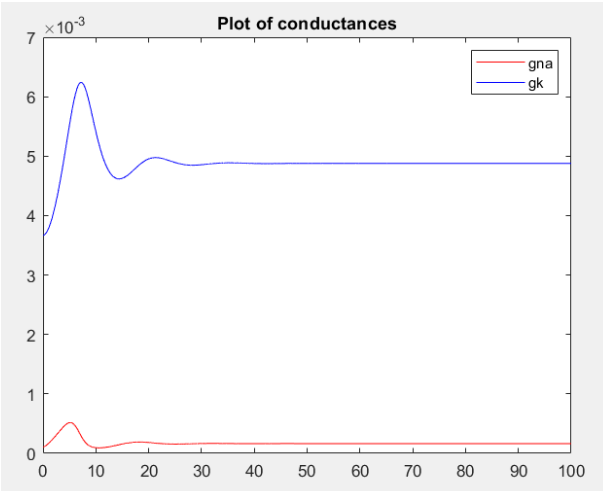


Fig: Plot of conductance for I=0.02µA



I1<I<I2:

Fig: Plot of Voltage vs Time for I=0.03 µA (I1<I<I2), V>0

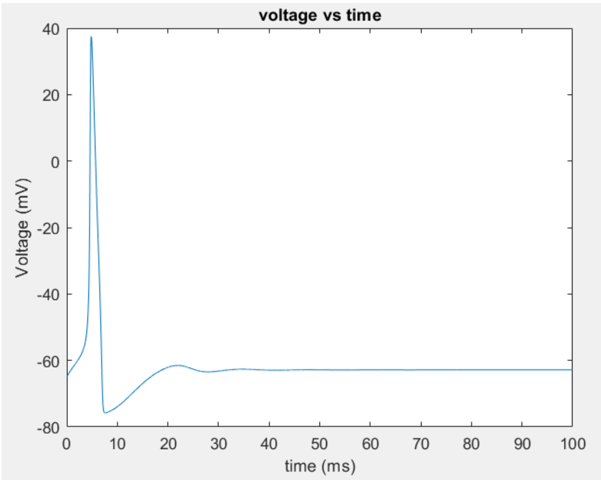


Fig: Plot of gating variables for I=0.03 µA

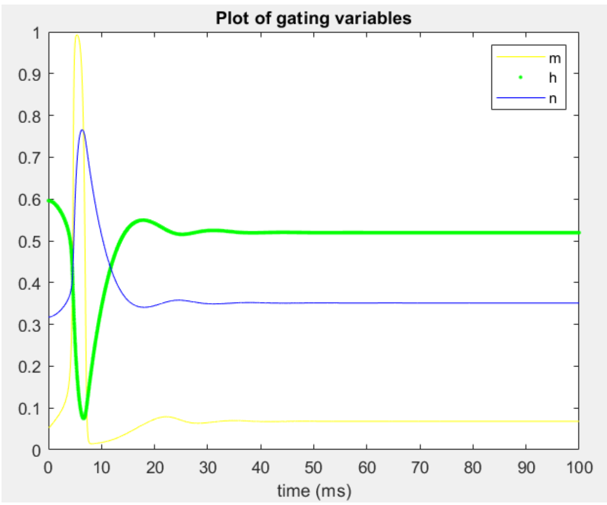
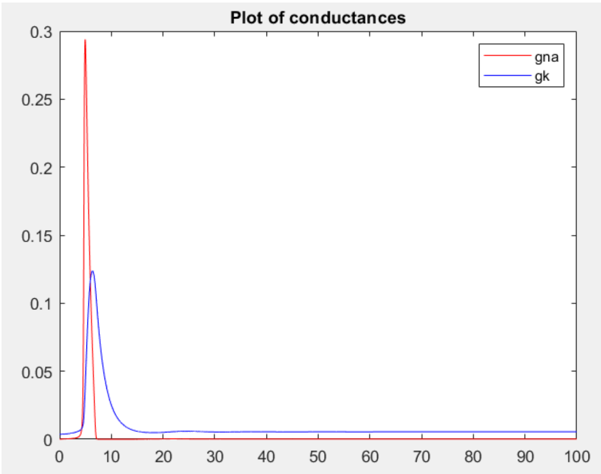


Fig: Plot of conductance for I=0.03μA



I2<I<I3:

