

# Davidson Noby Joseph

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## School Address

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## EDUCATION

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*PhD Student*, Physics  
University of Alberta, Canada Sep. 2025 → Present  
Field: Condensed Matter Theory.

*Master's 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](#).

*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

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POSITION: PhD Student Sep. 2023 → Present  
AFFILIATION: Department of Physics, University of Alberta.  
SUPERVISOR: Dr. Igor Boettcher.

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 to maintain, 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 are a means to solve the problem of fragility and preliminary calculations are necessary to narrow down this search. Unfortunately, predicting  $T_c$  is a very hard problem due to its non-universal nature presents itself as an obstacle. We presented 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 an ubiquitous toy model in solid-state physics that models magnetism and have been extensively studied for over a century. Using the so-called Feynman-Kac-Ward formalism, we derive tight upper bound to the critical temperature of any period lattice. Our work opens a new door to the field of  $T_c$  engineering—designing arbitrary lattices with high  $T_c$  that can be potentially used to aid in the quest for high temperature superconductors.

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 materials like its conductivity emerge from how their atoms are arranged. A pedagogical example is graphene, whose remarkable electronic properties tied to its honeycomb lattice. The discovery and subsequent analysis of the structure of graphene were recognized with the 2010 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 hopping of electrons 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 and combinatorially complex problem of counting walks using tools from Physics, and implemented our method on a collection of eleven lattices called Archimedean lattices that includes the honeycomb lattice.

**PROJECT:** Zero field Ising Model Archimedean Lattices

We generalized the method of Feynman, Kac & Ward (FKW) that computes the free 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 unwieldily 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:	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  $\lambda$ . 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 ( $\Delta_H$ ) 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  $\psi$  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	Jan. 2026 → Present
DEPARTMENT:	Department of Physics	
CLASS:	PHYS 297, Experimental Physics II	
INSTRUCTORS:	Dr. Frank Hegmann & Dr. Michael Woodside	
Part of course design, and 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, slides and supervising students for the Lab section for first year labs.

POSITION:	Teaching Assistant	Jan. 2025 → Apr. 2025
DEPARTMENT:	Department of Physics	
CLASS:	PHYS 297, Experimental Physics II	
INSTRUCTORS:	Dr. Frank Hegmann & Dr. 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.	

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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.	

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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 from PHYS 124.	

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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.	

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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.	

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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.	

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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.	

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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.	

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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

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| 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                               |
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## CONFERENCES AND PRESENTATIONS

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EVENT:	Quantum Horizons Alberta Symposium ( <i>qha</i> )	Aug. 2025
WHERE:	Banff Center for Arts, Canada	

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I presented a poster on my work with Archimedean lattices and walks.

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EVENT:	Graduate Physics Research Symposium	Oct. 2024
WHERE:	The University of Alberta, Canada	

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I gave a talk showcasing some of my results pertaining to using Graph theory on Archimedean lattices.

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EVENT:	MAPH 499 Honors Thesis	Apr. 2023
WHERE:	Department of Physics, University of Alberta	

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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.

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EVENT:	Department of Physics Poster Symposium	Sep. 2022
WHERE:	University of Alberta, Canada	

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

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EVENT:	Meet A Math Major	Sep. 2022
WHERE:	University of Alberta, Canada	

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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.

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EVENT:	Faculty of Science Undergraduate Research Symposium	Aug. 2022
WHERE:	University of Alberta, Canada	

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

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

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

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

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

## WORKSHOPS

EVENT:	Maglab Theory Winter School	Jan. 2025
WHERE:	National High Magnetic Field lab, Tallahassee	

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 not limited to Moiré materials, transition metal dichalcogenides (TMDs) and the physics of fractional quantum hall effect (QHE)

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

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 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<sup>th</sup> 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 undergraduate 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 discrete 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  $\mathbb{R}^2$  separated by the line  $x = -a$ .

TITLE:	Introduction to Tensors	Dec. 2019 → Present
SUPERVISOR:		

A Textbook in *LATEX* on Tensors that I started writing when I was engrossed by Tensor Algebra in my 1<sup>st</sup> year of Bachelors out of 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:	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 student committee to foster a collaborative environment between different students from the other disciplines in Physics.

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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 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.

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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 events to improve and strengthen the undergraduate Math community, including the introduction of "Mathmania" competition.

## TECHNICAL SKILLS

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### Programming Languages

PROFICIENT: Mathematica, *LATEX*

FAMILIAR: Python, gnuplot, TiKz

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### Teaching

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

## PROFESSIONAL MEMBERSHIPS

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AFFILIATION: American Physical Society (APS)

Sep. 2025 → Present

AFFILIATION: Theoretical Physics Institute (TPI), University of Alberta

Sep. 2023 → Present