Computational Neuroscience

Coursework Three

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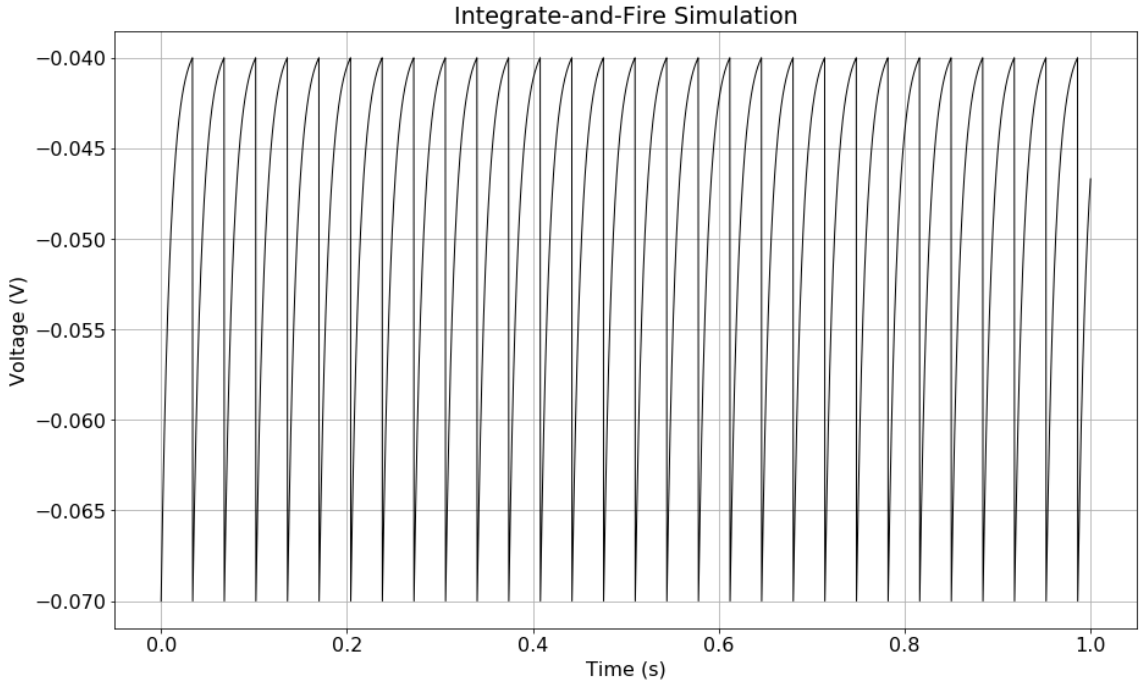
