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ELEC436 Project-2
Neuronal Impulse Propagation

1)

Time Step. Determine a suitable value for Δt, using the fiber parameters above, and the mesh ratio.
Δt=0.01 and mesh ratio is ..

Mesh ratio = $\frac{\Delta t}{r_i * c_m * \Delta x^2}$ <=0.01(As Rustam said in ps)

Then the suitable value for Δt given parameters is 0.01.

One result of numerical analysis as well as practical experience is the identification of the *mesh ratio*[11] as an important numerical indicator. The mesh ratio is

$$\text{mesh ratio} = \frac{\Delta t}{r_i c_m \Delta x^2} \tag{6.58}$$

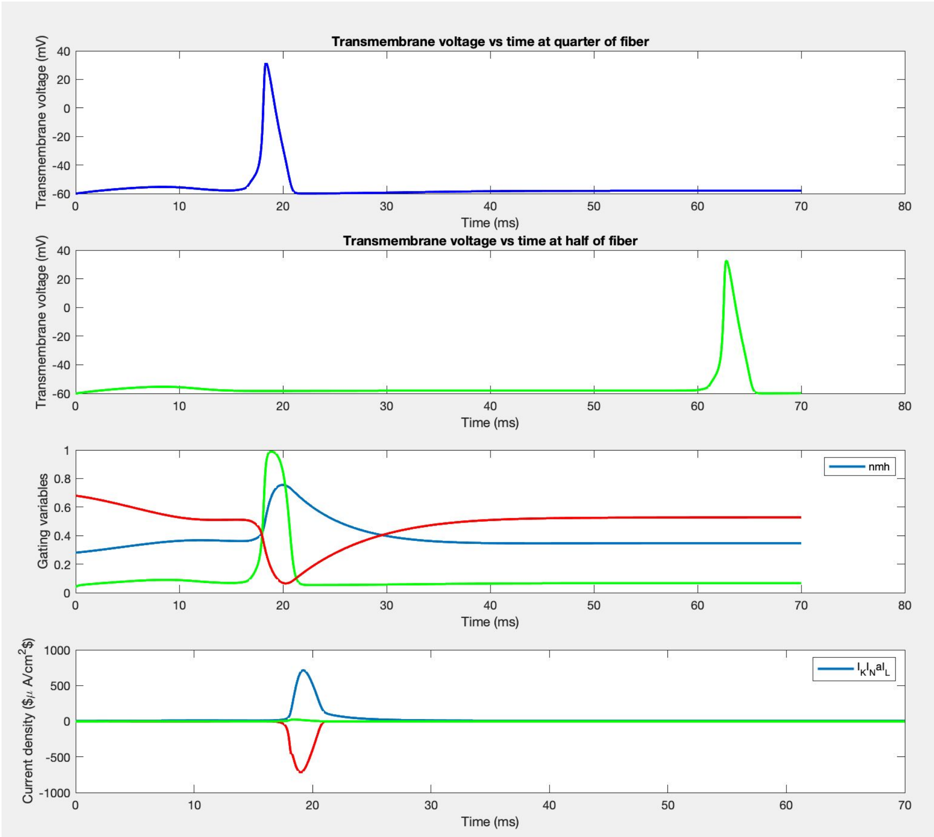
Numerical procedures for finding solutions for V_m in time and space remain stable, when values for Δt and Δx are selected that make the mesh ratio small, as compared to one. Conversely, solutions may become unstable when the mesh ratio becomes greater than one.

2)

