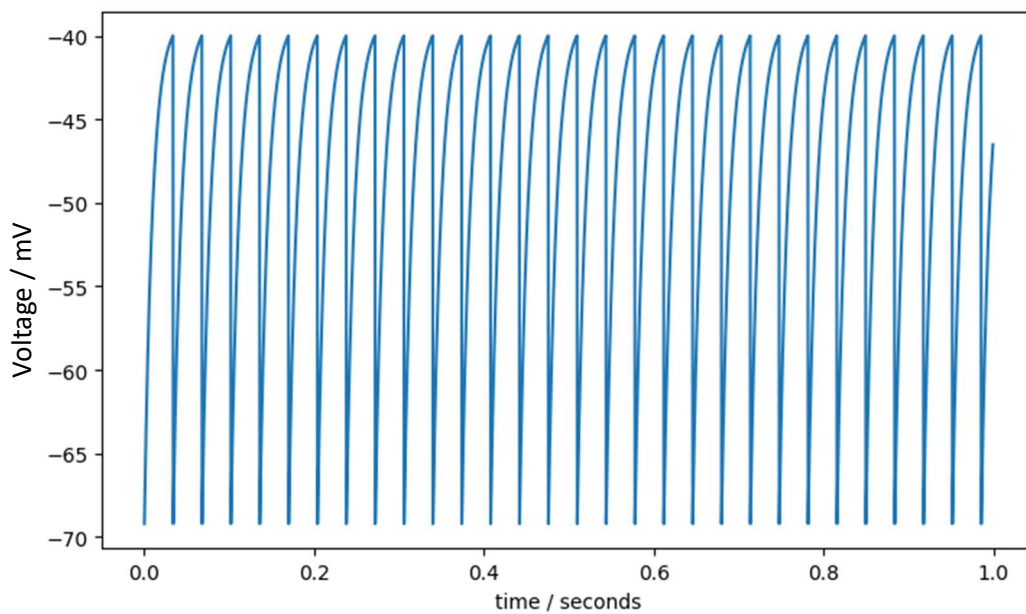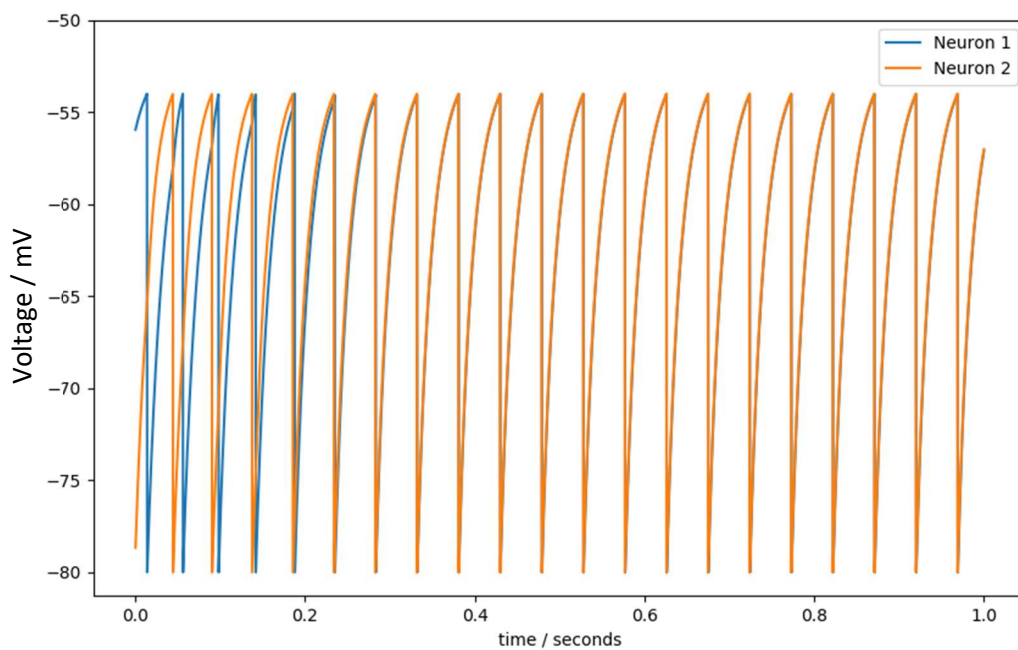## Part A – Integrate-and-Fire Neurons

