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EDUCATION

PhD Student, Physics

University of Alberta, Canada

Sep. 2025 → Present

Field: Condensed Matter Theory

Supervisor: Prof. Joseph Maciejko

Master of Science, Physics

University of Alberta, Canada

Sep. 2023 → Aug. 2025

GPA: 4.0/4.0

Field: Condensed Matter Theory

Thesis: [Walks, Spectral Graph Theory and Critical Phenomena on Archimedean Lattices](#).

Supervisor: Dr. Igor Boettcher

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 INTERESTS

Theoretical condensed matter physics: Statistical physics, Classical & Quantum many-body phenomena, Frustrated magnetism, Mathematical Physics.

PUBLICATIONS

D. N. Joseph and I. Boettcher, “Exact critical-temperature bounds for two-dimensional Ising models”, [Phys. Rev. E](#) **113**, 064113 (2026).

D. N. Joseph, C. M. Walsh, and I. Boettcher, “Families of planar lattices with arbitrarily high T_c for the ferromagnetic Ising model”, [Phys. Rev. E](#) **114**, 024133 (2026).

C. M. Walsh, I. MacPherson, D. N. Joseph, S. Kabra, R. S. Toor, M. Protter, and F. Marsiglio, “A simple quantum dot: Numerical and variational solutions”, [Am. J. Phys.](#) **94**, 465–475 (2026).

D. N. Joseph and I. Boettcher, “Walking on Archimedean lattices: Insights from Bloch band theory”, [Phys. Rev. E](#) **112**, 044118 (2025).

RESEARCH SUMMARY

POSITION: PhD Student
AFFILIATION: Department of Physics, University of Alberta.
SUPERVISOR: Dr. Igor Boettcher.

Sep. 2025 → Apr. 2026

PROJECT: Exact critical temperature bounds for two-dimensional Ising models

The emergence of collective phenomena in the case of ferromagnetism or superconductivity is an active area of condensed matter research with many long-standing questions to this day. These so-called ordered states that arise from the collective, many-body interactions are crucial for maintaining, for instance, the magnetic properties of a ferromagnet. However, these states are fragile against high temperatures and are only robust below a critical temperature T_c that depends on the properties of the material. Therefore, the search for high T_c lattices is a means to solve the problem of fragility and preliminary calculations are necessary to narrow down this search. However, predicting T_c is a very hard problem due to its non-universal nature. To resolve this, we present a simple criterion for the classical two-dimensional ferromagnetic Ising model that bounds T_c using only the maximum number of links present in the lattice. The Ising model is a ubiquitous toy model in solid-state physics that models magnetism and has been extensively studied for over a century. Using the Feynman-Kac-Ward formalism, we derive a tight upper bound to the critical temperature of any periodic lattice. Our work opens a new door in the field of T_c engineering—designing arbitrary lattices with high T_c that may be realized experimentally in Coherent Ising Machines or topoletric circuits in the future.

PROJECT: Families of arbitrarily high- T_c lattices for the Ising model

In the search for two-dimensional planar lattices with high T_c for the Ising model, we discovered the Compass-Rose lattice with a critical temperature higher than all the $k \leq 5$ uniform tessellations and their duals. The Compass-Rose belongs to a family of lattices (known as the Apollonian lattices) which includes the familiar Triangular lattice. Each subsequent member of this family is constructed by a procedure known as *iterative triangulation* wherein the next member is constructed by placing a site at the center of each triangle of the previous lattice and drawing bonds from it to the sites at the corners of the triangle. Iterative Triangulation produces a new lattice with a critical temperature higher than its predecessor, thereby producing lattices with arbitrarily high T_c . We presented several families of these lattices (which are triangulations) and analytically derived the exact asymptotic growth of $T_c(q_{\max})$ as a function of the maximal coordination number $q_{\max}$ for these lattices for each families.

POSITION:	Master's Student	Sep. 2023 → Aug. 2025
AFFILIATION:	Department of Physics, University of Alberta.	
SUPERVISOR:	Dr. Igor Boettcher.	

