

## EDUCATION

- **B.Tech., Engineering Physics**, Indian Institute of Technology Bombay ('20 - '24)  
GPA: 8.6/10.00, pursuing **Honors** in **Physics** and **Minor** in **Mathematics**  
Converted GPA: 3.69/4.0 ([Conversion Spreadsheet](#))

## RESEARCH - THEP

**Knot Polynomials from  $\mathcal{N} = 4$  SYM** | Bachelor's Thesis (Jan '24 - Present)  
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.

- Using 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 (Aug '23 - Dec '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](#) (Feb '24 - Apr '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** (Jan '24 - Present)  
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
- Extending the work of Rabitz and Hsieh to other fidelity measures and symmetry constraints on the Hamiltonian

**Asymptotic Symmetries of Curved Spacetimes** | [Report](#) | [Presentation](#) (Aug '23 - Dec '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** (Feb '23 - May '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 (Feb '23 - May '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](#) (Oct '22 - Dec '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 (Jun '23 - Aug '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

(May '23 - Present)

Guide : Prof. Pragya 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](#)

(Jul '22 - May '23)

Guide : Prof. Pragya 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

(Nov '22 - Jun '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 (Feb '23 - May '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](#)

(Sep '22 - Nov '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](#)

(Jun '22 - Oct '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)

(Oct '21 - Nov '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

(Mar '21 - Jul '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 (Dec '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 (Jan '24 - May '24, Mar '22 - Jul '22, Mar '23 - May '23)

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

- 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 (May '22 - May '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 (Jun '21 - Jun '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 (Dec '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 (Mar '24, Jan '23, Dec '21)

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

**Winter in Data Science Bootcamp** | Analytics Club, IITB (Nov '21 - Dec '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

<b>Physics :</b>	<b>Advanced General Relativity<sup>‡</sup>, Elementary Particle Physics, Special Topics in Particle Physics, High Energy Physics</b> , General Theory of Relativity, Relativistic Quantum Mechanics, Quantum Information Theory, Condensed Matter Physics, Astrophysics, Gravitational Wave Astronomy <sup>†</sup>
<b>Mathematics :</b>	<b>General Topology</b> , Basic Algebra, <b>Group Theory Methods</b> , Differential Geometry in Control Systems*, <b>Fourier Analysis</b> , Real Analysis, Complex Analysis, Numerical Analysis
<b>Miscellaneous :</b>	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

\*Courses to be completed by May 2024,

See full transcript [here](#).

<sup>†</sup>Sit-through courses, <sup>‡</sup>Officially named "Current Trends in Physics"

## 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 4<sup>th</sup> 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

---

### Prof. Pichai Ramadevi

Department of Physics  
Indian Institute of Technology Bombay  
[ramadevi@phy.iitb.ac.in](mailto:ramadevi@phy.iitb.ac.in)

### Prof. Pragya Das

Department of Physics  
Indian Institute of Technology Bombay  
[pragya@phy.iitb.ac.in](mailto:pragya@phy.iitb.ac.in)

### Prof. Sushil Sharma

Faculty of Physics, Astronomy and  
Applied Computer Science  
Marian Smoluchowski Institute of  
Physics  
Jagiellonian University, Krakow, Poland  
[sushil.sharma@uj.edu.pl](mailto:sushil.sharma@uj.edu.pl)