Karpur Shukla

https://centre.santafe.edu/thermocomp/Karpur_Shukla • kshukla@alumni.cmu.edu • +1 646 580-5277

https://orcid.org/0000-0002-7775-6979 • https://scholar.google.com/citations?user=NxRloBgAAAAJ

300 Wedgewood Road, Morganville, New Jersey, 07751 • U.S. Citizen (native-born), Overseas Citizen of India

Education and Awards

Doctor of Philosophy: Department of Electrical and Computer Engineering, Brown University
Center for Computing Research, Sandia National Laboratories — *May 2026 (Anticipated)*

Master of Science: Department of Electrical and Computer Engineering, Brown University — *May 2023 (Anticipated)*

Master of Science: Department of Physics, Carnegie Mellon University — *May 2016*

- *GPA*: 3.28 / 4.00
- *Awards:* Associate Member, Sigma Xi (Scientific Research Honors Society)

Bachelor of Science: Department of Physics, Carnegie Mellon University — *May 2014*

- *Awards:* Science and Humanities Scholar
  Senior Leadership Award, Department of Physics, Carnegie Mellon University

Publications

Reversible Computing and Thermodynamic Uncertainty Relations via the Geometry of Multiple Quantum Non-Equilibrium Steady States

(Sandia Technical Report, tracking R&A #1068410, in preparation for publication through Sandia National Laboratories.)

Karpur Shukla, Michael P. Frank

Synergistic Biophysical Techniques Reveal Structural Interactions of Engineered Cationic Antimicrobial Peptides with Membrane Mimics

Accepted for publication in Chemistry: A European Journal; to be published shortly.

Frank Heinrich, Aria Salyapongse, Akari Kumagai, Fernando G. Dupuy, **Karpur Shukla**, Anja Penke, Daniel Husterd, Robert K. Ernst, Anna Pavlova, James C. Gumbart, Berthony Deslouches, Peter Y. Di, Stephanie Tristram-Nagle

Invited, Workshop, and Conference Talks

Nonequilibrium Dynamics and Superadiabatic Fluxon Motion for Reversible Computing — *Feb. 2020*

Invited talk [🔗]

Host: Center for Computing Research, Sandia National Laboratories

Pathfinding Thermodynamically Reversible Quantum Computation — *Jan. 2020*

Authors: **Karpur Shukla**, Michael P. Frank

Invited talk, NSF Quantum Leap Challenge Institute Workshop on the Identification and Control of Fundamental Properties of Quantum Systems [🔗]

Host: Department of Physics, Brown University

Implementing the Asynchronous Reversible Computing Paradigm in Josephson Junction Circuits — *Oct. 2019*

Authors: Michael P. Frank, Rupert M. Lewis, **Karpur Shukla**

Submitted talk, 21st U.S. Workshop on Superconductor Electronics, Devices, Circuits, and Systems [🔗]

Host: Department of Electrical and Computer Engineering, Stony Brook University

Review of Holographic Second Laws for Conformal Field Theories Out of Equilibrium — *Mar. 2019*

Submitted talk, II Workshop on Quantum Information and Thermodynamics [🔗,🧠]

Host: International Institute of Physics, Federal University of Rio Grande do Norte

Nonequilibrium Disorder Operators and Topological Quantum Computation — *Aug. 2017*

Invited talk, Thermodynamics and Computation: Towards a New Synthesis

Host: Thermodynamics of Computation Group, Santa Fe Institute

Physical Aspects of Topological Quantum Computation — *Aug. 2017*

Invited talk

Host: Center for Computing Research, Sandia National Laboratories

Posters

Thermodynamic Dissipation Bounds on Classical and Quantum Reversible Information Processing — *Feb. 2020*

Authors: **Karpur Shukla**, Michael P. Frank

Submitted poster, 22nd Southwest Quantum Information and Technology Conference

Host: Center for Quantum Information and Control, University of New Mexico

Information Flows in Reversible Computing Out of Equilibrium, with Applications to Models of Topological Quantum Computing — *Feb. 2019*

Authors: **Karpur Shukla**, Michael P. Frank

Submitted poster, 21st Southwest Quantum Information and Technology Conference [🔗]

Host: Center for Quantum Information and Control, University of New Mexico

Work and Research Experience

Research Assistant: Department of Electrical and Computer Engineering, Brown University; and Center for Computing Research, Sandia National Laboratories — *Jun. 2020 – Present*

- Currently examining thermodynamic uncertainty relations for systems described by Gorini-Kossakowski-Sudarshan-Lindbladian (GKSL) dynamics with multiple steady states, in terms of the quantum geometric tensor induced by GKSL superoperators.
- Currently examining the dynamics and scattering of fluxons in long Josephson junctions under superadiabatic protocols, and finding conserved quantities of scattering processes via properties of classical conformal operator algebras and the sine-Gordon-modified-Korteweg-de-Vries hierarchy.
- Currently examining applications of Floquet theory of topological insulators to the generation of high harmonic frequencies in graphene.

