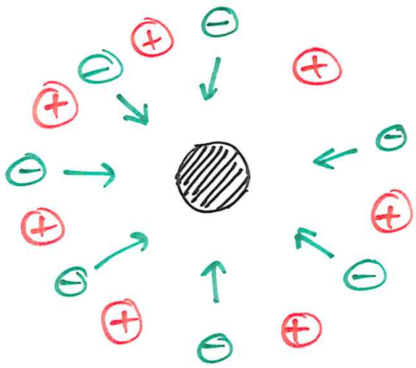
PLASMA SHEATH AND OBJECTS IN PLASMA

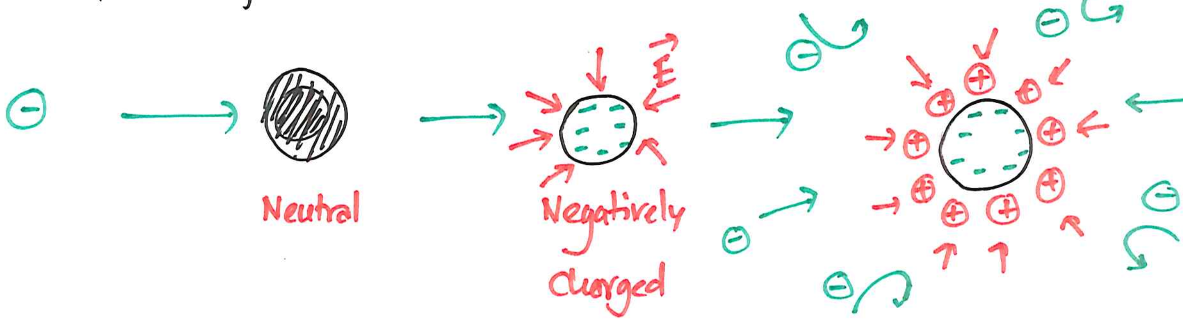


$$V_{the} \gg V_{thi}$$

$$\sqrt{\frac{KT_e}{m_e}} \gg \sqrt{\frac{KT_i}{m_i}}$$

usually, $T_e > T_i$

This object could be a probe, dust or surface of spacecraft.



- Electrons are fast, they will attach to the surface and will make the object -ve charged.

- The negatively charged object now has lower potential w.r.t. the background plasma. Hence inward electric field.