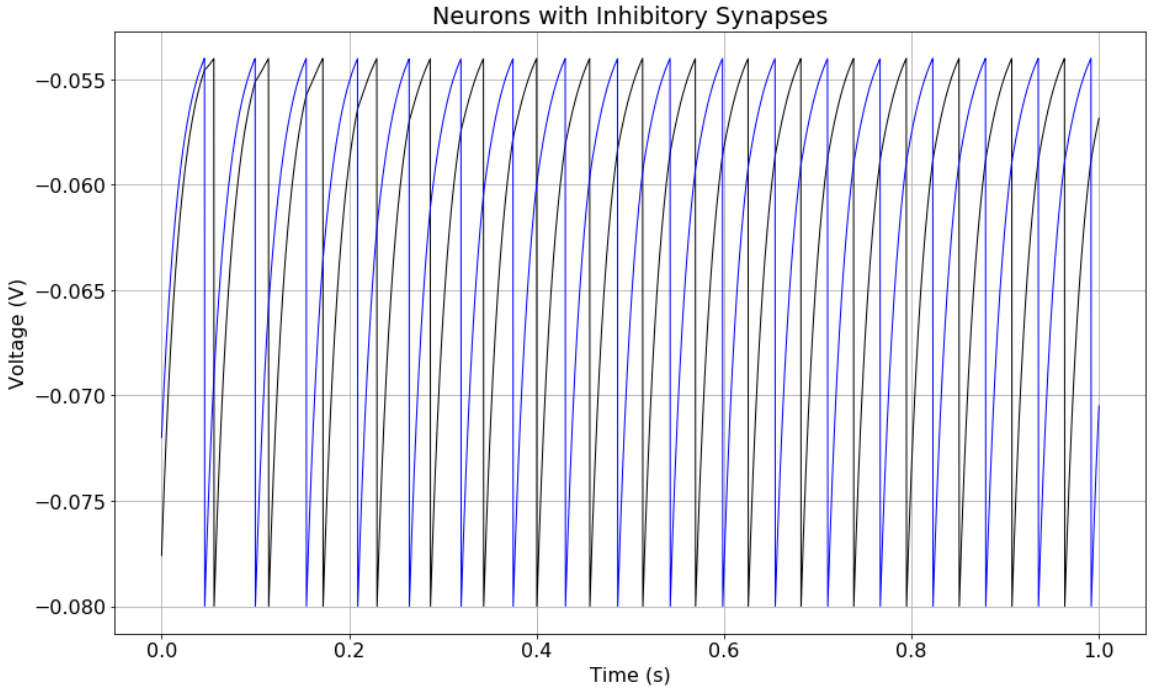
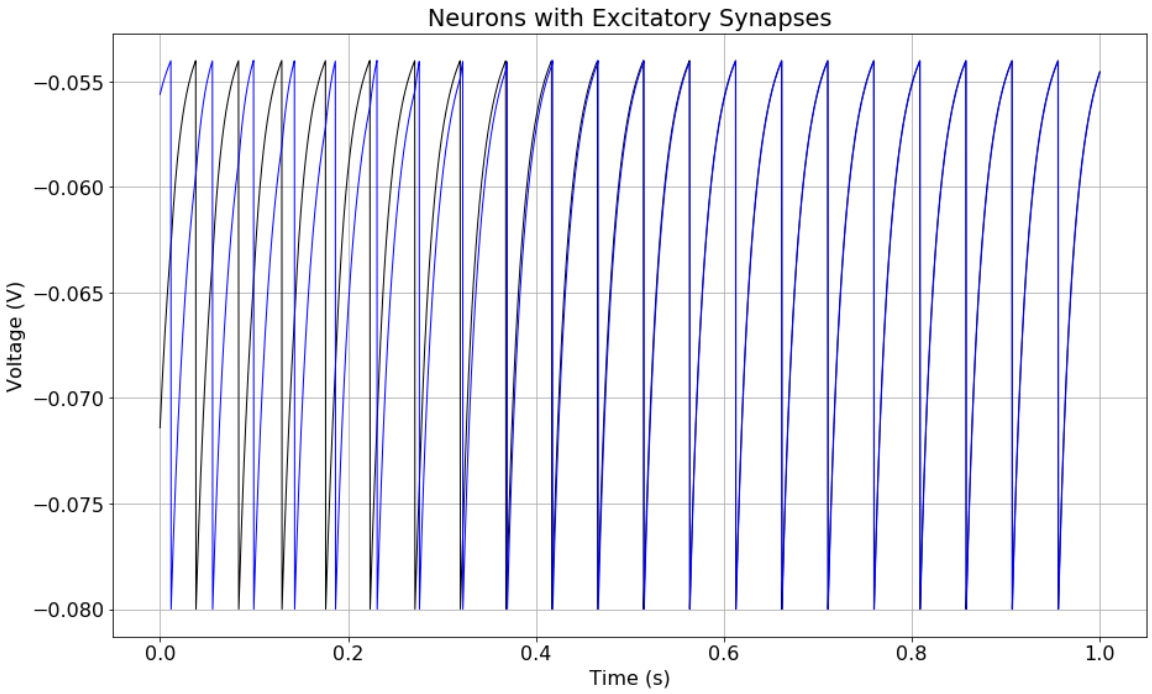
Part A - Integrate-and-fire Neurons