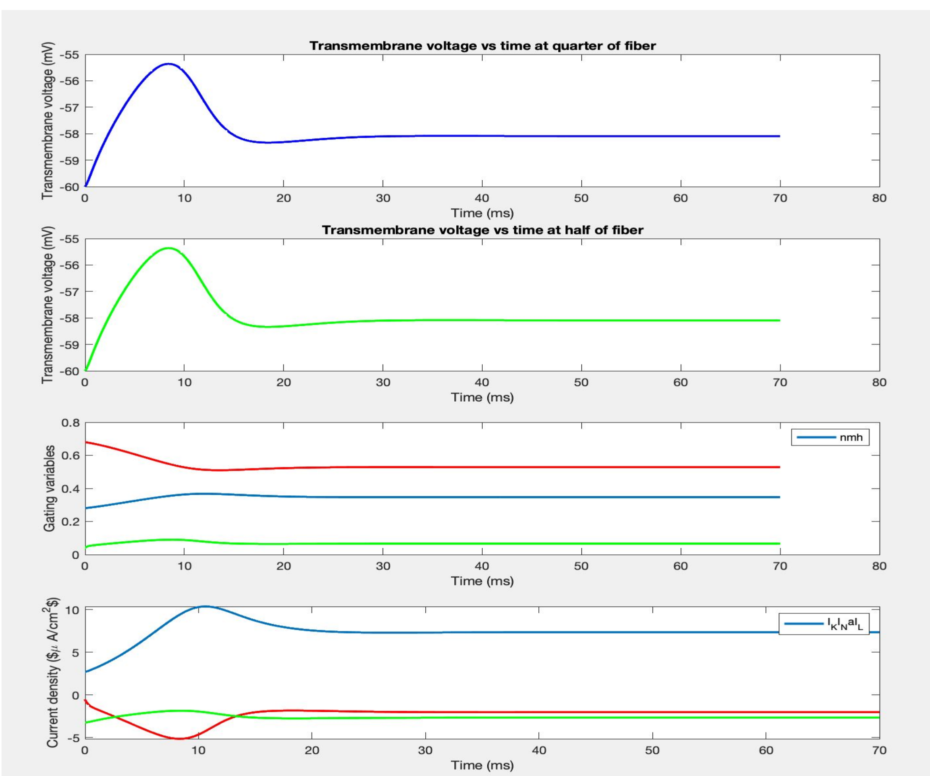
Threshold and strength–duration. Start with a simulation duration of 10 msec and a stimulus duration of 100 microseconds (μsec). Increase the stimulus amplitude until an action potential is produced. Judge the presence of an action potential by whether one later appears at the midpoint of the fiber.

a. Find the threshold—the amplitude that just produces an action potential, while a decrease to 50% of that amplitude fails. What is this amplitude?
I used parameters as length of fiber is 4 cm, simulation duration 70msec, and stimulus duration 00 microseconds (μsec). The found threshold amplitude is 40 mA.

Plot for Is = 40mA;



Plot for Is = 20mA;

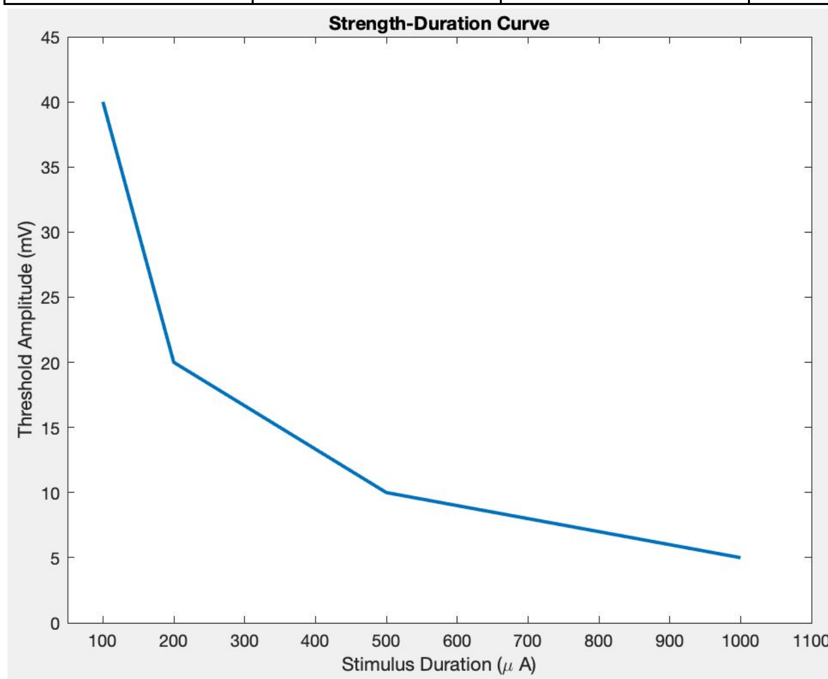


b. What happens to the time interval between the start of the stimulus and the midpoint of the action potential’s upstroke, for stimulus amplitudes just above threshold?

As the stimulus amplitude increases, time interval decreases.

c. Increase the duration to 200 μsec and again find the threshold. Then do the same for a duration of 500 and 1000 msec. Plot these points as a strength–duration curve.

Stimulus Duration(μsec)	100	200	500	1000
Threshold Amplitude (mA)	40	20	10	5



d. Compare the strength–duration curve obtained above to that for a patch (Chapter 7). Explain the differences that are present.
They are very similar. If we increase the sample point for stimulus duration, then we get exactly strength–duration curve for a patch from chapter 7.

