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EDUCATION

Master's of Science, Physics
University of Alberta, Canada — Sep. 2023→ Aug. 2025
GPA: 4.0/4.0
Field: Condensed Matter Theory.

Bachelor of Science, Honors in Mathematical Physics (First Class Honors)
University of Alberta, Canada — Sep. 2019 → Apr. 2023
GPA: 3.7/4.0
Concentrations: Physics & Mathematics.

RESEARCH EXPERIENCE

Position:	Master's Student	Sep. 2023 → Present
Affiliation:	Department of Physics, University of Alberta.	
Supervisor:	Dr. Igor Boettcher.	

Project: Band Theory & Density of States on Archimedean Lattices. (in prep)

Archimedean lattices are convex uniform tessellations of $\mathbb{R}^2$. First discovered by Kepler in 1619 and named after Archimedes, each vertex of the lattice is met with the same configuration of regular polygons (modulo rotation) and thus is "homogeneous" in this sense. The condition for completely tiling the whole plane yields only **11** unique such lattices including some of the well known canonical ones *viz.* "Square", "Triangle" & "Honeycomb" lattices. We studied a nearest-neighbour tight-binding model with hopping amplitude t on these 11 lattices Λ by considering the lattice as an embedded graph $G_\Lambda = (V, E)$. This graph theoretic picture naturally induces an adjacency matrix A_Λ of the lattice and the eigenvalue problem reduces to that of finding the spectrum of the $-tA_\Lambda$. We have computed their band structures and the Density of States (DOS) by exploiting translation symmetry and reducing the eigenvalue problem defined on a the unit cell in $\boldsymbol{k}$ space through "Bloch" Adjacency Matrix $A_\Lambda(\boldsymbol{k})$.

Project: Graphs & Counting Returning Walks on Archimedean Lattices. (in prep)

We formulated a systematic approach to construct A_Λ for all the 11 Archimedean lattices through tensor products of smaller Adjacency matrices. Moreover, we have computed the moments $\langle i|\hat{A}^n_\Lambda|i\rangle$ for these Λ, which corresponds to the number of returning walks in n steps on Λ (which we call *degenerate loop numbers*). These degenerate loop numbers were only known in the literature for the canonical lattices but had not been computed for the remaining 8. Moreover, we developed the theory of "Bloch" generating functions by explicitly constructing the functions $X_\Lambda(t, \boldsymbol{k})$ and proving that when integrated over the Brillouin Zone, these functions reduce to the ordinary generating function $X_\Lambda(t)$ whose coefficients yield the degenerate loop numbers. The method can be easily generalized to produce the generating function $X^*_\Lambda(t)$ for *non-backtracking* returning walks as well. Using these degenerate loop numbers, we have also computed the DOS of these Λ through the method of *continued fraction* by calculating coefficients $\{(a_n, b_n)\}_{n\in\mathbb{N}}$. We have constructed a faster, more reliable recursive method to compute these coefficients given the moments $\langle i|A^n_\Lambda|i\rangle$ through "Lanczos polynomials" which avoids computing repeated matrix products and sidesteps the problem of loss of orthogonality in standard Lanczos algorithm.

PROJECT: The Ising Model with $h = 0$ on Archimedean Lattices. (in prep)

We employed the method of Feynman, Kac & Ward in conjunction with our Bloch Adjacency Matrices $A_\Lambda(\boldsymbol{k})$ to solve for the free energy per site ($-\beta f = \frac{\ln(\mathcal{Z})}{N}$) for the Ising model without an external magnetic field and isotropic nearest-neighbour coupling J on all 11 Archimedean Lattices in the thermodynamic limit $N \to \infty$. Our results match the standard results in the literature for the Triangle, Honeycomb and the celebrated Onsager solution for the Square lattice. Our expressions for the critical temperature T_c are in good agreement with standard Monte-Carlo simulations.

