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Indian Institute of Technology,Bombay
Engineering Physics, 3^{rd} year undergraduate, B.Tech
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EDUCATION

Examination	University/Institute	Year	CPI/%
Undergraduate	IIT Bombay	2022	9.27
Intermediate	D.G. Ruparel College	2020	93.85%
Matriculation	St. Mary's High School (S.S.C)	2018	95.40%

RESEACRH INTERESTS

I am deeply interested in the Physics of **quantum systems** which have potential applications in quantum computation. In particular, I am interested in the study of **dissipative open quantum systems**, which are fundamental in modelling a qubit system in experimental settings. I am intrigued by novel physical phenomena that manifest at the quantum level. For instance, I am interested in the **Quantum Zeno effect**, and its relevance in quantum memory and weak value measurements.

Studying the different schemes for the physical realization of a two level quantum system occupy another major part of my interests. Modelling these systems analytically, studying how quantum operations can be performed on them and the related practical difficulties associated with these systems is one of the fascinating areas of research for me. I have a firm theoretical understanding of quantum mechanics and am eager to explore its applications in real-life experimental systems.

PROJECTS

Cooperative Resonance Scattering in 2-D Atomic Arrays | Research Intern *(May '22 - July '22)*

Guide: Prof. Ephraim Shahmoon, Weizmann Institute of Science, Israel

Periodic 2D arrays of atoms can act as perfect reflectors for certain frequencies of light, while transmitting other frequencies. These resonance frequencies are in general different from the natural frequencies of the atoms and depend on the lattice spacing of the array. We numerically simulated and demonstrated this **scattering of light** by a **2-D array** of **dipole-like atoms** , to study the **collective effect of dipole-dipole interactions** on **resonance frequency** of the array (Python codes that we wrote can be found here)

- Demonstrated the **complete reflection** of light incident at **cooperative resonance frequency** of array
- Obtained the variation **cooperative resonance frequency** as a **function of the array's lattice spacing**
- Plotted the variation in **intensity transmissivity** of the array as a function of its **lattice spacing**
- Studied the effects of **random disorder in the positions** of atoms on the transmissivity of the array

Quantum Zeno Dynamics | Supervised Project *(May '22 - present)*

Guide: Prof. Sai Vinjanampaty, Dept. of Physics, IIT Bombay

When a quantum system is subject to frequent 'selective' measurements, in the limit of 'continuous measurements', its time evolution freezes. If the measurements are not 'selective',the system evolution doesn't freeze, but its dynamics are limited to the Zeno subspace, a subspace of the Hilbert space. This can be used to **decouple a quantum system** from its environment.This project aims at studying the mathematical formalism of **Quantum Zeno dynamics** and its possible applications in Quantum Metrology.

- Developed a deep understanding of **open quantum system dynamics**, by scrutinizing the density matrix formulation; non-unitary evolution of ensemble mixtures and super-operator representation
- Studied the properties of completely positive trace preserving (CPTP) maps and the operator sum representation of quantum channels, that describe a general non-Markovian quantum channel
- Learnt the fundamentals of **dynamical decoupling techniques** used in liquid state NMR spectroscopy to control the decoherence in spin qubits using periodic Radio-Frequency pulses
- Studied the mathematical structure of the Quantum Zeno Effect as a limiting case of discrete time measurements of the system, with the time interval between succesive measurements tending to zero

Realization of Superconducting Qubits | Supervised Reading Project *(Nov '21 - May '22)*
Guide: Prof. Alok Shukla, Dept. of Physics, IIT Bombay
Superconducting circuits have proven to be a good way of manifesting quantum two level systems. This project involved a literature survey of different types of superconducting qubits, based on the use of Josephson's junction

- Studied the implementation of Qubits using superconducting circuits, chiefly Josephson's Junction
- Learnt about the formation of **Cooper pairs** in a superconductor and the associated wave functions
- Studied the properties of a **Josephson's Junction** and **flux quantization** in a superconducting circuit
- Scrutinized the application of Josephson's Junction in implementing **Charge, Phase and Flux Qubits**, learnt to set up the Hamiltonian for each of these systems and analyse their energy eigenstates

Great Lunar Expedition for Everyone (GLEE) | Student Satellite Team *(July '21 - April '22)*
Student Satellite Program at IITB is a **70+** students team dedicated to make IITB a centre of excellence in space technology. As a part of the **Instrumentation subsystem** of the team, worked for the **GLEE** Mission. GLEE is a global collaborative mission aimed at conducting space science on the lunar surface using student-built chip-sized satellites **(chip-sats)** using commercially-off-the-shelf components(which was initiated by CU, Boulder). Our work revolved around designing and implementing the payload of such a chipsat.

