Computational Neuroscience Coursework 1

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Question 1

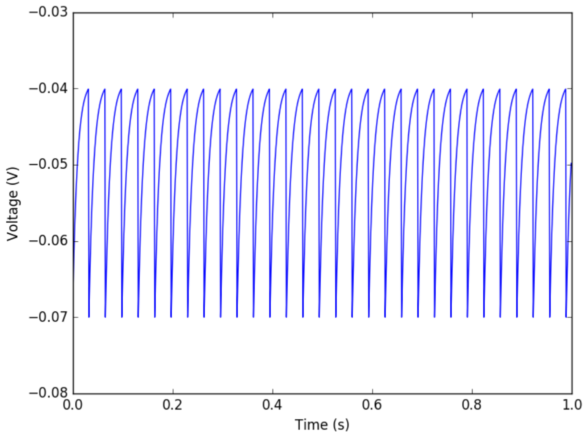


Figure 1: Internal neuron voltage against time for simulating a single neuron, showing thirty spikes over the course of 1 s.

Question 2

As we're modelling the neuron with a constant injected current I_e, we can solve the integrate and fire model for t, and constrain the equation such that at $t = 1$, $V(t) = V_T$ and at $t = 0$, $V(t) = V_r$.

$$V(t) = E_L + R_m I_e + [V(0) - E_L - R_m I_e]\ e^{-t/\tau_m} \tag{1}$$

$$V(1) = V_T = E_L + R_m I_e + [V_r - E_L - R_m I_e]\ e^{-1/\tau_m} \tag{2}$$

$$(V_T - E_L)\ e^{1/\tau_m} + E_L - V_r = I_e\ (R_m e^{1/\tau_m} - R_m) \tag{3}$$

$$I_e = \frac{(V_T - E_L)\ e^{1/\tau_m} + E_L - V_r}{R_m e^{1/\tau_m} - R_m} \tag{4}$$

Therefore using the values outlined in Q1 for the variables in equation (4) to compute I_e, we find that the minimum value that I_e can be to at least cause a single spike in a one second simulation is 3.0 nA.

Question 3

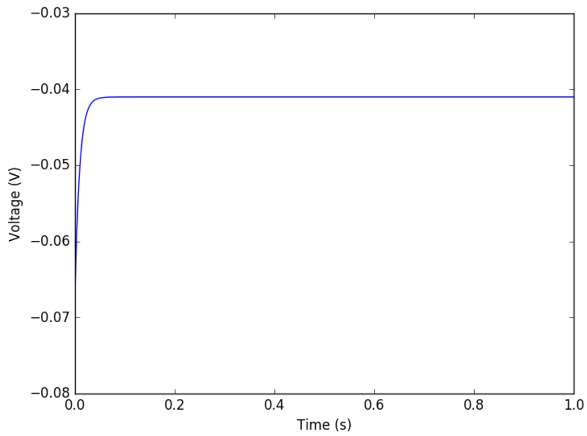


Figure 2: Simulation of a neuron for 1 s with an input current of amplitude I_e which is 0.1 [nA] lower than the minimum current computed in question 2. As shown the voltage fails to exceed the spiking threshold throughout the simulation.

Question 4

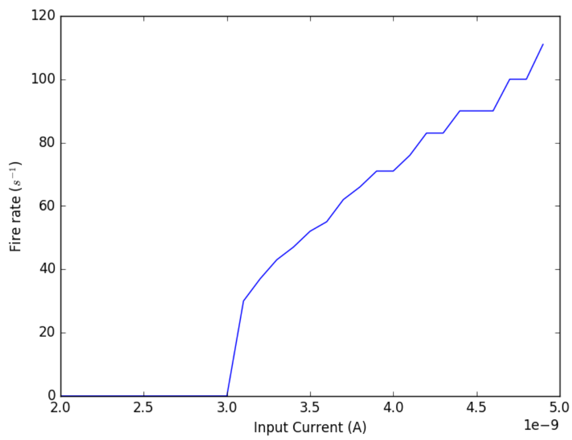
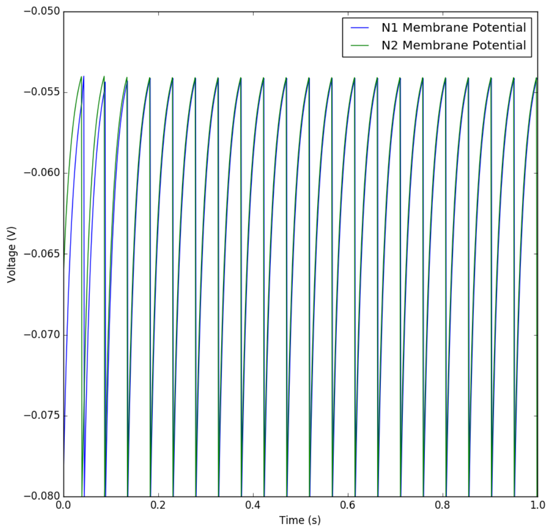
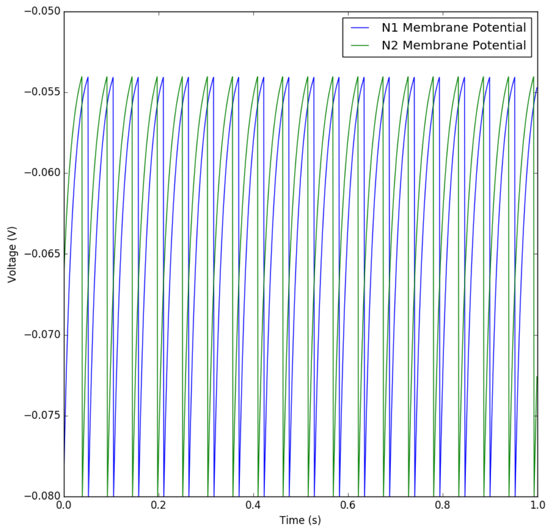


Figure 3: Fire rate per second plotted against input current to the neuron. This further verifies the results of question 2 and 3 as prior to an input current of 3.0 nA there is a fire rate of 0.

Question 5



(a) Internal neuron voltage against time for simulating two excitatory neurons feeding into one another over the course of 1 s. The graph shows that when one neuron fires it causes a notable boost in membrane potential for the other neuron. This in turn causes the post-synaptic neuron to spike sooner than it would have otherwise, the ultimate result of which is to cause the firing of both neurons to happen synchronously.



(b) Internal neuron voltage against time for simulating a single neuron, showing thirty spikes over the course of 1 s. This graph shows that when one neuron spikes there is a decrase in gradient of the other's membrane potential with respect to time

Question 6

Question 7

References