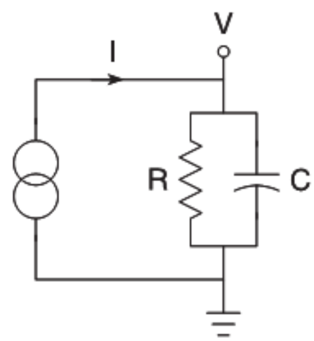
Lab 2 – Passive membrane properties

****make sure to include all generated figures and discuss results****

1. Passive membrane properties as RC circuit.

Open the Matlab m-file “rc.m”. In this simulation, we will investigate how the membrane potential responds to a steady current input. Here, the membrane potential is modeled using the parallel RC equivalent circuit model.



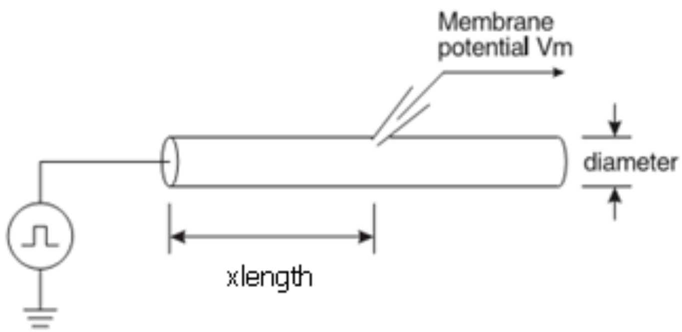
1a. Run the model with the default parameters (R = 10 MΩ, C = 1 μF, I = 1 nA) and describe the output. What is the steady state voltage? Approximately how long does it take the membrane potential to reach steady state (>99% of the steady state voltage)?
*Note: For all questions, adjust the x and y axes on your plots appropriately before pasting them into your lab notebook.

1b. Resetting to the default values each time (R = 10 MΩ, C = 1 μF, I = 1 nA), determine what effects the following parameters have on the resulting membrane potential time course and steady state values (make sure to describe the effects):
   i. Multiplying R by 5
   ii. Dividing C by 10
   iii. Multiplying R by 10 and dividing C by 10

1c. A way in which the time constant τ can be obtained when either R or C or both are uncertain is to measure the time after constant current onset where the membrane potential reaches approximately 63.2% of its steady state value (Hint: $0.632*V_{ss}= 0.632*I_{stim}*R$). Test this by varying the input current, the resistance and the capacitance and compare the measured values of τ (remember the stimulus is turned on at t = 10 sec!) to the theoretical values obtained from τ = R*C. Provide a table with the column headers below to display your input parameters and results for at least 6 trials. Provide a theoretical justification for why this method works.

Istim	R	C	τ	Vss	0.632*Vss	Time at 0.632*Vss

2. Investigating the Effects of Axial Resistance



Open the Matlab m-file "axialResistance.m". In this simulation, we will investigate how the membrane potential changes along the length of a semi-infinite cable, when we inject current at location x = 0.

2a. Run the model with the default parameters and describe how the membrane potential responds to a current step input delivered at t = 10 sec.
2b. Plot the steady state voltage for each location in 2a. What is the theoretical relationship (equation) between x and the steady state voltage? Add the theoretical relationship to your plot.
2c. Change the locations at which the voltage is being recorded by changing the "x" parameter (NOTE: keep the leading 0 in the x = [0 …] expression). At what distance from the current input is the steady state voltage reduced to 1/*e* of its original value (e.g. the length constant 'lambda')? How does this compare to the theoretical value of the length constant?
2d. What is the steady state membrane potential at a distance of one-fifth the length constant?
2e. Explain why there is a difference in steady state membrane potential between a location close to and a location far away from the current injection site.
2f. Using the results from the above steps, if this neuron used passive signaling instead of action potentials to communicate with a downstream neuron 5 mm away, what would the steady state membrane potential be at the terminal between the two neurons? Is this an effective communication strategy?
2g. There are a wide variety in geometries of axonal and dendritic processes amongst the various neuron morphologies, ranging from very small (< 1 μm) to very large (1 mm) diameters. With your voltage probe fixed at a distance of 1 mm from the current injection site, determine the effects of increasing the radius (variable "a"). Test many values of a, ranging from a very small radii to radii values much greater than what are naturally observed. Plot each peak (steady state) voltage measured as a function of the length constant, lambda. Describe the relationship between the steady state voltage and the length constant.