General: We’ll begin our first meeting going over the organization of our seminar. Let’s determine whether Tuesday evening is the optimum time slot for us (Andrew has a Tuesday afternoon seminar, Abram is busy Thursday night, I have commitments Wednesday night, some of you have commitments Monday night). We’ll start off doing some simple phenomenological aspects of plasma physics (plasma frequency, Debye shielding, plasma parameter) and simple drifts. I’ll do the first break.

Required Reading: Goldston, chapters 1 and 2

Supplementary Reading: I like what Nicholson does in his chapter 1. Chen chapter 1 and 2 are also illuminating.

Important Concepts: plasma frequency $\omega_{pe}$, Debye length $\lambda_D$, plasma parameter $\Lambda \gg 1$, simple drifts $E \times B / B^2$, $F \times B / qB^2$... Plasma is an ionized, quasineutral gas that exhibits collective behavior. We will see that the interparticle potential energy in a plasma is much less than the particle kinetic energy. It will be important to distinguish collective effects ($\omega_{pe}, \lambda_D$) from single particle effects ($\omega_c, \nu_c$).

Presentations: This week, let’s have everyone present a problem. Have a look at the others. I’ll be ready to jump in to help with any of them.

Andrew: Goldston 1.4... show that the plasma parameter $\Lambda$ is also a measure of the ratio of the mean plasma kinetic energy to the mean interparticle potential energy. This means that the “plasma criterion” that there be lots of particles in a Debye cube amounts to saying that plasmas have much more kinetic than potential energy.

Abram: Show that the following relativistic Lagrangian for a charge in an electromagnetic field lead to the correct equation of motion for the charge (ie the Lorentz equation):

$$\mathcal{L} = -mc^2\sqrt{1 - \frac{v^2}{c^2}} + \frac{e}{c} A \cdot v - e\phi$$

Matt: Show us something about $E \times B$ motion using Mathematica or IDL.

Mike L: Similar to Chen 2.7... An electron beam has a density of $n_e = 10^{14} m^{-3}$, a radius of 1 cm, and flows along a $B_0 = 1 T$ magnetic field. The beam makes it’s own electric field... find the $E \times B$ velocity at the edge of the beam. Compare the collective $E \times B$ rotation frequency to the local Larmor
frequency of the electrons. If the electron temperature is 10 eV, what is the electron Larmor radius?

Chris: Langmuir-Child law and plasma between plates. It’s interesting to see the transition from the vacuum solution to Laplace’s equation (ie a linear ramp) to the plasma solution to Poisson’s equation (ie flat with sheaths at the ends). Chen 1.6 is related and has an interesting connection between particle energy and λ_D. Griffiths 2.48 and/or Bellan 1.10 spell out the Langmuir-Child problem relating current to the voltage between the plates.

everyone: Similar to Chen 1.3, make your own log-log plot of \( n_e \) vs. \( T_e \) use Goldston table 1.1 and add some more (SSX, SPD, look in PRL for some plasma examples, etc). Go maybe 20 orders of magnitude in density (from \( 10^{-1} \) to \( 10^{20} \) \( cm^{-3} \) and from 0.1 to \( 10^4 \) eV in temperature. Put in some lines of constant Λ (say 1 and 1000) and constant \( \lambda_D \) (say 1 \( \mu m \) and 1 cm).

\( \omega_{pe}, \nu_c, \) and \( \Lambda \) (mb): There’s an interesting connection among Debye length \( \lambda_D \), plasma parameter \( \Lambda \), plasma frequency \( \omega_{pe} \), and collision frequency \( \nu_c \). It actually happens a lot in plasma and fluid physics that seemingly unrelated parameters are connected (often via a useful dimensionless number). For example, the Larmor radius and Debye length are each related the thermal speed and a characteristic frequency: \( \rho = v_{th}/\omega_c \) and \( \lambda_D = v_{th}/\omega_p \). We’ll see later on that the ratio of the ion Larmor radius to the ion inertial length is \( \sqrt{\beta} = \rho_i/\delta_i \).

**Assigned Problems:** just those above.

**Additional Problems:** none this week.

**Break:** Doc