PROJECT: Band Theory & Walks on Periodic Lattices

In condensed matter physics, various electronic properties of a material, like its conductivity, emerge from how its atoms are arranged. A pedagogical example is graphene, whose remarkable electronic properties are tied to its honeycomb lattice. The discovery and subsequent analysis of the structure of graphene were recognized with the Nobel Prize in Physics. A central object in the quantitative description of layered electronic materials is the so-called density of states (DOS) which can be experimentally measured with a variety of techniques. In certain regimes, the physics of the underlying lattice can be described by the tight-binding (TB) model that allows electrons to hop between nearest-neighbors. We presented a novel method to compute the single particle DOS from TB on periodic lattices which is related to the graph-theoretic problem of counting walks. We solved this mathematically rich problem of counting walks using tools from Band theory and implemented our method on a collection of eleven lattices called Archimedean lattices which includes the Square, Triangular and Honeycomb lattice.

PROJECT: Zero field Ising model on Archimedean Lattices

We generalized the method of Feynman, Kac & Ward (FKW) that computes the free energy density and critical temperature for the zero field Ising model for periodic tiling of the plane. The method of FKW for a lattice involves the computation of the so-called “Kac–Ward” matrix, an object that gets unwieldy in size complexity for arbitrary lattices. We presented a new method to simplify this calculation in terms of smaller, attainable blocks. We tested our method on all eleven Archimedean Lattices, matching our results with the existing literature and presenting novel results.

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

PROJECT: On Special Solutions of the Quasi-Einstein Equations

A Quasi-Einstein manifold is a triplet $(\mathcal{M}, g, X)$ with g 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 $ds^2 = dr^2 + \zeta^2(r)g(\mathbb{S}_{\text{can}}^{n-1})$, $n \geq 3$ for closed $X(r)$. We reformulated the problem in terms of admissible trajectories in a two-dimensional phase space 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 ground-breaking experiments with both superconducting resonators and topolelectric 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 besides the hyperbolic Laplace-Beltrami Laplacian (Δ_H) in the Schrödinger equation $(-\Delta_H + \epsilon Q)\psi = E\psi$ alters the time evolution of plane waves, which are 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.	
	The Illumination Conjecture, equivalent to the Covering Conjecture, posits 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 lower bounds for $k=2$ and $k=n-2$.	

TEACHING EXPERIENCE

POSITION:	Teaching Assistant	Sept. 2026 → Dec. 2026
DEPARTMENT:	Department of Physics	
CLASS:	PHYS 415, Intro to Condensed Matter Physics	
INSTRUCTORS:	Prof. Joseph Maciejko	
	In charge of grading assignments, hosting office hours and managing the course's Canvas page.	

POSITION:	Teaching Assistant	Jan. 2026 → Apr. 2026
DEPARTMENT:	Department of Physics	
CLASS:	PHYS 297, Experimental Physics II	
INSTRUCTORS:	Prof. Frank Hegmann & Prof. Michael Woodside	
	Involved in general course design including designing, implementing and conducting a new experiment. In charge of preparing lectures, grading and supervising students on the classic Frank-Hertz experiment.	

POSITION:	Teaching Assistant	Sep. 2025 → Dec. 2025
DEPARTMENT:	Department of Physics	
CLASS:	PHYS 124, Particles & Waves	
INSTRUCTOR:	Undergraduate Physics Labs (PHYSUGL)	
	In charge of preparing lectures and slides and supervising students in the first year lab section.	

POSITION:	Teaching Assistant	Jan. 2025 → Apr. 2025
DEPARTMENT:	Department of Physics	
CLASS:	PHYS 297, Experimental Physics II	
INSTRUCTORS:	Prof. Frank Hegmann & Prof. Michael Woodside	
	In charge of preparing lectures, grading and supervising students on the classic Frank-Hertz experiment.	
POSITION:	Teaching Assistant	Sep. 2024 → Dec 2024
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:	Prof. Aksel Hallin & Prof. Michael Woodside	
	In charge of preparing lectures, grading and supervising students on the classic Frank-Hertz experiment.	
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 first year lab experiments surrounding Newtonian mechanics and periodic motion from PHYS 124.	
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:	Prof. 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:	Prof. Jochen Kuttler	
	Grading students and standing in as a teaching assistant for both the midterm and final examinations.	

