SHASHWAT CHAKRABORTY

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EDUCATION

Indian Institute of Technology Bombay Nov '20 - present

- Fourth-year undergraduate enrolled in the B.Tech program in Engineering Physics
- **CPI: 9.75/10**

Delhi Public School Nov '05 - May '20

- **Grade 12:** All India Senior's Secondary Certificate Examination (2020): **97.8**%
- **Grade 10**: All India Secondary School Examination (2018) : **96.2**%

SCHOLASTIC ACHIEVEMENTS

- Secured **Department Rank 1** amongst a batch of 66 students of the Engineering Physics branch (B.Tech).
- Awarded **Institute Academic Award** for securing a **10/10** annual GPA (2023)
- Awarded **AP** grade in **Biology (BB101)** and **Statistical Mechanics (PH438)** for academic proficiency.
- Secured All India Rank - **768** in **JEE Advanced 2020** among 150,000 candidates.
- Achieved **99.955** percentile in **JEE Main 2020** among 1 million candidates.
- Awarded **Prime Minister's Trophy** by **Steel Authority of India Limited** for scoring the state highest in the **All India Senior's Secondary Certificate Examination** (2020).
- Qualified for **Indian National Olympiads** in Physics, Chemistry and Astronomy (2020).
- Among the top 300 students in India selected for Indian National Mathematics Olympiad **(INMO)** (2019).
- Bagged All India Rank - **130** and received the Kishore Vaigyanik Protsahan Yojana **(KVPY)** scholarship.

RESEARCH EXPERIENCE AND TECHNICAL PROJECTS

First Principles Calculation of Spin Spectra of Magnetic Systems May '23 - Present
Bachelor's Thesis Project | Prof. Marco Bernardi, Caltech

- Developed a code for computing **magnon dispersions** of materials with magnetic order using **Linear Spin Wave Theory** (LSWT).
- Performed **Density Functional Theoretic** (DFT) calculations to obtain electronic bandstructure, density of states (DOS), and phonon-dispersion of various materials using **Quantum Espresso**.
- Learned and employed the **Perturbo** code developed by the Bernardi Research Group to compute **electron-phonon matrix elements**.
- Calculated the **optical** (excitonic) and **magnetic** (magnonic) excitations of 2D ferromagnetic and antiferromagnetic materials using **YAMBO** code after a detailed literature survey on **Many-Body Perturbation Theory** (MBPT).
- Ideated a Quantum Espresso implementation of the **Broken Symmetry Method** to compute the **Heisenberg Exchange Couplings** for 2D antiferromagnetic and ferromagnetic materials.
- Developing a method to rectify the **Goldstone Theorem** violation encountered in the MBPT-based magnon band calculations.

Topological Electronics and Antiferromagnetic Spintronics Jul '22 - Present
Summer Undergraduate Research Program | Prof. Bhaskaran Muralidharan, IIT Bombay

- Studied the realization of topolgically non-trivial states in **Su-Schrieffer-Heeger** (SSH) chain and **graphene**.
- Analyzed **quantum transport** properties of 1D chain, 2D rectangular lattice and graphene tight-binding (**TB**) models after conducting a thorough literature survey on time-dependent **Keldysh** formalism based on Non-Equilibrium Green's Function (**NEGF**) method for nanoscale conductors under bias.
- Performed NEGF based modelling of magnetic tunnel junction (**MTJ**) devices and spin-transfer torque (**STT**) based Ferromagnetic memory devices.

- Developed a code to compute the STT and numerically model the magnetization dynamics using the coupled **Antiferromagnetic Landau–Lifshitz–Gilbert** equations.
- Working on novel reading and writing mechanisms for 2D antiferromagnetic spintronic memory devices by exploiting the topological Quantum Spin Valley Hall Phase (**QSVH**).