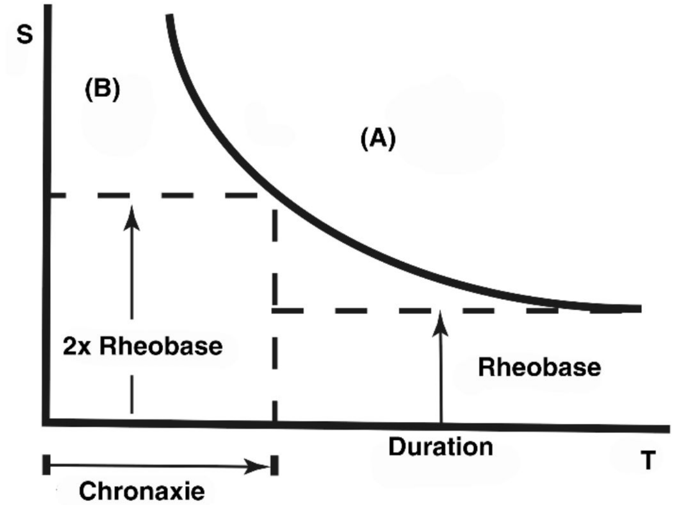


Figure 7.3. Strength–Duration Curve. Line $V_T = L$ shows the combinations of stimulus strength S (on the vertical axis) and stimulus duration T (on the horizontal axis) that are just sufficient to reach the threshold level. Combinations on side A of line L are above threshold and may lead to action potentials, while combinations on side B are below threshold. *Rheobase* is the value of stimulus current that is just sufficient to reach L with a long stimulus duration T. *Chronaxie* is the stimulus duration required to reach L if the stimulus current is set to twice rheobase.

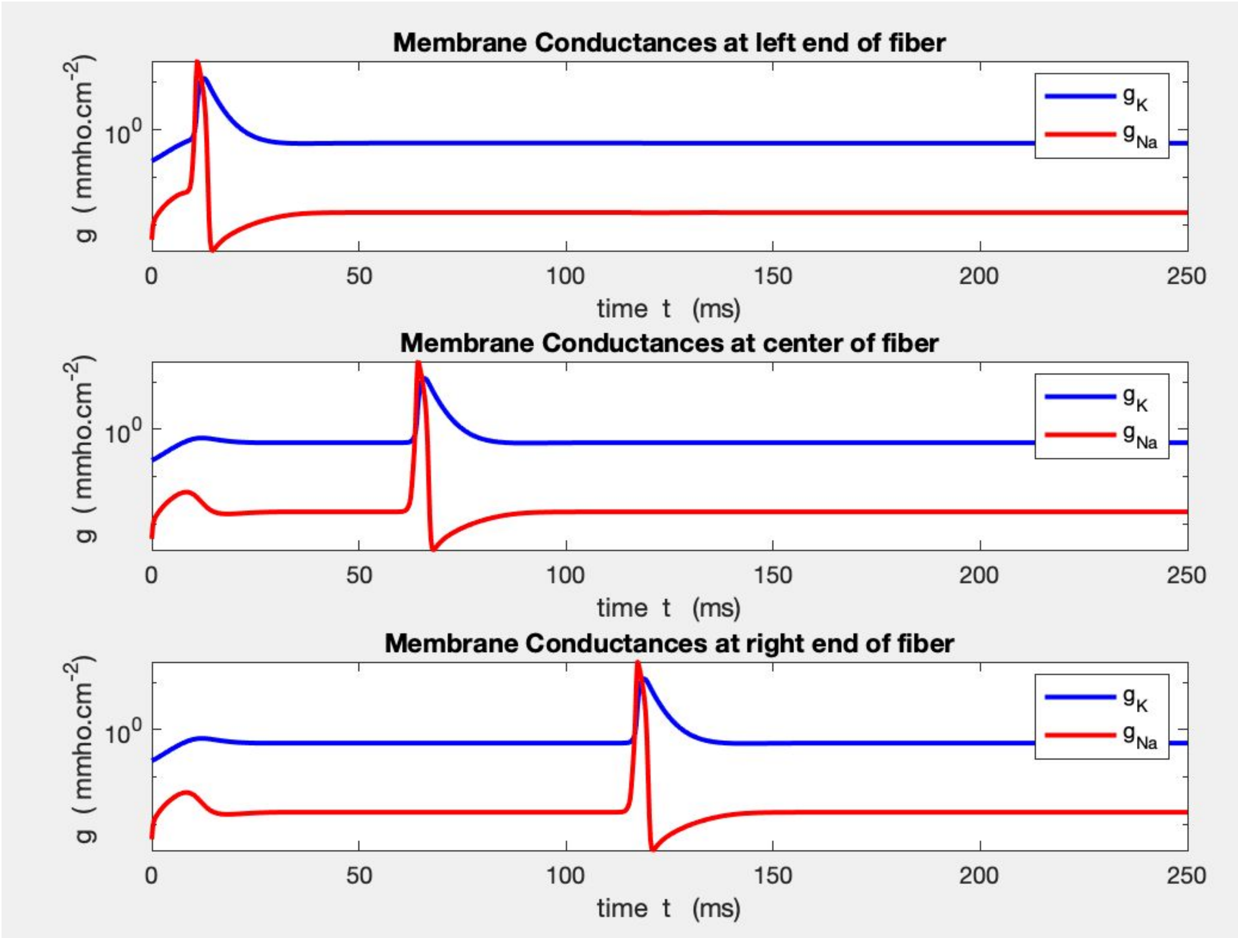
3)

