
# Algorithms (Part 1)

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# Core syllabus (1)

## Essentials

- **Review of probability and statistics:** Laws of large numbers, CLT, sampling and properties of sample averages. Variance and covariance.

## Monte Carlo

- **Introducing Monte Carlo:** Why use Monte Carlo? Variance reduction and importance sampling. Examples.
- **Drawing from simple distributions:** Transformation and rejection methods. Box-Muller, $SU(2)$ heatbath.

## Markov Chain Monte Carlo

- **Markov chains:** Properties and convergence. Detailed Balance. Metropolis.
- **Local (bosonic) theories:** Gibbs samplers (Cabbibo-Marinari). Over-relaxation. Example: $SU(2)$ Yang-Mills.
- **Autocorrelations:** Definitions and examples. Connection to physics - correlation lengths and scaling, topology freezing.

## Fermions

- **The fermion determinant:** Path integral and Grassmann integral. Gaussian representation and pseudofermions. Non-locality problem.

# Core syllabus





## Hybrid Monte Carlo

- **Hamiltonian dynamics:** Equations of motion. Dynamics on Lie manifolds. Symplectic integrators (leap-frog) and step-size errors. Metropolis, reversibility and area preservation.
- **Fermions and pseudofermions:** Equations of motion. The resulting linear systems.
- **Advanced methods:** Higher-order and Omelyan. Multiple time-scales. Force-gradient, Hasenbusch.

## Correlation functions

- **Hadronic two-point functions:** Wick contractions. Point and smeared sources.
- **Disconnected diagrams:** All-to-all techniques and stochastic representations.

# Core syllabus (4)

LaVA lattice virtual academy

## Multi-level methods

- **Introduction and examples:** Factorising path integrals. Fermion methods.

## Linear systems

- **Krylov spaces:** conjugate gradient and BiCG. Preconditioning (even-odd).
- **Eigensolvers:** Lanczos and Arnoldi. Tridiagonal forms. re-orthogonalisation and round-off.
- **Deflation and Multigrid:**