High-Intensity / Relativistic Optics

Problem set 3—mean temperature, Debye length, plasma frequency

1. **Exercise:** In a strictly steady state situation, both the ions and the electrons obey a Boltzmann distribution

$$n_{\mathrm{j}} = n_0 \exp\left\{\frac{-q_{\mathrm{j}}\phi}{\mathrm{k_B}T_{\mathrm{j}}}\right\} .$$

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

$$\frac{1}{\lambda_{\mathrm{D}}^2} = \frac{n_0 \mathrm{e}^2}{\epsilon_0}\left(\frac{1}{\mathrm{k_B}T_{\mathrm{e}}} + \frac{1}{\mathrm{k_B}T_{\mathrm{i}}}\right) .$$

   Show that λ_{D} is determined by the temperature of the colder species.

2. **Exercise:** The plates of a rectangular capacitor are at a potential difference of $\pm\phi_0$ and at a distance of $2R$. The capacitor is filled with a plasma which has a Debye length of λ_{D}. What is the potential and the electric fields between the capacitor plates?
   Discuss the limits of $R \gg \lambda_{\mathrm{D}}$ and $R \ll \lambda_{\mathrm{D}}$.

3. **Exercise:** Improve the derivation of the plasma frequency ω_{P} by taking into account the mass of the ions. Assume that the ions in the ion layer all move together.