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, $\lambda_D$, $n\lambda_D^3 > 1$ 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 → 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 → 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) $\tau_{ac}$ vs $\tau_b$, 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)