Please make sure to do the reading prior to completing the problem set.

Passive Membranes Lab Notebook

Reading: Passive Membranes

Name:
Date:
Purpose of Lab:

Note that these questions appear within the reading. Please make sure to do the reading before answering them.

Question 1: *If the charges are equal on each side of the membrane, will the net flow of potassium ions (and thus the net current) be into the cell, out of the cell, or balanced in both directions?*

Question 2: *If the charges are equal on each side of the membrane, what will the net membrane potential be: positive, negative, or zero?* (Note that membrane potential is usually measured as the potential inside the cell compared to the outside of the cell).

Question 3: *How will the potassium current (if any) change the potential of the membrane over time: will it increase it, decrease it, or not change it at all?*

Question 4: Assume that we add a small number of extra positive charges (other than potassium) to the outside of the membrane and a small number of negative charges to the inside of the membrane (this could be done by passing a current through an intracellular silver chloride electrode, for example). *Immediately after we add the charges, what will the net membrane potential be—positive, negative, or zero?*

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Question 5: *Immediately after we add the charges, will the net flow of potassium ions (and thus the net flow of charge) be into the cell, out of the cell, or balanced in both directions?*

Question 6: *How will the potassium current (if any) change the potential of the membrane over time: will it increase it, decrease it, or not change it at all?*

Question 7: *If we initially add twice as much charge as was added in Question 4, would the new potassium current be greater than, less than, or equal to the old potassium current?*

Please check your answers for this part in the reading.

Effects of Current on the Passive Membrane

Question 8: Exploring the simulation.

What happens when you double or halve the cell capacitance or conductance? What happens if you increase or decrease the cell's resting potential by 20 mV? Please do these one at a time, leaving the others unchanged. *Explain your results.*

Capacitance	
Conductance	
Resting Potential	

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Question 9: Exploring the simulation.

What happens if you double or halve the stimulus delay, stimulus current, pulse duration, inter-stimulus interval, or number of pulses? What happens if you double or halve the total duration? Once again, do these one at a time. *Explain your results.*

Stimulus Delay	
Stimulus Current	
Pulse Duration	
Inter-Stimulus Interval	
Number of Pulses	
Total Duration	

Question 10: Using Ohm's law.

Reset the simulation parameters, and run the simulation with these original values.

At what value does the membrane potential plateau? Use the cursor to obtain a value. You may find the feature described above for taking and storing measurements useful for this and following problems. Fill out the chart to see what happens at different current values.

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$g = 2\mu S$	
I_{STIM}	V_{MAX}
$10nA$	
$20nA$	
$30nA$	

Use Ohm's law to calculate the membrane resistance of the cell. *How does this compare with the value that is actually listed for the simulation?* Recall that conductance is the reciprocal of resistance, and don't forget to track the appropriate powers of ten for micro, nano, and milli, which will all enter into your answer.

Reset the simulation. Set the membrane conductance to half its current value. *Before running the experiments, predict whether this will make the neuron show larger or smaller responses to the same levels of currents. Now repeat the experiments you did above and again use Ohm's law to calculate the membrane resistance of the cell.*

$g = 1\mu S$	
I_{STIM}	V_{MAX}
$10nA$	
$20nA$	
$30nA$	

How does this compare with the actual value you set?

Try halving the membrane capacitance. *Does this change the maximum height of the membrane response?* (Increasing the membrane capacitance may have a more complicated effect - we'll explore that in the next question).

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[Required for graduate students, optional for undergraduates] *How would changing the resting potential of the membrane alter its response to current?* Reset the simulation, change the resting potential to -10 mV, and see if you can deduce the equation for describing the peak membrane potential in response to a current.

Question 11: Exploring the rise of the pulse.

Reset the simulation parameters. Increase the membrane capacitance to 6 nF, the stimulus delay to 5 ms, the stimulus current to 20 nA, the pulse duration to 20 ms, and reduce the number of pulses to one. Rerun the simulation. From question 10, *what do you expect the height of the pulse to be?* Measure it to confirm your prediction.

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How long does it take to reach half of this height? **(Use the cursor to measure the time from the beginning of the pulse to the point where it first reaches half of the peak membrane potential; in words, subtract off the time before the pulse starts!)**.

Length of Time to Reach…	
$\frac{1}{2}$ $original\ height$:	
$\frac{3}{4}$ $original\ height$:	
$\frac{7}{8}$ $original\ height$:	

What is the pattern in the previous numbers? Predict how long it will take to 15/16th of the height. Check your prediction.

