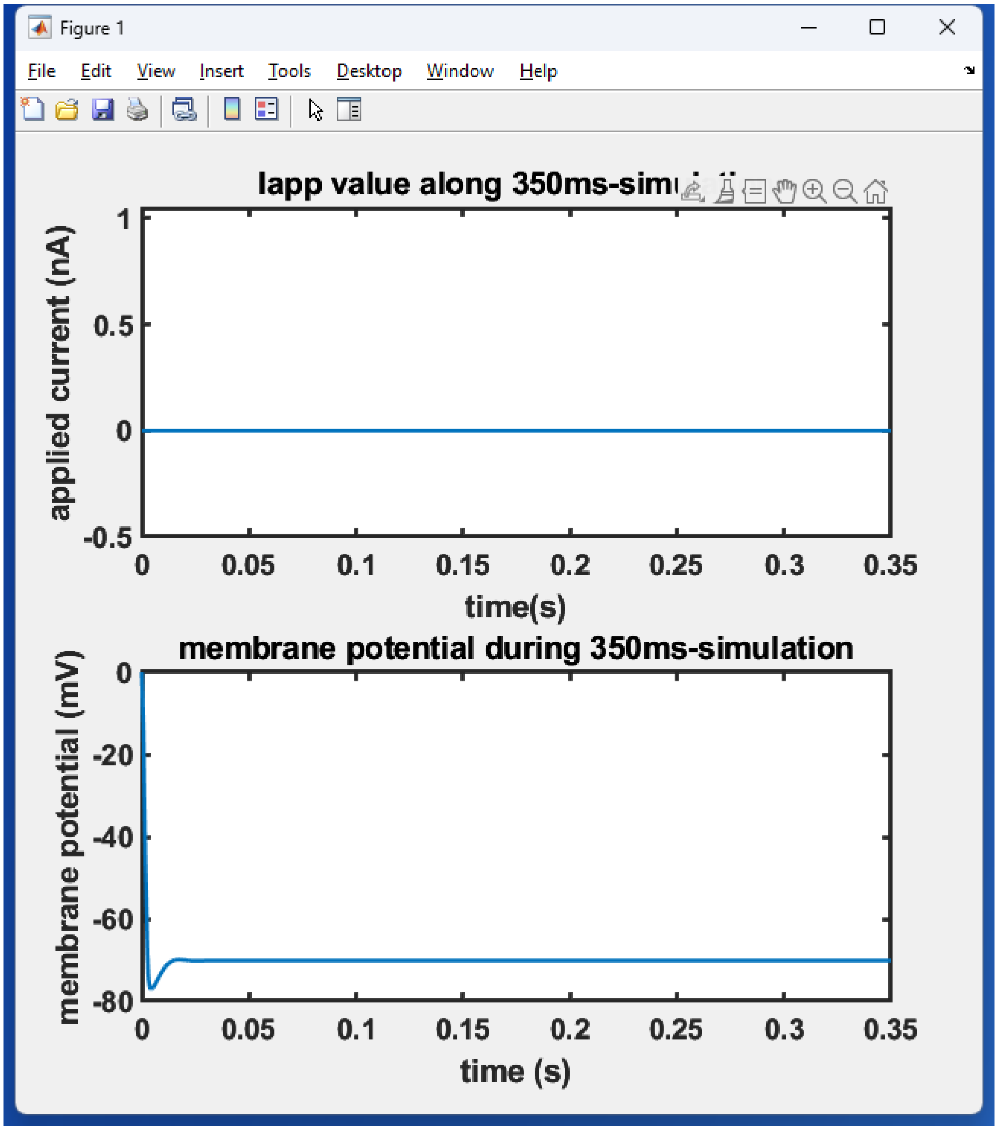
Code file: `HodgkinHuxley_model.m`.