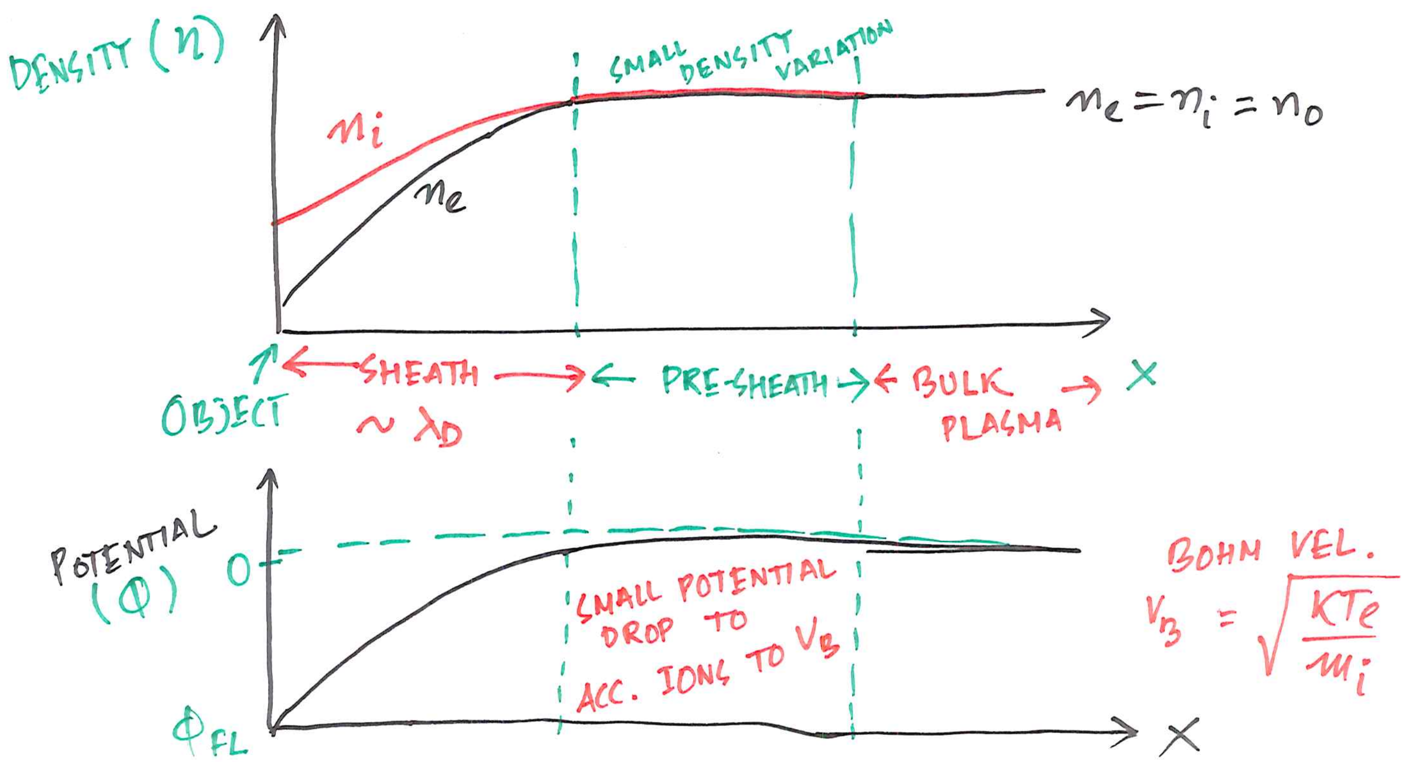
- The field will attaract ions in the vicinity and repel the electrons. (mostly). The electrons which have higher velocity still can reach the surface.

- Eventually, there will be a cloud of ions around the object to shield the electric field.

IN SUMMARY, THE DEBYE SPHERE IS BEING FORMED, WHICH IS ALSO KNOWN AS DEBYE SHEATH.

NOTE: THE CHARGING OF THE SPHERE WILL DEPEND ON THE SURFACE CONDITIONS, AND THE TYPE OF THE MATERIAL (i.e. CONDUCTIVE, INSULATOR). APART FROM THESE, THE GEOMETRY IS ALSO IMPORTANT.

