Plasma Physics for Fusion
Assignment 1

Part (a)

Describe two of the conditions that are necessary for an ionised gas to be considered a plasma. (15%)

A small, positively charged sphere is placed into a quasi-neutral plasma. If the sphere has charge Ze, where $-e$ is the charge of an electron, explain what happens. Include in your explanation:

(i) a description of Debye screening;

(ii) a description of the Debye length and how it depends on plasma density and temperature, and

(iii) an estimate of the order of magnitude of the electrostatic potential just outside the Debye sphere in a plasma of temperature T.

(25%)

Part (b)

If particles have a Maxwellian velocity distribution, show that the conservation of energy implies a Boltzmann relation between the density, n, and electrostatic potential, ϕ:

$$n = n_0 \exp\left[-\frac{Ze\phi}{T}\right],$$

where Ze is the particle charge and T is the plasma temperature. (20%)

A sphere of positive charge Ze and radius R is lowered into an infinite plasma. Assuming that the ion density is fixed, independent of the potential, and that the electron density satisfies the Boltzmann relation, show that:

$$\phi(r) = \frac{Ze}{4\pi\epsilon_0 r} \exp\left[-\frac{(r-R)}{\lambda_D}\right],$$

where r is the distance from the centre of the sphere. Derive an expression for the Debye length, λ_D. You may assume $e\phi/T \ll 1$. (40%)