Superconductor-Topological Insulator Junction May '23 - Present
Undergraduate Research Project | Prof. Hridis Pal, IIT Bombay

- Modeled a superconductor-vacuum junction using the **Bogoliubov de-Gennes** (BdG) theory for tight-binding models and calculated variations in superconducting **critical temperature** (T_c).
- Developing a code to calculate the **order parameter** configuration in superconductor-topological insulator heterostructures using the **Fu-Kane** model Hamiltonian.
- The project aims to physically model the boundary superconductivity exhibited by **Weyl materials**.

Feedback-assisted Quantum Annealing for Portfolio Optimization Aug '22 - Dec '22
Quantum Hackathon, QETCI | Prof. Siddharth Santra, IIT Bombay

- the project aims to obtain more reliable and optimal solutions from **quantum processors** with quantum speedup for portfolio optimization.
- Worked on a **hybrid quantum-classical algorithm** that provides statistically calibrated feedback to the quantum subroutine.
- Implemented the algorithm on DWave quantum computer after a detailed literature review on **Binary Quadratic Models**.

Group Theoretic Approach to Quantum Field Theory Nov '21 - Nov '22
Supervised Learning Project | Prof. Vikram Rentala, IIT Bombay

- Read about finite groups, Lie groups and Lie algebras, and the construction of linear representations.
- Learned about **Effective Field Theories**, **Renormalisation**, and Elementary Particle physics.
- Read about the **Poincare group** representations and construction of non-linear realisations of groups.
- Explored **Coleman-Callan-Wess-Zumino** (CCWZ) construction and chiral symmetry breaking.

Student Satellite Program | IIT Bombay Jun '21 - Jul '22
Communication Subsystem | Sanket - Antenna Deployment System

- The Student Satellite Program is a 70+ member student team dedicated to the vision of making IIT Bombay a center of excellence in space technology.
- The mission **Sanket** aims to develop an indigenous Antenna Deployment System with TRL-8.
- Interfaced two ATmega128 microcontrollers using USART and SPI communication protocols in Proteus.
- Programmed CC1125 transceiver using ATmega128 and established **wireless communication** between two **BOOSTXL-CC1125** transceiver boards.
- Ideated a setup and performed component-level testing of CC1125 transceiver.
- Established a transceiver-dipole antenna interface and demonstrated half duplex wireless communication.
- Worked on basic RF testing and devised a component-level **testing plan** for CC1125 transceiver.
- Designed an **RF PCB** for Low Noise Amplifier (LNA) using **Eagle** software.
- Secured the **second** position in **Student Design Competition** at the **International Conference for Small Satellites - 2022** for presenting the Sanket module.

Cosmology and Dark Matter May '21 - Jul '21
Maths and Physics Club, IIT Bombay

- Learned general relativity and understood the Friedmann–Lemaitre–Robertson–Walker metric.
- Explored the Newtonian and Relativistic approaches to constructing cosmological models.
- Read about the characteristics of **cosmological models** and briefly studied inflation theories.
- Documented the project in the form of a **report** covering the topics - Tensor Analysis, Einstein Field Equations, Cosmological models, Dark Energy, Dark Matter, and its candidates.

COURSE PROJECTS

Lagrangian Formalism for Electrodynamics Aug '22 - Nov'22

Course Project - Electromagnetic Theory | Instructor: Prof. Anshuman Kumar

- Learned about **topological insulator lasers** and their advantages over ordinary lasers.
- Studied 1D and 2D Su-Schrieffer-Heeger systems of resonators with edge-mode lasing.
- Analysed the realization of **topological edge-modes** and the occupation under selective lasing.

Topological Optical Parametric Oscillation Aug '22 - Nov'22

Course Project - Photonics | Instructor: Prof. Anshuman Kumar

- Learned about **topological insulator lasers** and their advantages over ordinary lasers.
- Modelled 1D and 2D Su-Schrieffer-Heeger systems of resonators using **Heisenber-Langevin** equations.
- Analysed the realization of **topological edge-modes** and the occupation under selective lasing.
- Developed a code to analyze **quadrature squeezing** displayed by 1D SSH chain of parametric resonators after a meticulous disquisition of **sqeezed states of light**.