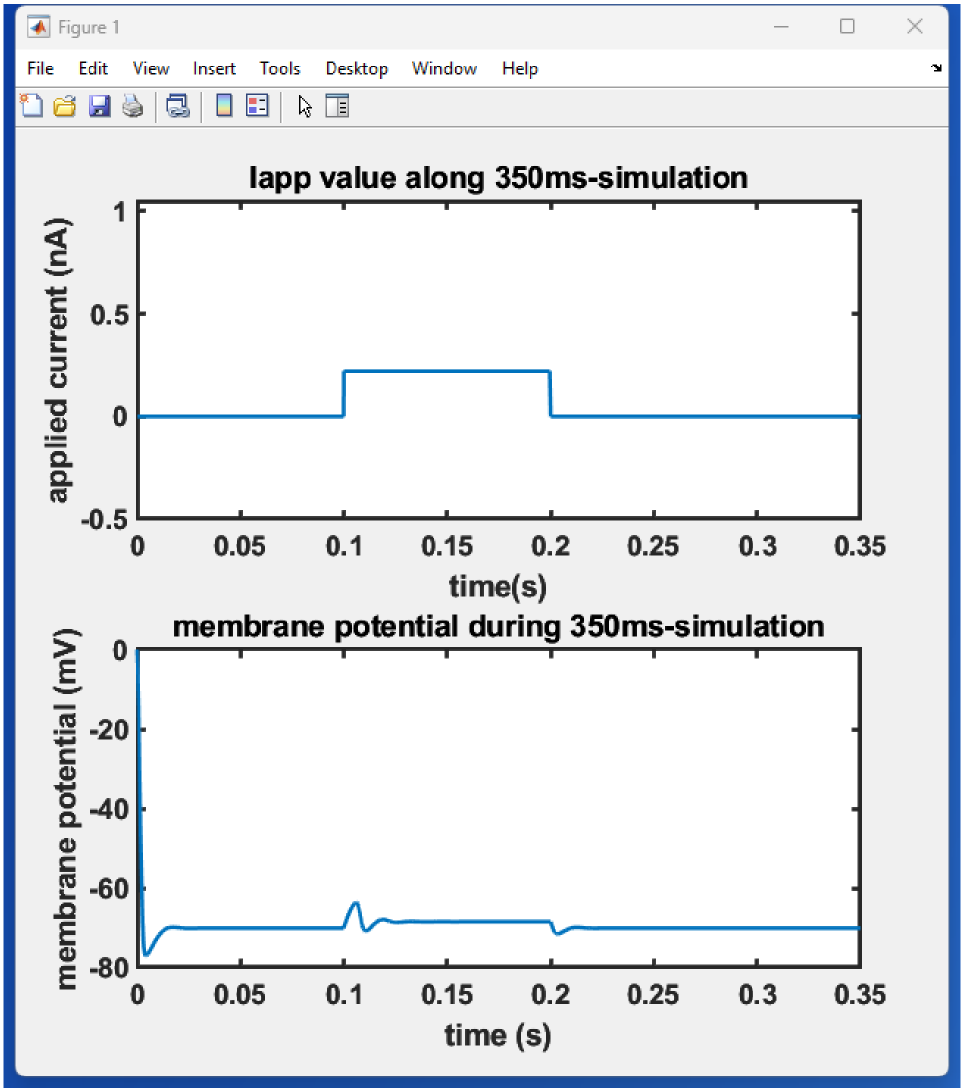
Alter input `question_number` to 1-6 to see the output in question a-f.

Question (a)



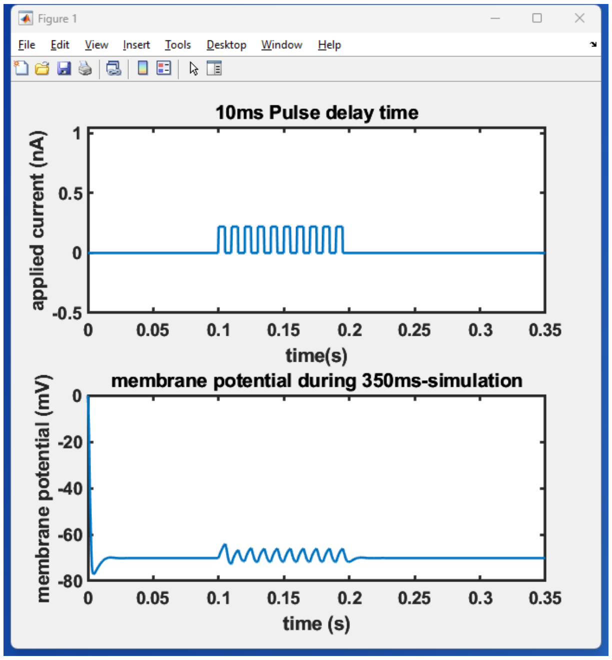
The applied current is 0 in question1. The membrane potential rests at 70.156 mV.

