



## ЦЕНТЪР ЗА ОБУЧЕНИЕ – БАН

1000 София  
ул. „Сердика“ № 4  
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### Basic Information:

Course Title: Introduction to stochastic processes

Lecturer: Prof. DSc Boyka Aneva

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Total Teaching Hours: 30

### Annotation (up to 150 words)

Multicomponent complex systems are found everywhere in nature in the processes of atomic and molecular formation, the growth of biological structures, and population dynamics; in reaction-diffusion mechanisms in physics and chemistry, in quantum optics, in finance and markets, and in the behavior of ecological and sociological systems. What these large ensembles of objects have in common is random behavior dependent on fluctuations that can give rise to macroscopic effects, such as dissipative structures. Complex systems are characterized by self-organization, to which the methods of equilibrium thermodynamics do not apply. The evolution over time and the spatial formation of complex systems can be better understood when stochastic dynamics is taken into account. Therefore, the theory of stochastic methods is particularly important for various fields of the natural sciences, modern technologies, the social sciences, communication sciences, and quantum information. The application of lattice spin non-equilibrium processes is a cutting-edge approach in quantum computing that enables the creation of stable qubits for simulating complex physical systems.

### Course content (brief description by topics or modules)

Topic / Module 1: Brownian motion. Probability distributions. Markov processes.

Topic / Module 2: Quantum-mechanical Markov processes.

Topic / Module 3: Stochastic processes and integrable models. Quantum groups and applications.

### Teaching and assessment methods

Lectures and consultations, assessment based on an interview or essay

### Competencies acquired as a result of training (3–5 points)

1. In-depth knowledge of contemporary areas of quantum physics, non-equilibrium physics, Markov processes, reaction-diffusion processes, and exactly solvable lattice models
2. Expertise in the modern mathematical apparatus of probability distributions, representation theory (Hecke algebras, tridiagonal algebras, quantum groups), topology, tensor analysis.
3. Critical thinking and initiative: evaluation of existing models and creation of theoretical models of many-body systems
4. Independent use of the literature and skills for independent preparation of scientific research
5. Presentation skills, preparation of a manuscript for a scientific journal



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### Literature:

1. R.Balescu, Equilibrium and Nonequilibrium Statistical Mechanics, NY, J Wiley, 1975
2. I.Prigogine, Nonequilibrium Statistical mechanics. NY, JW, 1962
3. C.W.Gardiner, Handbook of Stochastic Methods, Springer, Berlin, 1985
4. H.S.Wio, An Introduction to Stochastic Processes and Nonequilibrium Statistical Physics, World Sci., Singapore, 1994
5. G.Schuetz, Phase Transitions and Critical Phenomena, v.19, ed.C.Domb and J.Lebowitz, Acad.Press, London 2000
6. V.Chary and A.Pressley, A Guide to Quantum Groups, Cambridge University Press, 1994
7. Y.Manin, Quantum Groups and noncommutative geometry, Princeton Univ.Press, 1991
8. R.Baxter, Exactly solved models in statistical mechanics, Acad.Press New York, 1982
9. M. Will et al Probing non-equilibrium topological order on a quantum processor, Nature **645**, p.348, (2025)
10. Z. Wang, Quantum Computing: A quantum Group Approach, math.QA/1301.4612

### Additional information (optional)

The aim of this lecture course is to introduce students to the theory of stochastic non-equilibrium processes by developing ideas that form the basis of the theory of far-from-equilibrium phenomena in microscopically different random processes.

Program: Main topics of the lecture course

1. Brownian motion. Langevin equation. Reaction-diffusion processes.
2. Probability distributions. Distribution functions and mean values.
3. Binomial, Gaussian, and Poisson distributions
4. Markov processes. Stochastic processes. Chapman-Kolmogorov equation
5. Diffusion processes. Deterministic processes.
6. Liouville equation. Time evolution. Stationary processes. Ergodicity.
7. Examples – Wiener process, Random walk processes.
8. Fokker-Planck equation. Boundary conditions. Stationary solutions. Eigenfunction method.
9. Spatially distributed systems. Equation for the current.
10. Nonlinear model with second-order phase transitions.
11. Quantum mechanical Markov processes
12. Quantum harmonic oscillator.
13. Interaction with an external field. Coherent states.
14. Density matrix, probabilities, operator correspondence.
15. Quantum Liouville equation.
16. Time correlation functions.
17. Stochastic systems and quantum group symmetries.



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18. Deformed algebras and superalgebras, Hecke algebras.  
19. The Young–Baxter equation. Integrable lattice models.  
20. Stochastic systems and integrable spin models.  
21. Application of tridiagonal algebras and their representations via the Askey-Wilson polynomials for the exact solution of non-equilibrium processes.  
22. Quantum groups, spin systems, and quantum computations.

The course is intended for doctoral students in physics from the following fields:

- Theoretical and Mathematical Physics 01.03.01,
- Nuclear Physics 01.03.04,
- Particle Physics 01.03.05,
- Condensed matter physics 01.03.25, 01.03.26,
- Astrophysics 01.04.02

but may also be of interest to doctoral students from a broader range of specializations

Program prepared by:

Prof. DSc B. Aneva

19.05.2026