Topological Quantum Computation Aug '22 - Nov'22

Course Project - Topological Electronics | Instructor: Prof. Bhaskaran Muralidharan

- Learned about the various **anyon models** and their potential usage in quantum computation.
- Explored the methods of realizing anyons in physical systems such as fractional quantum hall states.
- Read about **Majorana Zero Modes**, the capability of **superconducting nanowires** to host them, and the scope of quantum computation based on **Majorana braiding**.

Data Analysis of Net Charge Fluctuations in p-p Collisions Sep '21 - Nov '21

Course Project - Data Analysis and Interpretation | Instructor: Prof. Sadhana Dash

- **PYTHIA** is a program for generation of high-energy physics collision events. **ROOT** is an open-source framework for data processing and statistically sound scientific analyses, created by **CERN**, mainly used in high energy physics.
- Measured the net charge fluctuations in data generated using PYTHIA 8 Monte Carlo Event Generator which included **4 million observations** obtained from a **p+p collision system** at center-of-mass energy $\sqrt{s} = 13$ TeV.
- Used ROOT to plot the **mean** μ, **variance** σ^2 and the ratio σ^2/μ of the net charge observed in an event as a function of the **multiplicity** - the number of charged particles produced in a collision at a given COM energy.
- Analysed the relationship between the number of particles that can and the ones that cannot be detected by a detector depending on certain thresholds. Created 2-D scatter plots to illustrate the obtained results.

Epidemic Modelling Aug '21 - Nov '21

Course Project - Nonlinear Dynamics | Instructor: Prof. Amitabha Nandi

- Aim of the project was to develop a mathematical model for explaining the COVID-19 spread.
- Learned about the basic **Susceptible-Exposed-Infected-Removed (SEIR)** model.
- Explored methods of incorporating sociological parameters like public perception and governmental action.
- Analysed and simulated COVID-19 spread statistics of a South Korean dataset using Python.

Huffman Coder-Decoder Feb '22 - Apr '22

Course Project - Digital Systems | Instructor: Prof. Maniraj Mahalingam

- Huffman coding is a **lossless data compression algorithm**. Variable length codes are assigned to input characters based on their frequencies. The most frequent character gets the smallest code and so on.
- Designed an extendable circuit using digital electronic components like timers, counters, flip-flops, registers, etc., for coding and decoding inputs consisting of three allowed characters, using the Huffman algorithm.
- The design consisted of three functional subdivisions: ASCII to 3-bit intermediate code converter, Huffman tree generator and Huffman to ASCII decoder.

Common-Emitter Amplifier with Feedback Apr '21 - May '22

Course Project - Introduction to Electronics | Instructor: Prof. Uma Sankar

- Analysed various circuit topologies involving **BJT**'s (Bipolar Junction Transistors) and **passive filters**
- Designed common emitter amplifier with **feedback** resistor mechanism to produce a voltage gain of 100.
- Learned about decoupling and by-pass capacitors and methods to fine tune their values.
- Used the **Falstad** circuit simulator for analysing the response of the circuit to various inputs.

All the project reports can be found here

SELF PROJECTS

Quantum Information and Computing May '22 - Jul '22

- Watched the online lecture series on Quantum Information and Computing by Prof. Sai Vinjanampathy, IIT Bombay, made available by the Centre For Distance Engineering Education Programme.
- Learned various quantum algorithms, spintronic quantum computing, and the use of atomic qubits in quantum computing from the online lecture series by Prof. Debabrata Goswami, IIT Kanpur, provided by the National Programme on Technology Enhanced Learning.
- Read three chapters of the book "Introduction to Quantum Control and Dynamics" by Dominico d'Alessandro.

