PHY 525 Homework 1 Due: Tue, Sept. 17, 2019

1. Plasma parameters

Find the Debye lengths, d_e , $d_{i,}$ the plasma parameters, N_{de} , N_{di} , the plasma frequencies, ω_{pe} , ω_{pi} , and the thermal velocities, v_{Te} , v_{Ti}, for elecrons and ions (protons) under the following conditions:

(a) A fusion device: $n_e=n_i=10^{16}$ cm^{-3}, $T_e=T_i=10^7$K;
(b) The Earth's magnetosphere: $n_e=n_i=10^4$ cm^{-3}, $T_e=T_i=10^3$K;
(c) The center of the Sun: $n_e=n_i=10^{26}$ cm^{-3}, $T_e=T_i=10^{7.2}$K;
(d) The solar corona: $n_e=n_i=10^8$ cm^{-3}, $T_e=T_i=10^6$K;
(e) The solar wind: $n_e=n_i=10$ cm^{-3}, $T_e=T_i=10^5$K;
(f) The atmosphere of a neutron star: $n_e=n_i=10^{12}$ cm^{-3}, $T_e=T_i=10^7$K.

Can all of these cases qualify to be described as ``plasmas''?

2. Particle interactions

Show that, in a nonrelativistic plasma ($kT << m_e c^2$), the mutual Coulomb (elecrostatic) force between two typical particles is much more important than the mutual Lorentz (magnetic) force.

3. Debye shielding

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 d_e. (Hint: assume a solution of the form e^{-kr}/r.)

4. Gravitational drift

What is the gravitational drift speed of an electron in a tokamak, with $|B_0|$=10kG? How about a proton? Does either of these drifts make it hard to confine a plasma in a volume of order 1 m^3 for a time of order 1s?