

# Final projects for “Metodi Numerici per la Fisica”

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## **Module 1. “Introduction to Markov Chain Monte-Carlo with applications to statistical mechanics”**

1. 2d Ising model: determination of critical properties (Metropolis single site update)
2. 2d Ising model on non-square lattices: determination of critical properties
3. 2d Ising model: determination of critical properties (cluster update)
4. 2d clock model: check that for  $q = 4$  the transition is in the same universality class of the 2d Ising model
5. 3d clock model: check that for  $q \geq 5$  the transition is in the same universality class of the 3d XY model
6. 2d Blume-Capel model: check that in some points of the phase diagram a transition in the 2d Ising universality class exists (see <https://arxiv.org/abs/1612.02138>)
7. 3d XY model: determination of critical properties (Metropolis single site update and micro-canonical update)
8. 3d XY model: determination of critical properties (cluster update)

## **Module 3. “Application of Monte-Carlo methods to the study of path-integral in quantum mechanics”**

1. Thermodynamics and spectrum of the harmonic oscillator
2. Thermodynamics and spectrum of the harmonic oscillator with an anharmonic  $gx^4$  correction
3. Study of the topological properties of the quantum mechanics of a particle on a circumference (local algorithms)
4. Study of the topological properties of the quantum mechanics of a particle on a circumference (parallel tempering and multicanonical update)
5. Study of the thermodynamic of a couple of identical particles (bosons and fermions) in an harmonic oscillator potential

## **Module 6. “Simulation of path-integral for quantum field theories”**

1. Thermodynamics and spectrum of the free scalar field
2. Study of the topological properties of the 2d U(1) gauge model
3. Implementation of the HMC algorithm for the 2d U(1) gauge model and validation of the algorithm against a local update
4. Study of the static potential in the 2d U(1) gauge model
5. Study of the static potential in the confined and deconfined phases of the 3d  $Z_2$  gauge model