POSITION:	Teaching Assistant	Jan. 2021 → May 2023
DEPARTMENT:	Department of Mathematical & Statistical Sciences	
WHERE:	Decima Robinson Support Center, University of Alberta	
EMPLOYER:	Prof. 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:	Prof. Sean Graves	
	Aided students with 100-200 level Math (including Honors courses) courses at the University of Alberta.	

GRANTS AND ACHIEVEMENTS

2019:	University of Alberta, International Student Scholarship
2020-23:	Dean's 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
2023:	University of Alberta, Graduate Recruitment Scholarship

CONFERENCES AND ORAL PRESENTATIONS

EVENT:	Quantum Horizons Alberta ($q\hbar a$) Symposium II	Jul. 2026
WHERE:	Banff Center for Arts and Creativity Banff, Canada	
	I presented a poster showcasing the work we did on the exact critical temperature bounds we derived for the ferromagnetic Ising model for planar lattices. In addition, I also presented our work on deriving the asymptotics of T_c under iterative triangulation.	

EVENT:	Global Physics Summit (APS March Meeting) 2026	Mar. 2026
WHERE:	Colorado Convention Center, Denver, USA	
	I presented a talk showcasing the work we did on deriving the new exact critical-temperature bounds for the ferromagnetic Ising model.	

EVENT:	Graduate Physics Research Symposium	Oct. 2025
WHERE:	University of Alberta, Edmonton, Canada	
	I presented my work on the Ising model where I generalized the Feynman-Kac-Ward method to periodic lattices.	

EVENT:	Quantum Horizons Alberta ($q\hbar a$) Symposium I	Aug. 2025
WHERE:	Banff Center for Arts and Creativity Banff, Canada	
	I presented a poster showcasing my work on Archimedean lattices and walks.	

EVENT:	MagLab Theory Winter School (TWS)	Jan. 2025
WHERE:	National High Magnetic Field Laboratory, Tallahassee, USA	
	I presented a poster on my work with Archimedean lattices, walks and the Ising model.	

EVENT:	Graduate Physics Research Symposium	Oct. 2024
WHERE:	University of Alberta, Edmonton, Canada	
	I gave a talk showcasing some of my results pertaining to using graph theory on Archimedean lattices.	

EVENT:	MAPH 499 Honors Thesis Defense	Apr. 2023
WHERE:	University of Alberta, Edmonton, Canada	
	Gave a public presentation describing the special solutions of the Quasi-Einstein equations on S^3 .	
EVENT:	Department of Physics Poster Symposium	Sep. 2022
WHERE:	University of Alberta, Edmonton, Canada	
	Presented my poster on anomalous quantum wave dynamics in hyperbolic space.	
EVENT:	Meet A Math Major	Sep. 2022
WHERE:	University of Alberta, Edmonton, 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, Edmonton, Canada	
	Poster Presentation on my work on the anomalous quantum wave dynamics in hyperbolic space.	
EVENT:	Young Mathematicians Conference (YMC)	Aug. 2022
WHERE:	The Ohio State University, Ohio, USA	
	Invited for a single student talk to speak on the work I did on the variant Illumination Conjecture.	
EVENT:	MATH 499 Honors Thesis Defense	Apr. 2022
WHERE:	University of Alberta, Edmonton, Canada	
	Gave a public presentation on the work I did on the variant Illumination Conjecture, which I disproved.	

WORKSHOPS

EVENT:	MagLab Theory Winter School	Jan. 2025
WHERE:	National High Magnetic Field Lab, Tallahassee, USA	
	I attended the MagLab theory winter school organized by the National High Magnetic Field Lab in Tallahassee, Florida. The school focused on strongly correlated physics including Moiré materials, transition metal dichalcogenides (TMDs) and the physics of fractional quantum hall effect (FQHE)	
EVENT:	Princeton Summer School on Condensed Matter Physics (PSSCMP)	Jul. 2024
WHERE:	The Institute for Advanced Study (IAS), Princeton, USA	
	I attended the 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 Modeling (MCM)	Feb. 2022
WHERE:	Remote	
	Our team of three used the Edmonds-Karp Algorithm to model the transport of water through the Colorado River Basin.	

