Time: Wednesday 2-4 (9:30 ~12:00) PI

PP.

Office: Composite building 48212

office hour: whenever I am in my office and not in a meeting. You can check my schedule from my lab's calender. Please go to ISAPS webpage to find my calender.

~~Homework:~~

Text book: Introduction to plasma physics and controlled fusion, by Francis F. Chen.

~~Additional~~

Reference book: - Introduction to Plasma Theory. by Dwight R. Nicholson.

- NRL Plasma Formulary
www.nrl.navy.mil/ppd/content/nrl-plasma-formulary

TA: TBA.

Homework: Homeworks are expected every other week.

Exam: 2 midterm + 1 final.

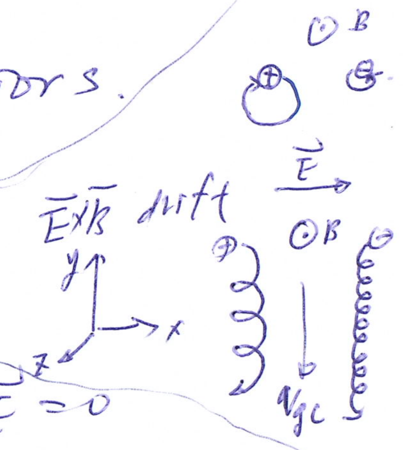
§ 0 Preface:

1. Introduction — Definition of plasma will be given.

~~2. Single Particle motions!~~

Plasma

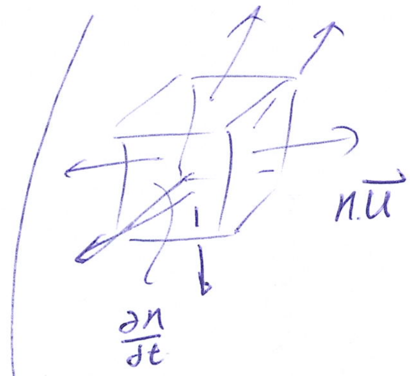
A plasma is a quasineutral gas of charged and neutral particles which exhibits collective behaviors.



2. Single - Particle motions.
   - Uniform $\vec{E}$ & $\vec{B}$
   - Nonuniform $\vec{B}$, $\vec{E} = 0$
   - Nonuniform $\vec{E}$, Uniform $\vec{B}$
   - Time - Varying $\vec{E}$, $\vec{E}, \vec{B}$ uniform in space
   - Time - Varying $\vec{B}$
   - Adiabatic invariants
     - 1st: $\mu = \frac{m v_\perp^2}{2B}$
     - 2nd: $J = \int_a^b v_\parallel \, ds$
     - 3rd: $\Phi = \int k \, ds$

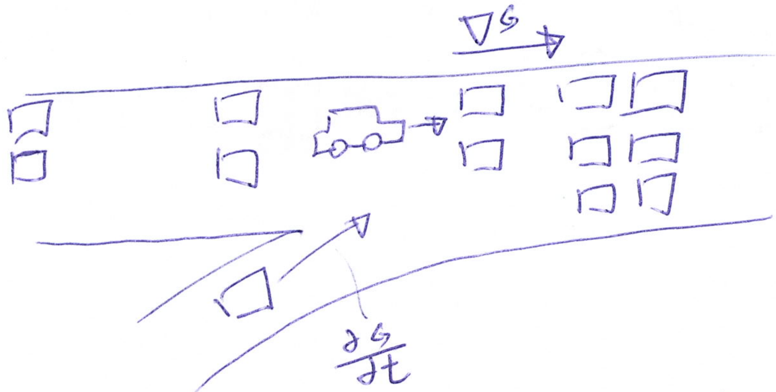
3. Plasma as Fluids.

$$\begin{cases} \dfrac{\partial n}{\partial t} + \nabla \cdot (n\vec{u}) = 0 & \text{Continuity eq.} \\ mn\left[\dfrac{\partial \vec{u}}{\partial t} + (\vec{u}\cdot\nabla)\vec{u}\right] = qn(\vec{E} + \vec{v}\times\vec{B}) - \nabla p & \text{momentum eq.} \end{cases}$$