Question 1
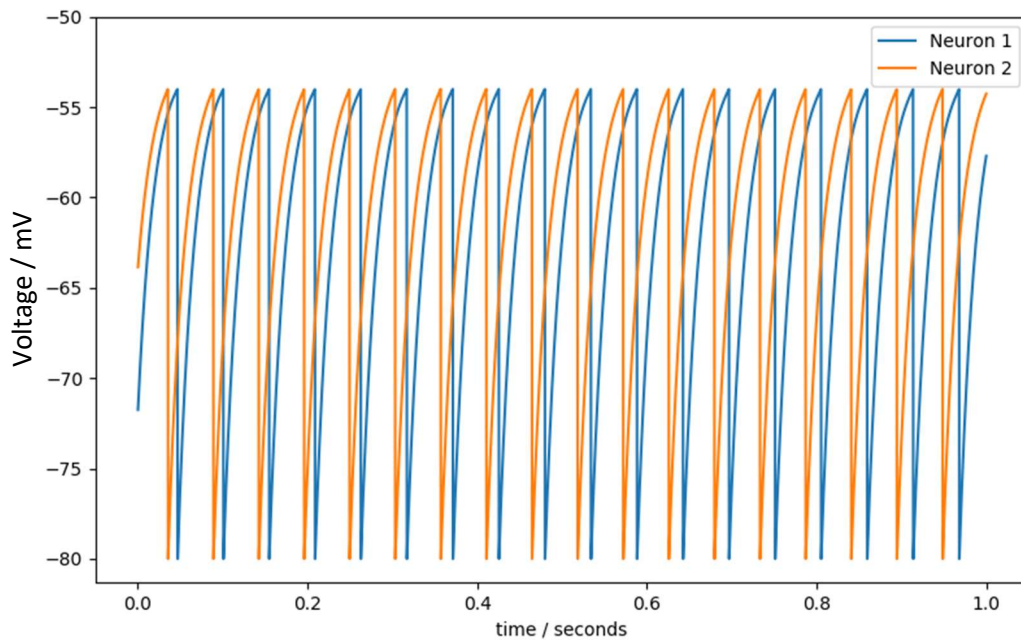

Question 2

Neuron Voltage Over Time with E_s = 0mV :

Neuron Voltage Over Time with Eₛ = -80mV :

For the excitatory synapses with E_s = 0mV, we see the firing times of the two neurons converge after about 0.2 seconds.

For the inhibitory synapses with E_s = -80mV, we see the firing times of the two neurons seeming to separate from each other as time progresses.

An explanation for this behaviour could be down to the fact that for excitatory synapses they increase the probability of each neuron firing and as the neurons are connected, this increased firing rate causes the time difference between their respective spikes to decrease. One neuron firing causes the other to do so momentarily later due to the increased R_mI_s value resulting from this. This causes the converging of the firing times of the two neurons, eventually firing synchronously.

With inhibitory neurons, the opposite is true. As the firing probability has been decreased, the R_mI_s value will stay at a decreased value for longer periods of time, meaning that firing rate for each neuron will be decreased. As the two neurons are connected, this causes the neurons to become asynchronous, with the time between neuron 1 and neuron 2 firing increasing over time.
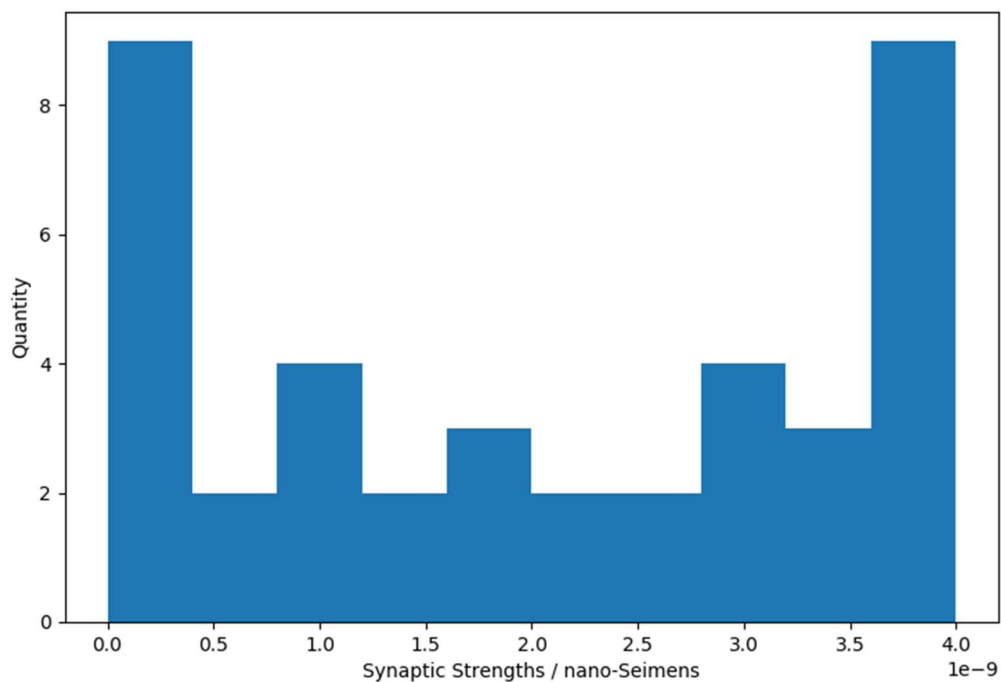
Part B – STDP

