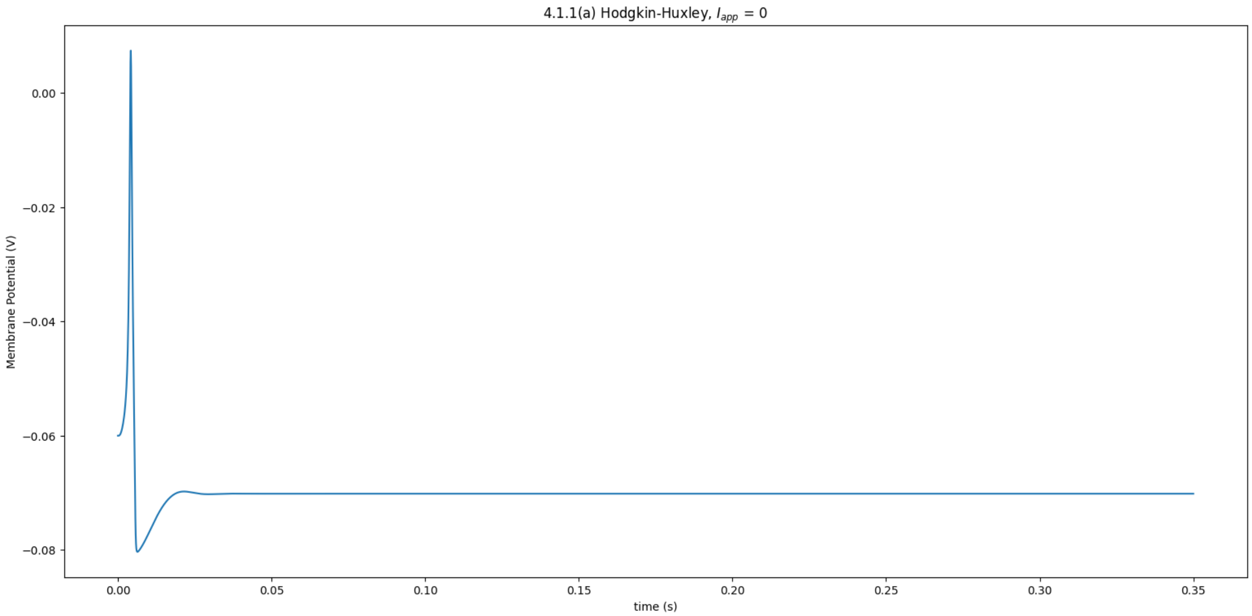
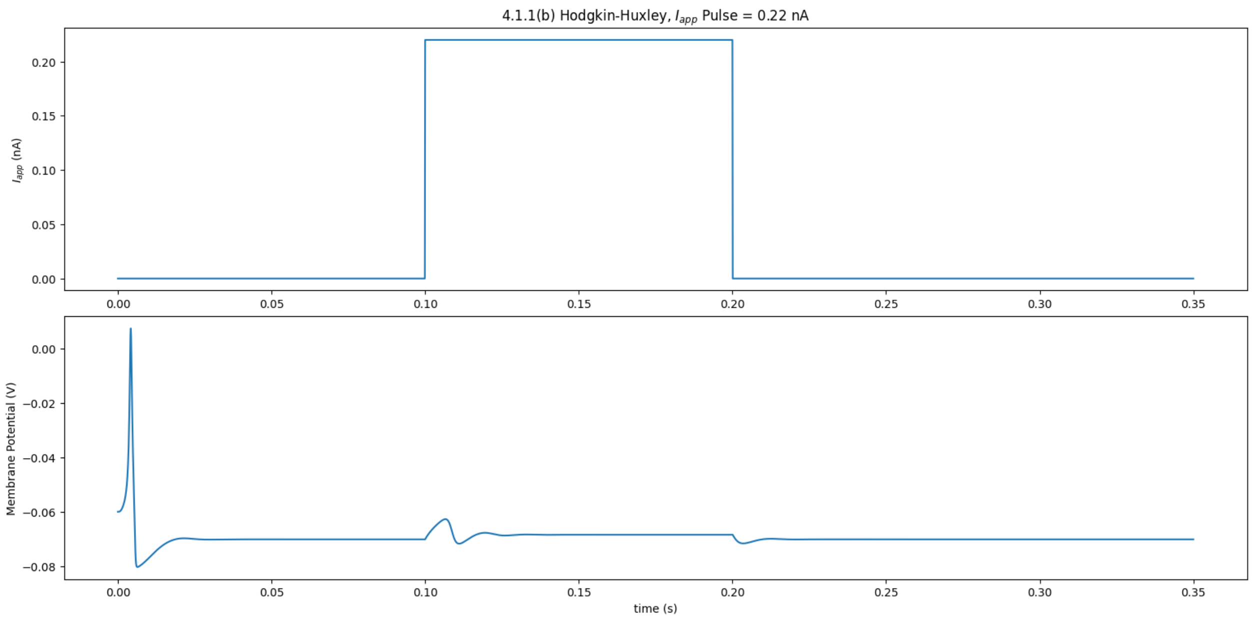
Caelen Hilty – Computational Neuroscience – Tutorial 4.1

