EE507 – Plasma Physics and Applications

Homework #1

1. Compute the typical Debye length for the various plasmas found in the plot of plasma density vs. electron temperature discussed in class. How many particles are there in a “Debye sphere” ($r = \lambda_D$) on each case?

2. The typical distance between two electrons in a plasma is of the order of $n_e^{-1/3}$. Show that the potential energy associated with bringing two electrons this close together is much less than their typical kinetic energy, so long as $n_e\lambda_D^3 >>1$.

3. An alternative derivation of λ_D may give further insight to its meaning. Consider two infinite, parallel plates at $x = \pm d$, set at potential $\phi = 0$. The space between them is filled by a gas of density n of particles of charge q.

    a) Using Poisson’s equation, show that the potential distribution between the plates is $\phi = nq\,(d^2 - x^2) / 2\varepsilon_0$.

    b) Show that for $d > \lambda_D$, the energy needed to transport a particle from a plate to the midplane is greater than the average kinetic energy of the particles.

4. A spherical conductor of radius a is immersed in a plasma and charged to a potential ϕ_0. The electrons remain Maxwellian and move to form a Debye shield, but the ions are stationary during the time frame of the experiment. Assuming $\phi_0 << kT_e/e$, derive an expression for the potential as a function of r in terms of a, ϕ_0, and λ_D.

5. Starting from the Maxwellian distribution function for the velocity (v_x, v_y, v_z), find the Maxwellian distribution $g(v)$ for the speed $v = (v_x^2 + v_y^2 + v_z^2)^{1/2}$. Using this distribution function, calculate (without consulting the class notes) the most probable speed v_p, the mean speed $\langle v \rangle = \int_0^\infty v g(v) dv$, and the root-mean-square speed $v_{rms} = \sqrt{\int_0^\infty v^2 g(v) dv}$.