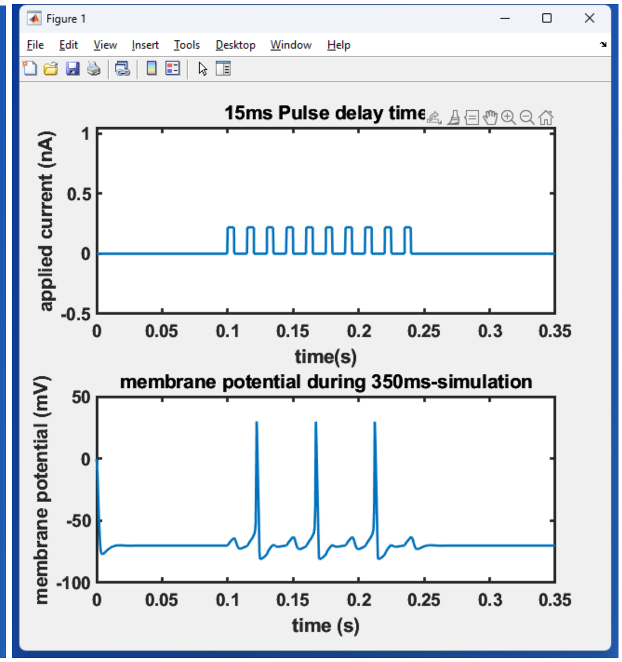
Question (b)

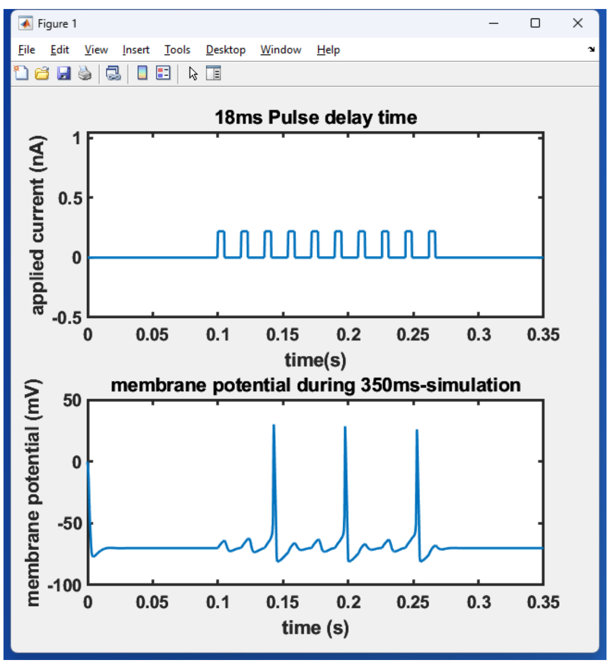


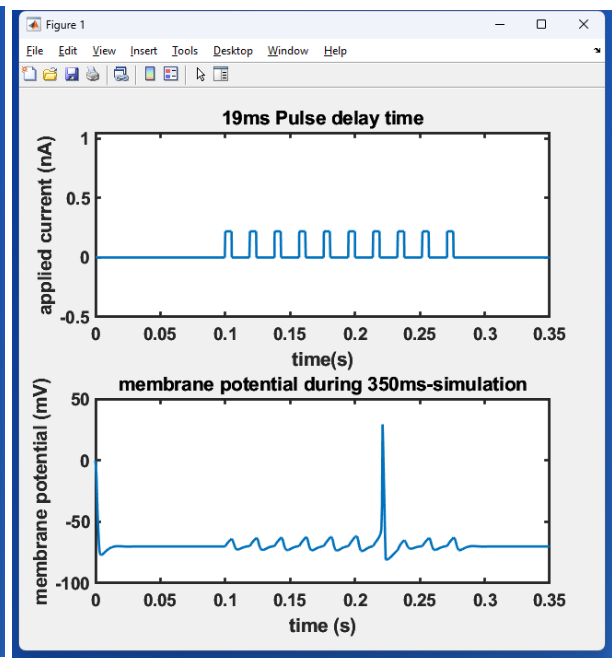
There’s no spikes in the plot.