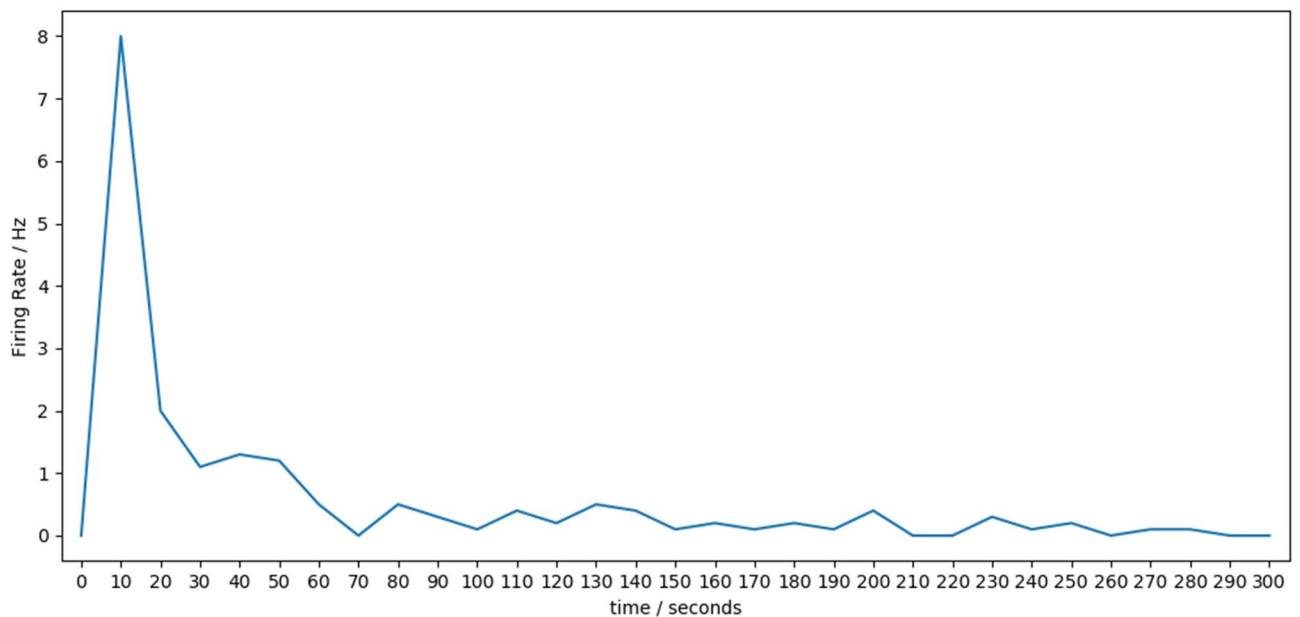### Question 1

Neuron's Voltage for One Second
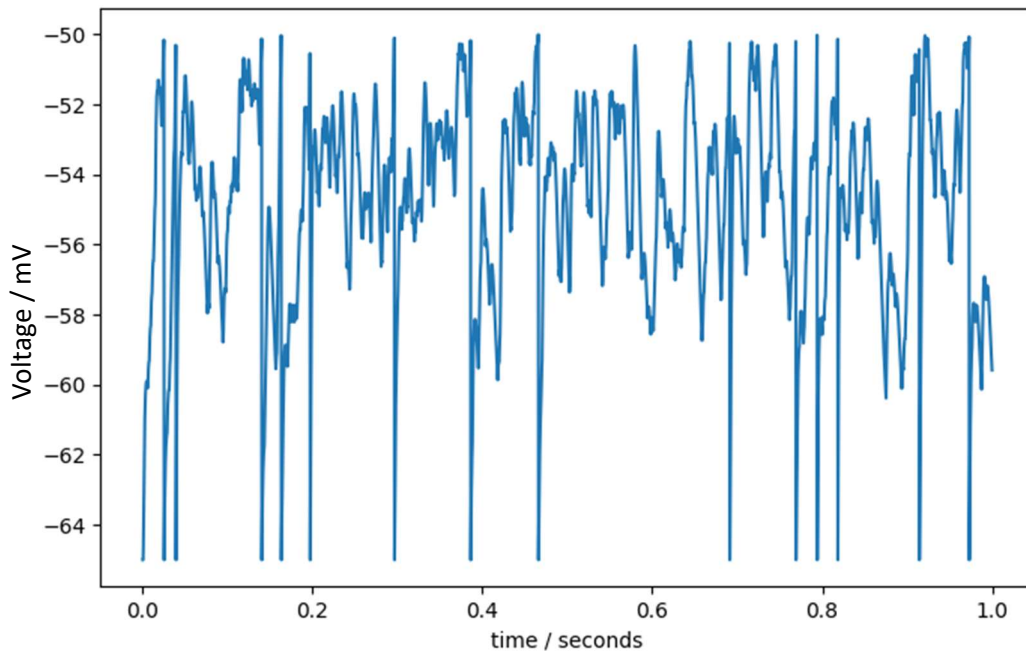
Question 2

The synaptic strength distribution at the end of simulation time of 300 seconds seems to converge to the minimum value (0 nano-Siemens) and the max value (4 nano-Siemens)

Steady-State Synaptic Weights After Simulation Run :

*Average Firing Rate of Postsynaptic Neuron (10 second time bins):*