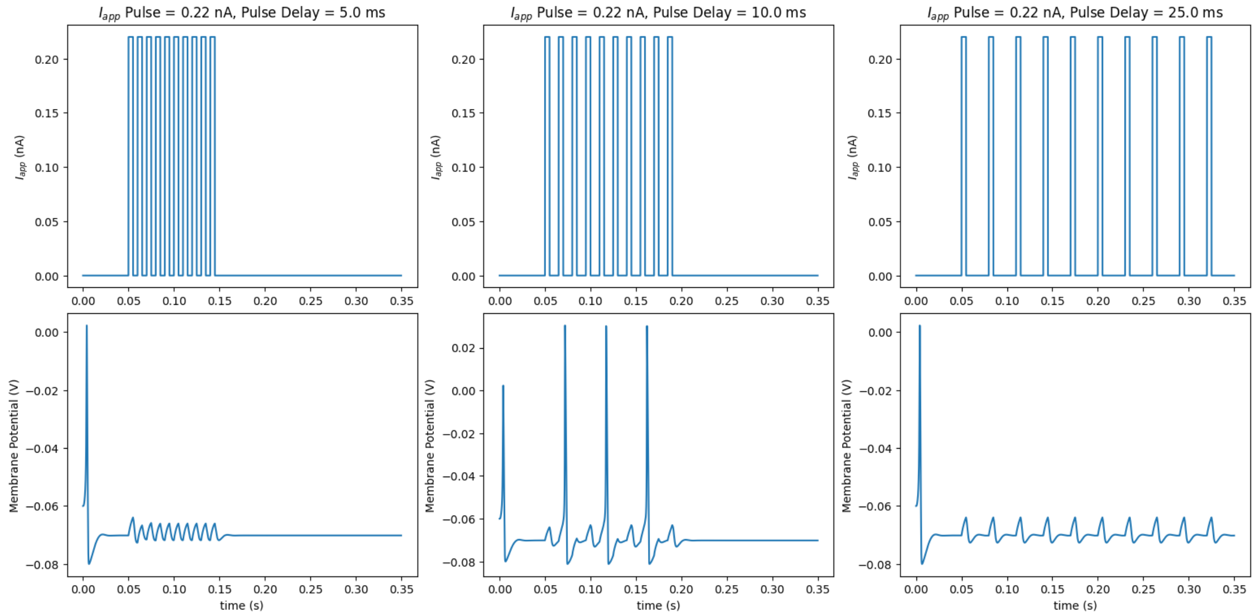
4.1.1(a)



4.1.1(b)