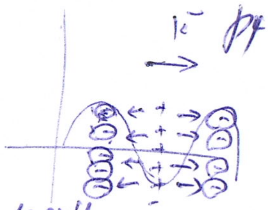
$$\frac{d\vec{G}(x,t)}{dt} = \frac{\partial \vec{G}}{\partial t} + \frac{\partial \vec{G}}{\partial x}\cdot\frac{dx}{dt} = \frac{\partial \vec{G}}{\partial t} + u_x\frac{\partial \vec{G}}{\partial x}$$

or
$$\frac{d\vec{G}(\vec{x},t)}{dt} = \frac{\partial \vec{G}}{\partial t} + (\vec{u}\cdot\nabla)\vec{G}$$

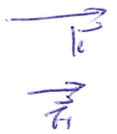


* The time derivative is to be taken at the "position of the particles (elements)". ~~However~~, The position is moving so that the gradient is taken into account.

4. Waves in Fluids.

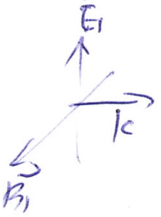


- Electrostatic wave: $\vec{B}_1 = 0$, $\vec{E}_1 \parallel \vec{k}$
  - Electron waves : ← high frequency, ion doesn't move
    - $\vec{B}_0 = 0$ or $\vec{k} \parallel \vec{B}_0$ Plasma Oscillation
    - $\vec{k} \perp \vec{B}_0$ Upper hybrid Oscillation

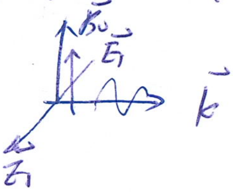


  - Ion waves : ← low frequency, electron moves w/ ions
    - $\vec{B}_0 = 0$ or $\vec{k} \parallel \vec{B}_0$ Acoustic waves
    - $\vec{k} \perp \vec{B}_0$ Electrostatic ion cyclotron waves / Lower hybrid oscillations

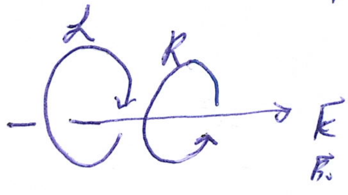
- Electromagnetic waves. $\vec{E}_1 \not\parallel \vec{k}$



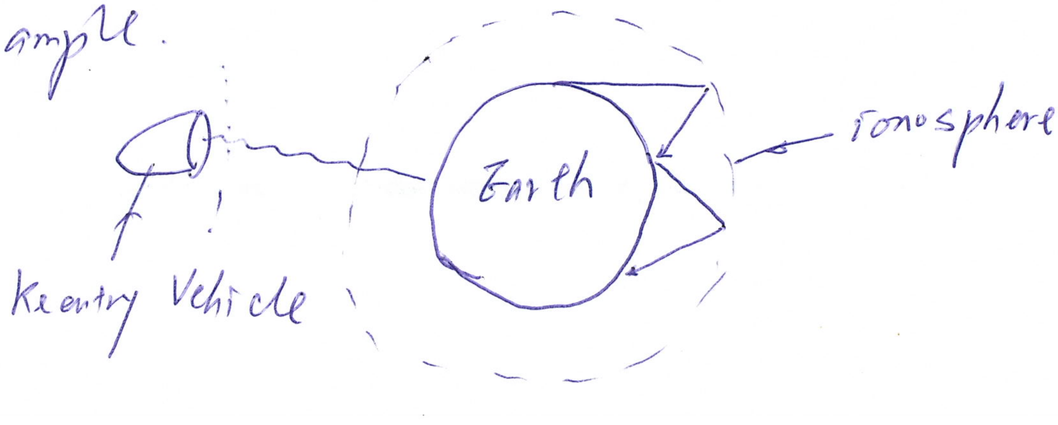
  - Electron waves ← high frequency
    - $B_0 = 0$ Light waves
    - $\vec{k} \perp \vec{B}_0$, $\vec{E}_1 \parallel \vec{B}_0$ O wave (Ordinary wave)