POSITION: Research Assistant — May 2023 → Aug. 2023
AFFILIATION: Department of Mathematical & Statistical Sciences, University of Alberta
SUPERVISOR: Dr. Eric Woolgar

PROJECT: On Special Solutions of the Quasi-Einstein Equations

A Quasi-Einstein manifold is the triplet $(\mathcal{M}, g, X)$ with g as the metric tensor on manifold $\mathcal{M}$, such that there exists a 1-form X (or equivalently its dual vector field $\vec{X}$) satisfying the Quasi-Einstein equation that arises in the near-horizon geometry of *extremal* black holes. The Quasi-Einstein (QE) equation is a generalization of the components of the Ricci tensor on the $(n-1)$-dimensional Horizon cross section that arises from a certain limiting process of the metric near the horizon (*near-horizon limit*) when $m = 2$ for a black hole in an $(n+1)$-dimensional spacetime with cosmological constant λ. We investigated the case when the manifold $\mathcal{M} = \mathbb{S}^n$ for the rotationally symmetric warped metric $ds^2 = dr^2 + \zeta^2(r) g(\mathbb{S}^{n-1}_{\text{can}})$, $n \geq 3$ for closed $X(r)$. We reformulated the problem in terms of admissible trajectories in 2-D phase space analysis by transforming the QE equation into an ODE system.

POSITION: Research Assistant — May 2022 → Aug. 2022
AFFILIATION: Department of Physics
SUPERVISOR: Dr. Igor Boettcher

PROJECT: Anomalous Quantum Wave Dynamics in Hyperbolic Space.

Hyperbolic lattices are simulations of hyperbolic space using discrete lattice geometries that produce an effective negative curvature. They have been realized in groundbreaking experiments with both superconducting resonators and topoelectrical circuits over the last four years. Importantly, the propagation of quantum or classical wave packets is the central experimental probe in these experiments. The emergence of a non-commuting operator, Q beside the (Laplace-Beltrami) Hyperbolic Laplacian (Δ_H) in the Schrödinger equation $(-\Delta_H + \epsilon Q)\psi = E\psi$ alters the time evolution of a plane wave which are the eigenstates of $-\Delta_H$ propagating through these lattices in a non-trivial manner. This operator naturally arises from the expansion of ψ on hyperbolic lattices embedded in the Poincaré Disk; hence, it emerges as a property of the lattice geometry. We characterized this anomalous behaviour through time via numerical simulations in both real and momentum space.

POSITION: Research Assistant — May 2021 → May 2023
AFFILIATION: Department of Mathematical & Statistical Sciences
SUPERVISORS: Dr. Beatrice Helen Vritsiou & Dr. Sergii Myroshnychenko

PROJECT: On the Illumination of k-dimensional faces of the n-dimensional cube. (in prep)

The Illumination Conjecture, equivalent to the Covering Conjecture presents an upper bound for the minimum number of light sources needed to illuminate the boundary of a Convex body $K \subset \mathbb{R}^n$ where the upper bound 2^n is satisfied in the case of the hypercube $[-1, 1]^n \subset \mathbb{R}^n$. A variant of the Illumination Conjecture which focuses on illuminating the k-dimensional faces of K posits a similar upper bound of 2^{n-k} defined by the k-dimensional faces of the hypercube. We disproved the variant conjecture for the hypercube by showing that it fails for $2 \leq k \leq n-2, \forall n \geq k+2$. We further showed that it is only true for $k = 1, \forall n \geq 3$. Moreover, we found matching upper and matching lower bounds for $k = 2$ and $k = n-2$.

TEACHING EXPERIENCE

Position:	Teaching Assistant	Sep. 2024 → Present
Department:	Department of Physics	
Class:	PHYS 530, Graduate Statistical Mechanics	
Instructors:	Dr. Igor Boettcher	

Grading duties and assignment help.

Position:	Teaching Assistant	Jan. 2024 → Apr. 2024
Department:	Department of Physics	
Class:	PHYS 297, Experimental Physics II	
Instructors:	Dr. Aksel Hallin & Dr. Michael Woodside	

In charge of preparing lectures, grading and supervising students through replicating the classic Frank-Hertz experiment for Hg and Ne as part of the Laboratory section.

Position:	Teaching Assistant	Sep. 2023 → Dec. 2023
Department:	Department of Physics	
Class:	PHYS 124, Particles & Waves	
Instructor:	Undergraduate Physics Labs (PHYSUGL)	

In charge of preparing lectures, grading and supervising students for the Lab section for first year labs. Experiments encompass aspects from Newtonian mechanics and periodic motion that relate to topics learnt in class.

Position:	Teaching Assistant	Jan. 2023 → May 2023
Department:	Department of Mathematical & Statistical Sciences	
Class:	MATH 216, Introduction to Analysis	
Instructor:	Dr. Arno Berger	

Grading duties.