Question (c)





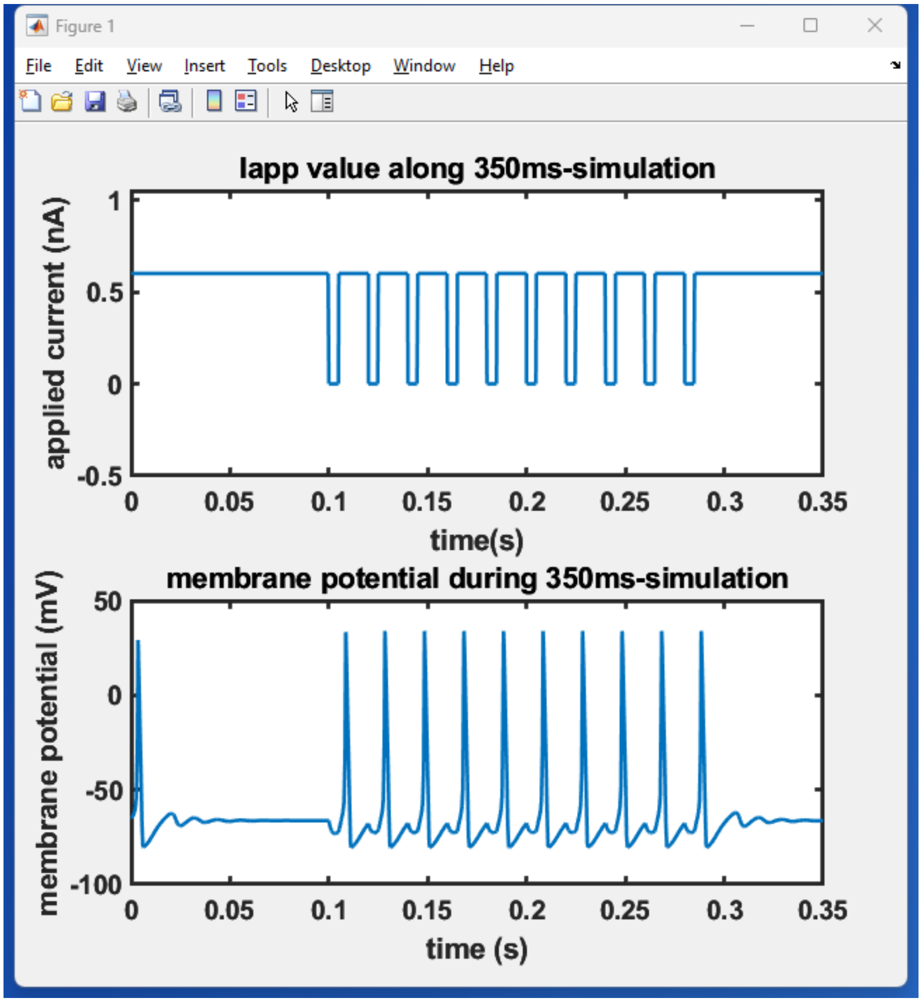




Edit variable `delay` in `case 3` to view plots with different delay time.
The delay time between 15ms and 19ms (inclusive) can generate spikes. Delay time outside of 15-19ms would not generate any spike. From the graph we can see that there's a small depolarization whenever there is an pulse onset appeared in applied current. The depolarization would accumulate and generate spikes. At 15ms-delay time, it takes two pulses to generate a spike, and the third spike makes membrane potential to depolarize from the hyperpolarized status; at 18ms-delay time, it takes three pulses to generate a spike; at 19ms-delay time, it takes 7 pulses to generate one spike. The reason that there's no spike generated when the delay time exceeds 19ms is that the time between pulse onset it too large to

make depolarization accumulate. In contrast, when the delay time is too short –less than 15ms—the depolarization from one pulse onset would be abbrupted by the following depolarization, so the neuron cannot accumulate and generate spikes.