Membrane conductances. Determine the membrane conductances as a function of time, at the left end, center, and right end of a fiber, from the time of the stimulus throughout an action potential.

a. Plot the changes in these conductances during and following the action potential. Use a large vertical scale,and consider a log scale. What are the largest values the conductances reach, at any one of the three sites?

For G_K = 11.7778 mS/cm^2

For G_Na = 26.7947 mS/cm^2



b. Are the conductance waveforms the same at all three sites?

Waveforms of conductance are the same at all three sites as the figure above. They are shifted versions of each other.

c. By what factors does each one change during the action potential? (make a ratio of the largest value over the smallest value).

Largest value For G_K = 11.7778 mS/cm^2

Smallest value For G_K = 0.2222 mS/cm^2

Ratio for G_K = 53.005. As the percentage, 238.54% increased during action potential.

Largest value For G_Na = 26.7947 mS/cm^2

Smallest value For G_Na = 0.0029 mS/cm^2

Ratio for G_Na_ = 9239.55 As the percentage, 3186052.32% increased during action potential.

4)

Refractory period. Set the stimulus duration and amplitude to produce an action potential within 1 msec of the start of the first stimulus, and set the stimulus duration to the time for propagation from one end of the fiber to the other, plus 20 msec. Initiate a second stimulus pulse with the same duration and amplitude, but starting at 8 msec.

My action potential propagates 111.7100-6.6300 = 105.08 ms to end of the fiber. My total simulation time should be 105.08 + 20 ms = 125.08ms. My second pulse and first pulse should be separated by 8 ms. Within 1 ms my first peak should create action potential and it needs to propagate to end. I set the stimulus current time to 5.63 ms since it is in 1msec of producing action potential time.I set the stimulus duration as 125.08 ms.

a. Does the 2nd stimulus produce a propagating action potential, as judged by what happens at the middle of the fiber?
If the stimulus duration bigger than 4 ms, then the 2nd stimulus produce a propagating action potential, as judged by what happens at the middle of the fiber. If the stimulus duration is 1ms, it does not produce.

b. If necessary, increase the stimulus amplitude of the stimulus at 8 msec, until it does produce a propagating action potential, as observed at the center of the fiber.
In the case of stimulus duration is 1 ms, I increased the stimulus amplitude to 100000 uA but still it does not produce a propagating action potential.

c. With the stimulus determined in part C, is the time interval between the upstroke of the first and of the second action potentials, as observed at the center of the fiber, 8 msec?
In the case of stimulus duration is 4ms, the time interval between the upstroke of the first and of the second action potentials, as observed at the center of the fiber is 23 msec.
The calculation is below.

```
>> [N out1] = spike_times(V_m(min(find(positions>0.5*x_max)),:),-45);
>> out1

out1 =

     6419     8719

>> timesteps(out1(2)-out1(1))

ans =   22.9900
```

5)

Temporal summation. Use a simulation duration of 10 msec. Decrease the amplitude of both stimuli to about 60% of the stimulus threshold (for membrane at rest).
The stimulus threshold for stimulus duration 100 μsec is 40mA. Therefore, I decreased the amplitude of both stimuli to 24mA.

a. What happens when the delay time of the second stimulus is reduced to 1 msec?
When the delay is 8msec, action potential isn't produced. After reducing delay time of second stimulus to 1msec 1st action potential is produced.

b. By looking at the time courses of the conductances, can you explain why a second subthreshold stimulus could cause an action potential after the first one failed?
The term of temporal summation is happened. The second stimulus encountered a slightly higher value than the original membrane conductance because the first stimulus increased membrane conductance a bit.

c. Increase the time until the onset of the 2nd stimulus. At what interval does neither stimulus produce an action potential?
I increased the time until onset of 2nd stimulus and neither stimulus produce an action potential for delay of bigger than 2ms of 2nd stimulus.