Question One



Question Two

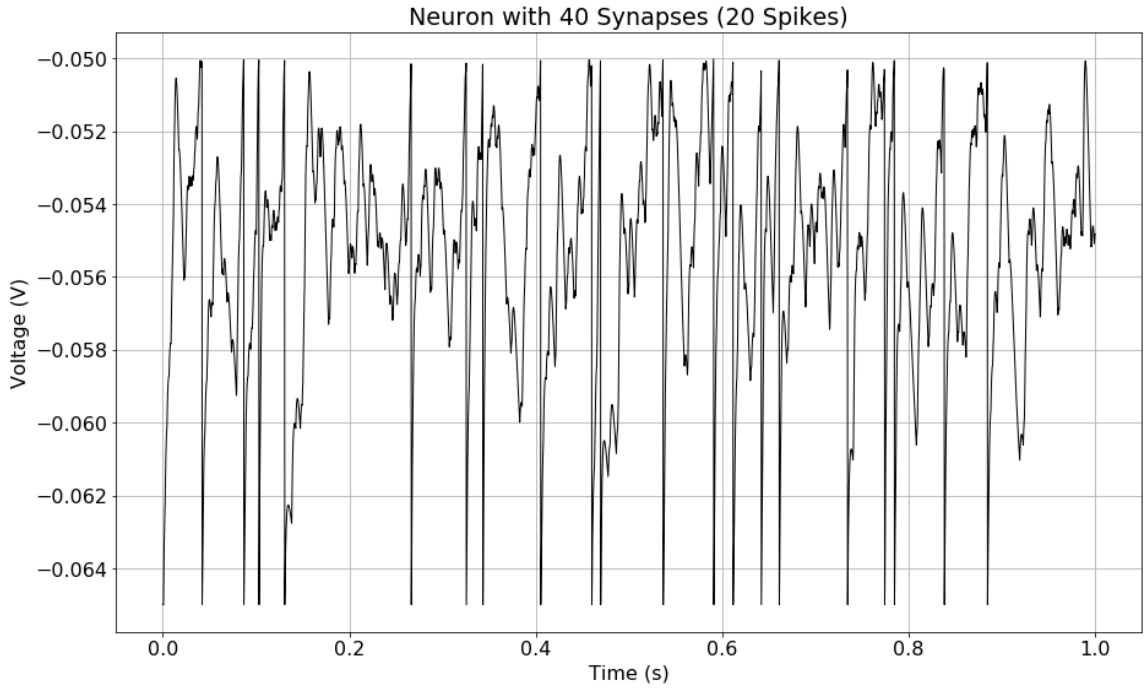




The simulated neurons connected with excitatory synapses have their voltage signals converge into one synchronous signal, whereas the voltage signals for neurons connected with inhibitory synapses diverges until they are out of phase with each other. The neuron voltages converge when connected with excitatory synapses as when one neuron spikes, the voltage of the second neuron increases, causing it to spike quicker; this repeated several times over causes the second neuron to start firing immediately after (in tandem with) the first. Inhibitory synapses cause spikes which decrease the neuron's voltage, so one spike delays the spike of the other neuron until both neurons delay each other equally, where their spikes are perfectly out of phase with each other.

