# Symmetry Methods in Nuclear Physics

## 1 Mathematical background

1. Angular momentum in quantum mechanics
2. Elements of the group theory
   - group definition and examples (point symmetry groups, groups of permutations, continuous groups)
   - classes, subgroups, isomorphic groups
   - elements of representation theory
3. Group theory in quantum mechanics
   - classification of energy levels and wave functions
   - group invariants and integrals of motion
   - accidental degeneracy (3-dimensional harmonic oscillator, Coulomb problem)
   - symmetry and dynamical symmetry, algebraic approach in physics
4. Rotation groups SO(2) and SO(3)
   - rotation operators
   - $D$-functions
   - matrix elements of irreducible operators

## 2 The nuclear shell model

1. One particle problem
   - harmonic oscillator potential
   - Hartree-Fock method
2. Two-particle problem
   - two-particle wave function
   - general review on effective interactions
   - calculation of matrix elements of operators
   - configuration mixing
3. n-particle wave function (coefficients of fractional parentage)
4. Transfer reactions

5. Electromagnetic transitions
6. Allowed $\beta$-decay
7. Second quantization
8. Modern shell model codes

# 3 Symmetries in the shell model

1. Racah's quasi-spin SU(2) model of pairing
2. generalized seniority model
3. Wigner's isospin-spin SU(4) symmetry
4. Elliott's SU(3) model of rotation
5. pseudo-symmetry (pseudo-SU(3), pseudo-SU(4))
6. Interacting boson approximation (basic principles)
    - interacting boson model
    - interacting boson-fermion model
    - supersymmetry in nuclei