# 029:194 Plasma Physics I: Summary

## 1 Detailed Outline of 029:194 Plasma Physics I

1. The Overall Framework of Plasma Physics: connecting the motion of particles to electromagnetic fields
2. Vector Calculus and curvilinear coordinates
3. Characteristic Scales of a Plasma
   (a) Debye length and Debye shielding
   (b) Plasma parameter
   (c) Mean free path
   (d) Plasma frequency
   (e) Larmor radius and cyclotron frequency
   (f) Plasma beta
4. Multiple timescale methods
5. Single Particle Motion and Drifts
   (a) Larmor Motion
   (b) $\mathbf{E} \times \mathbf{B}$ Drift
   (c) $\nabla \mathbf{B}$ Drift
   (d) Curvature drift
   (e) Polarization drift
   (f) Ponderomotive Force
6. Simple numerical modeling of plasma behavior using Matlab
7. Adiabatic Invariance
   (a) First Adiabatic Invariant
   (b) Second Adiabatic Invariant
   (c) Third Adiabatic Invariant
8. Magnetic Mirror Machine
   (a) Mirror ratio
   (b) Mirror force
   (c) Use of adiabatic invariants to determine motion
   (d) Pitch angle
   (e) Loss Cone
9. Collisions
   (a) Large vs. small angle collisions
   (b) Coulomb collision frequency
   (c) Resistivity
10. Plasma Descriptions and their relation
    (a) Klimontovich Equation
    (b) Plasma Kinetic Equation/Vlasov Equation
    (c) Two Fluid Equations
    (d) MHD Equations
    (e) Cold Plasma Equations
    (f) Velocity moments of kinetic equation
    (g) Closure Problem
    (h) Equations of State
        i. Adiabatic
        ii. Double Adiabatic
        iii. Isothermal
        iv. Cold Plasma
    (i) Ohm's Law
11. MHD Equations
    (a) MHD Approximation
    (b) Relation to Two Fluid Equations
    (c) Frozen-in Flux
    (d) Clebsch Coordinates
    (e) Derivation of MHD Dispersion relation
    (f) Characteristic MHD Waves: Alfvén , Fast, and Slow
    (g) Determination of linear eigenfunctions
12. MHD Equilibrium
    (a) Hopf's Theorem
    (b) Force-free vs. Force-balanced equilibria
    (c) Force-free equilibria in cylindrical coordinates
    (d) Force-balanced equilibria in cylindrical coordinates
    (e) Force-balanced equilibria in toroidal geometry and Grad-Shafranov equation
13. Cold Plasma Equations
    (a) Cold Plasma Approximation

(b) Cold, Unmagnetized Plasma Dispersion Relation
(c) Plasma Oscillations
(d) Modified Light Waves
(e) Electrostatic vs. electromagnetic

14. Warm, Unmagnetized Plasma Waves (finite $T_e$)
    (a) Difference from Cold Plasma Equations
    (b) Dispersion relation
    (c) Langmuir Waves
    (d) Ion Acoustic Waves
15. Finding limits of plasma behavior
16. Fusion
    (a) CNO and p-p cycles
    (b) D-T reaction
    (c) Lawson criterion
    (d) Magnetic Confinement
    (e) Inertial Confinement

# 2 Fundamentals learned in 029:194 Plasma Physics I

Important physics topics:

1. Important plasma length and time scales
2. Single particle drifts
3. Kinetic, two-fluid, and MHD systems and their relation
4. Basic MHD waves
5. Waves in an Unmagnetized Plasma

Mathematical and technical skills:

1. Use of vector notation and vector calculus
2. Use of the NRL Plasma Formulary
3. Basics of Multiple Timescale methods
4. Making equations dimensionless
5. Simple numerical modeling of plasmas using Matlab
6. Linearization of a system of equations and derivation of its dispersion relation
7. Taking limits to simplify equations