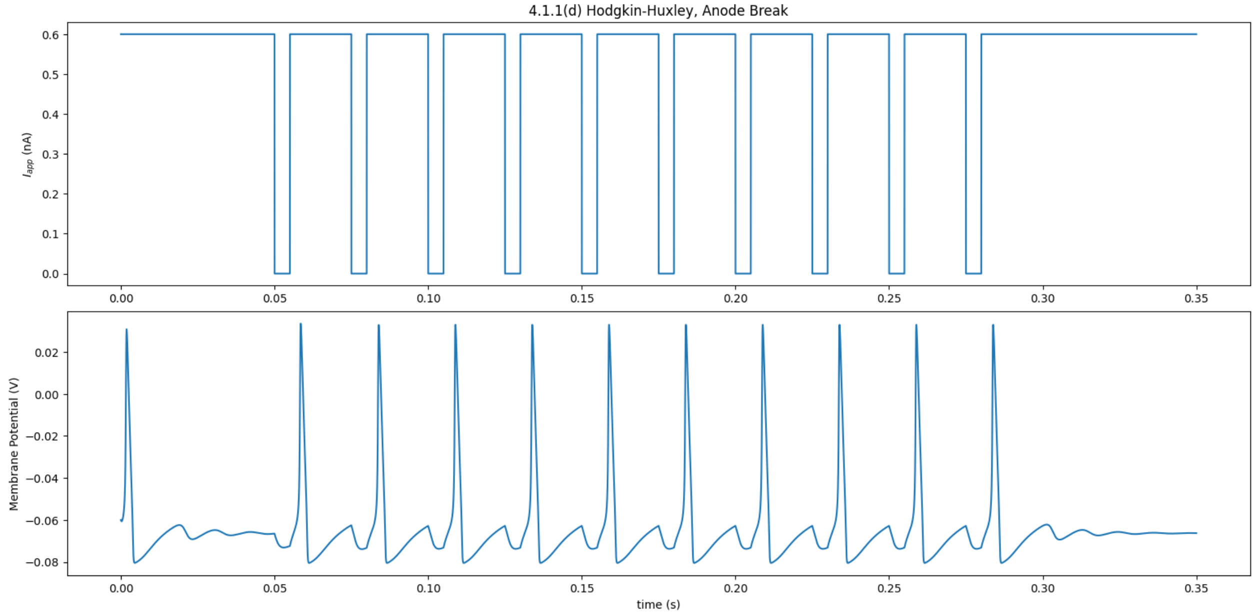


4.1.1(c)



When the neuron is sent the correct frequency of input current, it can cause spiking, but a frequency that's too high or too low will result in subthreshold oscillations. The membrane potential and the gating variables naturally oscillate on their own, so when the input current frequency matches the frequency of that oscillation, it amplifies the natural oscillation and causes spiking. When the frequency doesn't match, the input frequency damps the natural oscillations or doesn't amplify the oscillations enough to cause spiking.

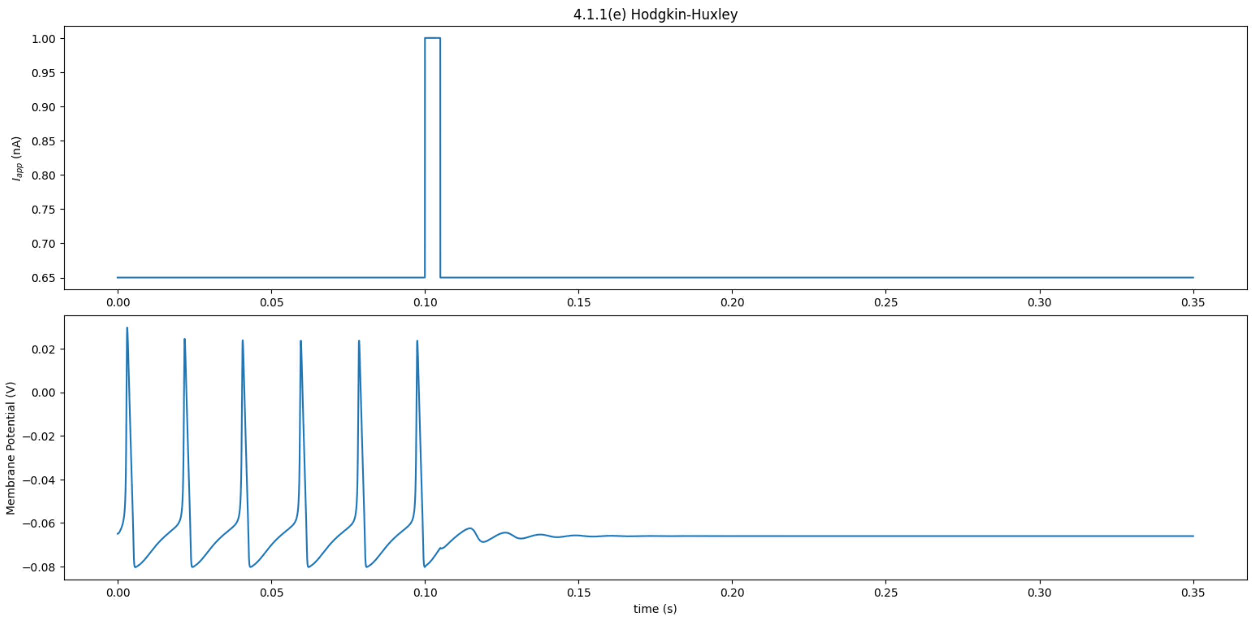
4.1.1(d)



