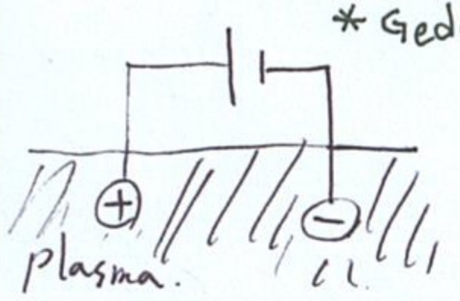
Definition of Plasma

A ***plasma*** is a "quasineutral" gas of charged and neutral particles which exhibits "collective behaviour".

What is the plasma?

* Gedank Experiment



$$\varepsilon_0 \nabla \cdot \vec{E} = \rho$$

$$\nabla^2 \phi = \frac{-\rho}{\varepsilon_0}$$

$$\frac{d^2\phi}{dx^2} \simeq \frac{e}{\varepsilon_0}(n_e - n_i) \simeq \frac{e}{\varepsilon_0}\left[n\left(1+\frac{e\phi}{kT_e}\right) - n\right] = \frac{ne^2\phi}{\varepsilon_0 kT_e} = \frac{1}{\lambda_D^2}\phi$$

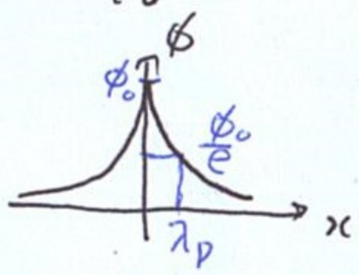
$$\lambda_D = \sqrt{\frac{\varepsilon_0 kT_e}{ne^2}}$$

$$\frac{d^2\phi}{dx^2} = \frac{1}{\lambda_D^2}\phi$$

$$\left(x=0,\ \phi=\phi_0 \quad ; \quad x\to\infty,\ \phi=0\right)$$

$$\Downarrow$$

$$\phi = \phi_0 e^{-\frac{|x|}{\lambda_D}}$$



$$\frac{\phi}{L^2} = \frac{e}{\varepsilon_0}(n_e - n_i) \rightarrow \left(e\phi << kT_e\right) \rightarrow \frac{e^2L^2}{\varepsilon_0}(n_e - n_i) << kT_e$$

$$\rightarrow \frac{e^2L^2}{\varepsilon_0}(n_e - n_i) = \frac{e^2 n}{\varepsilon_0 kT_e} \cdot \frac{(n_e - n_i)}{n} kT_e L^2 = \frac{L^2}{\lambda_D^2} kT_e \frac{(n_e - n_i)}{n} << kT_e$$

$$\rightarrow \frac{n_e - n_i}{n} << \frac{\lambda_D^2}{L^2} \quad \text{if} \quad \lambda_D << L \Rightarrow \left(\frac{\lambda_D^2}{L^2} \to 0\right) \Rightarrow \boxed{n_e \approx n_i}$$

quasi-neutrality

collective behaviour

$$\boxed{N_D = \frac{4}{3}\pi \lambda_D^3 n >> 1}$$

charged particle number — plasma density

$$\left|\frac{e\phi}{kT_e}\right| << 1$$

$$\Downarrow$$

$$* \; n_e = n \exp\left(\frac{e\phi}{kT_e}\right) \simeq n\left(1 + \frac{e\phi}{kT_e} + \cdots\right)$$

$\omega\tau >> 1$

ω : plasma frequency

τ : collision time.