SAS Nagar, India
rehmatsinghchawla (at) iitb.ac.in
rehmatsingh501 (at) gmail.com

Rehmat Singh Chawla

GitHub
LinkedIn
My Website

Education

- **B.Tech., Engineering Physics**, Indian Institute of Technology Bombay *('20 - '24)*
  GPA: 8.6/10.00, awarded **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 *(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 $\mathrm{SL}(2,\mathbb{R})$
- 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 Rentala, 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 relocalisation transform
- Derived the Belifante-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 callibration 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. 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 *(Summer '22 to Summer '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-acitivity 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 comparitive 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

See full transcript here.

*Courses to be completed by May 2024,
[†]Sit-through courses, [‡]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^{th} 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

Prof. Pragya Das
Department of Physics
Indian Institute of Technology Bombay
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