FOURTH (COMPUTER) ASSIGNMENT: DUE 5 NOV. 2007
PHYSICS 8120: PLASMA PHYSICS
Prof. Paul J. Wiita

This is a long-term assignment requiring you to model a small piece of a plasma, using an N-body code that you will write and debug. You can use any language in which you are competent, though I'd prefer code written in FORTRAN or IDL, because I know them better than BASIC or Mathematica, and much better than C(++)
. But, you are free to choose whichever language(s) you are most comfortable with; I should be able to read working code in any of these languages. If you want to use a language not mentioned above, we will need to discuss it. This project is not hard, but neither is it trivial, so to finish in time, you should start it soon.

Consider a very dilute hydrogen plasma, having some characteristics of the coronal phase of the interstellar medium, with $n_e = n_i = 10^{-3} \text{cm}^{-3}$ and $T_i = T_e = 3 \times 10^5 \text{K}$. At first, posit an (unrealistically large) uniform magnetic field of 10 Gauss along the $z$ axis, but no external electric fields. Set up your plasma in a cubic volume with length dimension, $x$, of 50 cm.

The initial conditions should place the electrons and protons randomly within that volume. Their velocities should also be randomly selected in direction, but they should be drawn from the Maxwellian distributions characterized by their temperatures.

Before doing anything else, calculate: $\omega_{ce}, \omega_{ci}, \omega_{pe}, \omega_{pi}$, and the crossing times, $\tau_{xe} \equiv x/\langle v_{th,e} \rangle$ and $\tau_{xi} \equiv x/\langle v_{th,i} \rangle$, with the 1-D values of the thermal velocities being used here. Calculate the cyclotron periods, $\tau_{ce,i} = 2\pi/\omega_{ce,i}$. Also calculate $g_{e,i}$. Does this really qualify as a plasma?

Assume that the only forces acting are the mutual electrostatic forces between the N electrons and N protons and the magnetic force each feels from the ambient magnetic field (i.e., neglect the magnetic forces each particle produces on the others, any element other than hydrogen, gravity, etc.)

You have at least two choices on how to treat particles that escape from the volume under consideration: 1) allow them to leave the computation volume or 2) bring them back in at the opposite side of the volume cube with the same velocity. Which is more realistic, and why? Use that one!

Perform three realizations of this puny plasmette, using different random initial positions and velocities. Each simulation should run for a time $T = 10 \times \max[\tau_{ci}, \tau_{xi}]$. You should choose time-steps no greater than $t = 0.03 \times \min[\tau_{ce}, \tau_{xe}]$.

A. For each of the realizations, plot the initial and final positions (preferably in 3-space, but projections on the $x-y$, $y-z$ and $x-z$ planes are acceptable) of each of the electrons and protons in your simulation (with separate symbols used for e’s and p’s and with different symbols also used for initial and final positions). For one of the realizations, plot the entire paths (again, either in 3-space or in orthogonal projections) for the 10th, 20th, 30th, 40th and 50th electrons and for the 5th, 15th, 25th, 35th and 45th protons at a reasonable selection of the time-steps your code uses The plots need to make the orbits clear, but you should be able to justify plotting some points [much] less frequently than every time-step.
B. As before, but now take a slightly more reasonable value of $B = 1\mathrm{G}$. You should use the exact same initial conditions as in Part A, so that comparisons can be made between the final results for cases A and B. (Why don’t I ask you to do this for a very reasonable $B = 2\mu\mathrm{G}$?)

C. You are also to turn in a hard-copy of your (very well-commented) program, along with all of the results. Or you can e-mail it to me at: wiita@chara.gsu.edu

Note that all of the questions asked in the above project description should be explicitly answered, and a top score on this project would involve a coherent discussion of the points raised by those questions as well as a working code and good answers to the queries.