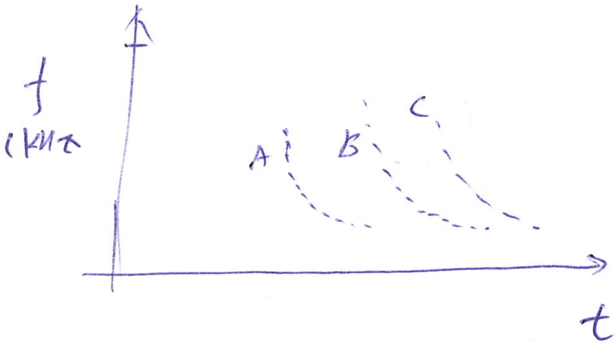
    - $\vec{k} \perp \vec{B}_0$, $\vec{E}_1 \perp \vec{B}_0$ X wave (extraordinary wave)
    - $\vec{k} \parallel \vec{B}_0$ R wave (whistler mode), L wave

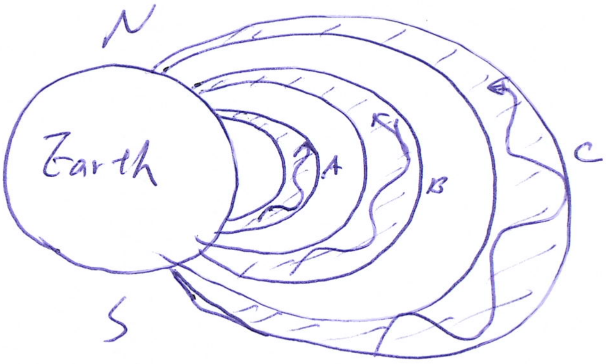


- Example.