DENSITY DISTRIBUTION AROUND THE OBJECT



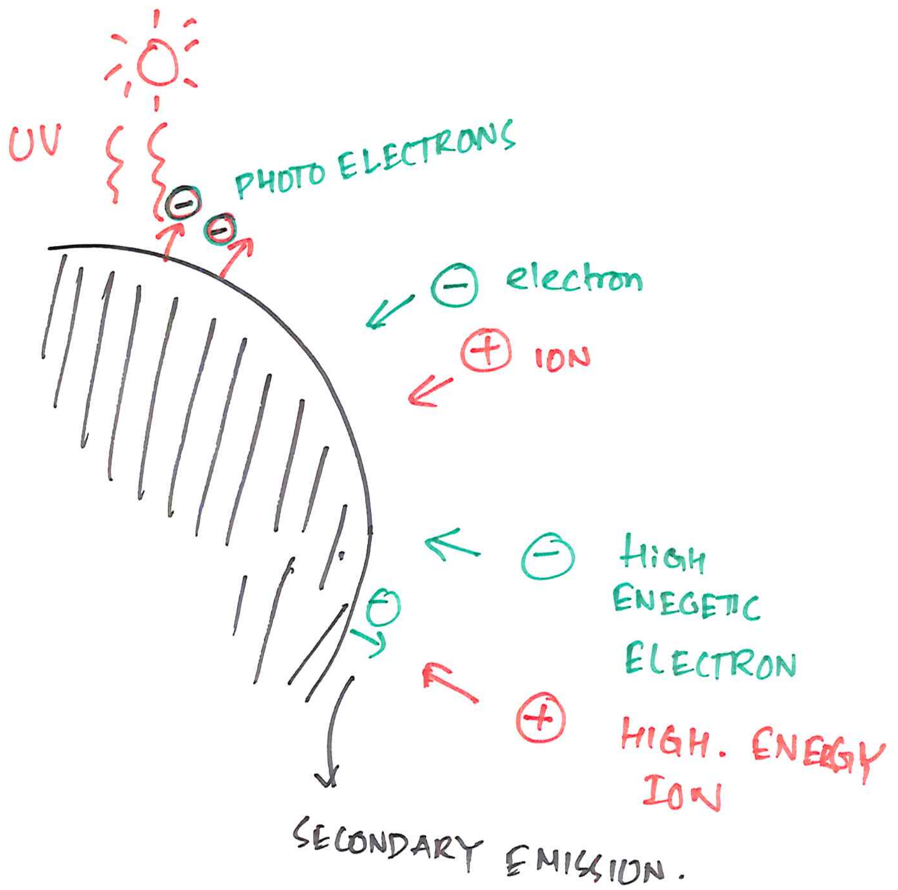
- The presheath electric field is responsible for the accelaration of ions to Bohm velocity (V_B).

- Bohm velocity is considered to be one of the important criteria to develop ion sheath and the spatial point points the sheath edge.

$$\frac{1}{2} m V_B^2 = q \Delta \phi$$

$$\Rightarrow \Delta \phi = 0.5 \left(\frac{KT_e}{q} \right)$$

A COMPLETE CHARGING SCENARIO



POTENTIAL OF THE OBJECT

$$\frac{dQ}{dt} = C\frac{dV}{dt}$$

In steady state, $\frac{dQ}{dt} \approx 0$

$$\sum_{i,e} I_{i,e} \approx 0$$

The stationary state in charging is defined or referred to the point when the charge of the object does not change anymore.

i.e. there is a balance between I_e and I_i.

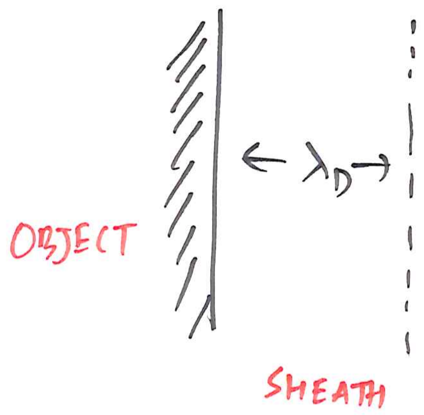
$\Rightarrow$ $I_i + I_e +$ OTHER CURRENTS ≈ 0

$\Downarrow$

Φ_{FL} FLOATING POTENTIAL

LARGE OBJECT (PLANAR SHEATH)

LARGE OBJECT $\longrightarrow$ r_0 (radius of the object) $\gg \lambda_D$



CURRENT TO THE SURFACE

$$I_e = j_e \cdot A$$

$$I_i = j_i \cdot A$$

Considering, Maxwellian distn.

$$f(v)\,dv = 4\pi v^2 \left(\frac{m}{2\pi KT}\right)^{3/2} e^{-\frac{mv^2}{2KT}} dv$$

$$j_{e,i} = \frac{1}{4} q_{e,i}\, n_{e,i} \langle V_{e,i} \rangle$$

$\langle V_{e,i} \rangle$ → Avg. velocity

$\frac{1}{4}$ → This factor comes due to the assumption that particles collected must have their velocity vector directed towards collecting surface.