When the applied current is held constant, there's subthreshold oscillations. When the applied current disappears briefly then returns, the neuron spikes.

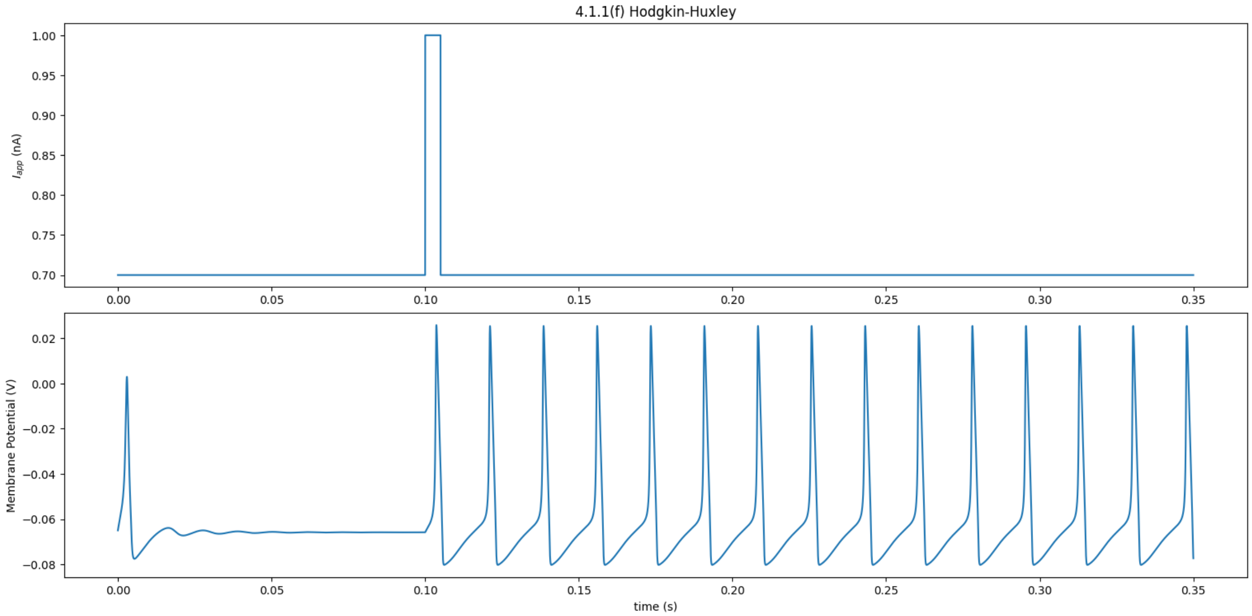
Here's why that happens. When the current is constant, the neuron approaches its steady state membrane voltage. Sodium channels are mostly deactivated and about half inactivated. Potassium channels are a little more than half deactivated. Then, the current disappears so the membrane hyperpolarizes, causing sodium channels to be more deinactivated and potassium to deactivate more. When the current returns, the neuron is poised to fire because sodium channels are deinactivated, so the voltage increase from the applied current is sufficient for sodium channels to almost all activate, causing a spike.

4.1.1(e)



The neuron fires at a constant rate, then becomes quiescent after an extra input current is applied. This happens because of the bistability of the neuronal firing rate. At first the neuron is oscillating, driven by a constant applied current, but when the current spike occurs, it interrupts the oscillations and flips the neuron's firing rate to its other stable state: quiescence.

4.1.1(f)



The neuron is quiescent at a constant applied current, then a brief current spike causes the neuron to fire at a constant rate. This happens because of the bistability of the neuronal firing rate. While the neuron is quiescent, the applied current causes subthreshold oscillations. The spike disturbs those oscillations enough that the neuron flips to its other stable firing rate.