Question (d)

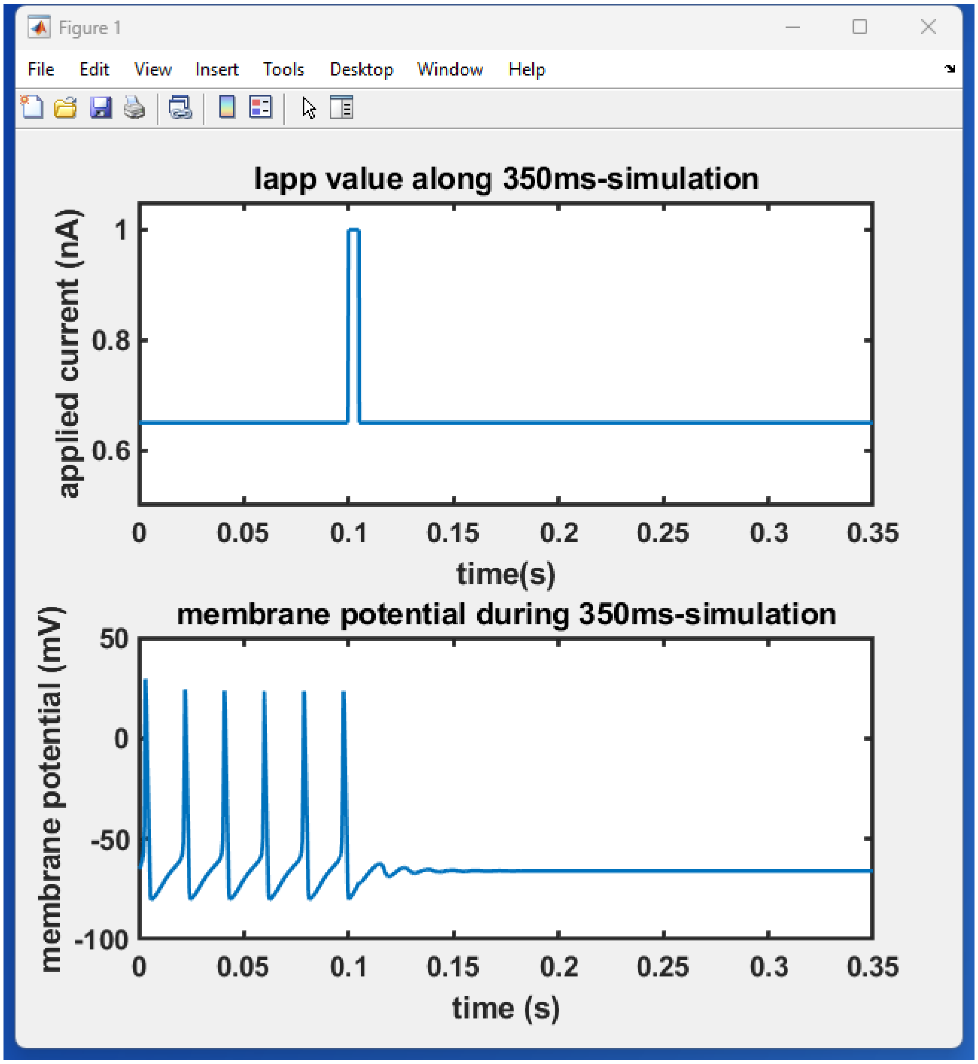


In plot for question d, there's spike generated at the start of simulation, which oscillates and reach stable states after hyperpolarization. The same spike is also generated every time after applied current returns from inhibitory pulse to base line.

When the applied current released to 0mV and returns to its baseline at 0.6nA, an action potential would be produced. However, the neuron is unable to generate spike at 0.6nA baseline current (below the threshold); therefore, the neuron would reach stable states when applied current stabilizes at baseline.