Average Steady state firing rate for STDP 'on' (averaged over last 30 seconds) after 5 simulation runs = (0.06666 + 0.16666 + 0.16666 + 0.13333 + 0.033333)/5 = 0.1133Hz

Average Steady state firing rate for STDP 'off' (averaged over last 30 seconds) after 5 simulation runs = (0.0 + 0.0 + 0.0 + 0.0 + 0.0)/5 = 0.0Hz
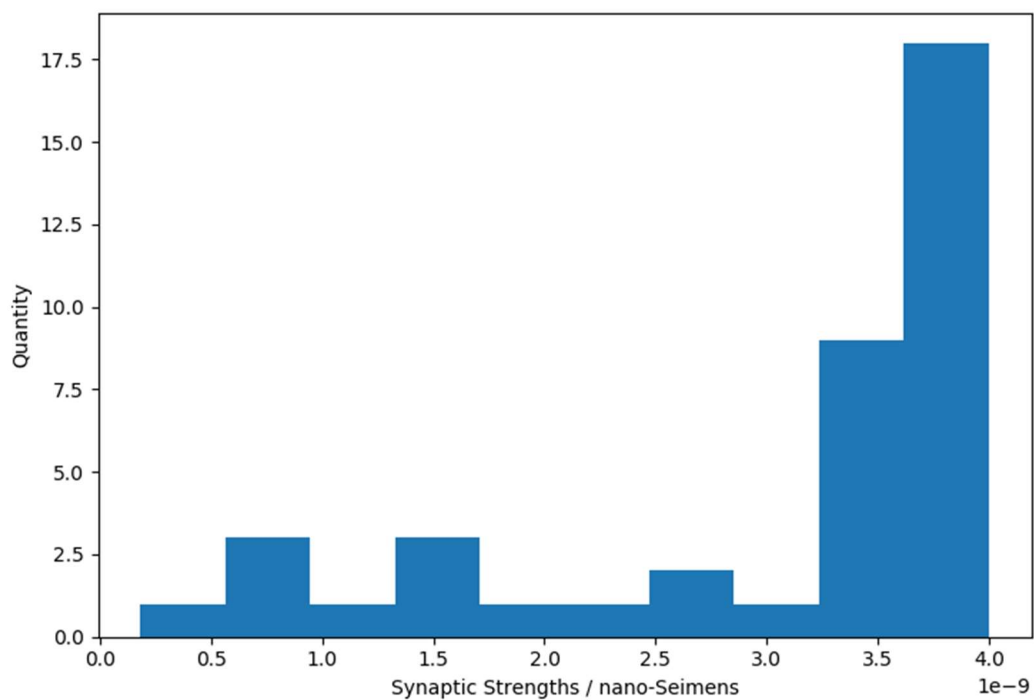
Question 3