- Worked on the **Micro-meteoroid Detection Payload**, aimed at estimating the **number flux of micro-meteoroids** impacting the lunar surface in the vicinity of the chip-sats by using sensors onboard.
- Implemented various **seismic source localization** and **beamforming** techniques to estimate the position of impact of the micro-meteoroid and direction of wave propagation,using **Python**
- Co-authored a research poster on '**Lunar Exploration via Chipsats: Micrometeoroid Detection Payload**', which was presented at the **National Space Science Symposium (NSSS 2022)**

Quantum Algorithms in Quantum Chemistry | Supervised Reading Project *(May '22 - July '22)*
Guide: Prof. Alok Shukla , Dept. of Physics, IIT Bombay
This project was aimed at studying the applications of quantum computation algorithms in quantum chemistry.It chiefly involved studying the phase estimation algorithm that can be used to find the energy eigenvalues of a system, given that the system is in one of its energy eigenstates.

- Gained a good understanding of different two-qubit and three-qubit quantum gates and their circuit representation, like the Hadamard, CNOT, T-gate, swapping gate, controlled-swap and Toffoli gates.
- Scrutinized the Grover's Search Algorithm, Deutsch Algorithm and Phase Estimation Algorithm
- Studied the Quantum Fourier transform along with its application in the phase estimation algorithm, to estimate the energy of an energy eigenstate of a molecule, and the associated quantum circuits

Huffman Coding Digital Circuit | Course Project *(Jan '22 - April '22)*
Guide: Prof. M. Mahalingam , Dept. of Physics, IIT Bombay | Digital Electronics
Huffman coding is an algorithm used for data compression. Unlike ASCII, where each character has a pre-determined code, Huffman coding uses variable length coding, giving the shortest code to the most frequently used character and the longest one to the least used character, thus saving storage space. We designed a digital circuit to perform this complicated algorithm, by taking input in ASCII form, determining the frequency of occurence of each character and encoding the data into Huffman codes.

- Designed a circuit to implement paradigmatic **Huffman coding** of ASCII characters, assigning codes of variable length depending on the **frequency of occurrence of a character**, using digital components
- Devised a circuit block to **count the number of occurrences** of characters and to generate **a Huffman tree** by **identifying the least occurring character** using counters, registers, logic gates & clock
- Conceived the block to **decode** a Huffman code and identify the equivalent ASCII character

Net-Charge Fluctuations in proton-proton collisons | Course Project *(Oct '21 - Nov'21)*
Guide: Prof. Sadhana Dash , Dept. of Physics, IIT Bombay | Data Analysis and Interpretation
Analysed the given simulated data of proton-proton collision events, using ROOT CERN software.

- Studied and plotted the net-charge fluctuation as a function of multiplicity of particles in an event
- Studied the multiplicity of particles as a function of their pseudo-rapidity by plotting 3 dimensional histograms

Digital and Analog Electronics | Lab Courses

Guide: Prof. Pradeep Sarin,Prof. Varun Bhalerao Dept. of Physics, IIT Bombay

Through these laboratory courses, I learnt to come up with creative solutions to complicated electronic problems, using simple electronic devices, like Bipolar junction transistors, Operational Amplifiers and combinational logic gates. This involved hands-on learning, physical circuit assembly and debugging. Some of the several circuits that I created included :

- A **disturbance measurement system** using Operation Amplifiers.This consisted of creating a feedback loop, with an LED being driven by an Op-amp and a photodiode.A disturbance in light intensity would be compensated for by the feedback loop.This served as a measure of the disturbance intensity.
- A digital implementation of a **finite-state automaton** demonstrating conditional state transition.
- Programming a series of LEDs to glow in a particular periodic pattern using registers and IC 555 timer, without using a micro-controller or other programming device.

SCHOLASTIC ACHIEVEMENTS

- An academic rank of **7**, among 60+ students in the department of Engineering Physics *(2022)*
- Secured **98.54 percentile** in JEE Main Examination among over 1 million candidates *(2020)*
- Secured **academic rank 1** in the first year of Junior College, at D.G. Ruparel College (Science) *(2019)*
- **Valedictorian** in standard 10^{th}(matriculation) at St. Mary's High School (S.S.C) *(2018)*

RELEVANT COURSES

- **Physics and related:** Quantum Mechanics I, Quantum Mechanics II (Perturbation Theory)*, Introduction to Quantum Chemistry, Introduction to Quantum Engineering*, Photonics*, Non-Linear Dynamics*, Special Theory of Relativity, Thermal Physics, Classical Mechanics, Electrodynamics
- **Mathematics:** Calculus, Linear Algebra, Complex Analysis, Differential equations, Introduction to Numerical Analysis
- **Computer Science and Electronics:** Data Structures and Algorithms, Logic in Computer Science, Computer Networks*, Introduction to Computer Programming and Utilization, Digital Electronics

  * *will be completed in Nov '22*

RELEVANT SKILLS

I have strong foundations in Quantum Mechanics and Mathematics. I have worked on designing, assembling and debugging complicated electronic circuits. I have excellent programming skills, and am more comfortable with Python and C++. I am good at conducting efficient literature reviews, and self-learning new concepts. I have an experience of working and coordinating in a large student's technological team, though I am highly self-reliant at work. I am an adept learner with passion to understand the fundamentally surprising aspects of Quantum Science and contribute in unravelling them.