Plasma Physics Fall 2002

Problem Sets 1

Due date: Monday Sept. 16

1. Distribution function and averages. The average of a quantity G(**v**) over a distribution function f(**v**) is defined as

The Maxwellian distribution (in three dimensions) is

$$< G >= \frac{\int G(\mathbf{v}) f(\mathbf{v}) d^3\mathbf{v}}{\int f(\mathbf{v}) d^3\mathbf{v}}$$

The Maxwellian distribution (in three dimensions) is

$$f(\mathbf{v}) = n\left(\frac{m}{2\pi T}\right)^{3/2} \exp\left(-\frac{mv^2}{2T}\right)$$

Note that the isotropy of this distribution means that all Cartesian coordinates are equivalent, there is no preferred direction.

(a) Prove that the form of f is correctly normalized, i.e. that $\int f d^3\mathbf{v} = n$

Evaluate the averages of the following

(b) a specific Cartesian coordinates: $< v_x >$

(c) the square velocity: $< v^2 >$, and hence the average particle energy $< \frac{1}{2} mv^2 >$

(d) the average speed $< |\mathbf{v}| >$

2. Copmpute λ_D and N_D for the following cases:

(a) A glow discharge, with $n = 10^{16}\ \mathrm{m}^{-3}, KT_e = 2\ \mathrm{eV}$

(b) The earth's ionosphere, with $n = 10^{12}\ \mathrm{m}^{-3}, KT_e = 0.1\ \mathrm{eV}$

(c) A θ − pinch, with $n = 10^{23}\ \mathrm{m}^{-3}, KT_e = 800\ \mathrm{eV}$

Are they all plasmas?

3. Suppose the degree of ionization of a gas discharge is governed by the Saha equation:

$$\frac{n_e n_i}{n_0} = 2\frac{(2\pi m_e T)^{3/2}}{h^3} \exp\left(-\frac{\chi_i}{T}\right)$$

- and the Debye length is small relative to the discharge size. Calculate approximately the temperature at which the gas is 50% ionized if $\chi_i = 13$ eV, and its total pressure is equal to one atmosphere. What is then the ratio of the electron density to the density of a room-temperature gas at the same pressure?