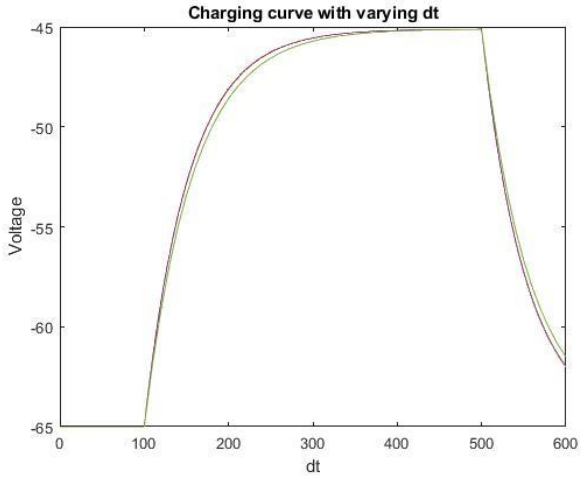
ASSIGNMENT 2 SOLUTIONS

QUESTION 1

Observations – As dt increases, steady state potential decreases and the overall charging and discharging curve slows down. Also, as dt increases, time taken for completing the simulation decreases.

Inference – The compartment is considered as an RC circuit. Hence the differential equation for both charging and discharging curve is plotted based on Backward Euler method. In this method, smaller the step size, better the accuracy. If dt is large, there can be oscillations in the solutions and this will cost one form of numerical instability. Hence, we notice the decrease in steady state potential as dt increases.



We know that points-plotted-per-ms is inversely proportional to dt. Hence as dt increases, overall points plotted decreases and hence would eventually take lesser time.

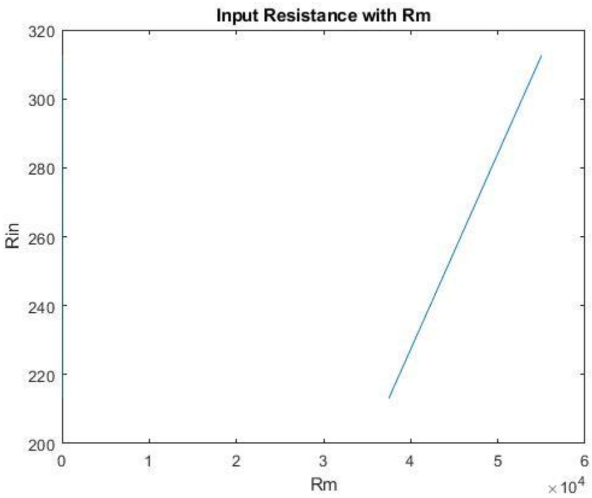
QUESTION 2

Observations –

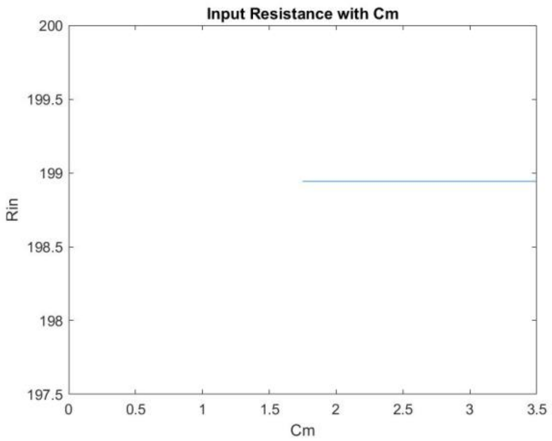
(a)

Rin increases with increase in Rm.

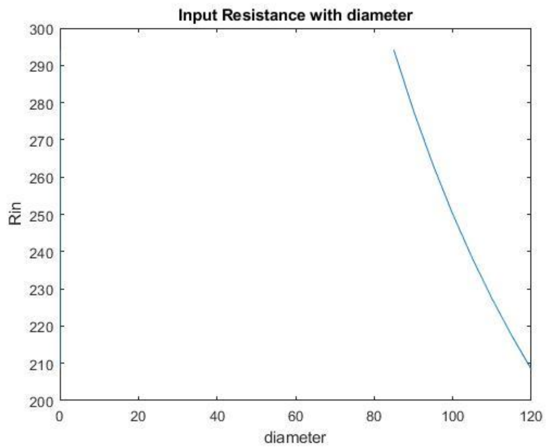
Reason- As membrane resistance increases, for the same injected current, by Ohms Law Voltage increases. Hence the voltage deflection increases, thereby increasing input resistance.



