ECE 366/566: Neural Engineering & Implantable Devices

Project: Designing a Peripheral Neural Stimulation System

Total Points: 100
Duration: 6 weeks

Instructions:

1. Submission deadline is **April 19th at 5 pm**. There will not be any deadline extension.
2. The project requires using both MATLAB and the Neuron Simulator. MATLAB components may also be done in Python, but MATLAB is recommended.
3. No cheating will be tolerated. Institute policies will be enforced if cheating is detected.

What to submit?

Each team will submit the following files. Failure to submission of all of these files will lead to 0 points.

- Report: Please submit a .pdf file of a typed (not hand-written) report.
  - The report template should be similar to a conference paper.
  - The report must have the following sections: Abstract, Introduction, Method, Results, Discussion, Conclusion, Acknowledgement, References.
    - You may have any additional section or subsection you would like to.
    - In the discussion section, mention the weaknesses and limitations of this work.
    - In the Acknowledgement section, please specify the contributions of each team member (i.e., mention which team member worked on which part/task of the project).
  - You should use a font size 11. The report (without references) must be between 2 to 4 pages. You can use either single-column or double-column format.
  - Please provide high-quality figures and clearly mention the axes' quantities and units on the plots. Do not forget figure captions.
  - You may want to look at published conference papers to get an idea about what a research paper looks like. For this, IEEE EMBS papers would be ideal.
- MATLAB/python script.
  - Please make sure to provide comments on your script. The submissions without comments will not be graded.
- All *modified* simulation files (.ses, .hoc) used for the Neuron Simulations.

Teamwork:

- The recommended team size is 3. However, you can also work as a team of 2.
- Ideally, each member is supposed to spend a total of 40 hours on this project.
- Each group is encouraged to work together on complex tasks (such as brainstorming and troubleshooting) and divide the more straightforward tasks among the team members (such as writing a section of the report).
- In the report, please specify the contributions of each team member.

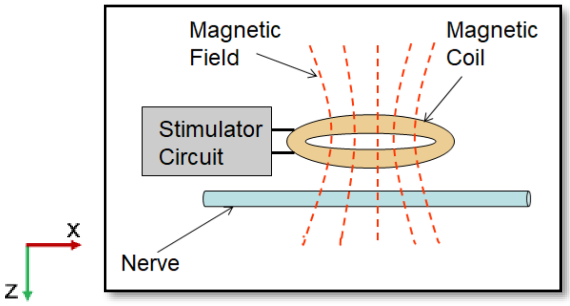
How to resolve a doubt?

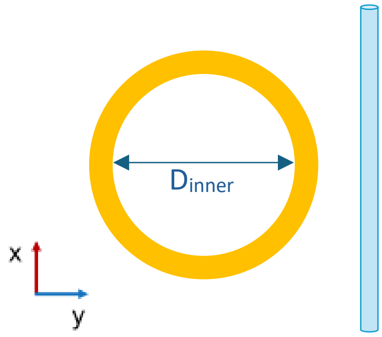
- Please ask your questions or doubts during office hours, TA hours, or the lectures.
- Online queries (through emails, chats, etc.) will not be answered.

Problem Definition

Each team will design a neural stimulation system for peripheral nerves in this project. Specifically, the aim is to use computational modeling to design a magnetic stimulation system for the sciatic nerve.

This involves (1) designing the stimulation coil, (2) the circuit to deliver the desired stimulation current through the coil, and (3) optimizing the placement of the coil with respect to the stimulation target site. In reality, this is a complex project involving several design constraints. However, we are considering the following assumptions to complete this project in the limited time.





Assumptions

- The stimulator circuit consists of only a DC voltage source and a capacitor (C = 5 mF).
- Assume a nerve thickness of 0.6 mm. Instead of modeling all the nerve fibers, model only one nerve fiber at the center of the nerve. The nerve fiber is myelinated with 55 nodes of Ranvier. The outer and inner diameters of the nerve fiber are 16 and 10 µm, respectively. The distance between two consecutive nodes is 1.6 mm.
- The simulation domain is considered homogeneous. That is, there is only one type of biological tissue for the nerve and surrounding space. Therefore, the induced electric field in the nerve can be calculated using analytical equations instead of complex numerical methods.

Test Case

Consider a single-turn circular coil, as shown in the figures. The coil's inner diameter is 5 mm. The minimum separation (along the z-axis) between the nerve and the plane containing the coil is 0.5 mm. There is an offset of 4 mm along the y-axis between the centers of the nerve and coil. Assume that the coil is made up of 22 AWG wires. Take an initial value of 400 V for the DC voltage source.

[CO1, CO2, CO3, CO4] Problem 1 [100 points]

Designing a Peripheral Neural Stimulation System

Design a neural stimulation system for the sciatic nerve using magnetic coils.

A. ***Coil Current for Test Case:*** Compute the current $i(t)$ passing through the stimulator coil of the test case. In the report, include plots of $i(t)$ and time derivative di/dt. Submit the MATLAB script used for this part. [10 points]

B. ***2D Electric Field for Test Case:*** Compute the electric field induced in the proximal nerve for the test case. In the report, include 2D plots of the electric field (Ex component) and electric field gradient (dEx/dx). For these plots, consider the XY plane passing through the nerve center. Submit the MATLAB script used for this part. [30 points]

C. ***Parametric Study:*** Perform a parametric study to optimize the position of the coil with respect to the nerve. In the report, include plot(s) that show how stimulation threshold varies with coil position. {To find the stimulation threshold, you need to predict the neural response. Neural response prediction can be done using the provided Neuron Simulation files. Further details are provided in the uploaded *ReadMe.txt* file} [20 points]

D. ***Novel Design:*** Propose a more efficient design for this stimulation system. Test the proposed design and provide validation results in the report. [20 points]

E. ***Report:*** Prepare a high-quality report. Please use Grammarly to avoid grammatical mistakes and improve your technical writing. [20 points]