EVENT: AI4Society ML-in-Physics datathon
WHERE: University of Alberta, Edmonton, Canada

Feb. 2022

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

NOTABLE ACADEMIC PROJECTS

TITLE:	Special Solutions to Quasi-Einstein Equations	Jan. 2023 → May 2023
SUPERVISOR:	Prof. Eric Woolgar	
	Honors thesis (Mathematical Physics) submitted for the completion of my undergraduate degree based on preliminary work done on Quasi-Einstein metrics on S^3 .	
TITLE:	Renormalization Group Flow on the Ising Model	Sep. 2022 → Dec. 2022
SUPERVISOR:	Prof. Andrzej Czarnecki	
	Final project for the completion of PHYS 495/595: INTRODUCTION TO QUANTUM FIELD THEORY in which I applied discrete real space renormalization techniques to the generalized one dimensional Ising Model to understand the behaviour of coupling constants J, h through renormalization group flow.	
TITLE:	On the variant Illumination Conjecture	Jan. 2022 → May 2022
SUPERVISOR:	Dr. Beatrice Helen Vritsiou & Dr. Sergii Myroshnychenko	
	Honors thesis (Math) submitted for the completion of my undergraduate degree based on the work done on the variant Illumination Conjecture.	
TITLE:	Phase Portrait Analysis of a Non-Linear ODE System	Jan. 2021 → May 2021
SUPERVISOR:	Prof. 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 $\mathbb{R}^2$ separated by the line $x = -a$.	
TITLE:	Introduction to Tensors	Dec. 2019 → Present
	A textbook in $\mathcal{L}^{\text{ATEX}}$ on Tensors that I started writing when I was engrossed by Tensor Algebra in my first year of Bachelors. The main idea was to learn the subject through explaining it. The textbook so far covers Linear Algebra essentials <i>viz.</i> , Fields, Vector spaces, Inner Product and Linear Transformations.	

LEADERSHIP AND EXTRACURRICULARS

POSITION:	Condensed Matter Representative	Oct. 2025 → Present
WHAT:	Graduate Physics Student Association (GPSA)	
	As a current representative of the condensed matter graduate students, I play an active role in the Graduate Physics Student Association (GPSA) in organizing various events throughout the academic year including the GPSA Symposium, the GPSA welcome BBQ and social events. I actively strive to foster a collaborative environment among students from other disciplines in Physics.	
POSITION:	Organizer	Aug. 2026 → Present
WHAT:	Ideas in Science Seminar Series	
	Since August 2026, I run the <i>Ideas in Science Seminar Series</i> , a seminar series exclusively for graduate students in physics from different sub-fields. The premise of the series is not to showcase field-specific research, but to have each speaker present the common tools used in their work, so that concepts and methods can cross-pollinate across sub-fields. The goal of the series is to bring graduate students together, both academically and socially in order to facilitate a cohesive student community.	

POSITION:	Representative at the Student Committee for Faculty Hire	Apr. 2024
WHAT:	Quantum Physics Faculty Hire (Department of Physics, University of Alberta)	
	As one of the four graduate students selected to be 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 interviews. 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:	Panelist	Nov. 2024
WHAT:	University of Alberta, Department of Physics Graduate Student Panel	
	As one of the five graduate students invited to answer questions from prospective graduate students, I shared my experiences in graduate school as well as advice on navigating the grad school life.	
POSITION:	President	May 2022 → May 2023
WHAT:	Undergraduate Mathematical Sciences Society (MSS)	
	As the president of the Undergraduate Mathematical Sciences Society, I organized the first ever Science Interdepartmental Club-run Research Symposium for Undergraduates from Mathematics, Physics, Chemistry, Computer Science & Psychology. I spearheaded an EDI high school outreach event where we invited High School students to mingle with Undergraduates in Math to provide insight into 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 events to improve and strengthen the undergraduate Math community, including the introduction of "Mathmania" competition.	

TECHNICAL SKILLS

Programming Languages

PROFICIENT:	Mathematica, $\text{\LaTeX}$
FAMILIAR:	Python, gnuplot, TikZ

PROFESSIONAL MEMBERSHIPS

AFFILIATION:	American Physical Society (APS)	Sep. 2025 → Present
AFFILIATION:	Theoretical Physics Institute (TPI), University of Alberta	Sep. 2023 → Present