Guru Kalyan Jayasingh

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Visa Status: F-1

Education

University of California San Diego (UCSD)
Ph.D. student, Department of Physics *2022–Present*

Indian Institute of Technology Bombay, India
Dual Degree (B.Tech + M.Tech) in Engineering Physics *2017–2022*
Specialization: Nanoscience | GPA: 9.44/10,
Honors: Institute Silver Medal · K. Seshia Research Excellence Award · Institute Academic Prizes (2019,2021)

Publications

2025: **G.K. Jayasingh** and Nigel Goldenfeld, Tricritical directed percolation controls the laminar–turbulent transition in pipes with body forces, Phys. Rev. Lett. 135, 104001 (2025).
https://doi.org/10.1103/46g3-n7cx

2025: S. Chakraborty, **G.K. Jayasingh**, H. Pal, Topological bound states inhibit superconducting order in quasi one–dimensional heterostructures (manuscript in preparation)

Honors and Achievements

2022: Received the **Institute Silver Medal**, recognizing the **top-ranked** student in the B.Tech–M.Tech Dual Degree cohort of 2017.

2022: Received **K. Seshia Research Excellence Award** for the best Master's thesis in Physics demonstrating research originality and rigor.

2022: Received the **Physics Excellence Award** from the Department of Physics, UCSD.

2021: Received **Institute Academic Prize** for the **highest GPA** in the physics department for 2020-2021.

2021: Ranked **third** all India in Indian Young Physicists League (IYPL), a national theoretical physics competition.

2020: Selected for Aalto Science Institute (**AScI**) internship programme to pursue research on Topological matter for 12 weeks at Aalto Institute, Finland.

2019: Received **Institute Academic Prize** for the **highest GPA** in the physics department for 2018-2019.

2019: Secured **AP** grade (for extraordinary performance) in MA-214 Introduction to Numerical Analysis at IIT Bombay.

2017: Secured **99.62 percentile** in JEE-ADVANCED 2017 among 200,000 applicants.

2017: Was in the **top 400** among a total of 40,000 students, selected to appear INChO (Indian National Chemistry Olympiad).

2015: Qualified KVS-RMO (Regional Mathematics Olympiad) and was among the **top 50** students from all over the country to attend a 10–day INMO (Indian National Mathematics Olympiad) preparatory camp.

2017: Awarded **KVPY (Kishore Vaigyanik Protsahan Yojana) fellowship** by Department of Science and Technology, India for identifying exceptional talent and promoting careers in basic sciences.

2016: Secured **National Top 1%** in NSEC (National Standard Examination in Chemistry).

Conferences and Summer Schools

2025: Invited talk at Joint Institute for Fusion Theory (JIFT) Workshop on Strong Turbulence, Avalanching and Structures in Boundary Plasma Turbulence, University of California San Diego.

2025: (Declined) Physics and mathematics of hydrodynamic and wave turbulence at Centre International de

Rencontres Mathématiques, Marseille.

2025: Contributed talk at APS Joint March and April Meeting Global Physics Summit 2025 , Anaheim California.

Key Research Experience

Transition to fluid turbulence as an ecological phase transition *Sep 2023 - Present*

Supervisor: Prof. Nigel Goldenfeld, Dept. of Physics, University of California San Diego.

- Turbulence is one of the most complex and unsolved problems in physics, especially in confined flows like pipes. My work explores how turbulence emerges from smooth (laminar) flow, building on the observation that this transition follows patterns seen in directed percolation - a non-equilibrium phase transition relevant to extinction transitions in predator-prey models of ecology.
- Predicted the existence of a tricritical fixed point in the phase diagram of transitional turbulence in curved and heated pipes, explaining recent experimental findings.
- Provided scaling predictions and identified body force strength as a tunable parameter to observe tricritical directed percolation exponents in experiments, guiding future studies on turbulence control in confined flows.

Electron - phonon equilibration via Keldysh field theory *Feb 2020 - 2021*

Supervisor: Prof. Rajdeep Sensarma, Tata Institute of Fundamental Research, Mumbai.

- Investigated the dynamics of a coupled electron-phonon system within Keldysh formalism, where both electrons and phonons evolve in time self-consistently, as opposed to the standard paradigm of one set of constituents forming a static bath for the other.
- Used a Yukawa-type interaction to derive self–energies diagrammatically and implemented an algorithm for the numerical solution of corresponding Dyson equations.
- Wrote extensive and modular Python (& Julia) code for evolving the coupled system. Tested constituents by connecting them to baths and studying their equilibration characteristics starting from specific initial conditions. [Link]

Fluctuations in non-centrosymmetric superconductors *Mar 2020 - Nov 2020*

Supervisor: Dr. Alexander Zyuzin, Aalto Institute, Finland.