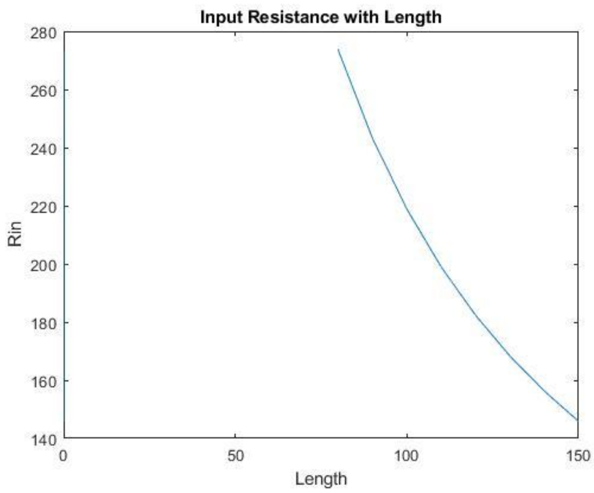
Rin does not vary with increase in Cm.
Reason – Cm affects only the membrane time constant. The only effect due to membrane time constant is the delay in reaching the steady state voltage. The voltage itself, remains unaffected. Hence Rin does not change.



Rin decreases with increase in diameter.
Reason – With increase in diameter, the injected current should traverse a larger surface area. Hence Voltage decreases and subsequently Input resistance decreases.



Rin decreases with increase in length.
Reason - With increase in length, the injected current should traverse a longer distance. Hence Voltage decreases and subsequently Input resistance decreases.



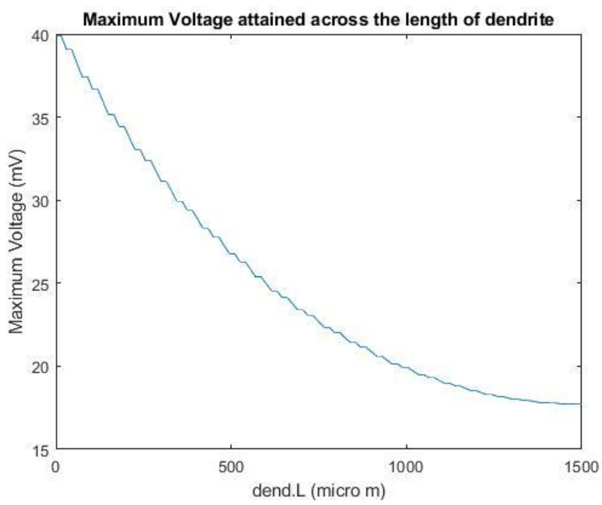
c. Theoretically, the cell is iso-potential. Rin = Rm/Surface area. And SA = 2*pi*r*L
With Rm = 35000 ohm cm^2, r = diam/2 = 40 mu m, L = 70 mu m.
Calculating, we get, Rin = 198.94 G ohms.
From the above formula, Rin should linearly increase with Rm (membrane resistance), and decrease with diameter and length, which is exactly the same trend that we observe in the above traces.
Observed value of Rin = 145.86185 G ohms.

d. Physiological significance of passive properties. –

- Changing the membrane potential with steady current injection resulted in significant differences in passive membrane properties.
- When measured across 3 classes of neurons, both Rin and tau were larger at more depolarised potentials. This can arise because of conductance activated by hyperpolarisation that decreases membrane resistivity at hyperpolarised potentials.
- When there are lower estimates of Rm provided by microelectrode recordings are generally assumed to reflect uniform somatic and dendritic membrane properties, this leads to artificially low estimates of input resistances, not only at the soma, but also at the site of synapses in the dendritic tree and on spine heads. The higher estimates of R, measured in the absence of somatic leak are likely to be much closer to reality for dendritic membrane even if physiological nonuniformities in Rm, exist in neurons. Thus, the higher membrane resistivity suggested by patch-clamp data implies that the change in membrane potential in response to a small current at any given point on the neuron will be larger than previously believed.

