*Approach*:

This course has two aims:

i.) an exposition of the theory of drift waves and drift wave turbulence, the third basic system in plasma dynamics, after the Vlasov-Poisson (218A) and MHD (218B).
ii.) a discussion of the physics issues confronting tokamak confinement and magnetic fusion.

## Topics:

*a.) Survey of Confinement Physics*

i.) profiles and drives
ii.) scale ranges, basic scalings
iii.) fundamental balance, Hasegawa-Mima model
iv.) mixing length theory, Bohm and Gyro-Bohm scaling
v.) ideas in transport: locality vs non-locality, stiffness
vi.) confinement regimes

*b.) Fundamental Models*

i.) Vorticity in Rotating Systems
ii.) Kelvin's Theorem
iii.) QG Equation, relation to 2D fluid
iv.) Rossby waves, basic properties
v.) Hasegawa-Mima Model re-visited
vi.) Hasegawa-Wakatani Model
vi.) Generalized Ohm's Law and relation to other models, especially reduced MHD

*c.) Developing the Drift Wave Model*

i.) Collisional Drift Waves: essential physics of dissipative instability
ii.) Mean Field Theory for H-W Model-Transport, Flow Generation
iii.) From Vorticity and PV Transport/Mixing to Zonal Flows
iv.) 2D Turbulence, Inverse Cascade, Rhines Mechanism
v.) Basics of Zonal Flow Dynamics
- structure
- generation: wave momentum transport, Non-Acceleration Theorem, Modulational Interaction
- feedback: shearing and k-space scattering
- dynamical systems models

*d.)* *More Complex Models and Their Consequences*

i.) Drift and Gyro-kinetic Equations: The Zoo of Micro-Instabilities
ii.) Collisionless Drift Waves
iii.) Trapped Electron Modes
iv.) ITG Modes: Slab and Toroidal, implications
v.) Some Geometry:
- sheared slab: outgoing waves, shear damping
- coupled magnetic and velocity shear
- torus: toroidal coupling and ballooning effects, inhibition of shear damping

vi.) Trapped Ion Modes

*e.)* *Macroscopic Consequences*

i.) Foundations of Basic Confinement Trends: LOC, SOC, L-Mode
ii.) GB Breaking: Mesoscopic Dynamics
- avalanching, relation to SOC phenomena, Burgers Model
- turbulence pulse propagation, spreading

iii.) Rotation: Toroidal and Poloidal
- basic concepts
- intrinsic rotation, residual stress, AKA
- poloidal rotation

iv.) Transport Barriers
- phenomenology of $L \rightarrow H$ transition
- theoretical models
- phenomenology of ITB's
- theoretical concepts

iv.) Advanced Topics: Non-Locality, PV and $E \times B$ staircases

*f.)* *Re-visiting MHD*

i.) Review, Reformulation of Energy Principle
ii.) Line-Tying and Magnetic Shear: Suydam Criterion
iii.) Sausage and Kink Modes, and hydro analogues
iv.) Reduced MHD for Resistive Modes
v.) Resistive Interchange and Related Transport
vi.) Tearing Mode, Island Dynamics, NTM
vii.) Stochastic Field Lines and MHD Turbulence
viii.) The RFP and Taylor Relaxation
ix.) Basic Ideas of Mean Field Electrodynamics
x.) Beta Limits
- quasi-modes, ballooning modes
- ideal kinks

xi.) Implications of MHD for Tokamak Operation

*g.)* *Additional Topics*

i.) Energetic Particles
- basics
- EPM and AW instabilities
- EP confinement
- BB model

ii.) Current Drive
- Self: Bootstrap Current
- RF

*h.)* *Concluding Look at the Outlook for ITER*