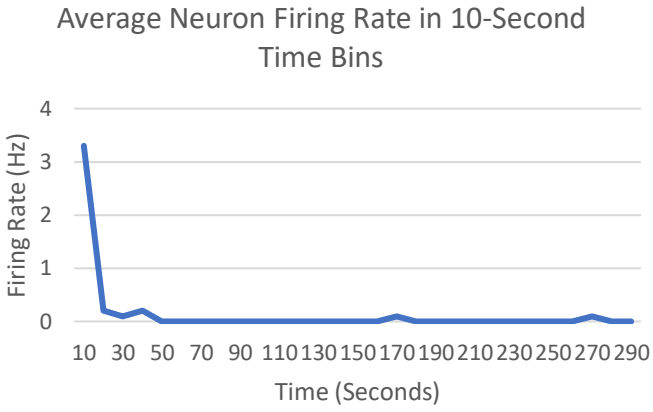
Part B – STDP

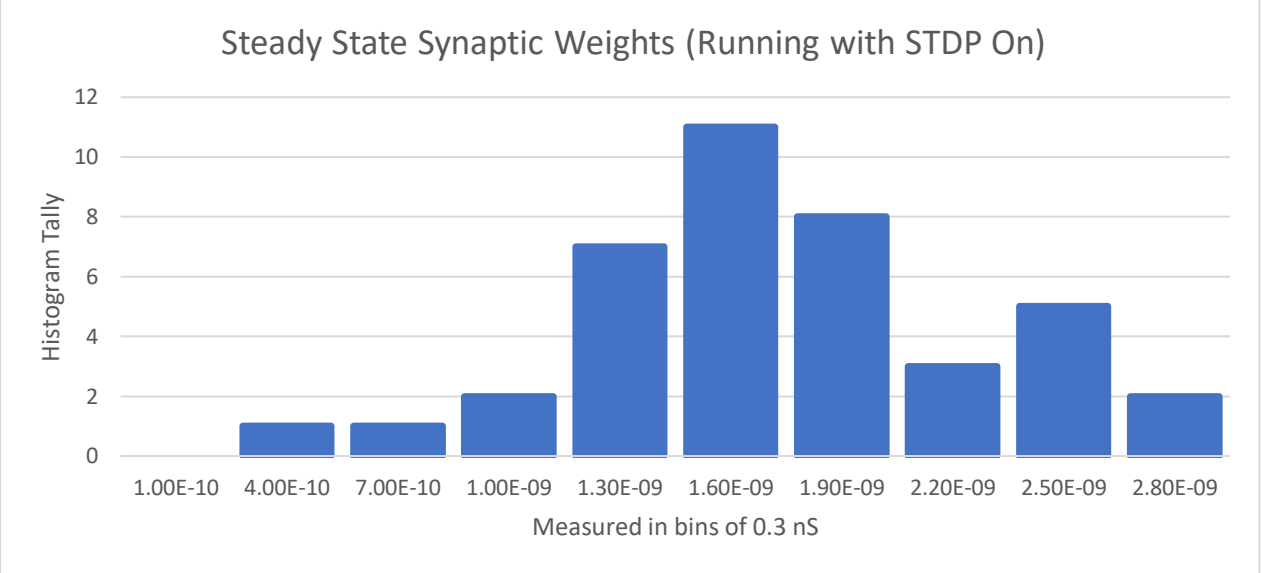
Question One



Question Two

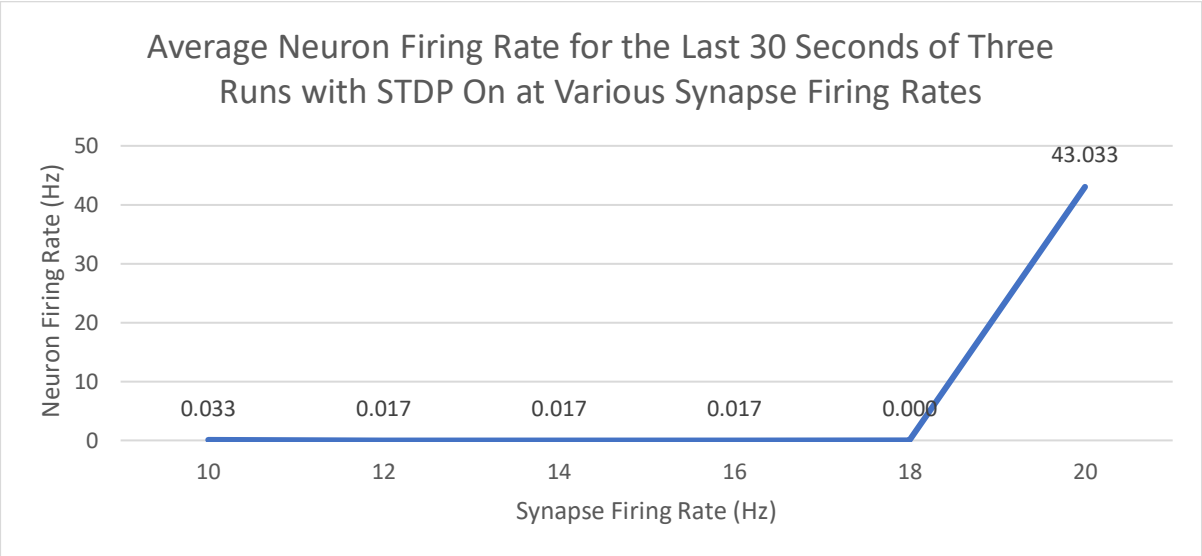
With STDP on, synaptic strength distribution converges towards a normal distribution averaging 1.89×10^{-9}. The steady state firing rate for the last 30 seconds of STDP on simulation is 0.022HZ (averaged over three runs) and for STDP off it is zero.