Electron Current

$$I_e = -\frac{1}{4} A e n_e \langle V_e \rangle e^{-e\phi/KT_e}$$

$e^{-e\phi/KT_e}$ → This term decides how much electron is capable of overcoming the sheath potential.

$$\boxed{I_e = -\frac{1}{4} A e n_e \sqrt{\frac{8KT_e}{\pi m_e}}\, e^{-e\phi/KT_e}}$$

For IONS, all incoming ions to the surface will be absorbed by the surface.

$$I_i = \frac{1}{4} A q_i n_i \langle v_i \rangle = \frac{1}{4} q_i n_i A \sqrt{\frac{8KT_i}{\pi m_i}}$$

FOR A STATIONARY SITUATION!

$$\sum_j I_j = 0$$

$$I_e + I_i = 0$$

USING EXPRESSIONS FOR I_i and I_e

$$\Rightarrow \quad \phi_{FL} = -\frac{KT_e}{e} \ln \frac{\langle v_e \rangle}{\langle v_i \rangle} + \phi_0$$

ϕ_0 → reference potential

NOTE: It only comes for space plasma, OTHERWISE '0'

Small factor ↓

$$\Rightarrow \quad \phi_{FL} = -\frac{KT_e}{2e} \ln \left[\frac{T_e m_i}{T_i m_e} \right]$$

$$\phi_{FL} \sim -T_e$$

For example, In Hydrogen plasma

$$\phi_{FL} \approx -3.75 \frac{KT_e}{e}$$

For COLD IONS: ($T_e \gg T_i$)

$$\phi_{FL} = -\frac{kT_e}{2e}\left[\ln\left(\frac{m_i}{2\pi m_e}\right) + 1\right] + \phi_0$$

$-\frac{kT_e}{2e}$

responsible for ion acceleration to Bohm vel.

IRVING LANGMUIR (1881 - 1957)

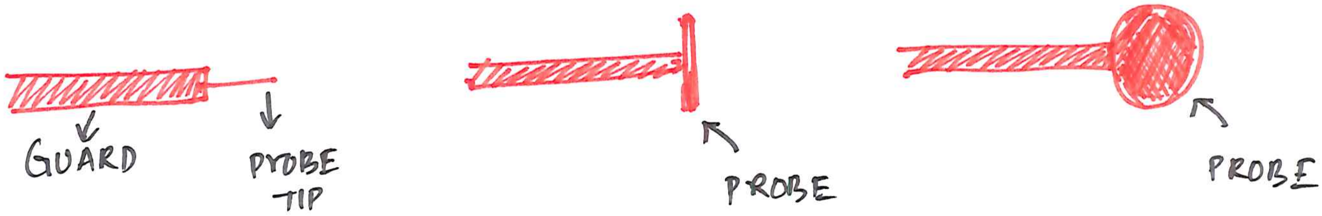
- LANGMUIR PROBES are one of the most used and fundamental diagnostics for any plasma environments.

WHAT ARE LANGMUIR PROBES ??

LANGMUIR Probes are thin metalic bodies with specific shapes that collects electrons and ions to provide a diagnostics of the plasma.

WHAT ARE THE MOST COMMONLY USED SHAPES?

1. Cylindrical 2. Planar 3. Spherical



- LANGMUIR PROBES ARE INSERTED INTO PLASMA AND THEY ARE CONNECTED TO A POTENTIAL SOURCE WHICH ALLOWS THEM TO COLLECT CHARGED PARTICLES WITH DIFFERENT ENERGIES.

