SCATTERING THEORY

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7th Semester. Lectures: 17 hours, Seminars: 17 hours

8th Semester. Lectures: 26 hours

The task of the course "Scattering theory" is to study basic concepts and methods of classical and quantum description of the processes of wave and particle scattering for atomic nuclear scale. The processes of elastic and inelastic collisions of particles are a basic instrument for studying the properties of microworld, i.e. molecular, atomic, nuclear and nucleon structure.

During the course a student should gain an insight into the experimental technique of measuring cross-sections of different processes, understand such notions as S-matrix, amplitude and scattering phase, get to know about stationary and nonstationary descriptions of scattering processes, understand the numerical solution of Schrodinger equation for scattering states and the use of different approximate methods for the calculation of basic quantities. The course "Scattering theory" is a compulsory introductory part of the following courses "Nuclear reactions with heavy ions", "Nuclear reactions, induced by neutrons and gamma-quanta" and "Nucleosynthesis", in which students should actively use the acquired knowledge to understand methods of description and analysis of complex nuclear-physical processes.

The contents of the discipline

1. Particle collisions in classical mechanics

1.1 Conservation laws, transition to the center-of-mass system, bringing it to the task of center of force scattering
1.2 Particle paths in the spherical field, deviation angle, scattering crosssection
1.3 Coulomb field scattering, Rutherford formula
1.4 Rainbow scattering, curling, gloria

2. Quantum description of the process of scattering

2.1 Hilbert space of state vectors, wavepackages
2.2 Evolution of state vectors, asymptotic states, wave operators
2.3 Scattering operators, unitarity
2.4 Differential cross-section, optical theorem

3. Stationary formalism of scattering theory

3.1 Stationary states of scattering
3.2 Green function and T-operator, Lippmann Schwinger equation
3.3 Stationary wave scattering functions and their asymptotics

4. Expansion in partial waves

4.1 Spherical functions and Bessel functions
4.2 Expansion in partial waves of a plain wave, Green functions and S-matrix
4.3 Partial wave functions, partial phases of scattering
4.4 Numerical integration of Schrodinger equation and determination of partial phases of scattering
4.5 Phase equation

5. Particle scattering in Coulomb field

5.1 Scattering purely by Coulomb potential
5.2 Potential with Coulomb asymptote

6. Approximate methods of elastic scattering theory

6.1 Low energies and scattering length
6.2 Born series, Born approximation in the method of distorted waves
6.3 One-dimensional WKB-approximation for partial waves and phase shifts
6.4 Quasi-classical approximation in a three-dimensional space, wave accidents and caustic surfaces.
6.5 Eikonal approximation

7. The processes of compound particle collision

7.1 Channels, channel Hamiltonians and states
7.2 Evolution of state vectors and multichannel scattering operator
7.3 Stationary states and multichannel Lippmann Schwinger equation
7.4 Born approximation in the method of distorted waves
7.5 Elastic scattering at the composite target, inelastic excitement of the target
7.6 Straight transfer reaction
7.7 Target state expansion and optical model

Methodical recommendations for tutors

The course of lectures is meant for the students of the department of experimental nuclear physics. Because of this, it is necessary to focus on discussing the material in its application to the tasks of researching reactions with nuclear particles. Lectures should be accompanied with illustrative descriptive material, computer presentations in particular. It is advisable to put special emphasis on practical calculations, made by students on their own, while they work on their tasks and course-papers. Students can be allowed to use computing packages, already in existence, for calculating properties of nuclear reactions, but in this case the task should be broadened. Programming, made by students on their own, should be encouraged.

As the amount of literature available on this subject is quite limited, one should formulate practical tasks in a detailed way and allow using the Internet while solving these tasks.

The knowledge of students should be checked in the form of a test on the tasks they did, and in the form of the defense of their course papers.

Methodical recommendations for students

The work of students on the practical tasks (course paper and others) should be performed to a great extent on their own. The use of the recommended by the tutor Internet resources is allowed.