Stochastic Processes

- **Lecturer:** Dr. Deepak Gupta (deepak.gupta@ifpan.edu.pl). Division of Theoretical Physics, IFPAN, Warsaw
- **Duration:** 13 sessions, 2 hours each + 2 students' project presentations (30 hours in total)
- **Time:** Every Thursday 0900-1100. First lecture: October 8th, 2026.
- **Place:** Room 15/XV, Institute of Physics PAS (al. Lotników 32/46)
- **Evaluation:** Students' engagement in the class, assignments, project presentation
- **ECTS:** 3
- **Language:** English
- **Prerequisite:** Basic knowledge of probability theory and mathematics is expected.

List of topics:

1. **Review of probability theory:** Random variables, probability distributions, characteristic function, moments and cumulants, Wick's theorem, multivariate distributions. Transformation of variables
2. **Central limit theorem:** Sum of random variables, introduction to large deviation function, numerical simulations.
3. **Stochastic processes:** Introduction to stochastic processes, Markov and non-Markov processes, discrete- and continuous-time Markov processes, master equation, stationary and non-stationary processes.
4. **Random walk:** Introduction to random walks, probability distributions, first-passage density, examples and solutions, numerical simulations.
5. **Langevin equations:** Brownian motion, Langevin equation, the Zwanzig approach to obtain the Langevin equation, exact solutions of the Langevin equations, and numerical simulations.
6. **Fokker-Planck equation:** Construction of the Fokker-Planck equation and its solution under different boundary conditions, first-passage density, reflecting-boundary solutions, numerical simulation methods, and solutions using physics-informed neural networks.
7. **Path integral:** Solution of the Fokker-Planck equation using the path-integral method, relaxation to the stationary state. Mapping the Fokker-Planck equation to the Schrödinger equation.
8. **Kramers' escape rate problem**: Backward Fokker-Planck equation, approximated and exact calculations, numerical simulations, machine learning.
9. **Chemical Reactions:** Dynamics of chemical reactions, open systems, unimolecular reactions, composite Markov processes.
10. **Renewal theory:** Basics of renewal theory, stochastic resetting and its application, numerical simulations.

References:

- N.G. Van Kampen, Stochastic Processes in Physics and Chemistry, Elsevier (2007)
- Daniel T. Gillespie, Markov Processes. An Introduction for Physical Scientists, Elsevier Science (1991).
- C. Gardiner, Handbook of Stochastic Methods: For Physics, Chem. Nat. Sciences, Springer (2004)
- Hannes Risken, Till Frank, The Fokker-Planck equation: methods of solution and applications, Springer (1996).