[Some of this work continues work done at Flame University.]

Research Associate: Centre for Mathematical Modeling, Flame University — *Jul. 2018 – Jun. 2020*

- Examined thermodynamic uncertainty relations for systems described by Gorini-Kossakowski-Sudarshan-Lindbladian (GKSL) dynamics with multiple steady states, in terms of the quantum geometric tensor induced by GKSL superoperators.
- Examined the dynamics and scattering of fluxons in long Josephson junctions under superadiabatic protocols, and finding conserved quantities of scattering processes via properties of classical conformal operator algebras and the sine-Gordon-modified-Korteweg-de-Vries hierarchy.

Visiting Faculty: Department of Applied Mathematics, Flame University — *Dec. 2017 – Dec. 2019*

- Faculty member for the Applied Mathematics major. As instructor and co-instructor, responsibilities involved lecturing; assigning required reading material, homework questions, and examination questions; and grading. For co-taught classes, each of these responsibilities was shared equally. As guest lecturer, responsibilities involved lecturing and assigning required reading material. Courses:
  - MATH202 (Linear Algebra)
    - Textbooks: *Matrix Analysis and Applied Linear Algebra* by C. D. Meyer
      Introduction to Linear Algebra (5th Edition) by G. Strang
  - MATH206 (Complex Analysis) [co-instructor]
    - Textbooks: *Complex Variables and Applications (8th Edition)* by J. Brown and R. Churchill
  - MATH303 (Partial Differential Equations) [co-instructor]
    - Textbooks: *Partial Differential Equations: An Introduction* by W. Strauss
  - PHYS101 (Introduction to Physics)
    - Textbooks: *University Physics (13th Edition)* by H. Young, R. A. Freedman, and A. Ford
      Foundation Mathematics for the Physical Sciences by K. F. Riley and M. P. Hobson
  - MATH331 (Mathematical Modelling) [guest lecturer]
    - Material: Markov processes, Monte Carlo simulations (integration, Markov chain Monte Carlo simulations, importance sampling, Metropolis-Hastings)

Research Assistant: Biological Physics Group, Carnegie Mellon University — *Jan. 2016 – May 2016*

- Examined phase transitions of DPPC lipid—antimicrobial peptide solutions via differential calorimetry spectroscopy. This included review of the electrical layout of equipment for optimizing data collection, and applying statistical techniques to examine collected data.
- Used multivariable linear regression, Fourier correlation analysis, and χ^2 analysis for composite curve fitting; and used the Akaike information criterion for model selection. All calculations were carried out in OriginLab 9.1 Pro, Python (via NumPy and SciPy), and Microsoft Excel.
  - Advisor (principal investigator): Stephanie Tristram-Nagle

Research Assistant: Quantum Condensed Matter Theory Group, Carnegie Mellon University — *Aug. 2013 – Dec. 2013*

- Examined the electrical response of topological insulator (TI) surfaces to circularly polarized applied light, primarily in the optical wavelength. Particular emphasis was given to the surfaces of the topological insulators Bi_2Se_3 and MoS_2.
- Used the techniques of weak-field quantum electrodynamics, finite-temperature (equilibrium) quantum many body theory, and nonlinear (quadratic) quantum response theory to analytically derive expressions for Berry curvature-dependent valley current transport on TI surfaces.
  - Advisor (principal investigator): Di Xiao

Research Assistant: Computational Condensed Matter Group, Carnegie Mellon University — *Aug. 2010 – Dec. 2010*

- Examined two- and four-point correlation functions
- Examined various two- and four-point correlation functions for a two-dimensional Ising model of quantum magnetism evolving over time.
- Used the analytic real-space renormalization group technique and Markov chain Monte Carlo simulations (applying the Metropolis-Hastings algorithm) to numerically calculate correlation functions and system values along spatial and time decimations.
  - Advisor (principal investigator): Robert Swendsen

Research Assistant: Theoretical Biological Physics Group, Carnegie Mellon University — *Jan. 2009 – May 2009*

- Examined dynamical behavior of cell membrane surfaces and interactions between particles due to the effects of cell membrane geometry and composition.
- Used differential geometry and variational calculus techniques to find minimal shape equations, constraint equations, and corresponding force relations on the surfaces of cell membranes.
  - Advisor (principal investigator): Markus Deserno

Programming Languages and Software Packages

- Python *(with NumPy, SciPy, PyLab, and Matplotlib)* {fluent}
- MATLAB / Octave {fluent}
- Mathematica 10 {fluent}
- Origin 2020 {fluent}

Natural Languages

- English {fluent}
- Hindi {fluent}
- Gujarati {fluent}
- Spanish {fluent}