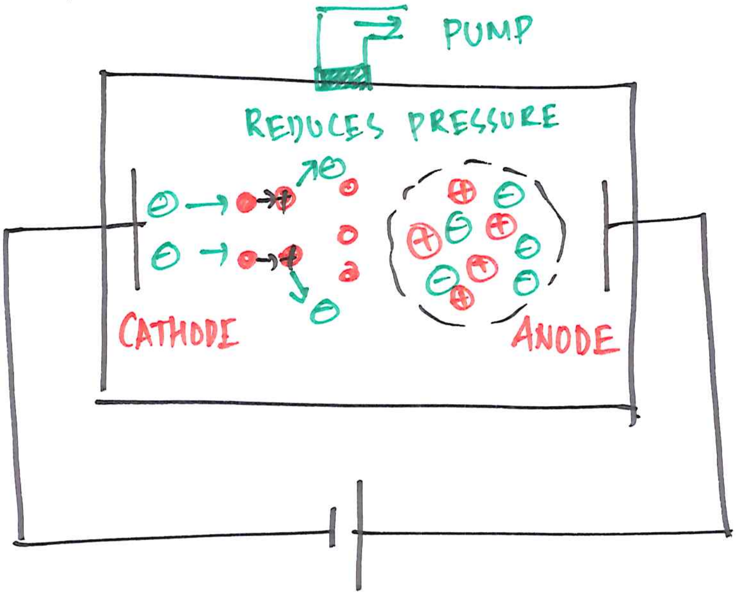
$$I_p = I(V_p)$$

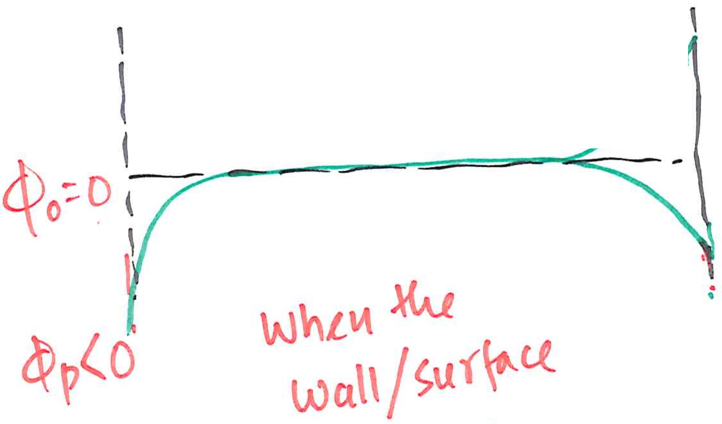
Probe current (I_p), Probe voltage (V_p)

provides I-V characteristics

LABORATORY PLASMA (DC DISCHARGE)

