

Physics 82, Advanced Lab

Plasma Physics 2002

General Information

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Part 1: Experimental The instructor (Doc) will familiarize you with the plasma apparatus. It is very much like the apparatus for the e/m experiment in P8. There is an array of tungsten filaments heated white hot by about 10 A of filament current. There is a bias voltage (-40 V or so) which accelerates electrons off the filament towards the anode (a grounded screen) producing a diffuse several ampere electron “beam”. There is also a small amount of argon gas admitted into the vacuum chamber. The main difference here is that the primary electrons partially ionize the argon gas and leave behind a tenuous plasma throughout the volume consisting of argon ions and electrons stripped from the argon. Bear in mind that there are two distinct populations of electrons in the machine: “primary” electrons with 40 V or so of drift energy and “plasma” electrons that are relatively cold. There are as many argon ions as there are total electrons (to a high degree of approximation).

A: The initial experiment consists of measuring the electron temperature and electron density with a Langmuir probe (refer to the folder containing supplementary notes from UCLA and Princeton). There are written procedures on how to pump the chamber down, how to vent the chamber, how to make a plasma, how to clean the probes and how to take and analyse data. Once a steady state plasma is maintained in the chamber and the probe is cleaned, begin to measure electron current to the probe as a function of probe voltage using the Keithley source meter. Scan from about -10 V to 10 V in small steps (say 100 mV). You’ll need to monitor parameters to make sure they don’t drift much (especially gas pressure and discharge current). Basically, you’ll want to plot the log of $I_{electron}$ (positive values) vs V_{probe} . The slope of the line is $1/T$ where T is in electron volts. You can estimate the density from $J = nev$ where J is the current density to the probe and v is the thermal velocity of the electrons. Once you’ve done the calculation below, you’ll want to fit the data to the predicted function for $I(V)$ to extract n and T (using Kaleidagraph).

B: Once you’ve established that you can do a single point measurement of n and T with a probe, try changing something. For example, it might be interesting to see how n and T change if you turn on a dc magnetic field (the coils aren’t cooled so don’t leave them on long). Try changing the gas pressure (predict what will happen to n and T). Since the probe is moveable, you can do a radial scan of T and n (predict what the profiles will look

like). Pulsing the discharge current is also possible (so you can study plasma buildup and decay). You might want to do the pulsed experiment and run the simulation described below to compare. Finally, there is a second grid in the machine which can be driven with an oscillating voltage and a detector grid at the end of the machine. Read up on ion acoustic waves then try to launch the wave and measure the signal. Under most circumstances the wave is heavily damped so the signal will be small. A boxcar averager or an averaging scope may be necessary if you choose this experiment.

Part 2: Calculations and computations The main calculation each of you should do is the integral which predicts the electric current to the probe tip as a function of voltage. Essentially, there is a Maxwell distribution of ions and electrons in the plasma so when you apply a voltage to the probe tip only a certain population of particles have enough energy to be collected. See the Owens' notes in the folder for details.

If you're interested, the instructor (Doc) can familiarize you with two plasma particle programs (MacES1 and MacPDP1). Each code basically calculates the net electric field (in 1D) at the location of each plasma particle (ion or electron) due to the presence of all it's neighbors and applied potentials. The particle feels a force (qE) and it's velocity and position are changed ($F=ma$). After all the particles are pushed, all the fields are re-calculated and the process is repeated. MacES1 is a periodic code (no boundaries, particles that leave one side appear on the other) and MacPDP1 is a bounded code (the boundaries can be sources or sinks for particles and can be set to arbitrary potentials).

The computational experiment consists of running several of the initial conditions and discussing what you see (red = electrons, blue = ions). In general, you'll want to watch the phase space plot (v_x vs. x) and the distribution function ($f(v_x)$) but have a look at as many diagnostics as you can (potential(x), charge(x) and $E(x)$ are interesting to watch too). Note that the more diagnostics you run, the slower the program goes. You'll need to quit the program each time you want to change the input file.

For each run, write down what you think is going on. Print any plots that look interesting (or save the data for a future analysis). You can even change the input files if you want (please re-name the file if you do this!!). Maybe you can run a simulation that sheds some light on an experiment from Part 1.

Here are some interesting input files to try...

MacES1 2.02: 2stream.inp, beamplas.inp, cold17.inp, ep.inp, epmass.inp, landau.inp

MacPDP1 2.02: bpd.inp, maxwell.inp, p111a.inp, qmach.inp, rfdh.inp, vc.inp