Fig: Plot of Voltage vs Time for I=0.3 μA (I2<I<I3), V>0

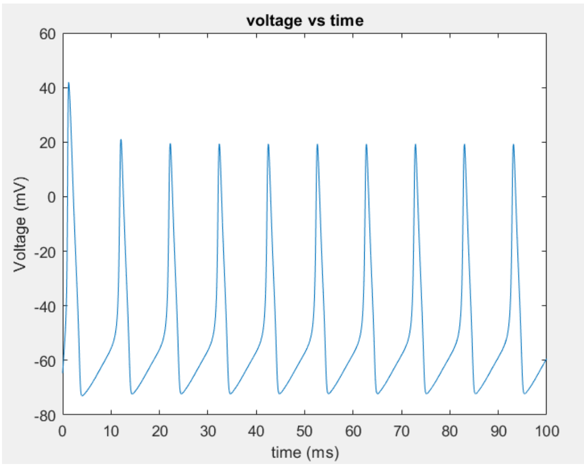


Fig: Plot of gating variables for I=0.3 μA

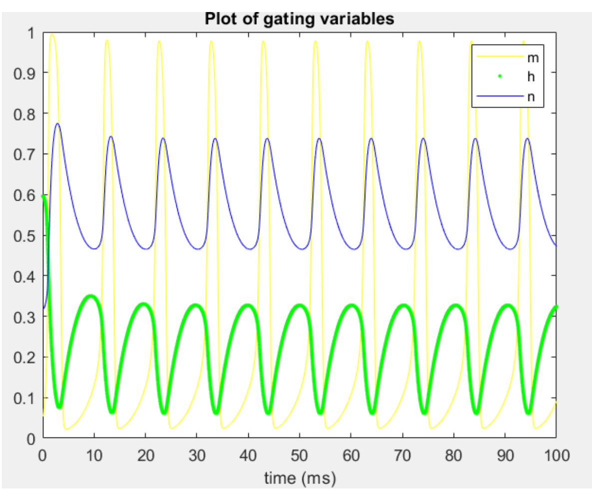
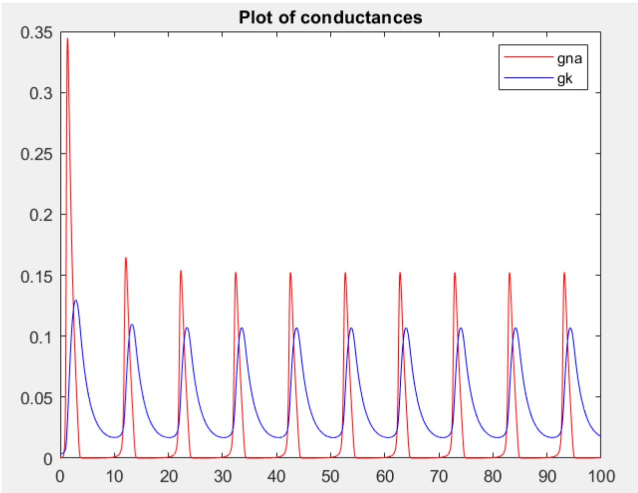


Fig: Plot of conductance for I=0.3μA



I>I3:

Fig: Plot of Voltage vs Time for I=0.67 μA (I>I3), peak value less than threshold (10 mV)

