Instrumentation

- Overview:
  - Magnetic field,
  - Electric field,
  - Plasma waves,
  - Plasma instruments,
  - Particle instruments.

- Pre-requisites:
  - Magnetohydrodynamics,
  - Properties of space plasmas.

- Keep in mind:
  - Understanding of space physics requires a skillful combination of instruments on a satellite,
  - If possible, combination of satellites for spatial information.

Magnetic field measurements I

- Pulsation magnetometer:
  - Three coils perpendicular to each other,
  - Measured quantity: induction due to magnetic field fluctuations,
  - Gives vector of fluctuations but no absolute values for the field.

- Fluxgate magnetometer:
  - Three sensors with axes perpendicular to each other,
  - Measures absolute field,
  - Measurement principle transformer: the outer field causes on earlier saturation of the core.

- Alkali vapor magnetometer:
  - Measurement principle Zeeman effect,
  - Two cells stimulated by radio signals.

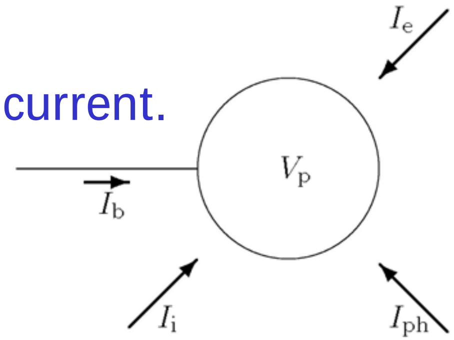
Magnetic field measurements II

- Proton precession instrument:
  - Absolute values but no fluctuations,
  - Proton-rich liquid inside a coil,
  - Orientation of proton spin due to a current in the coil,
  - Current switched-off: proton alignment along the external magnetic field leads to a precession with a frequency proportional to the field strength.

E-field probe

- Basic idea: measure the potential difference between two points.

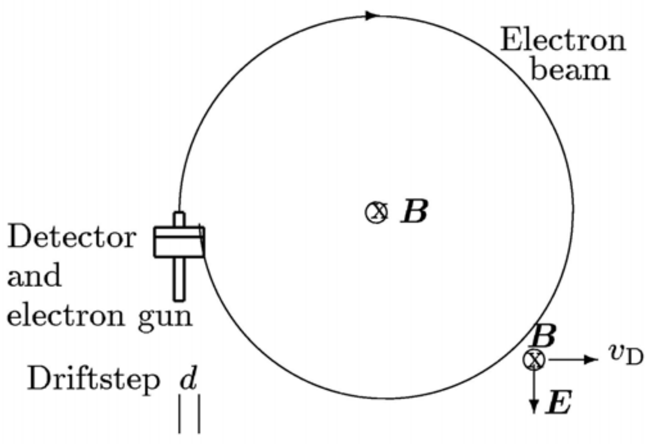
- Problem: potential modified by many disturbances
  - Motion of the satellite causes an uxB induction field,
  - Ionization due to hard electromagnetic radiation,
  - Interaction with the ambient plasma,
  - Compensation of these potentials by a bias-current.



- Alternatively: drift instrument.

Drift instrument E-field

- Components:
  - Electron gun, well-defined particle energy,
  - Coil, well defined magnetic field perpendicular to the electron orbit,
  - Position sensitive electron detector.



- Measuring principle: ExB drift causes offset d of the particle orbit proportional to the field.

- Advantage: plasma not influenced by the measuring principle,

- Disadvantage: magnet required (power, influence on other instruments)

Plasma measurements

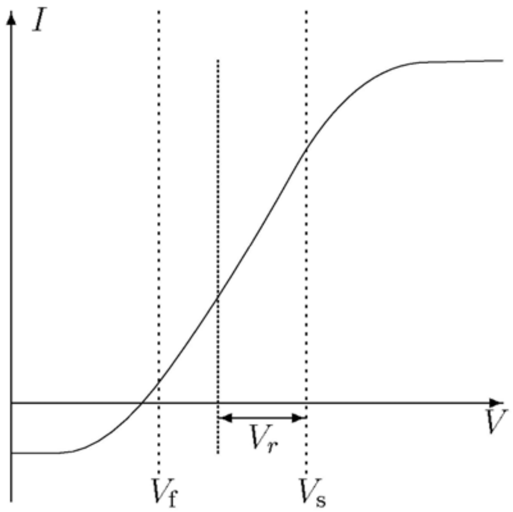
- Dense plasma (collective effects):
  - Langmuir probe (slide 7),
  - Retarding potential analyzer: Langmuir probe with additional grid (ion trap),
  - Impedance measurement: measurement of the dielectric constant with an oscillating circuit (frequency give capacity and thus ε),
  - Resonance method: medium between sender and receiver resonates with a frequency depending on its density.