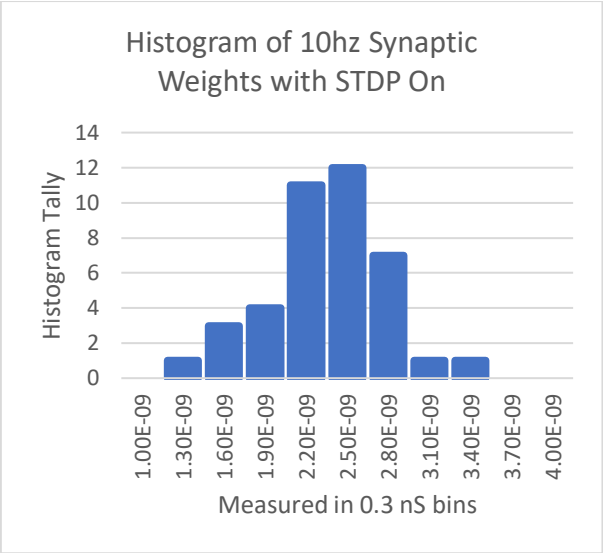


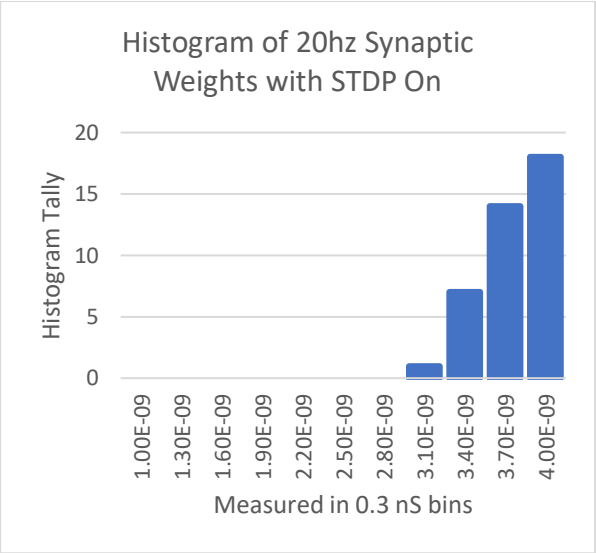


Question Three

The lower the synapse firing rate with STDP on, the slower it takes for the neuron firing rate to depress, causing a slightly higher firing rate to be seen for the 10hz average in the graph below. We see low firing rates until 20hz, when the effect of the post spike uplift of the neuron occurs so frequently that the synaptic weightings retain large values towards 4nS (see following histogram).