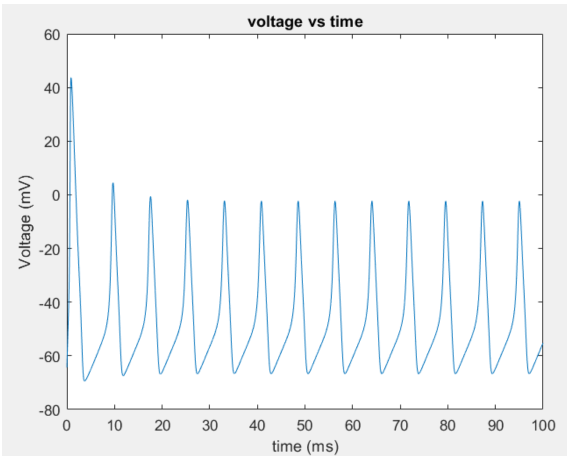


Fig: Plot of gating variables for I=0.67 μA

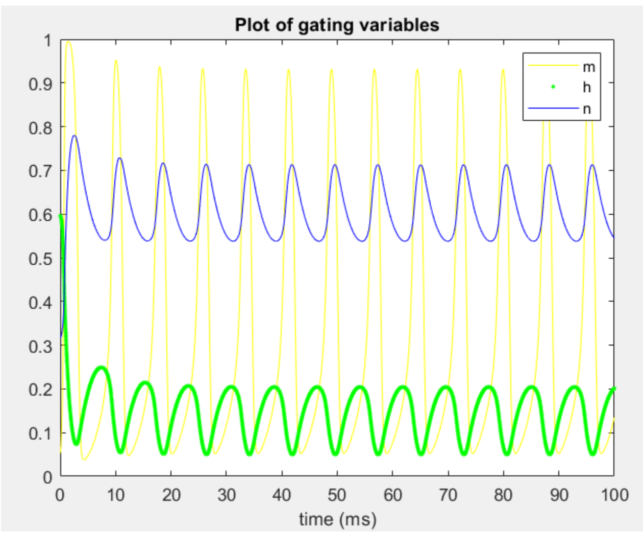
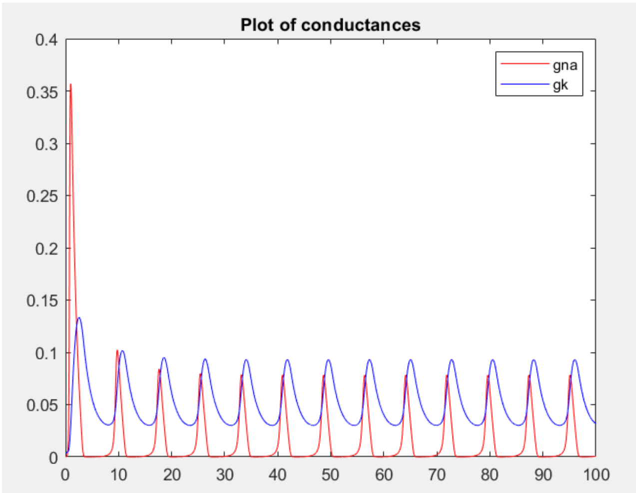


Fig: Plot of conductance for I=0.67μA



2. A graph which depicts the firing rate (frequency) as you change the applied external current (i.e. I_{ext} vs. Firing rate (f)).

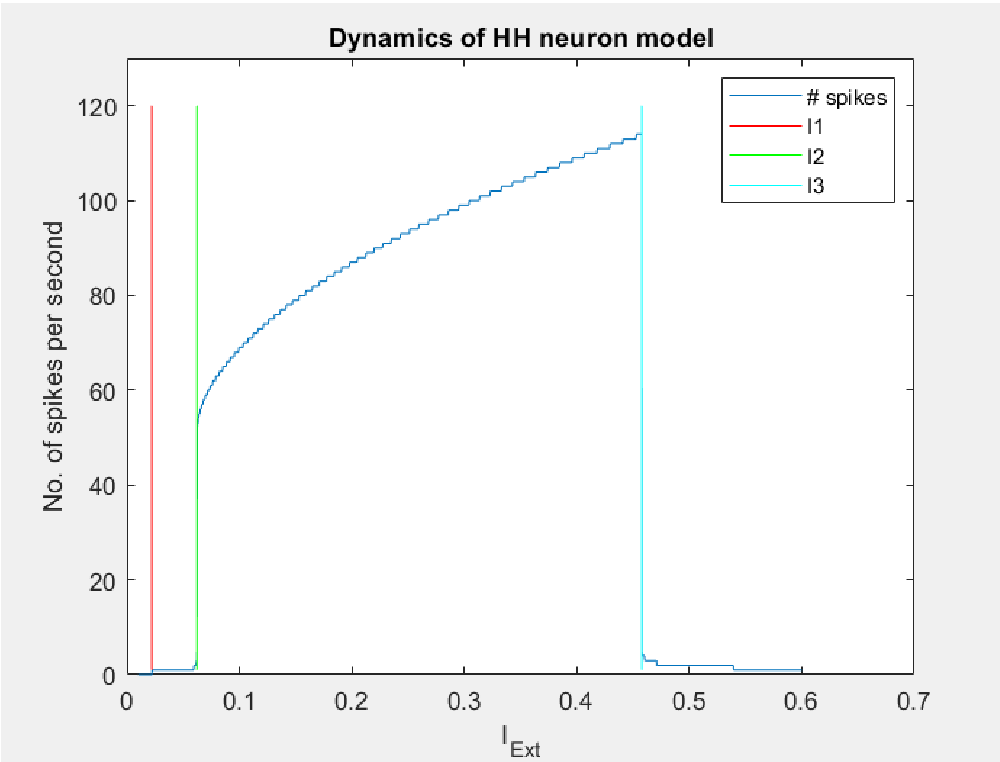


Fig: The firing rate (no. of spikes per second) as a function of the applied external current. I1, I2 and I3 are the three threshold current values in which shift of dynamical behavior from one to another is seen.