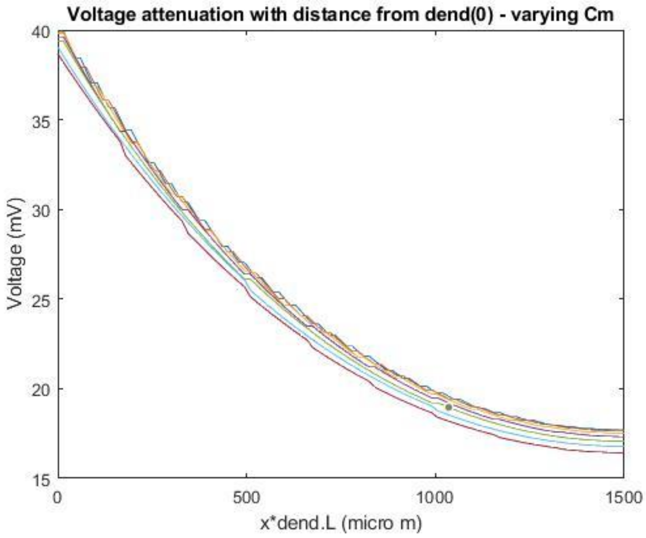
QUESTION 3

Voltage Attenuation with distance from dendrite was plotted.



(a)

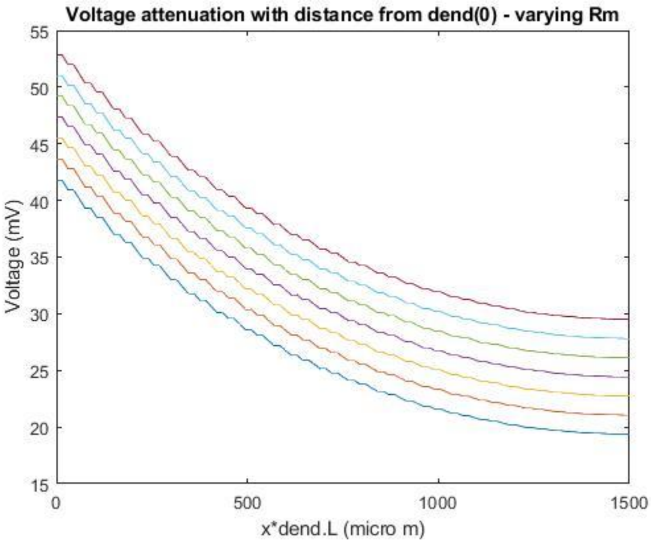
Steady state voltage attenuation does not depend on variation in Cm.



Reason -

Since, voltage attenuation is solely responsible by space constant and that in turn does not depend on the membrane capacitance, voltage attenuation is not affected by variation in Cm.

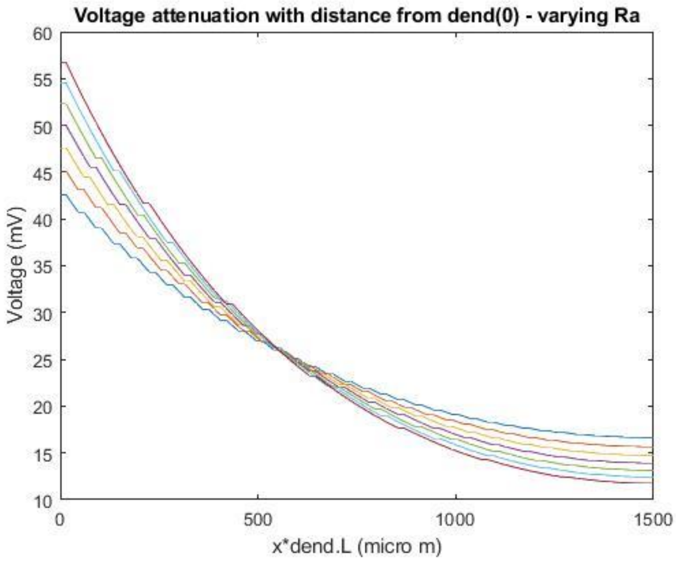
Steady state voltage attenuation decreases as Rm increases.



Reason –

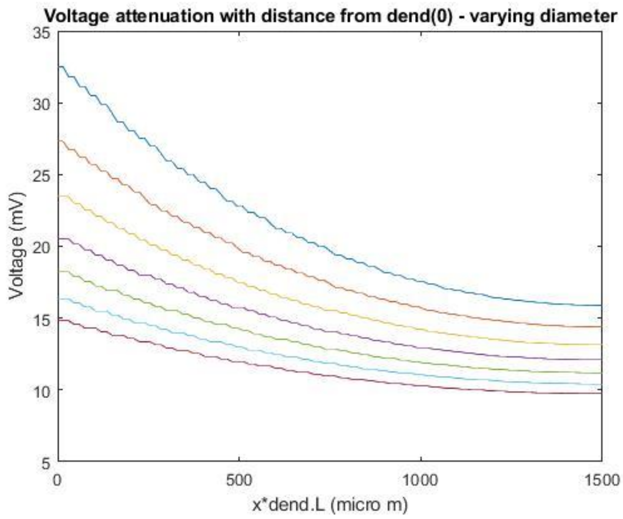
(By formula) As Rm increases, λ (space constant) increases. Hence voltage attenuates less with distance as compared to neurons with a smaller λ value.

