

EDUCATION

- **B.Tech., Engineering Physics**, Indian Institute of Technology Bombay (‘20 - ‘24)
GPA: 8.62/10.00, awarded **Honors** in **Physics** and **Minor** in **Mathematics**

RESEARCH - THEP

Knot Polynomials from $\mathcal{N} = 4$ SYM | Bachelor’s Thesis (Spring ‘24)

Guide : Prof. Pichai Ramadevi, Department of Physics, IIT Bombay

Polynomial knot invariants can be derived by counting the number of solutions of the BHN localisation equations in a $\mathcal{N} = 4$ SYM, in the presence of surface operators.

- Used knot parametrisations, numerical techniques on Lie groups to study BHN solution space and derive knot polynomials
- Surveyed surface operators’ role in supersymmetric theories and modification of BHN equations in their presence

Knot Polynomials from Perturbative Chern Simons | Bachelor’s Thesis | [Report](#) | [Presentation](#)

Guide : Prof. Pichai Ramadevi, Department of Physics, IITB (Fall ‘23)

The Chern-Simons topological QFT is exactly solvable but can also be studied perturbatively. The topological nature of the theory allows use in deriving knot invariants, objects which distinguish knots.

- Investigated knot parametrisations and integration techniques to efficiently compute invariants using Mathematica
- Derived integral forms of Vassiliev invariants from Wilson loop operators in a Chern-Simons theory

THEORETICAL PROJECTS

Knot Polynomials and Quantum Modular Forms | [Poster](#) (Spring ‘24)

Guide : Prof. Pichai Ramadevi, Department of Physics, IITB

- Surveyed literature on expression of polynomial knot-invariants in terms of quantum modular forms, which are complex functions on \mathbb{Q} with certain transformations under modular discrete subgroups of $SL(2, \mathbb{R})$
- Awarded Best Poster at Symphy 2024, the annual symposium of the Department of Physics, IIT Bombay

Optimal Control Landscape for Unitary Transformations (Spring ‘24)

Course Project : Differential Geometry in Control, Guide : Prof. Debashish Chatterjee, Department of Systems & Controls

- Explored the critical landscape of the Hilbert-Schmidt cost function for quantum gate synthesis from controlled Hamiltonians
- Extended the work of Rabitz and Hsieh to other fidelity measures and symmetry constraints on the Hamiltonian

Asymptotic Symmetries of Curved Spacetimes | [Report](#) | [Presentation](#) (Fall ‘23)

Course Project : Advanced General Relativity, Guide: Prof. Vikram Rantala, Department of Physics, IITB

- Studied asymptotic structure of gauge theories, symmetries arising from boundary conditions, and the infrared triangle
- Derived supertranslations and superrotations in the Bondi gauge for 4D GR in asymptotically flat and (A)dS spacetimes

Quantum Information in QFTs (Spring ‘23)

Course Project : Special Topics in Particle Physics, Guide : Prof. Urjit Yajnik, Department of Physics, IITB

- Studied the extension of quantum informatic ideas like entanglement and complexity to field theoretic definitions
- Surveyed the connection between renormalisation group flows and quantum error correction

Momentum of Light in Linear Media | Report (Spring ‘23)

Course Project : Electromagnetic Theory, Guide : Prof. Anshuman Kumar, Department of Physics, IITB

- Resolved Abraham-Minkowski controversy of stress tensor by demonstrating equivalence up to a localisation transform
- Derived the Belinfante-Rosenfeld stress tensor and balance equations field-theoretically for open and close systems
- Presented a lecture on the Lagrangian formalism for deriving Maxwell’s equations in a medium

Gravitational Waves in High-Frequency Regime | [Presentation](#) (Fall ‘22)

Course Project : Gravitational Wave Astronomy, Guide : Prof. Archana Pai, Department of Physics, IITB

- Used the WKB approximation to study high-frequency gravitational waves modelled as metric perturbations
- Drew analogies in propagation, amplitude and polarisation between high-frequency waves and geometrical optics limit

Reading Projects

String Theory Professor Shiraz Minwalla’s 2018 lecture series (Summer ‘24)

QFT in Condensed Matter Altland and Simons’ textbook on Condensed Matter Field Theory (Winter ‘23)

Lattice Field Theory Markov Chain Monte Carlo in QFTs (A Joseph), Computational QFT (K Langfeld) (Fall ‘23)

Gauge Theories Gauge theories, GWS and Yang-Mills from textbooks by Peskin, Schroeder, and Ramond (Summer ‘23)

Quantum Information and Computing Quantum Computation, Circuits and Algorithms from Ike & Mike (Winter ‘22)

Elementary Particle Physics Lie Algebras in Particle Physics (H Georgi), Introduction to EPP (D Griffiths) (Summer ‘22)

RESEARCH PROJECTS - MEDICAL IMAGING

Optimisation of Coincidence Selection for Energy Calibration | Research Internship

Guide : Prof. Pawel Moskal, Marian Smoluchowski Institute of Physics, Jagiellonian University (Summer '23)

The JPET gamma detector estimates energy with the Time-over-Threshold (ToT) technique. I worked on the calibration setup for this technique and optimised the algorithms for obtaining calibration data.

