**Objective of the course**

Aim of the course is to introduce the basic notions of non-relativistic quantum mechanics and its interpretation.

At the end of the course the students should:

1) have understood the definition of physical state and the superposition principle in quantum mechanics, the definition of physical observable, and the meaning of possible outcomes and average value of the measure of an observable;

2) know the physical consequences of the (in-)compatibility between (non-)commuting observables;

3) be acquainted with Dirac's formalism and Schroedinger's formulation; be able to translate the quantities of interest from one to the other formalism;

4) be able to determine the time evolution of a physical state from the Schroedinger equation and have understood the definition of stationary state;

5) be able to solve elementary quantum-mechanical problems in one dimension;

6) have understood the concepts of infinitesimal transformation, symmetry and invariance and their consequences for space- and time-translations, parity and time-reversal;

7) have understood the definition of angular momentum in quantum mechanics and the different representations of angular momenta and their eigenstates in dimensions two and three;

8) have learned the notion of spin and the difference between orbital angular momentum and spin;

9) be able to combine angular momenta;

10) be able to solve elementary problems in three-dimensions;

11) have understood the concept of identical and indistinguishable particles in quantum mechanics; be able to determine the states of a system of indistinguishable particles both for bosons and fermions;

12) be able to compute the shift of energy levels and the eigenstates of the Hamiltonian to first and second order in time-independent perturbation theory;

13) be able to compute, under a time-dependent perturbation, the time evolution of the wavefunction to first order and the transition probability per unit time (transition rate)

14) have understood the adiabatic theorem and its consequences.

**Outline of the program**

**Quantum Mechanics** (Prof. Ciccotti)

1) Waves and particles

2) Probability amplitudes and probability (density); superposition principle; probabilistic interpretation of the measure; possible outcomes

3) |ket> and <bra| vectors, linear, conjugate and hermitian operators

4) Eigenvectors and eigenvalues of an operator; physical observables as hermitian operators; continuous and discrete representations; the Dirac delta

5) Poisson parentheses and commutators; canonical quantization

6) Eigenvectors and eigenvalues of the momentum operator; Heisenberg uncertainty relations

7) Schroedinger equation, stationary states and conserved quantities

8) One-dimensional problems: potential well and potential barrier; tunnel effect; probability current and its conservation

9) Harmonic oscillator in Dirac and space representation

10) Operators of space- and time-translation; symmetries and their consequences

11) Angular momentum as generator of rotations; eigenfunctions and eigenvalues of angular momentum; commutation rules of scalars and vectors with angular momentum; angular momentum in spherical coordinates

12) Composition of angular momenta

13) Schroedinger equation in three-dimensions and variables separation; central potentials and hydrogen atom, eigenfunctions and energy levels

14) Spin and Pauli Hamiltonian; magnetic moment of a particle with spin

15) Identical particles in quantum mechanics; fermions and bosons; wavefunction for a system of n-particles; Slater determinant

16) Time-independent perturbation theory

17) Time-dependent perturbation theory; Fermi golden rule

18) Adiabatic theorem and its consequences

**Textbooks**

1) S. Patri’ e M.Testa, Fondamenti di Meccanica Quantistica (Nuova cultura);

2) R.Shankar, Principles of Quantum Mechanics, (Springer);

3) B.H.Bransden & C.J.Joachain, Quantum Mechanics, (Prentice Hall);

Also useful:

4) [C. Cohen-Tannoudji](http://www.amazon.com/s/ref=ntt_athr_dp_sr_1?_encoding=UTF8&sort=relevancerank&search-alias=books&field-author=Claude%20Cohen-Tannoudji), [B. Diu](http://www.amazon.com/s/ref=ntt_athr_dp_sr_2?_encoding=UTF8&sort=relevancerank&search-alias=books&field-author=Bernard%20Diu), and [F. Laloe](http://www.amazon.com/s/ref=ntt_athr_dp_sr_3?_encoding=UTF8&sort=relevancerank&search-alias=books&field-author=Frank%20Laloe), Quantum Mechanics (2 Vol set), (Wiley);

5) P.A.M. Dirac, Principi della Meccanica Quantistica, Ed. Boringhieri;

6) A. Messiah, Mecanique Quantique, Dunod (Paris) oppure Quantum Mechanics, (North Holland, Amsterdam).

7) J.J. Sakurai, Meccanica Quantistica Moderna (Zanichelli);