Poster Project Suggestions

Potential Poster Project Topics and Suggestions:

Randomness and emergent phenomena

- Develop your own cellular automata simulation (e.g. the Game of Life)
  - https://en.wikipedia.org/wiki/Conway%27s_Game_of_Life
  - https://en.wikipedia.org/wiki/Cellular_automaton
  - This is also related to the chaotic systems. Explain this in your project presentation
- 3D Ising Model
  - Extend and adapt what we did in the context of the 2D Ising model, now for 3D.
  - Make sure to plan for measurements and large-scale simulations, comparisons of parameters, etc.
- Spin glass model
  - Effectively, randomize the magnitude of J depending on location
  - https://en.wikipedia.org/wiki/Spin_glass
  - Discuss the concept and realization of phase and phase transitions in depth for this model

Numerical Differential equations

- Solutions of time-dependent Schroedinger equation for two particles
- Comparisons of time evolution for linear and nonlinear oscillators
- Projectile motion including air resistance
  - Write a program that simulates the motion of a golf ball with allowing for air resistance, Magnus force, and wind (use Runge-Kutta method for solving a system of differential equations)
  - Calculate effects of air resistance, Magnus force and wind on trajectories of golf balls.
  - Coefficients for the drag and lift (Magnus) forces can be found in H. Erlichson Am. J. Phys. vol. 51, 357 (1983), T. P. Jorgensen The Physics of Golf, American Institute of Physics (1999).

    - Generally, the drag coefficient C_d depends on the Reynolds number (see C. Frohlich Am J. Phys. 52, 325 (1984)).
- Effect of the solar wind on satellite motion (similar to above)
    - Calculate a trajectory of the satellite affected by the solar wind. Compare your anticipated trajectory with results of your computer simulations.
    - How does the total energy and total angular momentum change?
- Magnetic field for a finite solenoid, finding and displaying the magnetic field of a finite solenoid using either
    - numerical integration to evaluate the elliptic integrals that show up, or
    - using numerical integration directly with the Biot-Savart law.
- Classical motion in non-trivial magnetic fields.
    - Using Runge-Kutta to solve the equations of motion for a provided magnetic field.
    - There is, for example, a problem in Griffiths that has to do with particle motion over a disk with zero total magnetic flux (Problem 5.43 in the 3rd edition) — in the problem, you prove something about the nature of the motion but actually finding the trajectory must be done numerically, and it’s an interesting case.
    - A discussion can be found in https://arxiv.org/pdf/1603.01211.pdf.
- Modified theory predictions
    - Take a simple modification to E&M, say, like a Born-Infeld variant. Which puts a cut-off on the magnitude of the electric field (by analogy with the cut-off placed on the speed of a particle when using the relativistic momentum in Newton’s second law). What is the solution to this (with appropriate boundary conditions) for, say, a spherically symmetric charge distribution ⇢(r)? Compare and contrast with E&M.
        - https://www.dropbox.com/s/36kg4tvguw8x32l/Screenshot%202018-11-04%2009.16.11.png?dl=0
    - Simulation of the modifications to Maxwell's equations from an axion induced EM field would also be amazing
        - https://arxiv.org/abs/2303.10170
        - https://arxiv.org/abs/2211.06847
    - As another example, Einstein’s 1912 theory of gravity reads, for gravitational potential \Phi and mass density \rho (see, e.g. https://arxiv.org/pdf/1408.3594.pdf):
    - This is nonlinear, and could be solved numerically for spherically symmetric mass density ⇢(r). In this case, we can compare with the solutions to Newtonian gravity.
        - https://www.dropbox.com/s/3u9nz8l8snjcazm/Screenshot%202018-11-04%2009.16.41.png?dl=0

Fourier Transforms

- Sound/image filtering using the FFT and eigenvector pruning.
  - There is a lot of good image manipulation that can be done using the FFT on two-dimensional “picture” data.
  - One can also do image compression by removing eigenvectors and reconstructing images (with mathematical bounds on the image proximity to its uncompressed form)

Chaotic systems

- Interactive plots and animations for realistic double pendulum
- Dripping faucet
  - Simulates the time intervals between every two drops as a function of the drop interval finding strange attractors by creating Poincare maps, and trying different parameters like drop mass critical speed and flow rate.
  - Can use a Runge-Kutta algorithm is to solve the motion equations involved.

Neural networks

- Simulation of simple neural network, including training for specific task
  - The hardest part of getting an artificial neural network going is figuring out how to encode the data on which it acts.
  - if you take a pure oscillatory signal of frequency f, and generate a neural network model that takes in some data and is meant to spit out f, what is the best data to send in?
  - You could sample the signal and work on the discretized sample, or compute the Fourier transform and use that as the input data, or maybe some combination of the two.
- Transfer learning
  - Take a neural network model designed and trained for a specific task, for example binary classification of categories of images as either cat or dog.
  - Apply that model to a different task, such as classification of sea otter and seal

Monte Carlo simulation

- Biased Metropolis algorithm in particle physics or biophysics (among many others)

- Implementation of a sampling of the Bethe-Bloche equation and particle transport through a material
- Nuclear reactor absorber thickness (related to above)
  - Can consider this to be a kind of random walk through the absorber
  - Assume that the probability P to get through the absorber has the asymptotic exponential dependence as $P{\sim}e^{-ax}$ where x is the size of the shield. Estimate the exponent a.
- Radioactive decay simulations
  - The probability that a certain atom decays during a small time interval dt is given by: dP = \lambda dt, where the decay constant \lambda is related to the half life t_half by \lambda = ln(2)/t_half
  - Consider an ensemble of N_0 radioactive atoms and simulate the stochastic process of the decay using pseudo random numbers. Calculate average, standard deviation and distribution function of the number of surviving atoms. Compare the simulation with your theoretical expectations.