Au2025 PHYS5300 Final Project Rubric (Category points will be added shortly)

The goal of the final project is to synthesize the physics and numerical/computational methods that we have developed over the course of the semester. The final project will be graded out of 300 pts, but the majority of the points may be earned in a way that you choose (see the list below for examples). Point being: Do something you are interested in and find enjoyable to work on. When we discuss your project, we will agree on exactly how many of the optional parts you need to make a complete project. You can do more parts and help ensure that you get 100% on final ~~(no bonus though)~~ You may do an extra 30 pts (10%) of bonus (so I will allow you to get up to 330 / 300 points)

1. (Required) Physical Problem (75 pts)
    a. Decide on a sufficiently complex physics problem to investigate. (see examples below.)
    b. Describe the system using diagrams and mathematical expressions
    c. The system should be described in terms of the Lagrangian or Hamiltonian
    d. Discuss symmetries and assumptions in your setup that make the system easier to solve
    e. **You must clear your physics problem and project plan with me (Nov 14)**
2. (Required) Visualizations (75 pts)
    a. Numerical integration to solve the equations of motion – plots of trajectories in state/phase/coordinate space etc.
    b. Vector field plots for the differential equations to describe the evolution of the system across conditions
    c. All plots must have appropriate titles, labels, legends etc.
3. Submission of project code on github (25 pts, not for bonus though)
    a. You must create a github account
    b. You must create a repository, commit and push your code
    c. Make your repo public OR Invite me to your repository (username: jdbburg)
4. Exploration of Symmetries and Conserved quantities (75 pts)
    a. Make visualizations of the conserved quantities of the system and or illustrate how the symmetry of the system leads to these conserved quantities
    b. Explore whether or not your system exhibits (could exhibit) Chaos? If so how can you make analogies to e.g. period doubling / bifurcation diagram?
5. Interactivity (75 pts)

    a. Enable your visualization to be controlled by a widget (note notebook v6 vs. v7 differences for widgets)
    b. If a widget is not feasible, then create pre-rendered final outputs for various conditions and make the widget just display the result for various parameters
6. Animation (75 pts)
    a. Use the manim library (see examples on my github for the course) or the `%%capture` magic etc. to produce animations of the trajectories
7. Utilization of advanced numerical approaches (75 pts)
    a. Investigate multiple integration techniques / or multiple numerical linear algebra techniques
    b. Use ML/AI based numerical algorithms – describe the benefits / implementation details
8. Markdown Documentation of the code: (30 pts)
    a. Similar to the mini-project and the class notebooks
    b. The goal is to make a nice and self contained "lesson" out of your notebook
    c. If you have questions about how much is needed to get full points then ask me, it depends on the problem, but should be at least 1-2 pages of text/math.
9. Presentation: (100 pts = 75 pts + 25 bonus)
    a. Present ~10 mins on your project in class (last days of class)
    b. Prepare a few slides covering the topic and the categories that you chose
10. Hamiltonian vs. Lagrangian (75 pts)
    a. Explore the same problem in the lagrangian and Hamiltonian approaches. Illustrate the use of each
    b. Comment on benefit/physics intuition from the methods and especially point out potential benefits of the Hamiltonian approach

Example problems:

- 3-body (or n-body) gravitational problem
- N-pendulum system with springs instead of rigid rod connections
- Weather simulation with wind currents and temperature gradients
- Wave simulation in 2D
- Lattice of masses connected by springs
- N-body gravitation example of in-spiral (Black holes)
- Heat equation