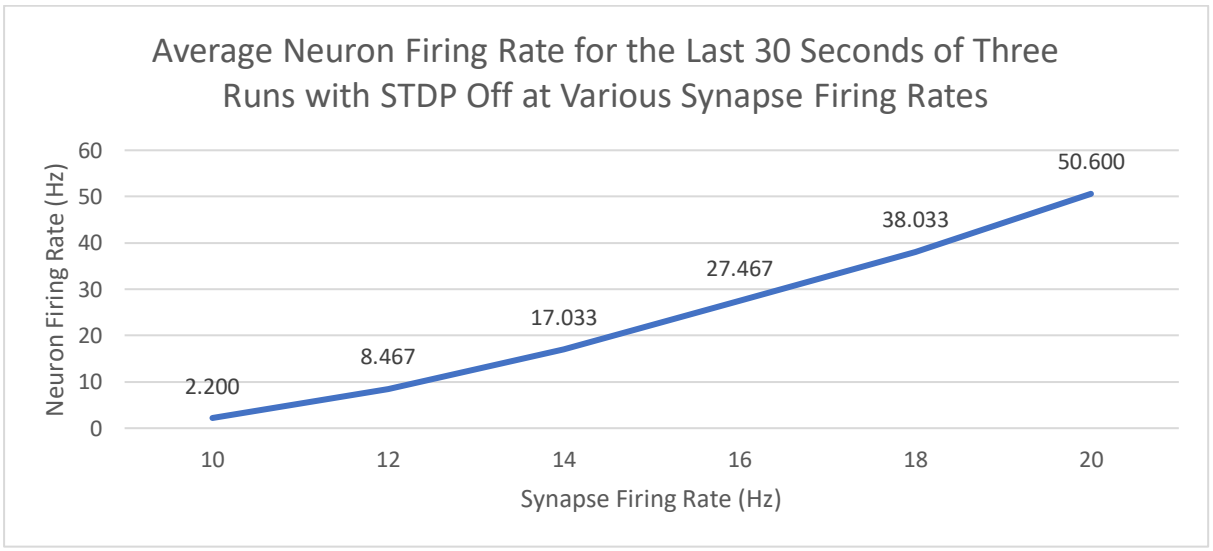




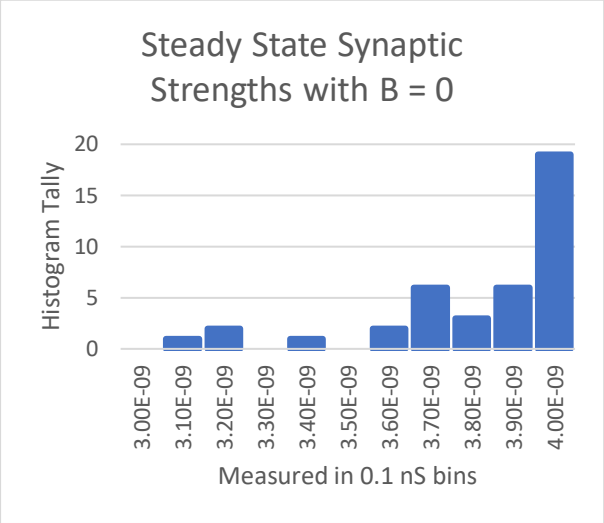


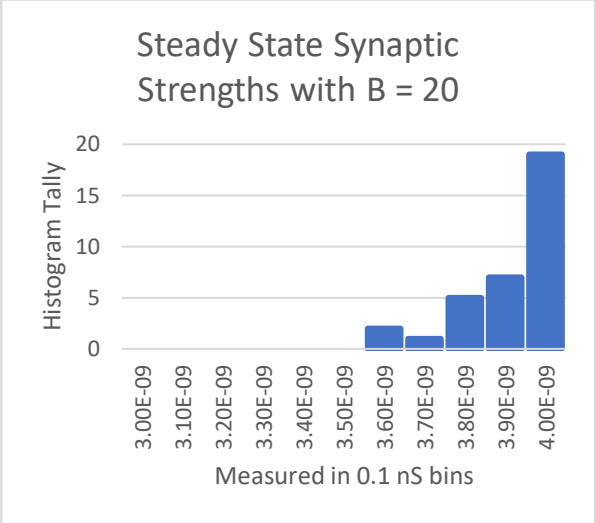
This makes sense as the inhibitory effect of one synapse firing on its own is overwhelmed by the excitatory effect of all the synapses combined causing the neuron to fire. At 20hz there are just enough post spike uplifts to synapse weightings to make this self-sustaining.

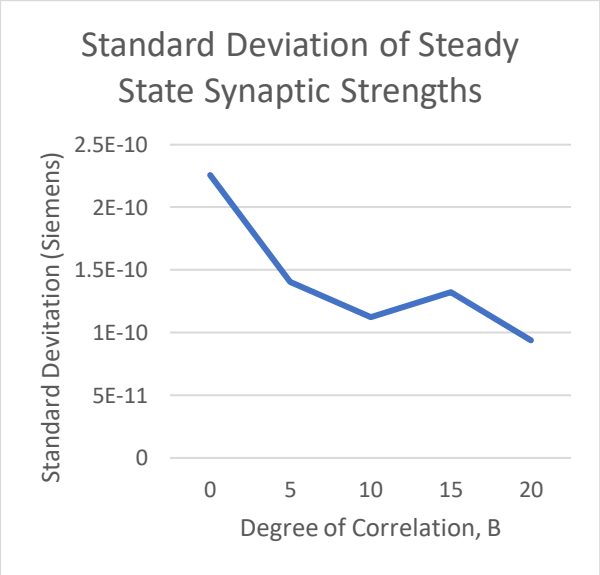
In the case of STDP being turned off, the input firing rate correlates to the output firing rate of the neuron. More synaptic spikes increase the neuron's potential and therefore increases its rate of spiking. The graph follows a slightly non-linear / exponential curve as the increased rate of all 40 synapses combined creates a multiplier effect.

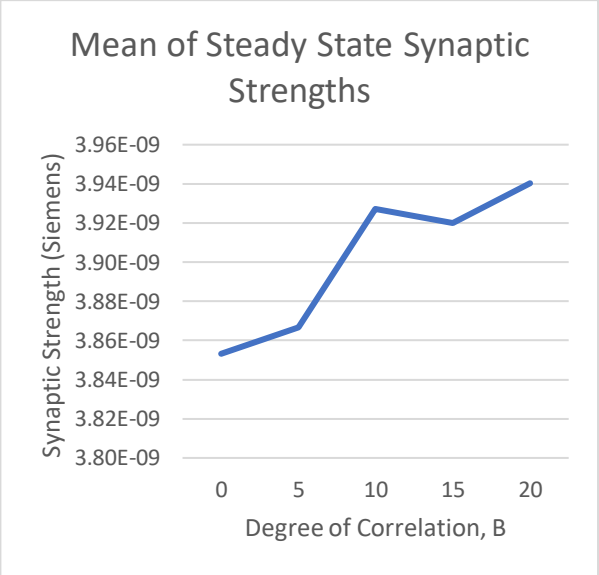


Question 4









Increasing the degree of correlation causes the synaptic strengths to converge towards the initial synaptic strength value. Increasing the correlation of synapse firing causes more post-synaptic neuron spikes in a short period, raising more synaptic weights in synchrony towards the maximum conductance value. As such, with less correlation, the synaptic weights vary more.