*Mean Output Firing Rate STDP 'on' :*
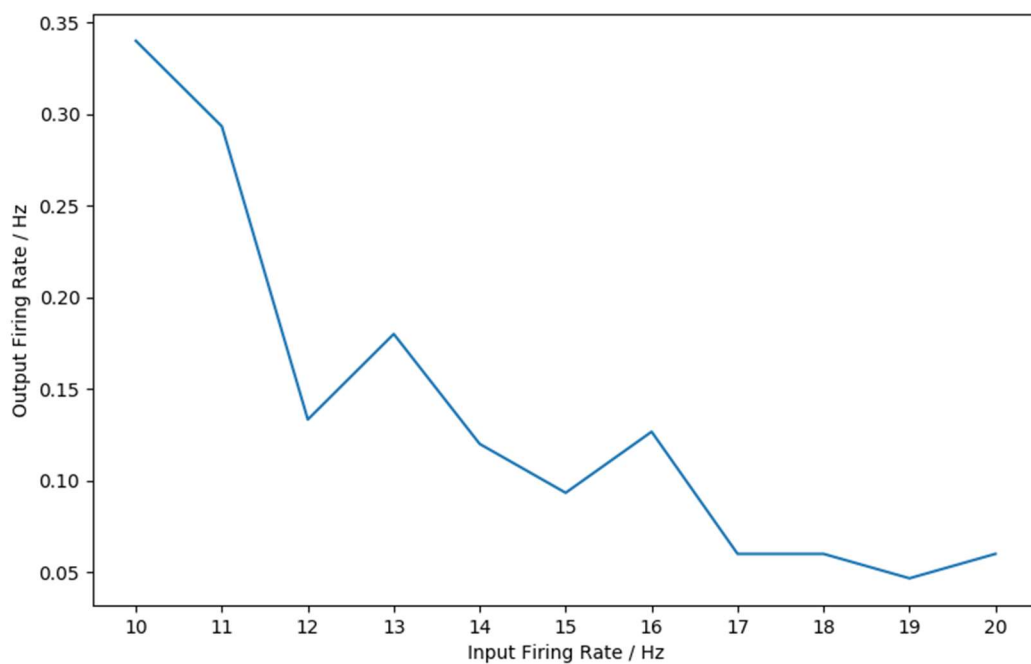
Mean Output Firing Rate STDP 'off' :
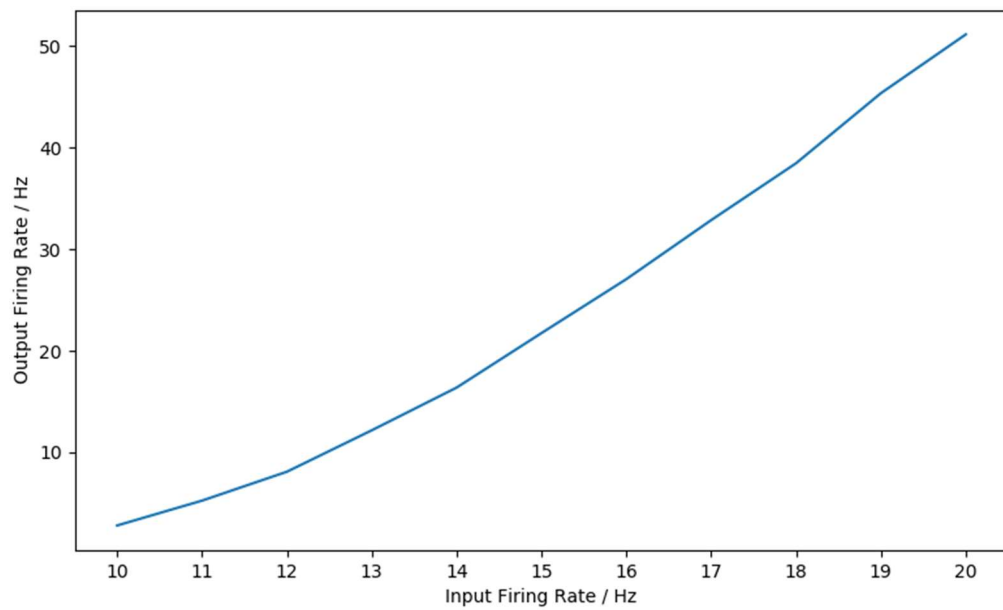
For STDP 'on', the steady-state output firing rate decreases as the input firing rate increases. For STDP 'off', the opposite is true, with steady-state output firing rate increasing as the input firing rate increases.