Steady state voltage attenuation increases on increase in Ra.



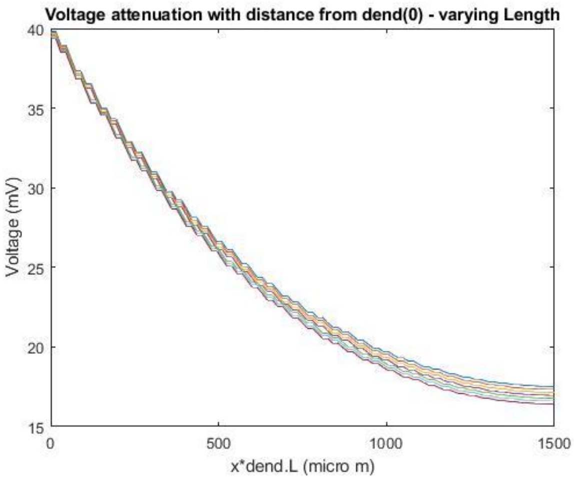
Reason –
Axial resistance is inversely proportional to the space constant. Hence as Ra increases, λ (space constant) decreases. Hence voltage attenuates more with distance as compared to neurons with a larger λ value.

(b)
Steady State Voltage attenuation decreases as diameter of the dendrite increases.



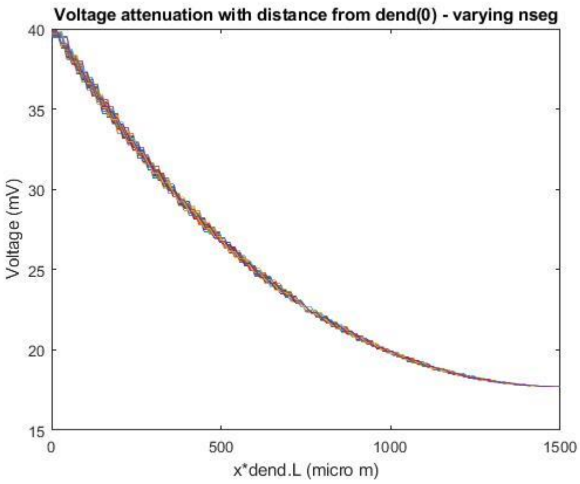
Reason-
(By formula) As diameter increases, λ (space constant) increases. Hence voltage attenuates less with distance as compared to neurons with a smaller λ value.

Steady state voltage attenuation increases as length of the dendrite increases.



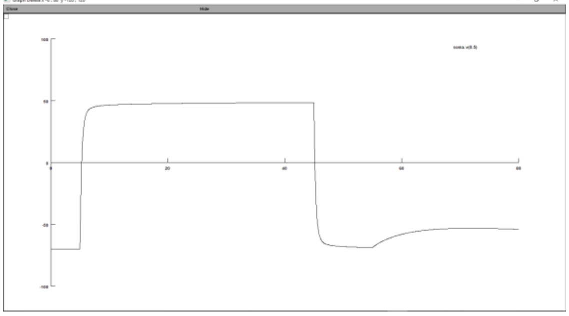
Reason-
Increasing the length would mean that the current will now have to traverse a larger distance. Hence it attenuates more.

(c)
Steady state voltage attenuation decreased with increase in the number of segments of dendrite.



Reason-
As Electronic length (L = l/space constant) increases, meaning lesser segmentation, potential decreases less with distance, meaning lesser attenuation. Therefore, more the value of nseg, more the attenuation.