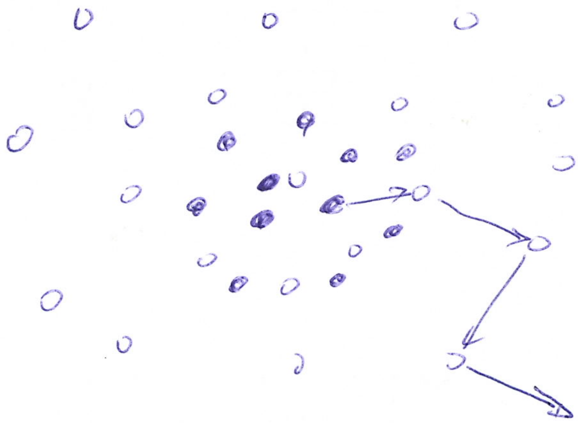


Whistler Mode

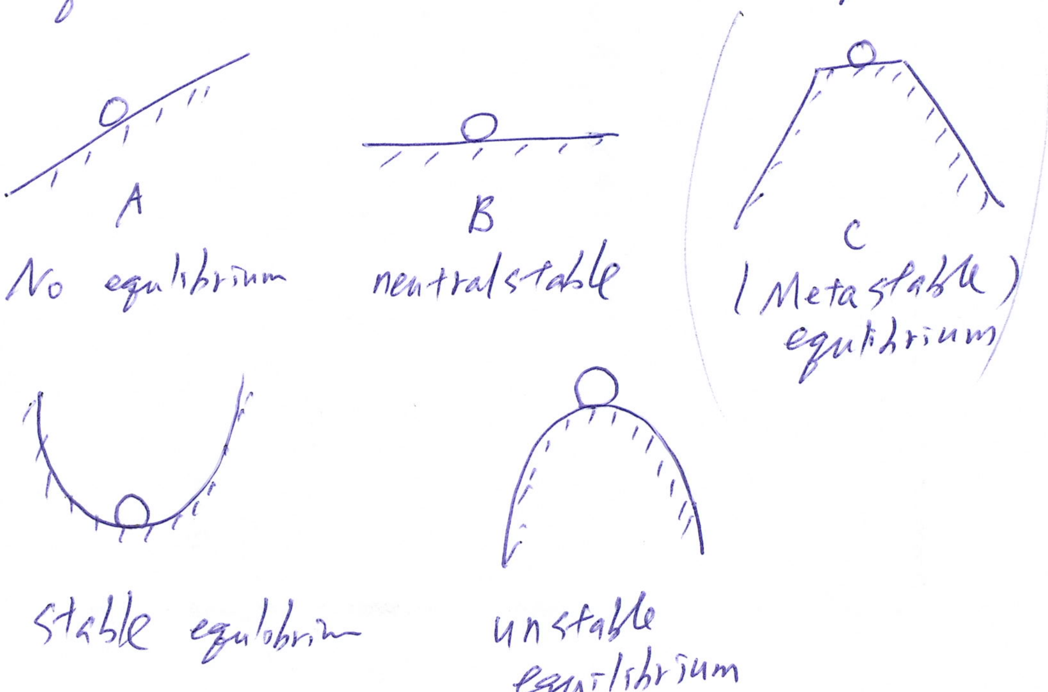




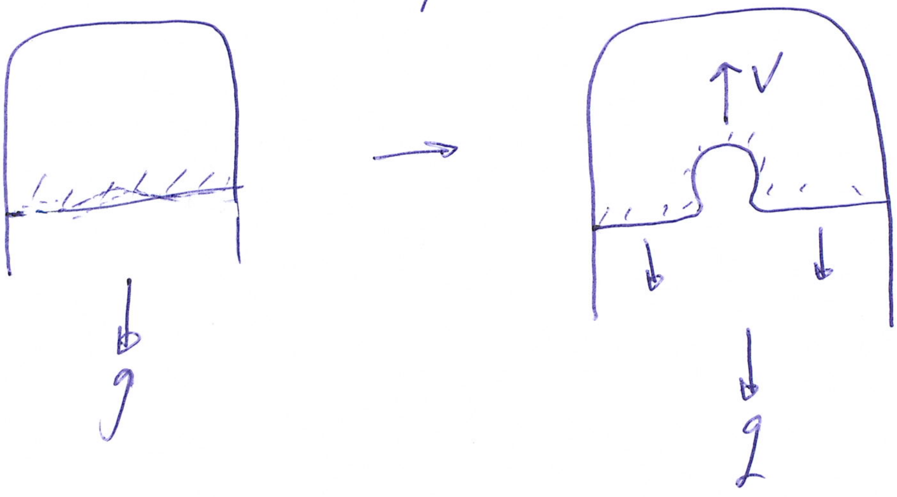
5- Diffusion and Resistivity

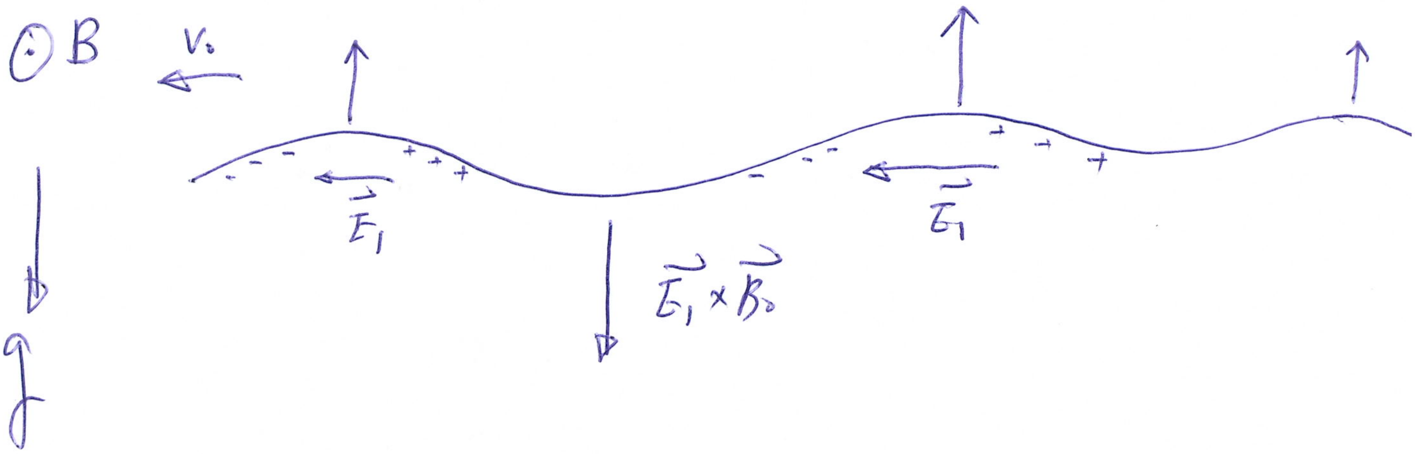


6- Equilibrium and Stability

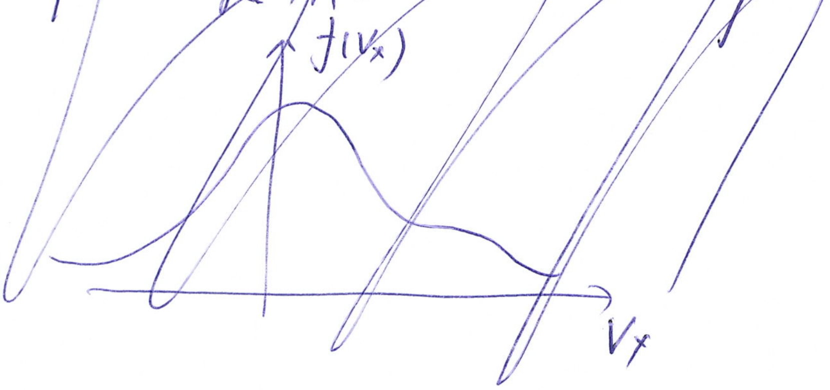


- Hydrodynamic Rayleigh-Taylor instability

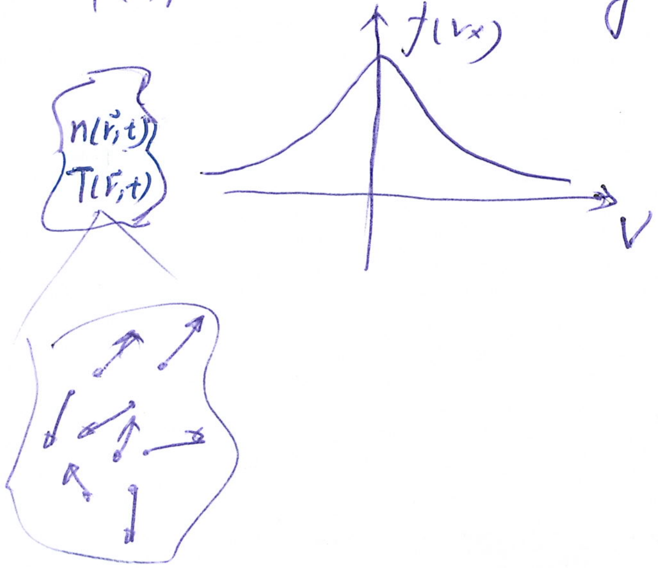




7- Kinetic Theory

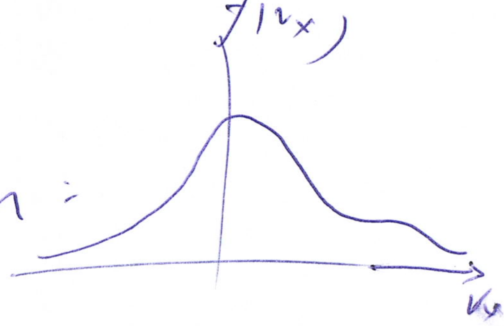


