Advanced Plasma Simulation

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November 7, 2025

1 Outline of proposed teaching and learning

Proposed is a set of twelve lectures, designed for people familiar with the concepts of physics modelling. The content will cover numerical methods employed in nuclear fusion plasma codes by means of examples, with particular reference to 'gotcha's' in the legacy software that remains in use. Since the material will be based largely on the lecturer's own publications, the content will be novel and it is hoped that ultimately an advanced textbook for general sale will result. Notes and course material will in any event eventually be posted on the web.

Suggested general reading
"Think before you compute", E.J.Hinch 2020, CUP
"Numerical simulation of magnetic fusion plasmas", W.Arter 1995, Reports on Progress in Physics 58, 1.
"Challenges for modelling fusion plasmas", W.Arter 2019 [1].

1.1 Ordinary differential equations

• Rate equations [2], fieldline tracing [3]
• UQ for FISPACT neutronics rate equations [4]
Gotcha failure of flux preservation [5], energy conservation in ANAC model [6].

1.2 Continuum models

• Dimensionless groups for numerics
• Finite elements for Maxwell's equations [7, 8]
Gotcha convergence failure on repeated non-orthogonal elements
• Finite differences for fluids, gas laser [9], 1-D tokamak transport [10]
Gotcha Alias-feedback instability [11], gross errors i) diffusive [9], ii) non-monotonic upwind scheme [12]

1.3 Particle methods

• Ray tracing for particle-wall collisions [13], sampling effects [14]
• Passive - neutrals, neutrons.

Gotcha losses due to defective geometry discretisation [14]
• Active - DRIFT code for particle-mesh [15], 3DPIC for magnetrons [16]
Gotcha clumping [15]

There will be a selection from the above examples accounting for (early) expressions of student interest.

1.4 Large open-source software projects

• See ExCALIBUR Project NEPTUNE report [17], style guide [18]

References

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