- Invented and compared algorithms across varied parameters and resolutions for 3- and 4-multiplet coincidences
- Developed a Python-ROOT-based pipeline to control simulations, data processing, and algorithm accuracy analysis
- Implemented chunked processing and selective reading to reduce memory usage and decrease runtime by 90%
- Derived analytic bounds on the 4-multiplet phase space; Surveyed CPT violation experiments using JPET

Adapting Single-Scattered Algorithm to Energy Blind Detectors (Summer '23 to Summer '24)

Guide : Prof. Pragma Das, Department of Physics, IITB

Singly-scattered photons are unused in PET scans. An geometric compton-scattering-based algorithm by Prof Das utilises them for imaging in two-ring systems. I try to adapt the algorithm to an energy-blind time-sensitive detector, eg JPET.

- Brainstormed a statistical alternative to the algorithm which overcomes energy-blindness for image reconstruction
- Surveyed Machine Learning models and dimensionality-reduction techniques to implement statistical approach
- Extended the approach to GATE-simulated data using time-of-flight and clustering techniques
- Generalising model to account for experimental constraints like imperfect coincidence detection and detector resolution

Coincidence Discrimination using Polarisation in PET | [Codes](#) | [Report](#) (Summer '22 to Summer '23)

Guide : Prof. Pragma Das, Department of Physics, IITB

For PET scans, same-source photons must be paired correctly for image reconstruction. Current detectors do not incorporate the entangled polarisations of these photons. I explore polarisation-modified algorithms for scattered photons.

- Studied differential cross sections of entangled photons arising from free positron annihilation and positronium decay
- Simulated PET scans incorporating correlated polarisations, implementing a Monte Carlo approach via rejection sampling
- Showed improved photon-pairing accuracy using polarisation-modified algorithms for high-activity sources
- Examined effectiveness of polarisation for varying phantoms; Contrasted classical and entangled polarisation correlations

TECHNICAL PROJECTS

DFT Simulations for Optical Materials

(Winter '22 to Spring '23)

Guide : Prof. Anshuman Kumar, Department of Physics, IITB

- Investigated optical behaviour and exciton physics of Transition Metal Dichalcogenide monolayers under strain
- Implemented DensityFunctional Theory simulations using QuantumEspresso on the SpaceTime supercomputing cluster

RR Lyrae Analysis with Growth India Telescope | [Codes](#) | [Report](#)

Course Project : Astrophysics, Guide : Prof. Varun Bhalerao, Department of Physics, IITB

(Spring '23)

- Automated photometric analysis using astropy, sextractor, and APT to study an RR-Lyrae variable across spectral bands
- Measured lightcurve periods via template matching, researched luminosity relations and estimated stellar characteristics

True Random Number Generator | [Codes](#) | [Report](#)

(Fall '22)

Course Project : Microprocessors Lab, Guide : Prof. Pradeep Sarin, Department of Physics, IITB

- Implemented a True Random Number Generator on an Arduino, taking advantage of the Thermal Jitter in the in-built RC oscillators and Avalanche effect in a Zener diode, and achieved a bitrate of 800 bps
- Outperformed standard PRNGs on randomness metrics in tests by the National Institute of Standards and Technology

Generating Gravitational Waveforms | [Codes](#) | [Report](#)

(Summer '22)

Simulating gravitational waves in a project organised by Astronomy Club of IITB

- Reviewed literature to understand dynamics of compact binary coalescence and wave frequency characteristics
- Simulated coalescence waveforms using Numerical Relativity and Post-Newtonian Approximations, and performing comparative analysis with LIGO data to understand how source parameters affect signals

Analysis of Proton-Proton Collisions using ROOT (CERN)

(Fall '21)

Course Project : Data Analysis and Interpretation, Guide : Prof. Sadhana Dash, Department of Physics, IITB

- Studied high energy proton-proton collisions by analysing moments of the net charge against collision multiplicities

Project PyRated | Summer of Code - Web and Coding Club, IITB

(Summer '21)

Developed a plagiarism detector as part of a 6-member team

- Used 3 layers and 6 tests of attribute-counting, structure and program-logic based comparison to create an efficient pipeline that minimises false positives without sacrificing accuracy in plagiarism detection
- Achieved an accuracy of 88.9% for plagiarised and 100% for non-plagiarised file pairs from a coding assignment dataset

MENTORING AND ORGANISATIONAL EXPERIENCE

Conference Volunteer, Indian Strings Meeting | IIT Bombay, ICTP Trieste (Winter '23)

- Assisted in organising the Indian Strings Meeting 2023, a week-long conference on String Theory, Quantum Gravity and related topics, with 240+ participants

Teaching Assistant (TA) | Department of Physics, IITB (Spring '22, '23 and '24)

Courses : Basics of Electricity & Magnetism | Classical Physics and Special Relativity | Electromagnetic Theory

- Guided problem-solving sessions and held weekly quizzes, evaluated answer books, conducted review sessions

Mentor for Reading Projects | Summer of Science (Summer '22, '23 & '24)