- Extended work by Egor Babaev's group (PhysRevB.102.184517) on the effect of spin orbit coupling (SOC) on superconductivity, particularly in models of non-centrosymmetric (lacking inversion center) materials.
- Studied path integral many-body theory (particularly BCS theory), Gor'kov green's functions, and microscopic derivation of Ginzburg Landau (GL) functional.
- Investigated effects of SOC on experimentally relevant fluctuation observables like diamagnetic susceptibility, specific heat etc. near the superconducting phase transition.
- Analytically calculated and analyzed the temperature & magnetic field dependence of these quantities and compared them to traditional results. [Report]

Characterizing topological insulator-superconductor junctions *May 2021- Present*

Master's Thesis

Supervisor: Prof. Hridis Kumar Pal, Dept. of Physics, IIT Bombay.

- Investigated the characteristics of a superconductor–topological insulator (SC–TI) junction, including the transition temperature (T_c) and critical fields, to understand the role of surface states in determining superconducting properties.
- Studied the characteristics of superconductor–metal junctions, learning the quasi-classical Green's function method to analyze heterostructures, and explored recent developments on the SC–TI junction problem.
- Derived a nonlocal Ginzburg–Landau functional for order parameter, and investigated the effects of topology in superconductor–topological insulator heterostructures.[Report]

Vortices in nematic superconductors *Jan 2021 - Mar 2021*

Supervisor: Dr. Alexander Zyuzin, Aalto Institute, Finland.

- Learned about the recently proposed superconducting state in doped topological insulator $Cu_xBi_2Se_3$ with odd parity triplet pairing and two component order parameters (nematic superconductivity).
- Studied fractional vortices in this model, their possible bound states and complete phase diagram based on energetics.
- Following a microscopic model, calculated spin-polarization around such vortices and discussed its experimental significance. [Report]

Talks

Tricritical directed percolation and transitional turbulence
Invited talk at JIFT Workshop on Strong Turbulence, Avalanching, and Structures in Boundary Plasma Turbulence *Aug 2025*

Presented a talk exploring how external body forces modify the universality and phase structure of the laminar–turbulent transition in pipe flows. The work extends the directed percolation framework to include body-force effects, revealing a tricritical regime bridging continuous and discontinuous transitions. The resulting theory explains the emergence of bistability, coexistence, and relaminarization observed in experiments on curved and centrifugal pipes, providing a unifying perspective on forced transitional turbulence.

Laminar-turbulent transition in pipes with body forces: continuous, discontinuous or both?
Contributed talk at APS Joint March and April Meeting Global Physics Summit 2025 *Mar 2025*

Presented work on how body forces modify the laminar–turbulent transition in pipe flow. Extending the directed percolation framework to include external forcing, we showed that sufficiently strong body forces induce a tricritical point separating continuous and discontinuous transitions. The resulting phase diagram explains bistability and spatial intermittency observed in experiments and simulations of forced pipe turbulence.

Low rank hypothesis of complex systems
Course presentation for BGGN246A AI and Brains neuroscience course at Salk Institute *Feb 2025*

Presented a talk on the low rank Hypothesis of complex systems, discussing how high-dimensional complex systems—such as ecosystems, neural networks, and social structures—exhibit effective low-rank behavior, enabling dimension reduction and interpretable dynamics. The talk covered Singular Value Decomposition (SVD) as a tool for analyzing low-rank structures, empirical validation of the hypothesis across real and random networks, and implications for neural dynamics, epidemiology, and physics. It also addressed cases where the hypothesis fails, such as the brain's criticality conjecture, and discussed open challenges in predictive modeling of low-rank structures. [Slides]

Bosonization and some applications
Condensed Matter Journal Club, IIT Bombay *Sep 2021*

Spanning 2 sessions, the first talk focused on derivation of Bosonization identities while second talk presented a physical and heuristic view of the technique. Discussed applications by calculating conductance in impurity-ridden Luttinger wire (employing renormalization group) to illustrate new physics spawning due to reduced dimensions, interactions, and mesoscopic nature of transport. [Slides]

Aspects of unconventional superconductivity
Condensed Matter Journal Club, IIT Bombay *Aug 2022*

Discussed classification of order parameters within a generalized BCS theory and nature of physical observables for different pairing symmetries. [Slides]

Fractals
Invited talk at non-linear dynamics course at IIT Bombay *Aug 2018*

Presented the notion of fractional dimension, methods to characterize dimension of a fractal, and relevance of fractals for stochastic processes to the non-linear dynamics class at the invitation of the course instructor.

Relevant Course Projects

***Structural Response Prediction and Fault Detection from Time Series**, Machine Learning* *Mar 2025*

- Built multivariate LSTM to forecast structural accelerations from excitation inputs on a 3-story dataset (with 34M+ entries) with 17 structural states (healthy and damaged).
- Achieved MSE about 0.00276 on baseline (undamaged) data (representing <2% prediction error); observed about 10x higher MSE on damaged states indicating degradation.
- Implemented logistic regression with frequency-domain features (Welch PSD) to classify structural health states; attained over 85% accuracy.

