Karpur Shukla

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Google Scholar | Native-born US citizen, Overseas Citizen of India

Education

Doctor of Philosophy May 2029 (anticipated)
School of Engineering, Brown University

Master of Engineering May 2025 (anticipated)
School of Engineering, Brown University (GPA: 4.0/4.0)

Master of Science in Physics May 2016
Department of Physics, Carnegie Mellon University (GPA: 3.28/4.0)

Awards: Associate Membership in Sigma Xi (Scientific Research Honors Society).

Bachelor of Science in Physics May 2014
Department of Physics, Carnegie Mellon University

Awards: Science and Humanities Scholar. Senior Leadership Award (Department of Physics, Carnegie Mellon University).

Grants Awarded

- **Sandia National Laboratories Purchase Order 2489418, 0** ($30k total for four months)
- **Sandia National Laboratories Purchase Order 2178181, 0** ($50k/year for three years)
  - Includes **Advanced Simulation and Computing Grant, National Nuclear Security Administration** ($50k/year for three years)

Skills

Programming & Scripting Languages: C++, Mathematica, MATLAB/Octave, LaTeX, Linux bash, Python (with NumPy, Pandas, and Seaborn)
Programs: Microsoft Office, OriginPro/LabPlot
Natural Languages: English, Gujarati, Hindi, Spanish

Work and Research Experience

Principal Mathematical Physicist
Nettle, LLC *Apr. 2025 - Present*

- **Real-Time Data Processing Models from Nonequilibrium Conformal Field Theory:** Developing proprietary models (ongoing) of real-time data processing networks bypassing PACELC theorem limitations; using conformal symmetry algebras and information geometric properties of classical channel encoding.

Doctoral Student Researcher – Computational Flow Group Providence, RI, USA
Department of Fluids and Thermal Sciences, School of Engineering, Brown University *Aug. 2023 - Nov. 2024*

- **Bubble Dynamics in Liquid Mercury:** Created a Newton-Raphson solver in C++ and used data analysis in Python and MATLAB to find an equation of state for liquid-gas mercury admixtures. Created algorithms to extend the open-source Fortran-Python thermal fluid simulation package MFC to incorporate various equations of state at various pressure, temperature, and specific volume regimes.
- **Lattice Boltzmann Simulation for Charged Bubbly Flows:** Created a lattice Boltzmann solver for moderate Knudsen number flows using AM3, BDF2, and RK4 time-steppers in C++, to be extended to a finite-volume high Knudsen number framework for multicomponent multiphase flow.

Doctoral Student Researcher – Laboratory for Emerging Technologies Providence, RI, USA
Department of Electrical and Computer Engineering, School of Engineering, Brown University *Aug. 2020 - May 2023*

- **Nonequilibrium Quantum Thermodynamics of Classical Reversible Computing:** Developed the equivalence between quantum models for conditional Landauer erasure protocols and catalytic thermal operations. Constructed an information-/non-information-bearing decomposition for reversible computing operations in terms of quantum channels embedded in GKSL dynamics with multiple asymptotic states.
- **Chirality-Induced Spin-Selectivity from Curved-Space Quantum Field Theory:** Calculated the spin polarisation of electrons passing through chiral molecules from the corresponding curved space quantum electrodynamic path integral. Calculated the resulting axial current, and used the subsequent effective Chern-Simons action to express the molecules as supersymmetric topological insulators.
- **Negative and Nematic Quantum Capacitance in MOSFETs:** Determined the impact of negative quantum capacitance on the design landscape of MOSFET structures by calculating the corresponding difference in the subthreshold swing. Created models for MOSFETs that exploit 2DEG Pomeranchuk instabilities to gain additional degrees of freedom, for use in low-power and low-temperature CMOS device operations.

Visiting Professor Pune, MH, India
Department of Applied Mathematics, Flame University *Dec. 2017 - Jan. 2020*

- Taught junior- and senior-level courses (Linear Algebra, Complex Analysis, and Partial Differential Equations) for the Bachelor of Science in Applied Mathematics program, as well as a freshman-level physics course (Introduction to Physics).

Graduate Research Assistant – Experimental Biological Physics Group Pittsburgh, PA, USA
Department of Physics, Carnegie Mellon University *Jan. 2016 - May 2016*

- **Phase Transitions of WLBU2- and D8-Embedded DPPC Lipid Solutions:** Used differential scanning calorimetry (DSC) to examine phase transitions of DPPC lipid membranes with either WLBU2 or D8 proteins embedded. Prepared solutions, ran DSC runs, and used nonlinear curve fitting in OriginLab to identify the changes in the phase diagram.

