Computational Essay Project

One of the most common activities that professional scientists do, regardless of field, is write computer simulations. They use these simulations to predict the behavior of new systems, to figure out the mechanism behind a system they don't understand, and to verify (or disprove) predictions made by other people.

In previous semesters of your physics courses, you have been asked to write programs to simulate the behavior of physical systems. However, most of these assignments have likely been very structured, with step-by-step instructions on how to write the simulation. This project will give you the opportunity to use the techniques you've learned to do something closer to what actual scientists do: to use a simulation to answer a question that is interesting *to you*, without the steps specified in advance.

In this project, you will be provided with several simulations of systems that involve the physics principles you have been learning about, including:

- Firing neurons
- Polar molecules in a liquid
- Electric dipole antennas
- Storm clouds and lightning
- Particle accelerators
- Magnetic traps
- Railguns

These simulations will include some of the basic physics involved and a description of what the code does, but not much else; they are meant for you to build on. You can choose to use one of these simulations, or use another simulation you've worked on (like an oblig), or write a new simulation if none of these seem especially interesting to you. You will then modify your chosen simulation it to answer a question about the system, like "how much charge would a cloud need to create a lightning strike in the desert?" or "how much current would a railgun need to launch a package to the International Space Station?"

In order to be successful in this project, you will have to do the following things:

1. Choose one of the offered simulations and familiarize yourself with how it works, use another existing E&M simulation, or write a new simulation yourself

2. Choose a question that you find interesting which can be answered with that simulation

3. Identify which assumptions you have to make or values you will need in order to answer the question, and look up information from articles or websites to justify those assumptions or values (Wikipedia is a useful source here). For example, how big is a normal storm cloud? What are reasonable dimensions for a cyclotron? What kinds of charged particles are typically trapped in magnetic bottles?

4. Play around with the simulation to answer the question. Here, you will need to substantively expand on the provided code (adding new physics, like forces or objects, for example); it's not enough to just change a few of the variables but leave most of the code untouched

5. Write up a short report, within the Jupyter Notebook, that includes a description of your problem, the code you used to investigate it (including descriptions of what the code does), and what you concluded from the investigation. You should also include 1-2 diagrams or pictures in order to show what the real example of the system looks like, and/or what the variables in your code actually mean

You can see several examples of the results of this type of project here: https://uio-ccse.github.io/computational-essay-showroom/index

Note that the goal of this project isn't necessarily to generate a perfect simulation—every simulation makes assumptions and ignores things that are actually very important in real life. Instead, the goal is to add enough new physics to one of these simulations that you can use it to learn something that you didn't understand before.

You are encouraged to do this project with a partner, but can do it yourself if you wish. Once you have completed your project, you (and your partner if you are working as a pair) will present the work to a small group of your peers. During this presentation, you will project your computational essay onto a screen and walk the audience through your investigation process, starting with the question you were trying to answer and ending with your conclusions. Students working alone will have 10 minutes to present (8 minutes + 2 for questions) and students working in pairs will have 15 minutes (13 minutes + 2 for questions). These presentations will be modeled after the way professional computational physicists present their work to the colleagues at research group meetings, so you do not need to spend a lot of time polishing these presentations—just be prepared to describe your question, approach, what you've uncovered, and answer a few questions.

The due date for your project will depend on when you sign up to present. At the beginning of the semester you will sign up for presentation slots, and you must have your project completed by the time you present. Immediately before or after your presentation, upload your project to the designated area of Canvas. The project will be graded *pass/fail*, and will be evaluated based on a rubric (attached, on the next page). You must achieve at least 70% (14/20 points) on this rubric to have the project approved. You can use this rubric as a baseline for the elements that must be present in your computational essay to pass (but we encourage you to look at the examples to see they ways in which these essays are often written).

You can expect to spend roughly 10 hours on this project, though you are welcome to spend more if you find the topic interesting (many students do!). Throughout the semester here will also be optional sessions held to specifically help you work on this project, where you can go for help with coding, ideas, or just for a place to work.

Project Grading Rubric

Requirement	Point Value	Novice Competence	Developing Competence	Mastering Competence
Investigation Question	**4**	There is no question for the investigation, or the question could be answered using the example code as given (without modification)	There is an investigation question, but it is not physical and/or is answerable by only tweaking variables in the example code	There is an investigation question, it is physically meaningful, and it requires significant additions to the example simulation to answer
		0 points ←--→ 4 points		
Coding	**4**	The code either doesn't work or is just the unmodified example	The code works, but only small changes have been made (i.e., only some variables have been changed)	The code works and there are significant additions to the code (i.e., several new steps or blocks added to the simulation)
		0 points ←--→ 4 points		
Physics in the Simulation	**4**	No additional physics has been added to the given simulation	Physics principles have been used to augment the simulation, but they are not clearly explained	Physics principles have been used to augment the simulation, and it is clear how they were derived and applied in the code
		0 points ←--→ 4 points		
Conclusion	**4**	There is no conclusion	There is a conclusion, but it only states the results and does not justify their meaning or reasonability	There is a conclusion which describes the results, interprets their meaning, uses them to answer the original question, and justifies their reasonability
		0 points ←--→ 4 points		
Written Report	**4**	There is no report, or report is uninformative and/or does not change the given notebook.	There is a report but it is sparse, does not adequately explain the code or steps of the investigation, and/or includes no pictures or diagrams	There is a report which clearly explains the steps of the investigation, fleshed out with at least 1 picture or diagram (beyond the pictures/diagrams given in the original simulation)
		0 points ←--→ 4 points		