218A - 9 Big Ideas

Here we list 9 'big ideas' in fundamental plasma physics from 218A. These are the key points one should glean from the course.

i.) **Coulomb force as long range**
- a.) screening, λ_D, $n\lambda_D^3 > 1$ for "plasma" state
- b.) difference from hard sphere gas
- c.) infrared divergence – Coulomb logarithm

ii.) **Waves and Instabilities**
- a.) plasma, ion-acoustic, EM
- b.) Wave Energy Theorem
- c.) Negative Energy Waves, Instabilities $\rightarrow$ how dissipation can be destabilizing
- d.) Two Stream Instability - bunching

iii.) **Nonlinear Waves**
- a.) Steepening and breaking mechanisms
- b.) collisional and collisionless shocks/solitons
- c.) collisionaless shock models

iv.) **Kinetics**
- a.) Vlasov Equation from BBGKY hierarchy
- b.) Landau Damping
- c.) Physics of Landau Damping
- d.) Landau Growth, B-O-T instability

v.) **Near Thermal Equilibrium**
- a.) Fluctuation-Dissipation Theorem
- b.) Test Particle Model
- c.) Equilibrium Fluctuation Spectrum

vi.) **Transport and Relaxation Near Equilibrium**
- a.) Diffusion, Central Limit Theorem, Fokker-Planck Eqn.
- b.) Boltzmann Eqn. + small momentum transfer $\rightarrow$ Landau Collision Operator
- c.) Lenard-Balsecu Eqn., via TPM and Relation to Landau Collision Operator
- d.) Rosenbluth Potentials and Calculation
- e.) Dreicer Field for runaway electrons

vii.) **Mean Field Theory for Instability Evolution**
- a.) Quasi-Linear Equations
- b.) Relation to Stochasticity, Time Scales
- c.) τ_{ac} vs τ_b, validity of unperturbed orbits
- d.) Energy-Momentum Theorems for mean field theory
- e.) Bump-on-Tail Saturation
- f.) Anomalous Resistivity

viii.) **Paradigms of Turbulence**
- a.) Nonlinear evolution → turbulence
- b.) K41 paradigm → singularity via *enstrophy* → *production* → *cascade*
- c.) Langmuir Turbulence → singularity via *collapse* → Disparate Scale Interaction

ix.) **Rayleigh-Taylor Instability – A Case Study in Macroscopics**
- a.) release of free energy
- b.) different cases, limits – b.c.'s, profiles, stabilization, dissipation
- c.) linear → nonlinear transition
- d.) nonlinear structure (spike and bubble)