Undergraduate Research Assistant – Theoretical Quantum Condensed Matter Physics Group Pittsburgh, PA, USA
Department of Physics, Carnegie Mellon University *Aug. 2013 - May 2014*

- **Quantum Electrodynamic Response of Topological Insulator Surfaces:** Reviewed the theoretical Berry phase dependence of the electrical current generated on topological insulator surfaces due to incident circularly polarised light. Used quantum statistical mechanics to theoretically extend this framework to include temperature dependence.

Publications

1. **K. Shukla**, S. Rajan, S. J. Gates, and J. Xu. "Chirality-Induced Spin Selectivity from the Curved Space Fermionic Axial Anomaly" (in preparation).
2. M. Frank and **K. Shukla**. "Quantum Foundations of Classical Reversible Computing". *Entropy* 23 (2021). (*Note: Both authors are co-first-authors.*), pp. 701–769. DOI: 10.3390/e23060701.
3. M. Frank, R. Brocato, T. Conte, A. Jain, N. Missert, **K. Shukla**, and B. Tierney. "Special Session: Exploring the Ultimate Limits of Adiabatic Circuits". *2020 IEEE 38th International Conference on Computer Design (ICCD)*. Vol. 1. 2020, pp. 21–24. DOI: 10.1109/ICCD50377.2020.00018.
4. F. Heinrich, A. Salyapongse, A. Kumagai, F. Dupuy, **K. Shukla**, A. Penk, D. Huster, R. Ernst, A. Pavlova, J. Gumbart, B. Deslouches, Y. Di, and S. Tristram-Nagle. "Synergistic Biophysical Techniques Reveal Structural Mechanisms of Engineered Cationic Antimicrobial Peptides in Lipid Model Membranes". *Chemistry – A European Journal* 26 (2020), pp. 6247–6256. DOI: 10.1002/chem.202000212.

Invited, Workshop, and Conference Talks

1. S. Rajan, **K. Shukla**, and J. Xu. "Quantum Geometry of the Chirality Induced Spin Selectivity Effect". American Physical Society 2023 March Meeting, Session M66: Topological States in AMO Systems II. Mar. 8, 2023.
2. M. Frank and **K. Shukla**. "Exploring Fundamental Limits of Reversible Computing Technologies from Nonequilibrium Quantum Thermodynamics". American Physical Society 2022 March Meeting, Session T42: Thermodynamics of Quantum Information Processing. Mar. 17, 2022.
3. M. Frank, H. Earley, and **K. Shukla**. "The Reversible Computing Scaling Path: Challenges and Opportunities". 2022 Energy Consequences of Information Workshop, U.S. Air Force Office of Scientific Research and U.S. Air Force Research Laboratory. Feb. 22, 2022.
4. **K. Shukla**, M.-J. Yu, and J. Xu. "Interplay of Negative Quantum and Ferroelectric Capacitances for Low-Power Transistor Operations". Materials Research Society 2021 Spring Meeting, Session EL09: Ferroelectricity and Negative Capacitance—Fundamentals, Applications and Controversies. Apr. 19, 2021.
5. **K. Shukla**. "Foundations of the Lindbladian Approach to Adiabatic and Reversible Computing". Physics & Engineering Issues in Adiabatic/Reversible Classical Computing Workshop, Computing Community Consortium, Computing Research Association. Oct. 5, 2020.
6. **K. Shukla**, V. Albert, M. Frank, and J. Xu. "Fundamental Thermodynamic Limits of Classical Reversible Computing via Open Quantum Systems". Physics & Engineering Issues in Adiabatic/Reversible Classical Computing Workshop, Computing Community Consortium, Computing Research Association. Oct. 5, 2020.
7. **K. Shukla**. "Nonequilibrium Dynamics and Superadiabatic Fluxon Motion for Reversible Computing". Invited talk, Center for Computing Research Sandia National Laboratories. Feb. 13, 2020.
8. **K. Shukla** and M. Frank. "Pathfinding Thermodynamically Reversible Quantum Computation". NSF Quantum Leap Challenge Institute Workshop on the Identification and Control of Fundamental Properties of Quantum Systems, National Science Foundation. Jan. 24, 2020.
9. **K. Shukla**. "Review of Holographic Second Laws for Conformal Field Theories Out of Equilibrium". II Workshop on Quantum Information and Thermodynamics, International Institute of Physics, Federal University of Rio Grande do Norte. Mar. 11, 2019.
10. **K. Shukla**. "Nonequilibrium Disorder Operators and Topological Quantum Computation". Thermodynamics and Computation: Towards a New Synthesis Workshop, Santa Fe Institute. Aug. 18, 2017.
11. **K. Shukla**. "Physical Aspects of Topological Quantum Computation". Invited talk, Center for Computing Research Sandia National Laboratories. Aug. 15, 2017.