Position:	Teaching Assistant	Sep. 2022 → Dec. 2022
Department:	Department of Mathematical & Statistical Sciences	
Class:	MATH 117, Honors Calculus I (Analysis)	
Instructor:	Dr. Jochen Kuttler	

Grading duties.

Position:	Teaching Assistant	Jan. 2022 → May 2022
Department:	Department of Mathematical & Statistical Sciences	
Class:	MATH 144, Calculus for the Physical Sciences	
Instructor:	Dr. David McNeilly	

Grading duties.

Position:	Teaching Assistant	Sep. 2021 → Dec. 2021
Department:	Department of Mathematical & Statistical Sciences	
Class:	MATH 117, Honors Calculus I (Analysis)	
Instructor:	Dr. Jochen Kuttler	

Grading students and stand in TA for both Midterm and Final examination.

Position:	Teaching Assistant	Jan. 2021 → May 2023
Department:	Department of Mathematical & Statistical Sciences	
Where:	Decima Robinson Support Center, University of Alberta	
Employer:	Dr. Sean Graves	

Aided students with 100-200 level Math including proof-based Honors Math courses at the University of Alberta.

Position:	[Volunteer] Teaching Assistant	Sep. 2021 → Dec. 2021
Department:	Department of Mathematical & Statistical Sciences	
Where:	Decima Robinson Support Center, University of Alberta	
Employer:	Dr. Sean Graves	

Aided students with 100-200 level Math (inc Honors) courses at the University of Alberta.

GRANTS AND ACHIEVEMENTS

2019:	University of Alberta, International Student Scholarship
2020-2023:	Deans Honor Roll
2020:	University of Alberta, Continuing Undergraduate Scholarship
2021:	Mathematical & Statistical Sciences Undergraduate Summer Research Award (MSS USRA)
2021:	Golden Bell Jar Undergraduate Scholarship in Physics
2021:	Murray Thomas Gibson Memorial Scholarship in Mathematics
2021:	University of Alberta, Continuing Undergraduate Scholarship
2022:	Department of Physics, Summer Undergraduate Physics Research Experience Award (SUPRE)
2023:	University of Alberta, Graduate Recruitment Scholarship

CONFERENCES AND PRESENTATIONS

Event:	Graduate Physics Research Symposium (Talk)	Oct. 2024
Where:	The University of Alberta, Canada	

I gave a talk showcasing some of my results pertaining to using Graph theory on Archimedean lattices including the introduction of Bloch Generating Functions and the free energy per site for the Ising model on these lattices.

Event:	MAPH 499 Honors Thesis	Apr. 2023
Where:	Department of Physics, University of Alberta	

Gave a public presentation on the work I did on where I describe the kind of special solutions on $\mathbb{S}^3$ for the Quasi-Einstein Equations.

Event:	Department of Physics Poster Symposium	Sep. 2022
Where:	University of Alberta, Canada	

Presented my Poster on Anomalous Quantum Wave Dynamics in Hyperbolic Space.

Event:	Meet A Math Major	Sep. 2022
Where:	University of Alberta, Canada	

Gave a talk titled "What Does Math Mean To You?" in which I talked about my journey in mathematics research alongside scholarship & funding opportunities as well as finding joy in the beauty of the subject. The Meet A Math Major event was part of an Equity, Diversity and Inclusion (EDI) outreach program by the Mathematical Sciences Society in collaboration with the Department of Mathematical & Statistical Sciences to make math research accessible and to encourage students, especially those who are underrepresented in the field to pursue research in mathematics.

Event:	Faculty of Science Undergraduate Research Symposium	Aug. 2022
Where:	University of Alberta, Canada	

Poster Presentation consisting of my work on the Anomalous Quantum Wave Dynamics in Hyperbolic Space.

Event:	Young Mathematicians Conference (YMC)	Aug. 2022
Where:	The Ohio State University (OSU), Ohio	

Invited for a Single Student talk to speak on the work I did on the variant Illumination Conjecture.

EVENT:	MATH 499 Honors Thesis	Apr. 2022
WHERE:	Department of Mathematics & Statistical Sciences, University of Alberta	

Gave a public presentation on the work I did on the variant illumination disproving the variant Illumination Conjecture.

WORKSHOPS

EVENT:	Princeton Summer School on Condensed Matter (PSSCMP)	Jul. 2024
WHERE:	The Institute for Advanced Study (IAS), Princeton	

I attended Princeton Summer School on Condensed Matter focused on Quantum Matter, Superconductivity, Topology and Correlations, specifically the new and exciting physics on Moiré materials.

