Project Description

The purpose of doing this project is to deepen your computing skills by applying them from a new angle to a problem that you already learned about this term. We do this in a group to allow for more complex problem-solving and to build collaboration skills, which are crucial for anyone who does physics.

You are tasked with demonstrating your ability to use computing to work through a problem related to physics. Some ways to demonstrate this are:

- Describe the problem at hand in your own words.
- Explain the computational methods you need to use to solve your problem.
- Write code using the computing tools we learned in this class.
- Use your code to convey your findings, for example through clear commentary or data visualizations.
- Explain your findings using the context of the original problem.
- Explain the limitations of your results, and/or explain why you were unable to reach a clear answer.

Unlike the mini-projects, you are responsible for determining what is important to put in your solution to convey your results clearly. You and your group will turn in a single notebook that the group worked on together. Your notebook should demonstrate your group's project work in alignment with the bullet points above.

In summary, you must:

- Team up with other students (group size 3-5).
- Pick a problem from the list below.
- Work on the problem together, documenting your progress in a single jupyter notebook.
- Ensure the notebook portrays a combination of narrative and code that tells a complete story about the work your group did.
- Present your solution to the class in the form of a presentation.

The project notebook is due on **Monday, March 10 at 11:59pm**, but it is not expected to take you more than the allotted class time to complete.

The presentation will take place in class on **Wednesday, March 12** and should take 4-6 minutes. The presentation should highlight a broad overview of your group's approach to the problem, your final results, and takeaways you learned from navigating challenges related to computing and/or physics.

Project Options

1. **Initial Value Problem:** Employ `solve_ivp` to solve a physical system that is described with *multiple* coupled ODEs and visualize your solution. A full solution will describe the chosen physical system, solve the problem using `solve_ivp`, and visualize the solution.
    - *Example problem: Model the spread of rumors through social networks. More info here.*
2. **Ising Model Magnetization Region:** Using simulations of the long-term behavior of the Ising model, create an aesthetically pleasing visualization comparing the lattice energy with the temperature of the system, and shade in the temperature region where magnetization is occurring in the material. A full solution computes energies from many simulations of different temperatures and visually highlights the temperature region where magnetization is occurring in a plot of energy vs. temperature.
3. **Blurring Animation:** Create an animation that blurs an image of your choice using the method of relaxation (i.e., averaging the values of neighboring pixels). A fully working animation shows the gradual blurring of an image by applying this relaxation process frame by frame.
    - *Example problem: Blur an image of a beaver. Use the animation code from Day 12 and Day 14 as a starting point.*
4. **Create a Probability Density:** Starting from a data set of a continuous variable of your choosing, create a probability density using kernel density estimation (https://en.wikipedia.org/wiki/Kernel_density_estimation). A full solution describes the data set and the continuous variable, and it demonstrates the kernel density estimation process by creating a continuous, normalized probability density from it.
    - *Example problem: Start with a data set on "Z --> 2 electrons" from the CMS experiment. Create a probability density of the invariant mass values from the data set, using the kernel density estimation process described in the wikipedia link above. Raw data here.*
5. **Collapsing Wavefunction:** Model a wavefunction that collapses at several times, demonstrating the process of repeatedly measuring the position of a quantum particle. A full solution includes an animation of the wavefunction, either in wave or probability form, which can run long enough to see several measurements/collapses that show the random nature of measuring position from a probability density.
6. **Choose you own adventure:** You can propose a problem to work on if you have something else in mind. If you go this route, you **must** get approval from the instructor by Wednesday of Week 9 (March 5, 2025).