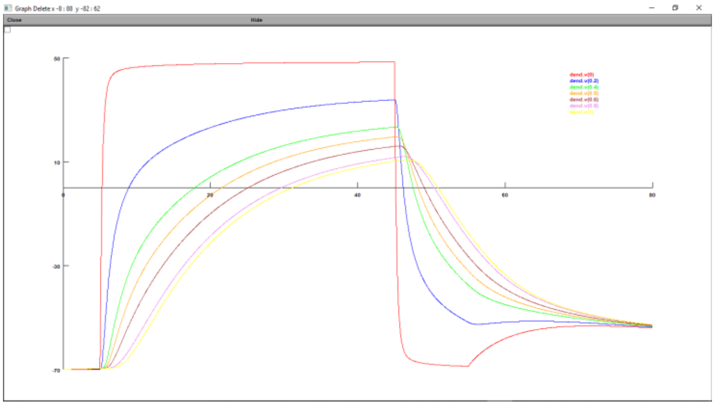
QUESTION 4
(a)



I expected a sharp step voltage.

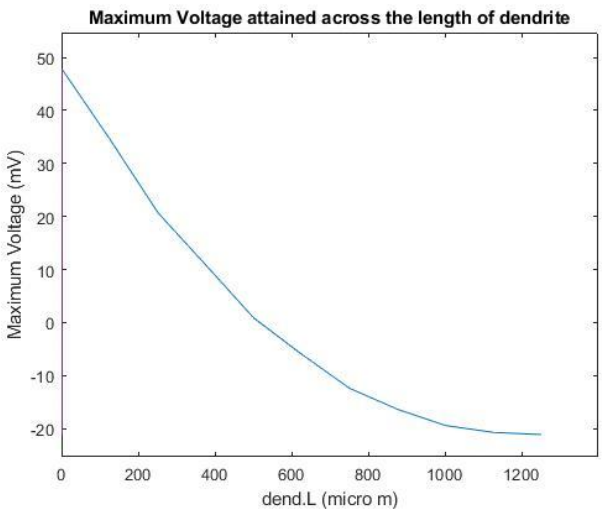
At t=45 s, there is a sudden change in voltage. This induces a capacitive current and that in turn increases the voltage across the membrane. Hence, final voltage recorded across the membrane will not be equal to -70 mV. This could also be due to the electrode's resistance that happens to be on a series connection with the compartment. Therefore, due to the ionic current through electrode causes an increase in the membrane voltage even after the voltage pulse ends. The microelectrode can also act as a capacitor since the electrolyte inside the electrode is separated by an insulator (glass) from the solution outside. This could also give rise to the observed deflection.

(b)



Voltage clamp does not cover the entire neuron. In fact, the maximum voltage attained at dend.(0) is less than the holding voltage. And subsequent voltages across the dendrite also reduces.

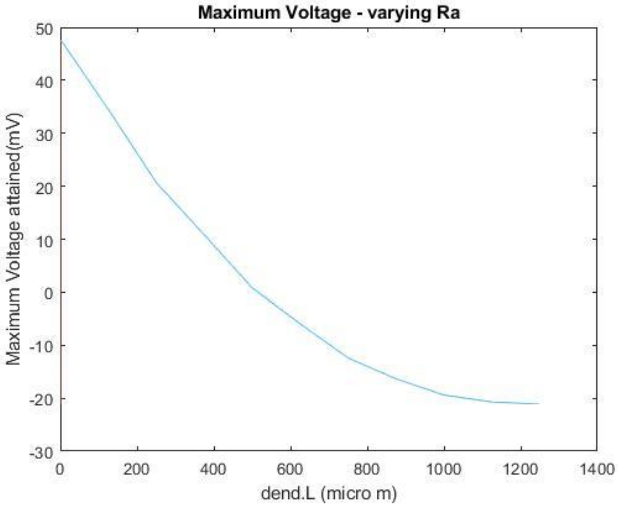
(c)