RELEVANT COURSES

- **Theoretical Physics**: Quantum Mechanics I, II & III, Photonics and Nonlinear Optics, Topological Electronics, Nonlinear Dynamics, Thermal Physics, Classical Mechanics, Waves Optics, General Theory of Relativity, Condensed Matter Physics, Statistical Mechanics, Electromagnetic Theory, Quantum Information and Computing, Atomic and Molecular Physics*
- **Experimental Physics:** Optics and Spectroscopy Laboratory, Solid State Physics and Nuclear Physics Laboratory
- **Maths**: Calculus, Linear Algebra, Differential Equations - I & II, Complex Analysis, Numerical Analysis
- **Electronics**: Labs - , Theory - Analog & Digital Electronics
- **Data Analysis**: Data Analysis and Interpretation
- **Additional**: Economics, Molecular and Cellular Biology, Evolutionary Biology, Computer Programming

** to be completed by November '23*

TECHNICAL SKILLS

Languages: Python, MATLAB, Embedded C, C++, HTML

Softwares Packages: Quantum Espresso, VASP, Microchip Studio,, Eagle PCB, ROOT-Cern

Simulation Softwares: LTspice, Falstad, Proteus

POSITIONS OF RESPONSIBILITY

Mentor | Department Academic Mentorship Program Jun '23 - Present

Department of Physics, IIT Bombay

- Mentored 6 sophomores, providing them with **academic guidance** and general **counselling**.
- Organised a department introduction session for incoming sophomores as part of the DAMP team
- Worked to collect course reviews, internship reviews, and academic resources, which would be published on the DAMP Blog for everyone to view and use.

Teaching Assistant Dec '21 - Present

Department of Maths | Department of Physics, IIT Bombay

- Delegated the responsibility of Teaching Assistantship for the courses MA 214 - **Numerical Analysis**, MA205 - **Complex Analysis**, MA 207 - **Differential Equations** and PH107 - **Introduction to Quantum Mechanics**.

- Responsibilities include conducting tutorial sessions on a regular basis for a batch of 45 first-year undergraduate students, to improve their problem-solving skills, taking tests, and correcting answer scripts.
- Conducting regular doubt sessions for resolving theoretical queries.

Mentor | Summer of Science May' 22 - Jul '22
Math and Physics Club, IIT Bombay

- Guided students with projects on" General Relativity,"" Cosmology," and" Quantum Mechanics."
- Tasks included chalking out plans of action, clearing doubts, and regularly reviewing the mentees' work.

Mentor - Vocals| Advanced Learning Program Sep '21 - Jan '22
Symphony Club, IIT Bombay

- Entrusted with the responsibility of mentoring selective 15 students for **advanced singing techniques**.
- Primary tasks included creating content for weekly sessions of teaching **Hindustani Classical music**, improvisation in other forms of music and basic **voice culture**, making and assessing weekly assignments.

EXTRA-CURRICULAR ACTIVITIES

Presentations:

- Presented about transceivers at the **Ground Station Workshop** conducted by Ham Radio Club, IIT Bombay, for equipping 120+ participants from 20+ colleges to set up their ground station.

Sports:

- International rated chess player with **FIDE rating: 1820**.
- Bagged the **first** position in the Chess General Championship 2023 - IIT Bombay.
- Awarded the **first** prize in the Freshers Open Chess Tournament 2020 - Chess Club, IIT Bombay.
- Stood **fifth** in the All India Open FIDE Rating Chess Tournament 2016 (Nasik, Maharashtra)
- Won the **first prize** in the U-15 **State** Chess Championship 2016 (Chhattisgarh).
- Won the **silver medal** in **CBSE National** Chess Championship 2015 (Kolkata, West Bengal).

Music:

- Completed a 6-year course in Hindustani Classical Music and received the title of **Sangeet Visharad**.
- Stood **second** in the Indian Classical Vocals competition in the **Freshiezza** event organized by the Institute Cultural Council at IIT Bombay
- Received the **Kala Ratna Samman** on the occasion of **6th International Cultural Olympiad of Performing Arts 2017** organised by Hindustan Art & Music Society.