

Physics Assignment 1

PHY411: Do problems 1-3

PHY 506: Do all four problems.

Accept the assignment from github classroom: <https://classroom.github.com/a/IG6NiYSW> . You will then get a link to your own github area.

You should submit your code through github classroom. Submit your writeup, and a link to your github classroom area where your code is, on UBLearn.

Problem 1 : Diffusion

Start from the “random_walkers” python notebook. Plot the quantity $\langle |\vec{x}_n|^2 \rangle$ versus n in 1, 2, and 3 dimensions. For each dimension, calculate the diffusion constant from your simulation, compare with theoretical expectations.

Problem 2 : Ising model

Start from the “ising” python notebook.

- A. Recall that sudden reversals of the magnetization occur from time to time in systems of finite time. What is a reasonable value of L to be chosen to maintain one single domain instead of flipping throughout? What value of N do you need to ensure an appropriate MC simulation? Show a plot of the average magnetization per spin at temperature $T = 2.0$ for various values of L and N .
- B. Recall from class that the average magnetization per spin $\langle m \rangle$ can be estimated analytically as

$$m \sim (T_c - T)^\beta$$

Re-run your simulation from part A (fixing L and N to a reasonable number) and varying the simulation as a function of T . Fit for the critical exponent β and critical temperature T_C .

- C. Similarly to part B, numerically compute the energy per spin, and then compute the heat capacity

$$C = \partial E / \partial T$$

Problem 3 : Computational Fluid Dynamics

Start from the “16_Step_12” python notebook. Repeat the calculation, but add a small rectangular obstruction in the center of the pipe of length 1 / 20 and width 1/40. What boundary conditions are needed? Plot the resulting vector field.

Problem 4 (506 only) : Cosmic inflation

There is no code for you to start from explicitly. But, you can use “planetary.ipynb”, for example, as an inspiration.

Assume space is completely flat so $k = 0$, and set $R(t) = 1$ at the present time. You may work in scaled units of the density and pressure as we did in class. The Friedmann equations are then

$$H^2 = \left(\frac{\dot{R}}{R} \right)^2 = \frac{8\pi G}{3} \rho$$

and

$$\dot{H} + H^2 = \left(\frac{\ddot{R}}{R} \right) = -\frac{4\pi G}{3} (1 + 3w) \rho$$

With

$$\dot{\rho} = -3H (1 + w) \rho$$

- A. Solve this analytically for $w = 0, 1, -1/3$.
- B. Solve this numerically with an adaptive RK4 scheme for $w = 0, 1, -1/3$, and compare to the analytic solution.