UC San Diego
PHYSICAL SCIENCES
Physics

Theory of Magnetically Confined Plasma

Approach

This course will discuss the theoretical underpinnings of critical elements in magnetic fusion today. It will also present open issues and hot topics, with an eye to a future of ITER, CFETR, etc. The aim is to leave the student ready to participate actively in research, MFE conferences, etc. Necessarily, it can't cover everything. The style will be intuitive, in the spirit of Kadomtsev's "The Tokamak as a Complex Physical System".

Topics

I) Overview, History of the Tokamak
How does a temperature profile $T(r)$ form?
- Sources
- Transport
- Boundary
- Stability constraints

II) Transport
- Heuristics
- Models: reduced MHD, multi-fluid, basic gyrokinetics
- Instability modes (ITG, CTEM, etc.)
- Fluxes
  - Mixing, mixing length, avalanching
  - Scaling, gyro-Bohm breakdown
  - Channels: heat, particles, momentum, etc.
  - Pinches and residual stress, intrinsic rotation (i.e. How to form $n(r), v_\phi(r), J(r)$?
- Nonlinear dynamics
  - Cascades — 2D turbulence
  - Shearing, zonal flows
  - Nonlinear wave–particle interaction
  - Mixing Length Theory, revisited: multi-scale mixing
- Isotope effect

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III) Stability — mostly ∇P
- Ideal interchange — review, Energy Principle
- Resistive interchanges
- Wave packets — twisted slicing modes
- Ballooning formalism and modes
- Kinetic and resistive ballooning
- Tearing and Rutherford island problem
- Bootstrap current
- NTM islands
- Turbulent reconnection
- Beta limits

IV) Boundary Physics
- Introduction and overview
- L–H transition
- ELMs → peeling–ballooning and more
- SOL width, heat loads, blobs
- Density limit physics
- Towards a unified model of the boundary?!
- PMI and walls for physicists

V) Other Issues
- Disruption and runaways
- ITBs
- Energetic particles, AEs (a mention, only)

VI) No Conclusion
- The problem of integration
- Critical trade-offs