

# Guru Kalyan Jayasingh

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Visa Status: F-1

## Education

**University of California San Diego (UCSD)** 2022–  
PhD student, Dept. of Physics  
**Indian Institute of Technology Bombay, India** 2017–2022  
Dual Degree (B.Tech + M.Tech) in Engineering Physics  
Specialization: Nanoscience | GPA: 9.44/10,  
Awards: 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 **Institute Silver Medal** for highest performance in the B.Tech+M.Tech Dual Degree for class of 2017.  
**2022:** Received **K. Seshia Research Excellence Award** for the Master's thesis, IIT Bombay  
**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.  
**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 long 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, University of California San Diego  
**2025:** (Declined) Physics and mathematics of hydrodynamic and wave turbulence at Centre International de Rencontres Mathématiques, Marseille  
**2025:** Laminar-turbulent transition in pipes with body forces: continuous, discontinuous or both, APS Joint March and April Meeting Global Physics Summit 2025, Anaheim California Meeting

## Key Research Experience

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### ***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 seen in extended predator-prey models in ecology.
- Predicted the existence of a tricritical fixed point in the statistical mechanical 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.
- Investigating how localized turbulent patches (puffs) evolve into expanding turbulent regions (slugs) to uncover the global phase diagram for transitional turbulence.

### ***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*** **Master's Thesis**

May 2021- Present

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

- Investigating characteristics of a Superconductor (SC)-Topological insulator (TI) junction such as transition temperature ( $T_c$ ), critical fields etc. and understand the role of surface states on superconducting properties.
- Studied characteristics of Superconductor-Metal junction learning quasi-classical Green's function method to treat heterostructures, and recent attempts at SC-TI junction problem.
- Found a linearized form of standard BdG formalism suitable for calculating  $T_c$  of SC-TI junctions. [[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 2 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**

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### **Tricritical Directed Percolation and Transitional Turbulence**

*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?**

*APS Joint March and April Meeting Global Physics Summit 2025, Anaheim California*

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 physical observables for different pairing symmetries. [\[Slides\]](#)

### **Fractals**

*Invited talk at Non-linear dynamics course at IIT Bombay*

Aug 2018

We presented 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

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### **Structural Response Prediction and Fault Detection from Time Series, Machine Learning** Nov 2020

- 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 non-local 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]

### **Introduction to Quantum Field Theory, Supervised Learning Project** Aug - Nov 2019

Studied quantization of scalar and spinor fields, S-matrix, perturbation theory, and calculated scattering amplitude to various orders in a toy model (scalar Yukawa theory). [Report][Presentation]

### **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 Institute of Science Education and Research.

Spent a summer studying Banach spaces, fixed point theorems and its practical use in Google's page rank algorithm, etc. Attended a summer school on mathematics for beginning undergraduates. [Report]

## Organisation and Leadership

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### **Teaching Assistant**

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 personal interaction.
- Assisted instructors in conducting exams, correcting answer sheets, and selecting relevant problems for practice sets.

### **Manager, Maths and Physics Club, IIT Bombay** Apr 2019 - Apr 2020

- Led a team of 5 sophomores to foster enthusiasm in 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 five-fold increase in participation in PhysX GC - an experimental physics cum engineering themed event requiring participants to build the longest-running Rube Goldberg's machine with maximum complexity.

## Key Courses

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**Physics (Theory)** - Topological Aspects of Quantum Matter\*, Theoretical Condensed Matter, Advanced Statistical Mechanics, Semiconductor Physics, Quantum Devices, Introduction to Condensed Matter, Statistical Physics, Quantum Field theory (Supervised Seminar), Quantum Mechanics -I &II, Atomic & Molecular Physics, Nonlinear Dynamics.

**Nanoscience** (*Experiment oriented*) - Introduction to Nanoscience, Thin Film Physics, Analytical Techniques, Nanomaterials & Nanofabrication, Solid State Physics Laboratory.

**Math** - Complex Analysis, Calculus, Group Theory, Differential Equations - I & II, Numerical Analysis.

**Programming & Miscellaneous** - Computer Programming and Utilization, Data Analysis, Microprocessor lab, Digital Electronics.

\* Graduate course audited at Tata Institute of Fundamental Research, Mumbai

## Technical skills

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**Languages:** Pytorch, Python, JULIA, C/C++

**Softwares:** L<sup>A</sup>T<sub>E</sub>X, Mathematica, Sagemath, Git

**Packages:** Sklearn, Scipy, Numba, Pandas

## Extracurricular Activities

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**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 TEQIP-Kite III initiative. The program, under the aegis of World Bank and Govt of India, aims to improve quality of technical education system in the country.