Basic Space Plasmas Physics
Assignment 1

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1 Temperature and Energy

In plasma physics, temperature T and energy E are closely related; it is customary to give temperature in units of energy. That is $E = kT$. Here k is Boltzmann's constant. Compute the conversion factor.

2 Saha Equation

Saha equation tells us the amount of ionization to be expected in a gas in thermal equilibrium:

$$\frac{n_i}{n_n} \approx 2.4 \times 10^{21} \frac{T^{3/2}}{n_i} e^{-U_i/kT} \tag{1}$$

Here n_i and n_n are, respectively, the number density (number per m^3) of ionized atoms and of neutral atoms, T is the gas temperature in K, k is Boltzmann's constant, and U_i is the ionization energy of the gas-that is, the energy required to remove the outermost electron from the atom.

For ordinary air at room temperature, we may take $n_n \approx 3 \times 10^{25} m^{-3}$, $T \approx 300K$, and $U_i = 14.5eV$ (for nitrogen). Compute the fractional ionization $n_i/(n_n + n_i)$; what about in a vacuum of $0.01Pa$ at $5 \times 10^3 K$?

3 Debye Shielding

In a strictly steady state situation, both the ions and the electrons will follow the Boltzmann relation

$$n_j = n_0 \exp(-q_j \phi / kT_j) \tag{2}$$

For the case of an infinite, transparent grid charged to a potential Φ, show that the shielding distance is then given approximately by

$$\lambda_D^{-2} = \frac{ne^2}{\epsilon_0} \left(\frac{1}{kT_e} + \frac{1}{kT_i}\right) \tag{3}$$

Show that λ_D is determined by the temperature of the colder species.

Hint: Use Possion's equation: $\nabla^2 \phi = -\frac{q}{\epsilon_0}$ ($\vec{E} = -\nabla \cdot \phi$, $\nabla \cdot \vec{E} = \frac{q}{\epsilon_0}$).

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