



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

Plasma physics –lecture - 02

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Plasmas are QuasiNeutral

- If a gas of electrons and ions (singly charged) has unequal numbers, there will be a net charge density, ρ

$$\rho = n_e(-e) + n_i(+e) = e(n_i - n_e) \quad (2)$$

- This will give rise to an electric field via

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} = \frac{e}{\epsilon_0}(n_i - n_e) \quad (3)$$

Example: Slab

$$\frac{dE}{dx} = \frac{\rho}{\epsilon_0} \quad (4)$$

$$\rightarrow E = \rho \frac{x}{\epsilon_0} \quad (5)$$

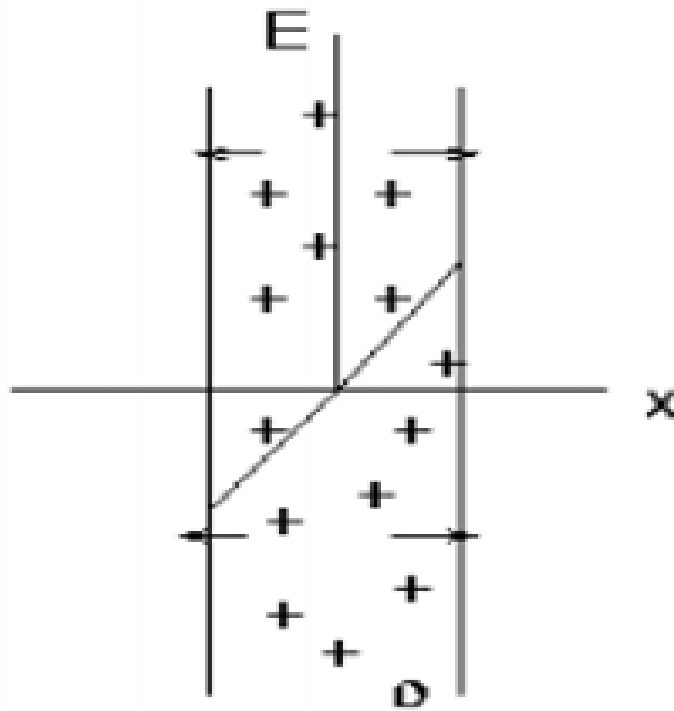


Fig. 3: Charged Slab

- This results in a force on the charges tending to expel whichever species is in excess. That is, if $n_i > n_e$, the E field causes n_i to decrease, n_e to increase tending to reduce the charge. This restoring force is enormous
- Example
- Consider $T_e = 1\text{eV}$, $n_e = 10^{19}\text{m}^{-3}$ (a modest plasma; c.f. density of atmosphere $n_{\text{molecules}} \sim 3 \times 10^{25}\text{m}^{-3}$). Suppose there is a small difference in ion and electron densities $\Delta n = (n_i - n_e)$

$$\text{so } \rho = \Delta n e \quad (6)$$

- Then the force per unit volume at distance x is

$$F_e = \rho E = \rho^2 \frac{x}{\epsilon_0} = (\Delta n e)^2 \frac{x}{\epsilon_0} \quad (7)$$

- Take $\Delta n/n_e = 1\%$, $x = 0.10\text{m}$

$$F_e = (10^{17} \times 1.6 \times 10^{-19})^2 0.1 / 8.8 \times 10^{-12} = 3 \times 10^6 \text{ N.m}^{-3} \quad (8)$$

- Compare with this the pressure force per unit volume $\sim p/x$: $p \sim n_e T_e (+n_i T_i)$

$$F_p \sim 10^{19} \times 1.6 \times 10^{-19} / 0.1 = 16 \text{ Nm}^{-3} \quad (9)$$

- Electrostatic force \gg Kinetic Pressure Force.
- This is one aspect of the fact that, because of being ionized, plasmas exhibit all sorts of collective behavior, different from neutral gases, mediated by the long distance electromagnetic forces E , B .
- Another example (related) is that of longitudinal waves.
- In a normal gas, sound waves are propagated via the intermolecular action of collisions.
- In a plasma, waves can propagate when collisions are negligible because of the coulomb interaction of the particles.