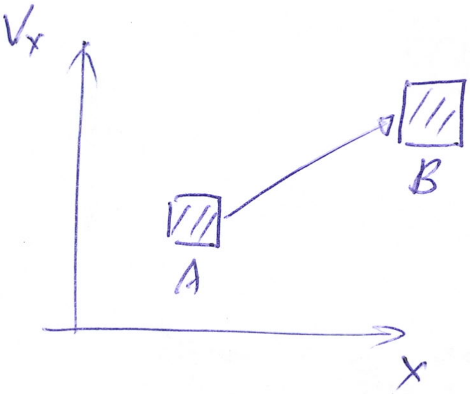
7. Kinetic Theory



$$f(v_x) = \left(\frac{m}{2\pi KT}\right)^{1/2} \exp\left(-\frac{v_x^2}{v_{th}^2}\right)$$

→ Non kinetic distribution:

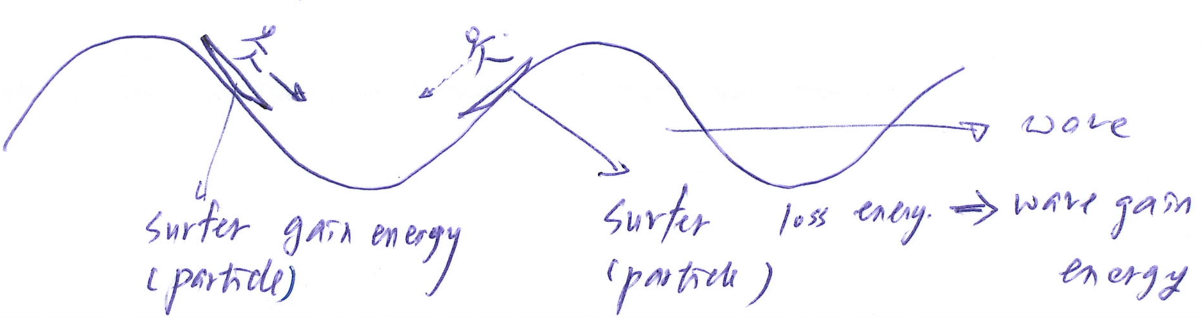




* use phase space $(\vec{x}, \vec{v})$ to ~~des~~ represent the position and velocity coordinates of a group of particles.

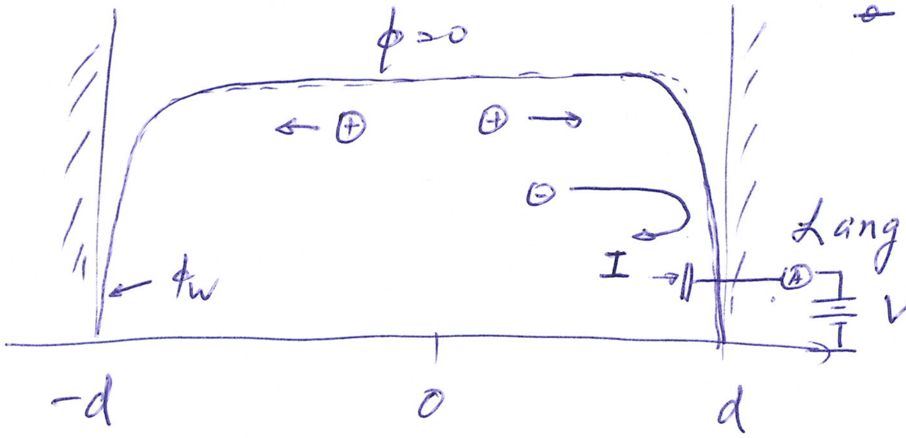
$$\frac{\partial f}{\partial t} + \vec{v} \cdot \nabla f + \frac{\vec{F}}{m} \cdot \frac{\partial f}{\partial \vec{v}} = \left(\frac{\partial f}{\partial t}\right)_c$$

* Landau damping:



8 Nonlinear Effects.

- Sheaths



$$\frac{1}{2}mv^2 \sim kT \Rightarrow v \propto \sqrt{\frac{T}{m}}$$

$v_e \gg v_i$ for $T_e = T_i$

- Langmuir probe use the I–V curve of the probe to determine the density and temperature of the plasma.