Vihaan Dheer

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Education

Hackley School, Tarrytown, NY, 2023 2014-present

SAT Scores: ▪ Composite: 1560 ▪ EBRW: 760 ▪ Mathematics: 790

AP Scores: ▪ AP Physics C: Mechanics - 5 ▪ AP Physics C: E&M - 5 ▪ AP Calculus BC - 5 ▪ AP Computer Science A - 5 ▪ AP Chemistry - 5

Relevant Coursework: Multivariable Calculus/Linear Algebra, AP Physics C: Mechanics and Electricity & Magnetism, Independent Study: Higher Category Theory and Homotopical Algebra, Submersible ROV Engineering, Calculus-based AP Statistics

Independent Research Program: Research projects in quantum computing and category theory

Online Coursework 2020–2021

- **MIT OpenCourseWare:** 8.09 Classical Mechanics III, 8.322 Quantum Theory II, 8.321 Quantum Theory I
- **Stanford Lectures:** General Relativity I
- **Coursera:** Introduction to Complex Analysis, Macroeconomics
- **Khan Academy:** Multivariable Calculus, Linear Algebra, Calculus II

Extra-scholastic Independent Studies (self-study, through textbooks; see Appendix) 2020–2022

- **Mathematics:** Higher Category Theory, Algebraic Topology, Lie Group Theory, Real Analysis & Measure Theory, Quantum Category Theory, Category Theory, Discrete Mathematics, Tensor Calculus & Manifold Theory, Differential Forms
- **Physics:** Quantum Field Theory, Special & General Relativity, Quantum Algorithm Theory, Particle Physics, Path Integrals, Classical Electrodynamics

Research

Mathematical Physics: Quantum Computing 2020–2021

- Conducted research in the field of quantum computing, entitled “The Optimization of Flux Trajectories for the Adiabatic Controlled-Z Gate on Split-Tunable Transmons”; published as sole-authored research in the peer-reviewed journal of the American Institute of Physics, *Advances*, DOI: 10.1063/5.0087364 (abstract in appendix)

Pure Mathematics: Category Theory 2021–2022

- Conducted research in the field of category theory, entitled “An Infinitary Model of Diagrammatic Calculus in Unbiased Monoidal Categories” (abstract in appendix)

Work Experience

E. I. Investments 2020–present

Software Developer & Designer

- Working with trader/investor on software product for market data analysis and automated trading

Changements.com 2020–present

Web Application Developer & Designer

- Developing web application for Changements.com, a startup which connects potential donors with small non-profits in India and other developing countries

Programming Tutoring 2020

Python Tutor

- Tutored 5th grader (virtually) in introductory Python scripting and development

Awards/Honors

- **Award in Mathematics** June 2022

  "Math Award" given by Hackley School to the junior who best "demonstrates mastery in math as well as interest in and passion for the subject beyond coursework."

- **Sole-authored Research Publication** September 2022

  Research in quantum computing published in peer-reviewed journal American Institute of Physics *Advances*; DOI: 10.1063/5.0087364

- **2022 Regeneron Westchester Science & Engineering Fair** March 2022

  Earned 2nd place award in Physics & Astronomy Category, and Mu Alpha Theta award for use of mathematics; both awards won for research project in quantum computing

- **Marine Advanced Technology Education (MATE) ROV 2022 Competition** May 2022

  Competed alongside teammates with a built-from-scratch submersible remotely operated vehicle (ROV) in the 'Navigator' category; earned 1st place in Product Demonstration, 1st place in Poster Display

Extracurricular Activities

- **Sports:** Tennis, Hackley varsity team & club tennis; squash, Hackley varsity team
- **Music:** Drums, Guitar, Piano, Digital Music Production
- **Service Work:** Soup Kitchens, Backpack Drives, Park Cleanups

Additional Skills

- **Programming Languages:** Python, Swift, Java, Objective-C, JavaScript, C++, Unix Shell Script
- **Research Tools**: MATLAB, Wolfram Language (Mathematica), LaTeX
- **ML & Cloud Computing:** TensorFlow, Keras, PyTorch, Amazon Web Services, Firebase

Appendix

- **Mathematics Textbooks Studied:**

  Higher Categories and Homotopical Algebra, Cisinski

  An Introduction to Algebraic Topology, Rotman

  Lie Groups, Lie Algebras, and Some of Their Applications, Gilmore

  Measure, Integration, & Real Analysis, Axler

  Categories for Quantum Theory, Heunen & Vicary

  Introduction to Category Theory, Roman

  Discrete and Combinatorial Mathematics, Grimaldi

  A Practical Introduction to Differential Forms, Schulz & Schulz

  Tensor Analysis on Manifolds, Bishop & Goldberg

- **Physics Textbooks Studied:**

  Relativistic Quantum Mechanics and Field Theory, Gross

  Gravitation, Misner, Thorne, & Wheeler

  Quantum Computation and Quantum Information, Chuang & Nielsen

  Quarks and Leptons, Halzen & Martin

  Quantum Mechanics and Path Integrals, Feynman & Hibbs

  Introduction to Electrodynamics, Griffiths

- **Abstract for "The Optimization of Flux Trajectories for the Adiabatic Controlled-Z Gate on Split-Tunable Transmons":**

  In a system of two tunable-frequency qubits, it is well-known that adiabatic tuning into strong coupling-interaction regions between the qubit subspace and the rest of the Hilbert space can be used to generate an effective controlled Z rotation. We address the problem of determining a preferable adiabatic trajectory along which to tune the qubit frequency, and apply this to the flux-tunable transmon model. The especially minimally anharmonic nature of these quantum processors makes them good candidates for qubit control using non-computational states, as long as higher-level leakage is properly addressed. While the statement of this method has occurred multiple times in literature, there has been little discussion of which trajectories may be used. We present a generalized method for optimizing parameterized families of possible flux trajectories and provide examples of use on five test families of one and two parameters.

- **Abstract for "An Infinitary Model of Diagrammatic Calculus in Unbiased Monoidal Categories":**

  Properties of morphisms represented by so-called 'string diagrams' of monoidal categories (and their braided and symmetric derivatives), mainly their resistance in value to isotopic deformation, have made the usage of graphical calculi commonplace in category theory ever since the correspondence between diagrams and tensor categories was rigorously established by Joyal and Street in 1991. However, we find it important to make three major modifications to their treatment: firstly, we employ a structure inherently resistant to isotopy, thus at first avoiding unnecessary topological details. Next, we determine the inverse correspondence, permitting for promotion to a monoidal equivalence with a "category of diagrams." Lastly, we coherently introduce the infinitary tensor product and transfinite composition into the diagrammatic theory.