COMPETITIONS

EVENT:	The Mathematical Competition in Modelling (MCM)	Feb. 2022
WHERE:	Remote	

Our team of three used the Edmond- Karp Algorithm to model the transport of water through the Colorado River Basin.

EVENT:	AI4Society ML-in-Physics datathon	Feb. 2022
WHERE:	University of Alberta, Canada	

Our team of five, won 4^{th} place in the First Arrival Identification Challenge that used an ML model to predict earthquakes before its arrival.

NOTABLE ACADEMIC PROJECTS

TITLE:	Special Solutions to Quasi-Einstein Equations	Jan. 2023 → May 2023
SUPERVISOR:	Dr. Eric Woolgar	

Honors thesis submitted for the completion of my undergradauate degree based on preliminary work done on Quasi-Einstein metrics on $\mathbb{S}^3$.

TITLE:	Renormalization Group Flow on the Ising Model	Sep. 2022 → Dec. 2022
SUPERVISOR:	Dr. Andrzej Czarnecki	

Final project for the completion of PHYS 495/595: INTRODUCTION TO QUANTUM FIELD THEORY in which I applied descrete real space renormalization techniques to the Generalized $1-$D Ising Model to understand the behaviour of coupling constants J, h through renormalization group flow.

TITLE:	Phase Portrait Analysis Of a Non-Linear ODE System	Jan. 2021 → May 2021
SUPERVISOR:	Dr. Xinwei Yu	

Final project for the completion of MATH 336: HONORS ODE in which I studied a Non-Linear coupled ODE system of two variables $\dot{x} = y, \dot{y} = ay + x - x^2 + xy$ dependent on a free parameter $a \in \mathbb{R}$. We studied the behaviour of the equilibrium points using the Grobman-Hartman theorem and used theorems of Dulac, Poincaré-Bendixson to conclude the non-existence of closed orbits on two regions of $\mathbb{R}^2$ seperated by the line $x = -a$.

TITLE:	Introduction to Tensors	Dec. 2019 → Present

A $T_{\text{E}}X$ Textbook on Tensors that I started writing when I was fascinated by Tensor Algebra in 1^{st} year out of pure interest. The main idea was to learn the subject through explaining it. The Textbook so far covers Linear Algebra essentials *viz.* Fields, Vector spaces, Inner Product and Linear Transformations.

LEADERSHIP AND EXTRACURRICULARS

POSITION:	Representative at the Student Committee for Faculty Hire	Apr. 2024
WHAT:	Quantum Physics Faulty Hire (Department of Physics, University of Alberta)	

As one of the four graduate students selected to be a part of the student committee for Quantum CIFAR (Canadian Institute For Advanced Research) faculty hire search at the Department of Physics, University of Alberta, I attended the colloquium talks, research plan talks and informal lunch sessions with all the faculty hire candidates invited to the department for their final rounds of interview. The student committee presented collective thoughts on the candidates based on their mentorship qualities, teaching abilities and their ability to excite the graduate students about their research. I played an instrumental role in representing the graduate theoretical condensed matter students by providing invaluable comments regarding the candidates' research plans, their fit in the physics department, and the incorporation of machine learning methods in their research.

POSITION:	President	May 2022 → May 2023
WHAT:	Undergraduate Mathematical Sciences Society (MSS)	

Acting President of the Undergraduate Mathematical Sciences Society. Organized the first ever Science Interdepartmental Club-run Research Symposium for Undergraduates from Mathematics, Physics, Chemistry, Computer Science & Psychology. Spearheaded an EDI high school outreach event where we invited High School students to mingle with Undergraduates in Math to provide insight on what it means to be a Math Major. We gave talks on how to get involved in Mathematics research and outreach. Organized both social and academic events like game nights or research outreach eventsto improve and strengthen the undergraduate Math community, including the introduction of "Mathmania" competition.

TECHNICAL SKILLS

Programming Languages

PROFICIENT:	`Mathematica`,LaTeX
FAMILIAR:	`Python`, `gnuplot`, , `TiKz`

Teaching
Offline & Online teaching in Mathematics and Physics at the University of Alberta, including supervising lab work.

PROFESSIONAL MEMBERSHIPS

AFFILIATION:	Theoretical Physics Institute (TPI), University of Alberta	Sep. 2023 → Present
AFFILIATION:	Canadian Association of Physicists (CAP)	Sep. 2023 → Present