Outline for Cockcroft Lectures on
"Practical Nonlinear Dynamics for Particle Accelerators"

The goal will be to equip students with a set of tools for accurate modelling of particle dynamics in accelerator beamlines where nonlinear effects are important (i.e. most modern accelerator beamlines).

By the end of the course, students will be able to:

- perform simple dynamical calculations using action-angle variables;
- use generating functions to express nonlinear maps in implicit form;
- evaluate a Lie transformation as a Taylor series (up to some order);
- describe nonlinear phenomena in terms of features in phase-space portraits;
- perform normal-form analysis of linear and nonlinear maps;
- apply "integrator" methods to express nonlinear maps in (approximate) explicit form;
- describe the use of numerical techniques such as frequency map analysis, to analyse the characteristics of the complex nonlinear systems.

The course will focus on applications in accelerators, particularly (but not exclusively) storage rings. The emphasis will be on practical techniques: theorems (Chirikov criterion, KAM theorem) will be treated qualitatively rather than rigorously.

The course will cover:

1. basic tools and concepts (action-angle variables, symplecticity, lie operators);
2. representations of non-symplectic and symplectic maps (Taylor series, generating function, Lie transformation);
3. maps for accelerator elements (even a drift space is nonlinear!);
3. phase-space portraits and phenomenology of nonlinear maps (tune shift with amplitude, resonances, Chirikov criterion);
4. normal form analysis (linear normal form, nonlinear normal form);
5. integrators (symmetric factorisation; Forest-Wu integrator);
6. numerical techniques (KAM theorem, frequency map analysis).

The material will be covered in eight lectures.

Prerequisites:

- basic accelerator physics (including transverse and longitudinal dynamics);
- classical (Hamiltonian) mechanics;
- calculus;
- linear algebra (eigensystems).

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