- Rarefied plasma (single particle measurement):
  - Mass spectrometer: similar to laboratory experiment but simpler because no vacuum required.
  - Time-of-Flight spectrometer (slide 8).

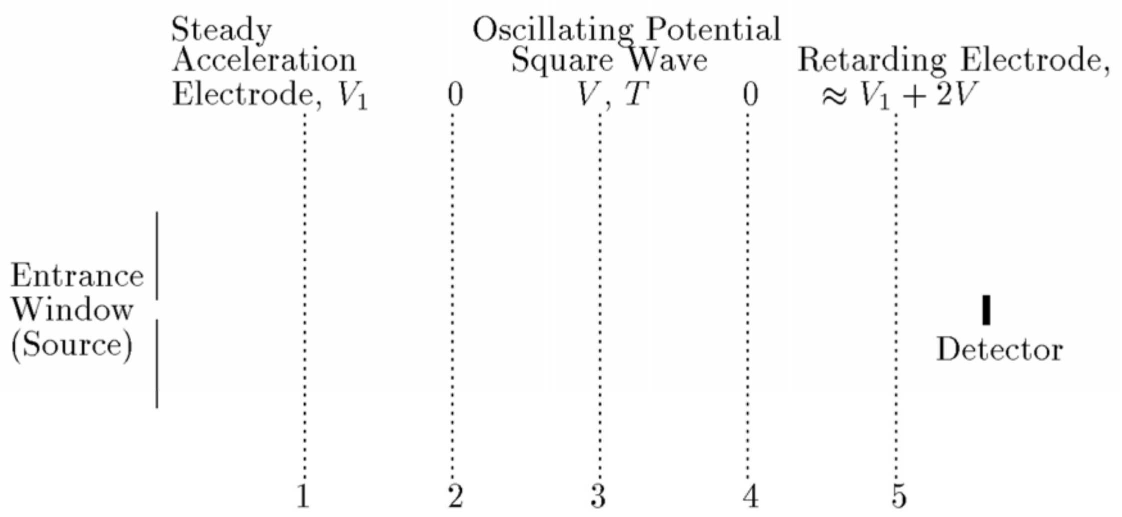
Langmuir probe

- Space Potential Vs as universal reference potential.
- Floating Potential Vf: negative charging in a quasi-neutral plasma due to the higher electron speed.

- Variation of the potential:
  - Larger than space potential: attraction of electrons and repulsion of protons
    $\Rightarrow$ current determined by the electron density.
  - Potential between space and floating potential: only the faster electrons reach the probe.
  - Potential below floating potential: repulsion of electrons, measurement of protons and ions.

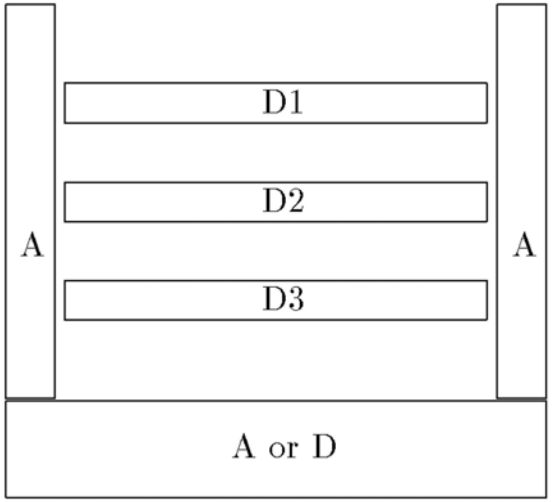


Time of Flight Method



- Potential difference between 1 and 2 accelerates particles with a well-defined Δv depending on m/q.
- Oscillating potential at 3 selects particles with speeds close to 2d/T (T oscillation period, d distance 2 – 3).
- 5 filters all particles with speeds below maximum speed.
- Particles hitting the detector are sorted by speed and m/q.

Particle telescope



- Pre-requisite:
  - Particle energy high enough to ionize,
  - Particle flux small enough to allow for single particle measurement.

- Measuring principle:
  - Energy losses in a detector stack give:
    - Total particle energy (sum of losses in the detectors),
    - Particle species (thresholds for energy loss in the upper detectors),
  - Direction of incidence (entrance aperture, sectorized detectors),
  - Particles incident outside the entrance aperture are identified by an active anticonincidence.

Pulse height analysis

- Exact identification of particle species and energy,
- Energy loss in the second-last plotted versus residual energy in the last detector,
- Scatter around locus because of
  - Statistics,
  - Particles incident under different angles,
  - Multiple scattering.