9 Big Ideas

Here we list 9 "big ideas" in fundamental plasma physics from a previous 218A course. 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, Adiabatic Theory for Waves
- 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) Collisionless shock models

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

v) **Near Thermal Equilibrium: How to Compute Fluctuation Spectrum**
- 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
  Lenard-Balsecu Eqn., via TPM and Relation to Landau Collision Operator
- c) Rosenbluth Potentials and Calculation
- d) Dreicer Field for runaway electrons

vii) **Mean Field Theory for Instability Evolution**
- a) Quasi-Linear Equations
- b) Relation to Chaos, 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)