Topics covered here are:

- What is Plasma?
- Its Characteristics
- Plasma Oscillations
- Plasmon and plasmon frequency

Sources used here are:

http://farside.ph.utexas.edu/teaching/plasma/Plasmahtml/node1.html

https://www.britannica.com/science/plasma-state-of-matter/Plasma-oscillations-and-parameters

What is Plasma

The electromagnetic force is generally observed to create *structure*: *e.g.*, stable atoms and molecules, crystalline solids.

Structured systems have binding energies larger than the ambient thermal energy. Placed in a sufficiently hot environment, they decompose: *e.g.*, crystals melt, molecules disassociate. At temperatures near or exceeding atomic ionization energies, atoms similarly decompose into negatively charged electrons and positively charged ions.

These charged particles are by no means free: in fact, they are strongly affected by each others' electromagnetic fields. Nevertheless, because the charges are no longer bound, their assemblage becomes capable of collective motions of great vigor and complexity. Such an assemblage is termed a *plasma*.

Of course, bound systems can display extreme complexity of structure: *e.g.*, a protein molecule. Complexity in a plasma is somewhat different, being expressed *temporally* as much as *spatially*. It is predominately characterized by the excitation of an enormous variety of *collective* dynamical modes.

Its occurrence and characteristics

Since thermal decomposition breaks interatomic bonds before ionizing, most terrestrial plasmas begin as gases. In fact, a plasma is sometimes defined as a gas that is sufficiently ionized to exhibit plasma-like behavior.

- Note that plasma-like behavior ensues after a remarkably small fraction of the gas has undergone ionization. Thus, fractionally ionized gases exhibit most of the exotic phenomena characteristic of fully ionized gases.

- Plasmas resulting from ionization of neutral gases generally contain equal numbers of positive and negative charge carriers. In this situation, the oppositely charged fluids are strongly coupled, and tend to electrically neutralize one another on macroscopic length-scales. Such plasmas are termed *quasi-neutral* (``quasi'' because the small deviations from exact neutrality have important dynamical consequences for certain types of plasma mode).

- Strongly *non-neutral* plasmas, which may even contain charges of only one sign, occur primarily in laboratory experiments: their equilibrium depends on the existence of intense magnetic fields, about which the charged fluid rotates.

- It is sometimes remarked that 95% of the baryonic content of the Universe consists of plasma. This statement has In earlier epochs of the Universe, everything was plasma. In the present epoch, stars, nebulae, and even interstellar space, are filled with plasma.

- The Solar System is also permeated with plasma, in the form of the solar wind, and the Earth is completely surrounded by plasma trapped within its magnetic field.

- Terrestrial plasmas are also not hard to find. They occur in lightning, fluorescent lamps, a variety of laboratory experiments, and a growing array of industrial processes. In fact, the glow discharge has recently become the mainstay of the micro-circuit fabrication industry.

- Liquid and even solid-state systems can occasionally display the collective electromagnetic effects that characterize plasma: *e.g.*, liquid mercury exhibits many dynamical modes, such as Alfvén waves, which occur in conventional plasmas.

Plasma oscillation, in physics, the organized motion of electrons or ions in a plasma. Each particle in a plasma assumes a position such that the total force resulting from all the particles is zero, thus producing a uniform state with a net charge of zero. If an electron is moved from its equilibrium position, the resulting positive charge exerts an electrostatic attraction on the electron, causing the electron to oscillate about its equilibrium position. Because the interaction between electrons is strong, they all oscillate together at a characteristic frequency that depends on the nature of the particular plasma. Such plasma oscillations occur in the Earth’s atmosphere and in interstellar gas clouds.

Just as a lightweight cork in water will bob up and down about its rest position, any general displacement of light electrons as a group with respect to the positive ions in a plasma leads to the oscillation of the electrons as a whole about an equilibrium state. In the case of the cork, the restoring force is provided by gravity; in plasma oscillations, it is provided by the electric force. These movements are the plasma oscillations that were studied by Langmuir and Tonks. Analogously, just as buoyancy effects guide water waves, **plasma oscillations are related to waves in the electron component of the plasma called Langmuir waves.** Wavelike phenomena play a critical role in the behaviour of plasmas.

Plasmons:

The free electrons in a metal may be considered an electron plasma. In this case a plasmon is a quasiparticle resulting from the quantization of plasma oscillations of the free electron gas density with respect to the fixed positive ions. Plasmons are Bosons.

The plasmon energy can be estimated as:

$$E_P = \hbar \sqrt{\frac{n \cdot e^2}{m_e \cdot \varepsilon_0}}$$

- n... conduction electron density
- e... elementary charge
- m... electron mass
- ε_0... Permittivity of free space
- $\hbar$... Planck constant

We can define the characteristical plasmon frequency ω_P:

$$\omega_P = \sqrt{\frac{n \cdot e^2}{m_e \cdot \varepsilon_0}} \rightarrow E_P = \hbar \cdot \omega_P$$

The optical properties of metals can be described with plasmons. Light of frequency below the plasmon frequency is reflected, because the electrons in the metal screen the electric field of the light. Light of frequency above the plasma frequency is transmitted, because the electrons cannot respond fast enough to screen it. Most metals and semiconductors are reflective in the visible range because their plasmon frequency is in the ultraviolet. Some metals, such as copper and gold, have electronic interband transitions in the visible range, whereby specific energies (colors) are absorbed. Thus, those metals have a distinct color.