Langat Singh College, Muzaffarpur
NAAC Grade 'A'
Under B. R. A. Bihar University, Muzaffarpur

# Plasma physics –lecture - 04

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# Plasma Density in Electrostatic Potential

- When there is a varying potential, ϕ, the densities of electrons (and ions) is affected by it.
- If electrons are in thermal equilibrium, they will adopt a Boltzmann distribution of density

$$n_e \propto \exp\left(\frac{e\phi}{T_e}\right) \qquad (18)$$

- This is because each electron, regardless of velocity possesses a potential energy $-e\phi$.
- Consequence is that (fig 5) a self-consistent loop of dependencies occurs.
- This is one elementary example of the general principle of plasmas requiring a self consistent solution of Maxwell's equations of electrodynamics plus the particle dynamics of the plasma

# Debye Shielding

- A slightly different approach to discussing quasi-neutrality leads to the important quantity called the Debye Length.
- Suppose we put a plane grid into a plasma, held at a certain potential, $\phi_g$.

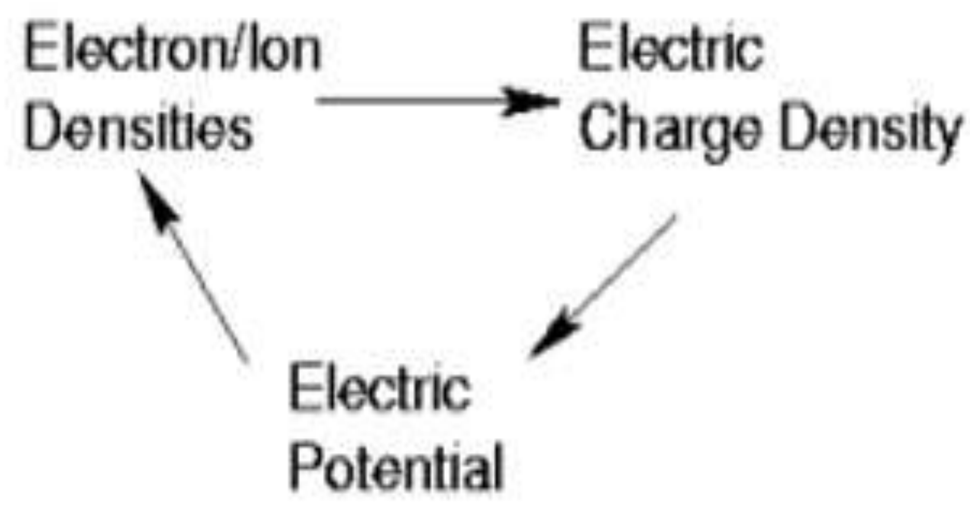


Fig. 5: Self-consistent loop of dependencies

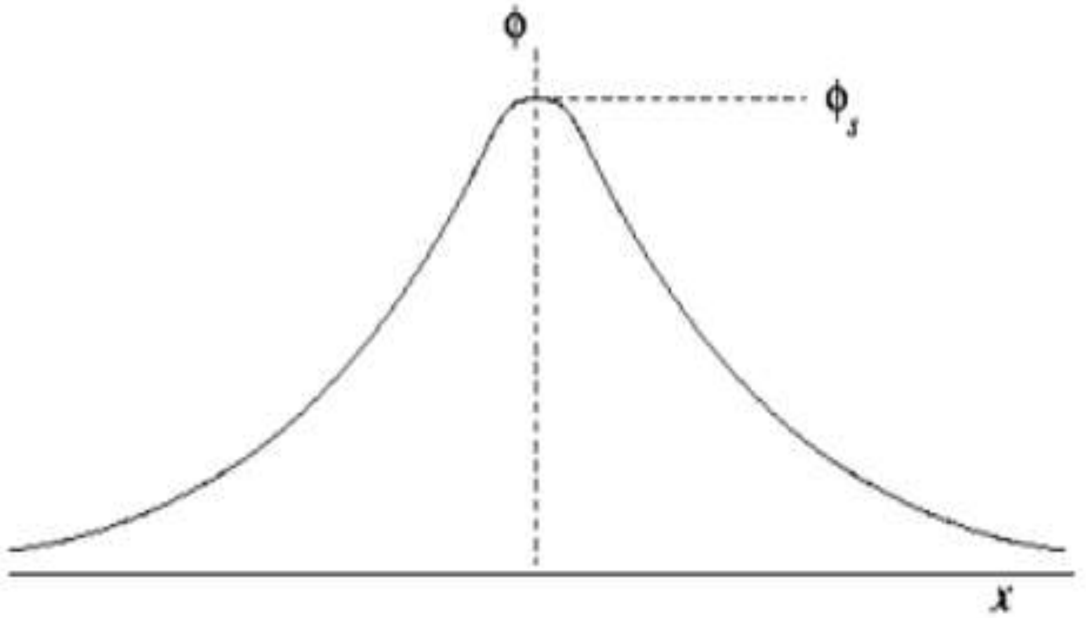


Fig.: 6 Shielding of fields from a 1-D grid

Then, unlike the vacuum case, the perturbation to the potential falls off rather rapidly into the plasma. We can show this as follows. The important equations are:

Poisson's Equation $$\nabla^2 \phi = \frac{d^2\phi}{dx^2} = -\frac{e}{\epsilon_0}(n_i - n_e) \quad (19)$$

Electron Density $$n_e = n_\infty \exp(e\phi/T_e). \quad (20)$$

[This is a Boltzmann factor; it assumes that electrons are in thermal equilibrium. $n_\infty$ is density far from the grid (where we take $\phi = 0$).]

$$\text{Ion Density} \quad n_i = n_\infty \,. \tag{21}$$

[Applies far from grid by quasineutrality; we just assume, for the sake of this illustrative calculation that ion density is not perturbed by $\phi$ perturbation.] Substitute:

$$\frac{d^2\phi}{dx^2} = \frac{e n_\infty}{\epsilon_0}\left[\exp\left(\frac{e\phi}{T_e}\right) - 1\right] \tag{22}$$