Steady-State Synaptic Strength Distribution for Firing Rate = 10Hz, STDP 'on' :

Steady-State Synaptic Strength Distribution for Firing Rate = 20Hz, STDP 'on' :
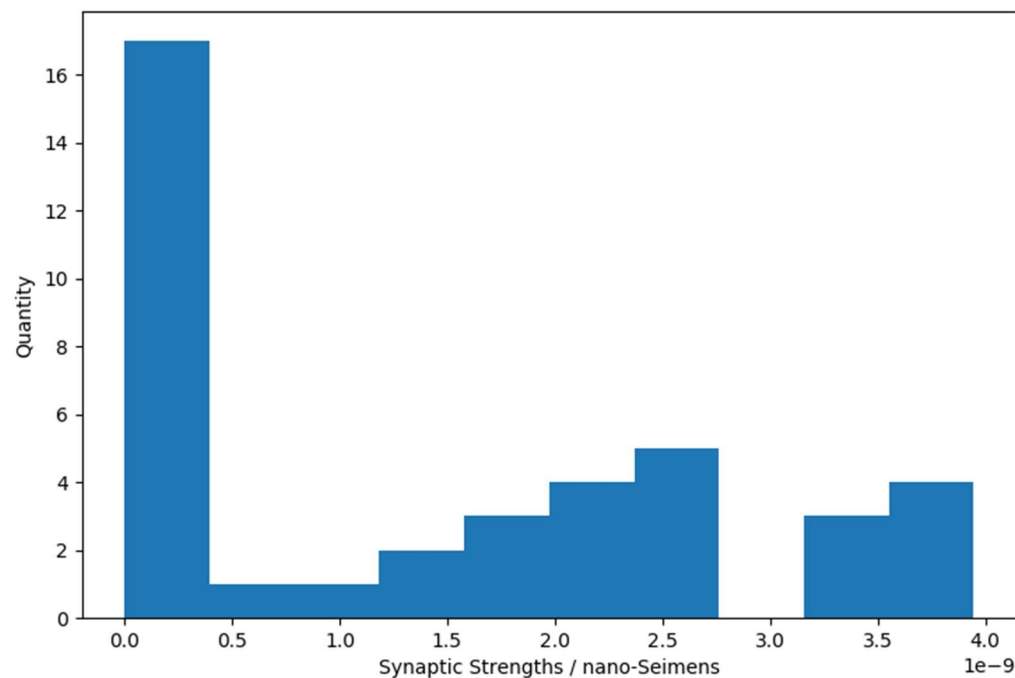

The lower firing rate of 10Hz means that more post-synaptic spikes will occur and therefore the synaptic strengths are more likely to be strengthened/increased. The opposite is true for a higher firing rate of 20Hz as this will increase the number of pre-synaptic spikes, and so the synaptic strengths will be depressed towards 0.

Question 4

The steady-state synaptic weights marginally decrease with degree of correlation between 0Hz and 10Hz. Between degree of correlation values of 10Hz and 20Hz, steady-state synaptic weights increase dramatically, as seen from the plotted mean below.