***Dualities in Ising model**, Advanced Statistical Mechanics* *Nov 2020*

- Studied series expansions of lattice models (specifically Ising model), Kramers–Wannier duality, and $\mathbb{Z}_2$ lattice gauge theory for 3D ising model.
- Explored Elitzur's theorem and idea nonlocal order parameter in 3d ising gauge theory. Presented my study along with the solutions of related problems to the instructor. [Report]

***Dielectric function, screening, and plasmons in graphene**, Theoretical Condensed Matter* *Nov 2020*

We studied the paper (PhysRevB.75.205418) by Hwang et al. and reproduced derivations of polarization function, plasmon dispersion, and dielectric function in graphene. Presented our findings to the course instructor at the end. [Slides]

***Spontaneous Symmetry breaking in statistical physics**, Reading Group* *Jun - Aug 2020*
Supervisor: Prof. Sumiran Pujari, IIT Bombay
Organized weekly meetups to discuss the phenomena of symmetry breaking in many-particle systems following arxiv:1909.01820. We presented our study to a faculty guide in a series of 4 talks at the end. [Notes]

***Investigation of Fukushima-Daiichi Nuclear Disaster**, Nuclear and Particle Physics* *Oct 2020*
- Analyzed publicly available datasets to formulate a diffusive model that quantifies the spread of radioactive debris post-explosion.
- We modeled spread as a function of distance, time and direction. Our analysis successfully folded in the effect of two consecutive explosions. [Slides]

Banach Spaces and their Applications *May - Jun 2018*
Supervisor: Dr. Sutanu Roy, School of Mathematics, National Insitute of Science Education and Research.
Spent a summer studying Banach spaces, fixed point theorems and its practical use in Google's page rank algorithm, art etc. Attended a summer school on mathematics for beginning undergraduates. [Report]

Teaching and Academic Service

University of California San Diego *2022–2024*
Courses (UC San Diego): Emergent States of Matter (Graduate, taught by Prof. Nigel Goldenfeld), Phys 1–2 Series (Undergraduate: Mechanics, Electromagnetism, Waves & Oscillations Labs)
- Led weekly discussion sections for both graduate and undergraduate courses, reinforcing lecture material and guiding students through advanced problem sets.
- Held office hours to address conceptual questions and provide one-on-one academic support.
- Assisted faculty with grading, exam preparation, and logistical coordination of course activities.

Indian Institute of Technology Bombay *2019-2022*
Courses (IIT Bombay) : Statistical Physics (Spring 2022), Advanced Statistical Mechanics (Autumn 2021), Complex Analysis (Autumn 2020) & Electromagnetism (Summer 2019)
- Conducted weekly tutorial sessions (both online and offline) for a batch of over 35 students throughout the course and helped clear conceptual doubts through individual interaction.
- Assisted instructors in conducting exams, correcting answer sheets, and selecting relevant problems for practice sets.

Leadership and Organization

***Manager, Maths and Physics Club**, IIT Bombay* *Apr 2019 - Apr 2020*
- Led a team of 5 sophomores to foster enthusiasm in the pure sciences, tending to a community of 400 - 500 on campus with an online presence of over 9000.
- Organized a trip to Atomic Physics and Quantum Optics Lab at IISER Pune. Lab hosts presented experiments using ultracold atoms for quantum information processing, atom interferometry, quantum chaos, etc.
- Oversaw a fivefold increase in participation in PhysX GC - an experimental physics cum engineering themed event requiring participants to build the longest-running Rube Goldberg machine with maximum complexity.

Technical Skills

Languages: Python · C/C++ (working familiarity) · PyTorch
Software: LaTeX · Mathematica · Git · Jupyter · Markdown
Packages: NumPy · SciPy · scikit-learn · Pandas · Numba · Matplotlib · Seaborn

Key Courses

Physics - Advanced Condensed Matter, Advanced Statistical Mechanics, Semiconductor Physics, Graduate Non-Equilibrium physics, Graduate Quantum Field Theory, Advanced Quantum Mechanics, Nonlinear Dynamics.

Math - Complex Analysis, Calculus, Group Theory, Partial Differential Equations, Numerical Analysis.

Programming & Miscellaneous - Machine learning, Programming, Data Analysis

Extracurricular Activities

2019: Gave presentations titled "Why a Maths and Physics Club?" to over 100 college math faculty from all over India as a part of Advanced Pedagogy workshop under the TEQIP-Kite III initiative. The program, under the aegis of World Bank and Government of India, aims to improve quality of technical education system.