Physics 138
Plasma Physics 2003
Seminar 3

General: Now that we know something about drifts of individual particles in complex electromagnetic fields ($\mathbf{E}(\mathbf{r}, t), \mathbf{B}(\mathbf{r}, t)$), the next step is to consider an ensemble of particles acting as a fluid. Some authors (Nicholson, Bellan) introduce the electron and ion distribution functions $f_{e,i}(\mathbf{v}, \mathbf{x}, t)$ at this point and then consider “moments” of the distribution function. For example, the mean density is the integral of $f(\mathbf{v}, x)$ ($n(x) = \int f(\mathbf{v}, x)v^0 dv$), the mean velocity flux of each species is the first moment ($n(x)v(x) = \int f(\mathbf{v}, x)v^1 dv$), etc. Goldston chooses to defer this approach (called “kinetic theory”) until later. This allows us to get into waves and MHD earlier.

Chen makes an interesting point in his chapter 3. One might think of a magnetized plasma as a magnetic medium. However, simple magnetic materials have a linear relationship between field and magnetization ($\mathbf{M} = \chi_m \mathbf{H}$, $\chi_m$ is the susceptibility and $\mathbf{B} = \mu \mathbf{H}$, so $M \propto B$), plasmas have an inverse relationship ($\mu = W_\perp / B$ so $M \propto 1/B$). We’ll find that a dielectric treatment of plasma will be fruitful. Goldston discusses the low frequency perpendicular dielectric constant for a plasma on p. 54 (ch. 4).

Bellan points out in the introduction to his book that there is no clear starting point for plasma physics (nothing like the postulates of quantum mechanics). The various approaches to plasma physics are connected and the arguments are circular. This is why plasma texts are so different. This is also why various disciplines study plasmas from such different perspectives (fusion science vs. solar vs. astrophysics vs. industrial plasmas). Nonetheless, the concepts are completely scalable so the same physics applies to plasma waves in a 1 $\mu$m laser plasma as it does to a 1 $Mpc$ astrophysical jet.

Required Reading: Goldston, chapters 6 and 7. We’ve been doing a lot of reading the past few weeks (hopefully in more than just Goldston) but I think the concepts haven’t been that hard... there’ll be less reading and more challenging material next week.

Supplementary Reading: Check out Chen chapter 3, Bellan chapter 2, and Nicholson chapter 7.


Presentations: We could do two or three...
**Diamagnetic drift (Andrew):** Discuss the diamagnetic drift. Review it’s physical origin ala figure 7.1 in Goldston. The diamagnetic drift isn’t a bone fide particle drift like we studied last week (you can have a diamagnetic current without a net transport of particles). Do Chen 3.7, 8, 9 (all linked), which says a cylindrically symmetric plasma column in a uniform $B$ has

\[ n(r) = n_0 \exp(-r^2/r_0^2), \quad n_i = n_e = n_0 \exp(e\phi/kT) \]

Show $v_E$ and $v_{De}$ are equal and opposite. Show that the plasma rotates as a rigid rotor. Calculate the diamagnetic current. How much does the diamagnetic current reduce $B$ on axis?

**Pressure tensor (Abram):** Talk to us about the pressure tensor $P_{ij}$ and it’s role in momentum balance. Do Goldston 6.1. Show that $P_{ij}$ is diagonal if $f(v)$ is spherically symmetric in $v$ (ie not necessarily Maxwellian). What does it mean if $P_{ij}$ is diagonal but say $P_{11} = P_{22} \neq P_{33}$? What do finite off-diagonal elements mean?

**Fluid equations from distribution functions (Mike L):** Look at Bellan chapter 2 and summarize the connection between particle distribution functions and the fluid equations. Goldston gets to this in his chapter 22 so we’ll see this again.

**Assigned Problems (good background for everyone):** Goldston 6.1, 6.3, 7.1, 7.2, Chen 3.7 (see above).

**Additional Problems:** none this week.

**Break:** Matt