Mean of Steady-State Synaptic Strengths :
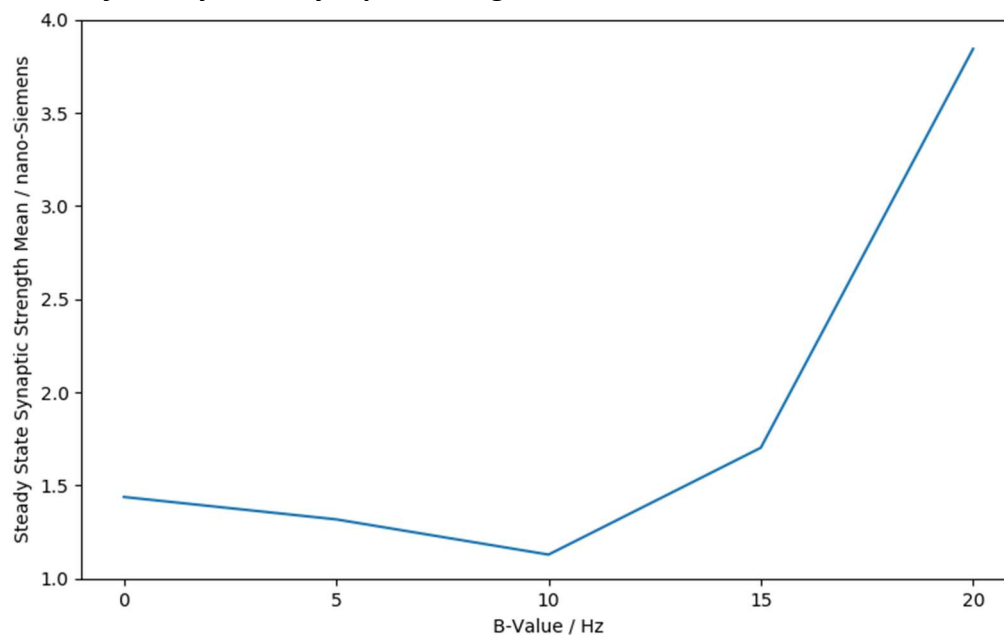
Standard Deviation of Steady-State Synaptic Strengths :
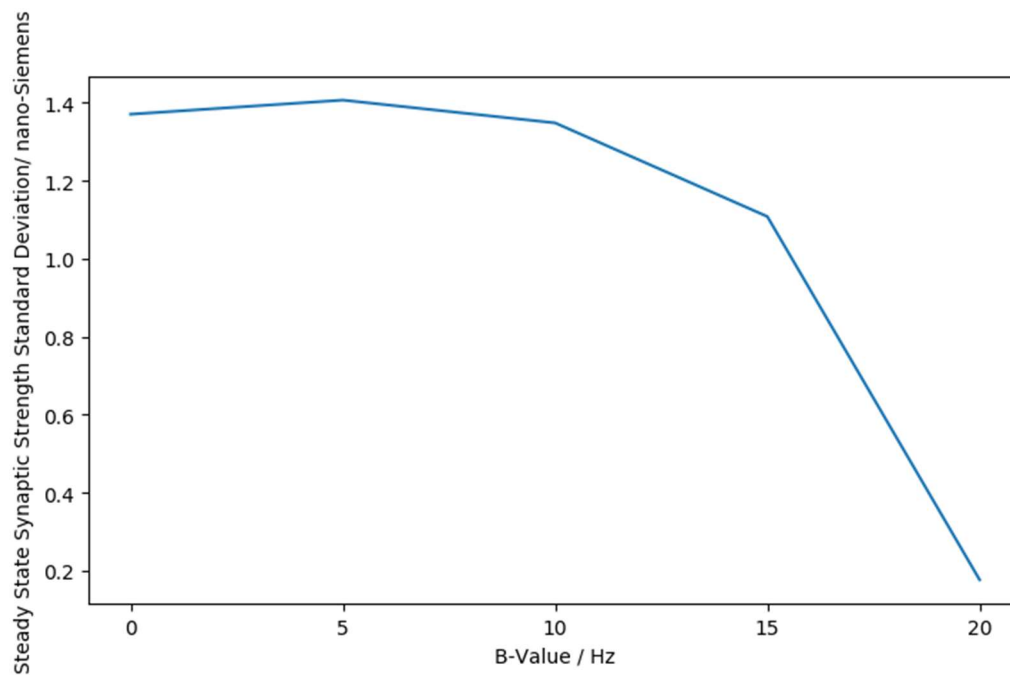
Steady-State Synaptic Strengths for B = 0Hz :
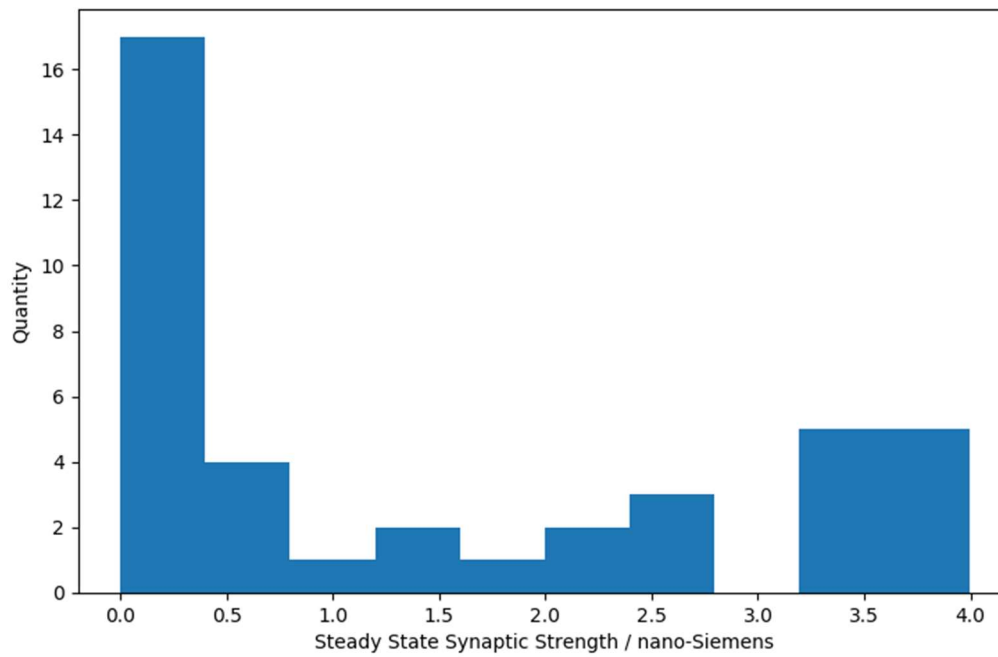
Steady-State Synaptic Strengths for B = 20Hz :
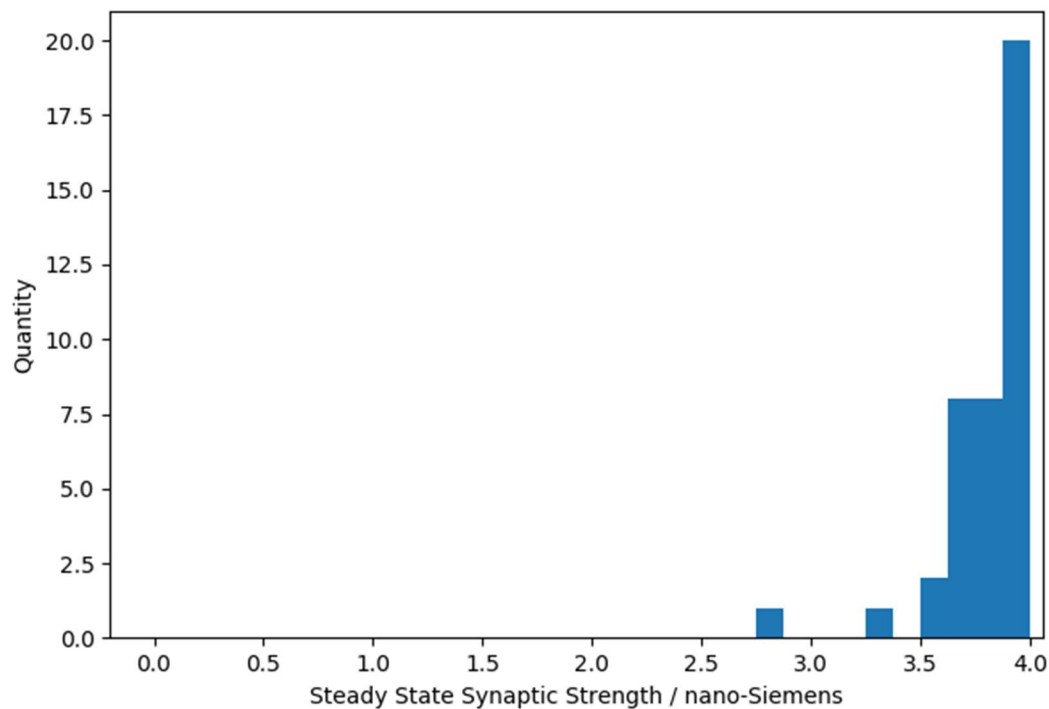
With very low correlation values, the firing rate stays around the average firing rate $\langle r \rangle_0$=20Hz. This gives us similar results to previous STDP simulations where pre-synaptic spikes are fairly common, and so the synaptic weights are depressed towards 0nS more commonly.

However, with high correlation values there are periods of very low firing rates for all synapses due to the sinusoidal form of the firing rate expression. This causes the synaptic strengths to be increased towards the maximum value of 4nS across all synapses frequently. The extent of the correlation can be seen with the considerably lower variance with higher correlation values (15-20Hz) compared with the higher variability seen with lower correlation values.