Question 12: Now examine the effects of membrane capacitance on the rise of the potential.

Set the simulation parameters as in question 11, but set the membrane capacitance to 2 nF. *Predict the maximum pulse height and check it. Measure the time to reach half of maximal height.*

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Double the membrane capacitance to 4 nF. *Does this affect the maximum height of the pulse?* Keeping the membrane capacitance at 4 nF, *how long does it take to reach half of the maximum height?* Repeat this measurement with the membrane capacitance set to 6 nF and 8 nF.

Membrane Capacitance	Maximum Height
$4\ nF$	
$6\ nF$	
$8\ nF$	

Look at the times to reach half maximum height you've recorded for membrane capacitances of 2, 4, 6, and 8 nF. *Do you see a pattern?* Remember that your measurements may have a small amount of error. *Try to predict the time to reach half maximal height for with a membrane capacitance of 10 nF, and check your result.*

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Question 13: Next, look at the effects of injected current and membrane conductance.

Starting with the settings from question 11, set the membrane capacitance to 4 nF. Measure or recall the time to reach half maximal height with the stimulus current set to 20 nA. Change the stimulus current to 10 nA. *Predict the height of the pulse and measure it to check your prediction.*

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Measure the time to reach half maximal height with the 10 nA stimulus current and compare it with the time for 20 nA. *Does stimulus current affect the time to reach half of maximum membrane potential?*

Question 14: Examine how changing membrane conductance affects the time for the simulation to reach half of the maximum height.

Starting with the settings from question 11, set the membrane capacitance to 4 nF. Measure or recall the time to reach half maximal height with a membrane conductance of 2 µS. Double the membrane conductance to 4 µS. Calculate the maximum pulse height, and measure the time to reach half the maximum height. Halve the membrane conductance to 1 µS. Calculate the maximum pulse height, and measure the time to reach half the maximum height.

Membrane Conductance	Max Pulse Height	Time to Reach Half Max Height
1 µS		
2 µS		
4 µS		

Look for a pattern and predict the time to reach half maximal height with a membrane conductance of 3 µS. Check your prediction.

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Question 15: Examine how the potential returns to its resting value after a pulse.

Start with the settings from question 11. It may help to increase the simulation time to 60 ms.

Measure the time from the end of the current pulse to when the membrane potential reaches half, one quarter, and one eighth of its initial maximal value after it begins to fall. Look for a pattern *and predict the time required to fall to one sixteenth of the maximal value*.

Length of Time to Reach…	
$\frac{1}{2}$ *original height*:	
$\frac{3}{4}$ *original height*:	
$\frac{7}{8}$ *original height*:	

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Measure the time required to fall to half maximal with a membrane capacitance of 4, and 8 nF. Look for a pattern, and try to *predict the time required to fall to half of the maximal value when the membrane capacitance is 5 nF. Check your result.*

Membrane Capacitance	Time
4 nF	
8 nF	

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The Electrical Equivalent Circuit for the Resting Membrane

Question 16: What determines the resting potential when the membrane is much more permeable to one ion than the others?

Try setting the sodium and chloride conductances to 0.01 μS and the potassium conductance to 30 μS. What is the membrane resting potential?

Membrane Resting Potential:	

Try setting the chloride and potassium conductances to 0.01 μS and the sodium conductance to 30 μS. What is the membrane resting potential?

Membrane Resting Potential:	

From the previous two results (or using **Equation 7**), predict the resting potential when the sodium and potassium conductances are 0.01 μS and the chloride conductance is 30 μS. Test your prediction.

What determines the resting potential when the membrane is much more permeable to one ion than the others?

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Question 17: What determines the resting potential when the membrane is equally permeable to two ions?

Try setting the sodium conductance to 0.01 μS and the potassium and chloride conductances to 30 μS. What is the membrane resting potential?

Membrane Resting Potential:	

Try setting the chloride conductance to 0.01 μS and the sodium and potassium conductances to 30 μS. What is the membrane resting potential?

Membrane Resting Potential:	

From the previous two results (or using **Equation 7**), predict the resting potential when the potassium conductance is 0.01 μS and the sodium and chloride conductances are 30 μS. Test your prediction.

What determines the resting potential when the membrane is equally permeable to two ions?

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Discussion:

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