Biol635 / Math635 / Biol432 / Math430
Fall 2025
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Assignment 2

Answer the following questions.

- Justify your answers.
- Explain your results.
- Provide the necessary calculations in a clear way.
- Provide the necessary supporting graphs and codes.
- Make sure the graphs are properly labeled and include the information (title and parameter values) necessary to understand your explanations.
- You may write your own code or adapt the template code provided in class.

1. Consider the following passive membrane equation

$$\tau \frac{dV}{dt} = -(V - E_L) + R\, I_{app}(t) \tag{1}$$

with $E_L = -60$ mV, $C = 1$ μF/cm^2, $G_L = 0.1$ mS/cm^2, Write a Matlab code (or use the template code) to solve eq. (1). Use $V(0) = -60$ mV and the following units for V, t and I_{app} respectively: $[V] =$ mV,$[t] =$ msec, $[I_{app}] = \mu$A/cm^2.

   (a) Calculate the time constant τ.
   (b) Compute the steady-state solution for $I_{app} = -0.5$ and $I_{app} = 0.5$
   (c) For each these values of I_{app}, compare the numerical and analytical solutions to the passive membrane equation (1) by
      i. Plotting superimposed graphs of these solutions
      ii. plotting the error (absolute value of the difference between these two solutions).

Run your simulation for enough time so to allow V to reach a close vicinity of its steady state.

Use the initial condition $V(0) = E_L$

(d) Consider the following oscillatory current

$$I_{app}(t) = I_0 \ \sin(2\,\pi\,f\,t/1000).$$

with $I_0 = 0.5$. The input frequency f is given in Hz (number of cycles per second) and the units of time are msec.

i. Plot the numerical solution to the passive membrane equation (1) for $f = 1$, $f = 5$, $f = 10$, $f = 20$, and $f = 100$.
ii. Plot a graph relating the output frequency (y-axis) vs. the input frequency (x-axis)
iii. Plot a graph relating the amplitude of the output oscillations (y-axis) vs. the input frequency (x-axis)
iv. What is the effect of increasing and decreasing the time constant τ?

2. (Graduate level)

Repeat question 1d for a square-wave current $I_{app,sqw}(t)$ with amplitude equal to 1.

Note: You can construct the square-wave current by making $I_{app,sqw}(t) = 1$ if $t \geq 0$ and $I_{app,sqw}(t) = -1$ otherwise.

3. Find examples in the literature of both biological neuronal systems and models that behave like

- (Undergraduate level) low-pass filters
- (Graduate level) band-pass filters
- Speculate on the differences between them by sharing information between members of the two groups