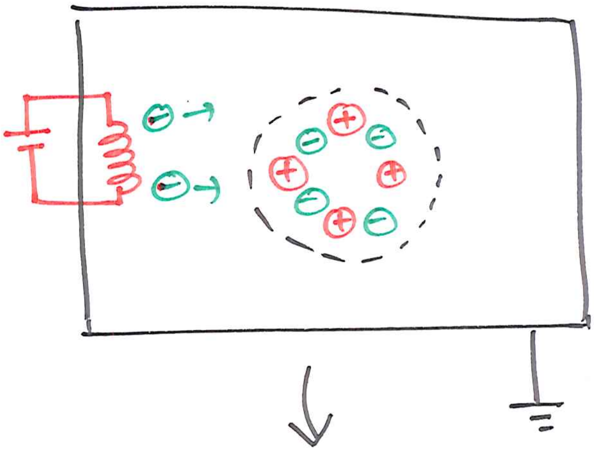
TYPE-I

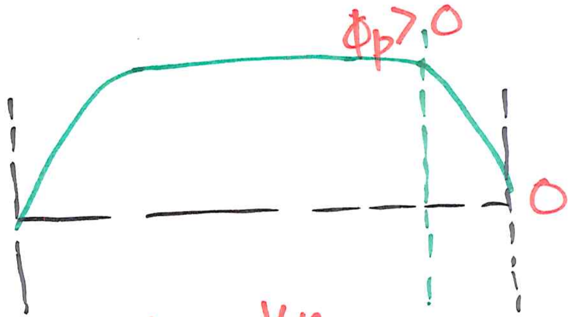




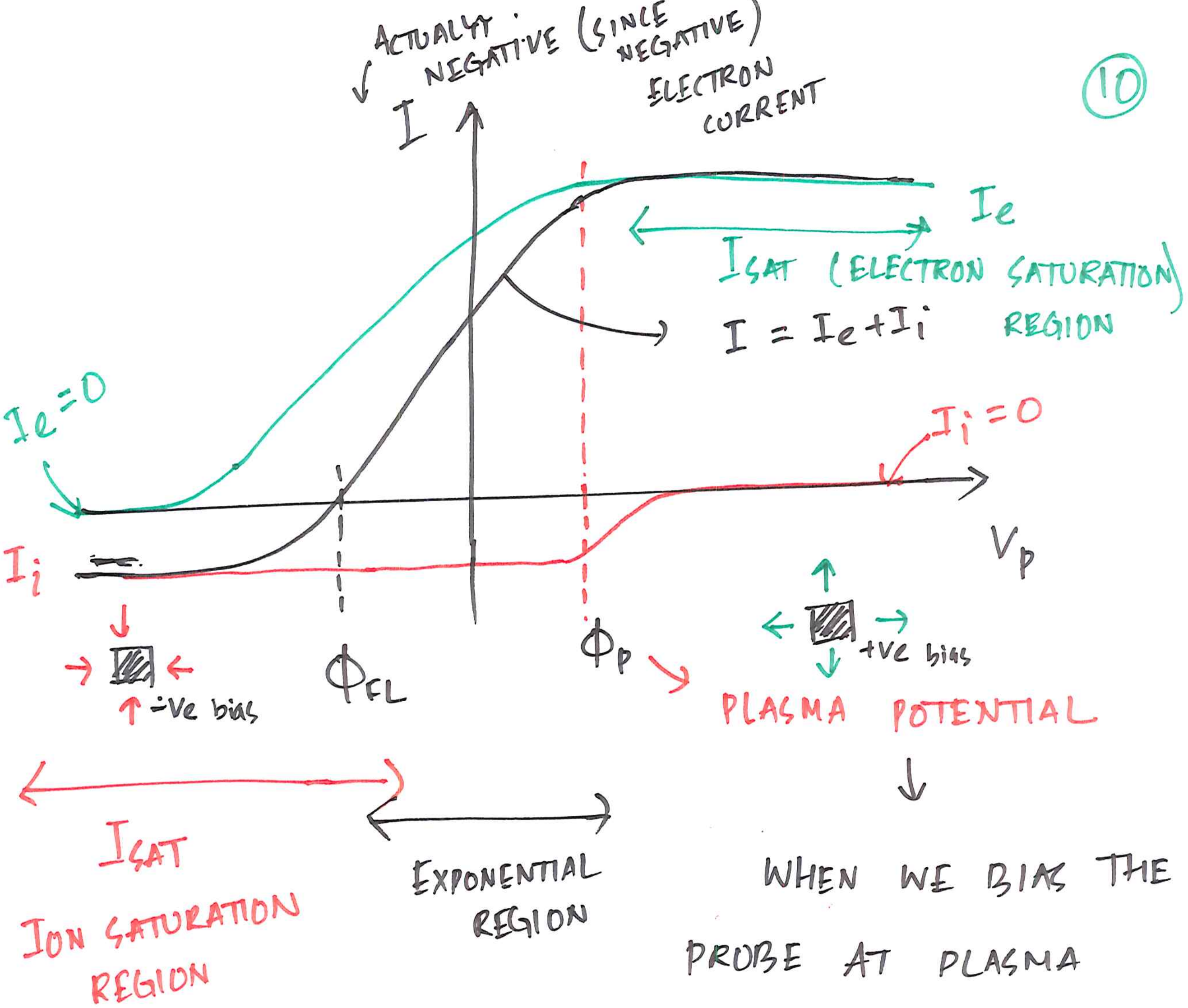
When the wall/surface is floating

TYPE-II





When the wall/surface is grounded



WHEN WE BIAS THE PROBE AT PLASMA POTENTIAL, THERE WILL BE EFFECTIVELY NO CURRENT OR, NET CURRENT 0 (ZERO)

EFFECT OF SHAPES