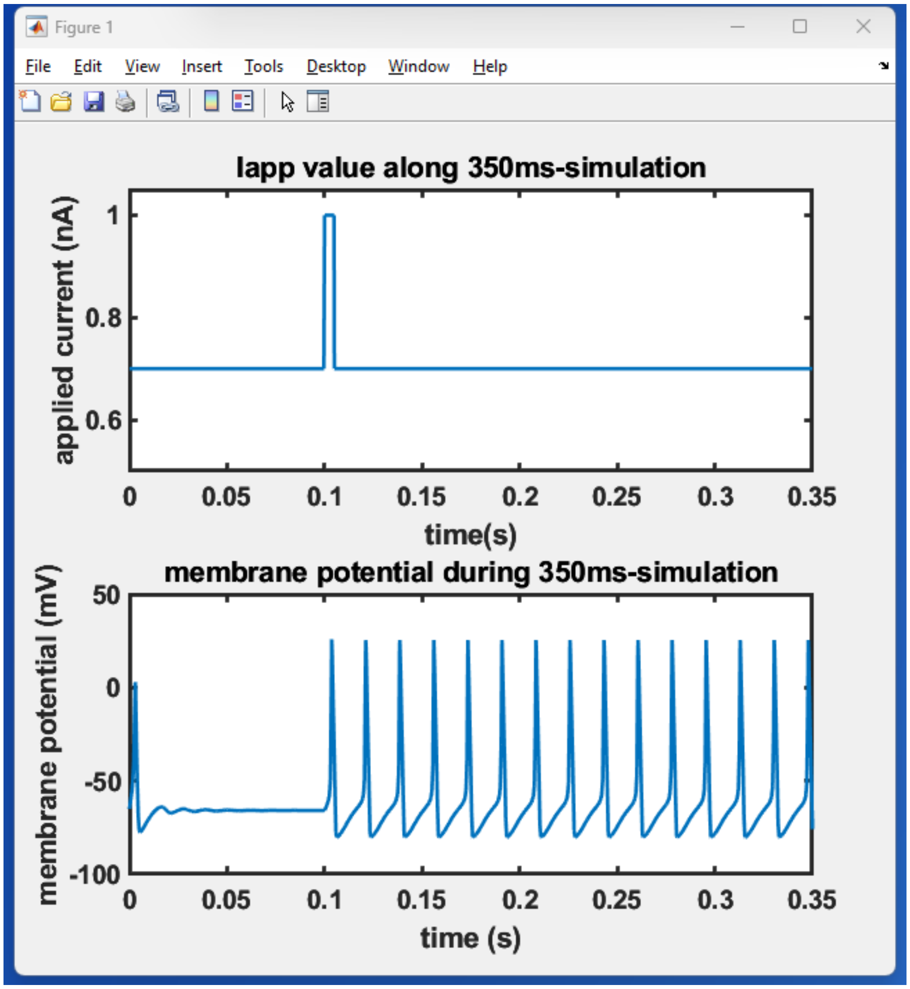
This explains why there's an action potential produced at the beginning of simulation, as well as every 5ms-duration inhibitory pulses. The membrane potential initiates from resting potential (-65mV), so there's a spike generated at the beginning. Membrane potential hyperpolarizes during inhibitory pulse onset and spikes when it switches to the offset.

Question (e)



From plots for question e, we can see that the neuron is spiking in with a stable inter-spike interval. When the 5ms pulse with 1nA amplitude is applied, the neuron stopped firing and oscillates to steady state after hyperpolarization. This is because 0.65nA applied current it the threshold for the neuron to maintain firing (neuron cannot maintain firing when applied current is ≤0.64nA). The 1nA pulse onset would not make the neuron cease spiking, but rather makes it spiking faster as we increase the pulse onset from 5ms to 50ms (we can observe a smaller inter-spike interval). Instead, what makes the system stop firing is the sudden drop from pulse onset to offset, which is equivalent to an inhibition. Because the baseline current is slightly above the spiking threshold, such inhibition would be strong enough to stabilize the system into steady state.

Question (f)



From the figure for question f, we can observe that the neuron spikes at the beginning of simulation, and the oscillates to stable until the pulse onset. After the 5ms pulse onset, the neuron fires at a stable firing rate until the end of simulation.

This is because in this system with all gating variables initialized as zero, 0.7mV baseline applied current is not able to generate spike; all gating variables rest at a stable state. The threshold baseline current is 0.94nA to let the system spike constantly (in other words, system would start spiking without excitatory pulse when baseline current is 0.94nA). However, the sudden rise of pulse activates the system to start spiking –even if the onset amplitude is slightly below 0.94nA. I tried an onset of 0.90nA, which could still trigger spiking in the system. An 1nA onset pulse, as described in question f, would be powerful enough to turn on the system to spike. The excitatory pulse triggers gating variables to change from stable states, which causes the system to fire.