Maths and Physics Club, IIT Bombay

- Mentored 6 students in reading projects on Special & General Relativity, Elementary Particle Physics and Quantum Field Theory; Guided them in choosing topics, finding resources, and designing a comprehensive study plan

Department Academic Mentor | Department of Physics, IITB (Summer '22 to Summer '24)

Part of a 12-member team selected out of 30+ applicants after extensive interviews and peer reviews

- Mentored 6 Physics sophomores by providing academic guidance and general counselling throughout the year
- Organised and hosted sessions about course planning, resume creation, internship and job applications
- Interviewed 10+ alumni and seniors about internship and research experiences to provide peers clarity on career paths

Literary Arts Convener | Institute Cultural Council, IITB (Summer '21 to Spring '22)

Part of a 7-member council responsible for organising Literary Arts events for 10,000+ students

- Executed Literarium, an annual Literary Arts festival, consisting of 8 events over 3 days, garnering 60+ submissions
- Organised "Literati Poetry Writing Month", which garnered 80+ poetry submissions for 30+ prompts
- Redesigned the institute's quizzing blog and posted 100+ questions, increasing engagement by 400% y-o-y
- Created content for 50+ social media campaigns, increasing the club's online engagement by 150%

CONFERENCES AND WORKSHOPS

Indian Strings Meeting | IIT Bombay, ICTP Trieste (Winter '23)

- Attended a week-long conference on Field Theories, Quantum Gravity, Quantum Information and String Theory

SYMPHY 2024, 2023, 2021 | Annual symposium, Department of Physics, IITB

- Awarded Best Poster for review on Knot Polynomials and Quantum Modular Forms in SYMPHY 2024
- Attended lectures on Quantum Information, High Energy Physics, Photonics & Cosmology

Winter in Data Science Bootcamp | Analytics Club, IITB (Winter '21)

A 4-week course on Data Science and Analysis and Machine Learning

- Completed 2 assignments performing Exploratory Data Analysis and implementing machine learning models using sklearn

SCHOLASTIC ACHIEVEMENTS

- Secured 99.37 percentile out of 0.16+ million candidates in the IIT-JEE Advanced examination, the national-level highly-competitive examination for admission to the Indian Institutes of Technology ('20)
- Achieved 99.92 percentile out of 1+ million candidates in the IIT-JEE Mains examination, the national-level competitive examination for admission to Science and Engineering programs ('20)
- Awarded the National Fellowship in Basic Sciences (KVPY) by Department of Science, Govt of India ('19 - '20)
- National winner of the Scholarship Program for Awareness, Reasoning and Knowledge (SPARK), among 300 out of 300,000+ candidates; conducted by Times of India and Bennett Coleman & Co Ltd ('17)

RELEVANT COURSEWORK

Physics :	Advanced General Relativity[†], Elementary Particle Physics, Special Topics in Particle Physics, High Energy Physics , General Theory of Relativity, Relativistic Quantum Mechanics, Quantum Information Theory, Condensed Matter Physics, Astrophysics, Gravitational Wave Astronomy [†]
Mathematics :	General Topology , Basic Algebra, Group Theory Methods , Differential Geometry in Control Systems, Fourier Analysis , Real Analysis, Complex Analysis, Numerical Analysis
Miscellaneous :	Data Analysis, Optics Lab, Nuclear Physics Lab, Digital Systems, Electronics Lab I (Basic circuits), II (Op amp circuits), III (Digital Electronics) & IV (Microprocessors), Programming Lab

TECHNICAL SKILLS

Languages: Python, C++, MATLAB, Mathematica, HTML/CSS
Software: GATE, Quantum Espresso, LTspice
Libraries: ROOT, Geant4, Sklearn, Pandas, SymPy, Astropy, FeynCalc, Qiskit, QuTiP, Manim, SageMath

OUTREACH

Education Scripted, performed and produced 7 videos of do-at-home science experiments intended for high school students under the Online Laboratory Initiative of the National Service Scheme

Research Organised a lecture series by seniors to introduce freshmen to the various fields of Physics;
Presented a talk on "The HEP Toolkit" focusing on Path Integrals and Feynman Diagrams

EXTRACURRICULAR ACTIVITIES

- Established the THEP Journal Club at IITB to encourage student discussion; Presented a talk on Generalised Symmetries
- Published a 10,000+ word story in an anthology compiled by the Chandigarh Literary Society after attending their 2-day creative writing workshop in 2016; took part in IITB's inter-hostel English Creative Writing competitions in '21 and '22
- Bagged 4th of 50+ teams in the inter-hostel quizzing championship, representing IITB in Quizzing at nationwide competitions such as Electron '23, Inter-IIT Culturals '22 and '23, conducting practice sessions and workshops on quizzing.
- Played finals as part of IITB's 16-member contingent for Inter-IIT Scrabble League 2021
- Judged the slam poetry competitions of Mood Indigo, IITB's annual cultural festival, and the National Cadet Corps
- World Scholar's Cup '18 : Visited Athens for a global round and Yale for the finals of an international multi-subject writing, quizzing, & debate tournament. At finals, obtained 5th place in History out of 1500+ students, and 83rd place out of 500+ teams overall.

REFERENCES

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