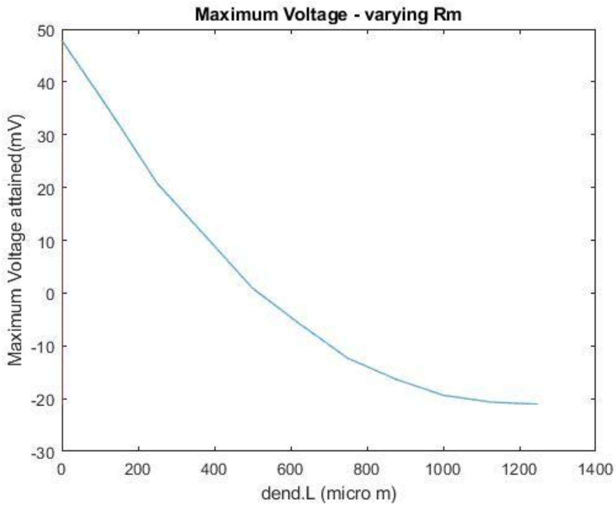


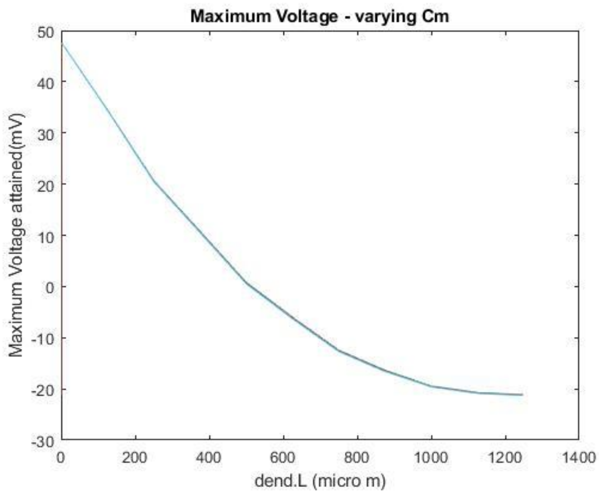
We observe that the whole neuron is not clamped to the holding voltage. The electric potential can differ within a cell with complex shape. Such differences in electric potential within the cell are caused by electric resistance (axial and membrane) between distant points within the same cell. As a result, controlling the membrane voltage at the soma with the voltage clamp only partially controls the membrane voltage in locations distant from the soma. This issue is referred to as poor *space clamp*.

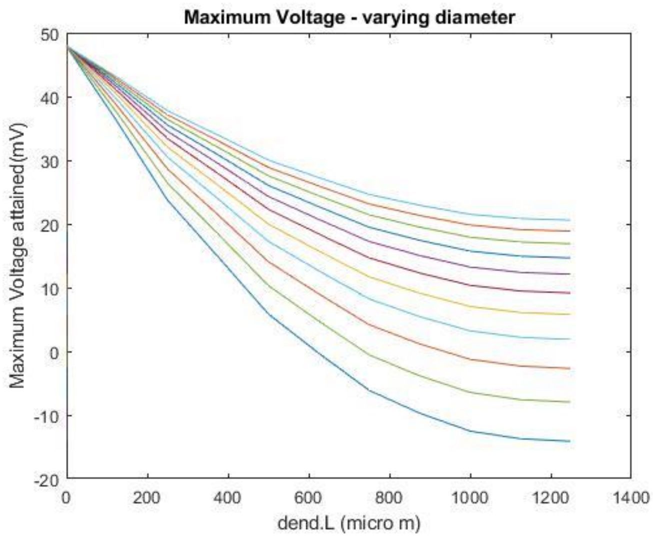
(d)

Maximum voltage attained across the length of the dendrite for various values of passive properties (Rm/Ra/Cm) was plotted. We notice that all the graphs are coinciding. This shows that change in the passive properties does not vary the plot distinctively.

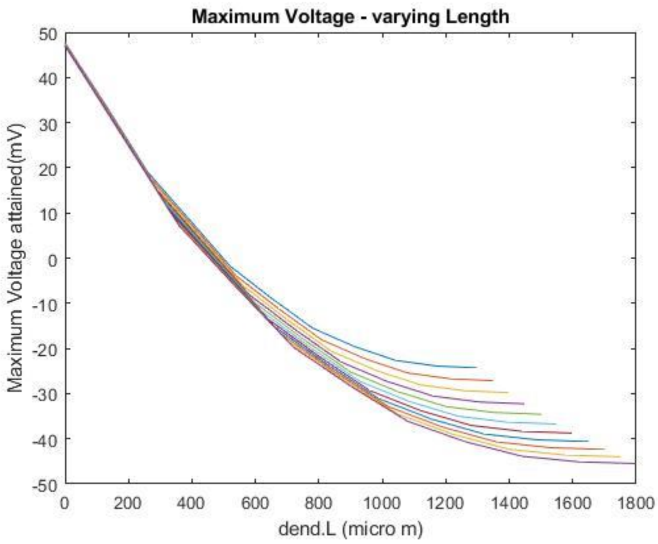








As diameter increase, maximum voltage recorded across dendrite widely decreases. This is because, as diameter increases the surface area that the current should traverse increases. Hence lesser current reaches the distant parts of the dendrite. Hence, maximum voltage recorded drops.



Increasing the length would mean that the current will now have to traverse a larger distance. Hence it attenuates more.