March 2023

# Farita Tasnim

Farita Tasnim | farita.me
Research Assistant, MIT

Nonequilibrium Statistical Physics
(Stochastic Thermodynamics) of
Distributed Computational Systems

Advisors: Joe Paradiso (MIT)
David Wolpert (SFI)

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DOB: September 18, 1997 | U.S. Citizen

## EDUCATION

Massachusetts Institute of Technology | Cambridge, MA *Jun. 2021 - Present*
Ph.D. Candidate, Stochastic Thermodynamics of Distributed Computational Systems (@MIT Media Lab)

Massachusetts Institute of Technology | Cambridge, MA *Jun. 2019 - May 2021*
Master of Science, Biomedical Engineering (@MIT Media Lab)
Relevant Coursework: *Materials at Equilibrium (Thermodynamics) (G), Electrical, Optical, & Magnetic Properties of Materials (G), Statistical Physics of Particles (G)*

Massachusetts Institute of Technology | Cambridge, MA | 3.5 years *Sep. 2015 - Dec. 2018*
Bachelor of Science, Electrical Engineering
Total GPA: 4.9/5.0 | In-Major GPA: 5.0/5.0
Relevant Coursework: *Analog Electronics Lab, Fundamentals of Programming, Solid-State Circuits, Medical Device Design (G), D-Lab: Education and Learning, Cellular Neurobiology and Computation, The Challenge of World Poverty, Signals, Systems, & Inference, Intro to Machine Learning, Feedback System Design (G), Microeconomic Theory & Public Policy, Microfabricated Devices (G), Intro to Deep Learning*

## TEACHING EXPERIENCE

Teaching Assistant for 2 courses
MAS.809 Decoders 1.1: Introduction to Microfabrication (Fall),
MAS.810 Decoders 1.2: Project Realization (Spring)
*Sep. 2018 - May 2019*

As an MIT undergraduate student, I taught MIT graduate students in MAS.809 and MAS.810 about the theory and hands-on experimental methods involved in microfabricating devices for conformable personal health monitors. TA duties involved designing lecture material, delivering lecture content, designing lab experiments for hands-on student experiments, and assisting students with microfabrication experiments in the cleanroom. MAS.810 additionally involved guiding students in the design and fabrication of their own ideas for microfabricated conformable devices.

Teaching / Lab Assistant for 6 courses
6.01 (x2) Introduction to Electrical Engineering and Computer Science,

6.002 Circuits and Electronics,
6.169 Application of Circuits and Electronics,
6.101 (x2) Analog Circuits

*Feb. 2016 – May 2018*

As an MIT undergraduate student, I taught fellow undergrads how to break down complex electronics and programming problems into do-able chunks, and how to design, test, and debug analog and digital circuits, often to perform signal processing tasks. I helped run lab sessions and shape teaching methods. I was also requested to be a TA for 6.320 Feedback Systems and 6.036 Introduction to Machine Learning, but could not partake due to multiple ongoing projects.

YEP (Youth Electronics Program) Bangladesh Founder

*Jan. 2017 - Sep. 2017*

I started an initiative at MIT, partnered with JAAGO Foundation, aimed at stopping the cycle of poverty through education. I obtained funding from MIT D-Lab, created a curriculum for a three-week workshop to teach Bangladeshi Class VI students coming from Dhaka slums how to design basic circuits and how to build them on breadboards. For their culminating project, each student built a heartbeat monitor using a PPG sensor. Please read more here: https://bit.ly/2BJ73ac

MIT MISTI Global Teaching Lab (GTL) Israel

*Jan. 2017*

I taught first year Israeli college students at ORT Yami in Ashdod how to read and understand datasheets as well as how to debug simple circuits.

## TEACHING PROJECTS -------------------------------------------------

Networked Course Development, Contractor, SFI Complexity Explorer

*Jan. 2023 - Present*

Given my interest in open digital learning, I am working from scratch to build a custom interactive network visualization web application, the goal of which is to organize and visualize the complex web of concepts often taught in any course. My reasoning: I love books deeply, but due to their linear format, it is extra time-consuming to tie different concepts together to form a coherent whole in the naturally nonlinear mind. Why not represent this nonlinear, interconnected network of concepts in the form of an elegant web-app? I speak of something similar to the HyperPhysics - of course, clicking on any concept will provide a detailed description of that concept; however, I'm building something that is crucially different in the following ways: it can (i) dynamically portray the local graph of any particular concept (e.g. presence of a miscibility gap), (ii) display its adjacent nodes and the reason for connection with those nodes (e.g. regular solution model, quasi-chemical model, order-disorder transformations related to miscibility gaps, etc.), (iii) allow for seamless navigation breadth-wise or depth-wise through related concepts, (iv) provide the option to organize the graph in different layouts (e.g. all statistical mechanics concepts versus thermodynamic concepts) and, (v) provide the option to choose to show only specific subgraphs of the network (e.g. all topics related to the determination of binary phase diagrams or to statistical modeling of polymers). I am currently developing this networked course for statistical physics and stochastic thermodynamics, since those are my most fresh areas of expertise.

## PH.D. RESEARCH PROJECTS ---------------------------------------------

Extending stochastic thermodynamics to describe distributed computational systems *Jul. 2021 - Present*

Stochastic thermodynamics applies regardless of the size of a system, so long as its dynamics can be modeled as a continuous-time Markov chain (CTMC). However, as it has traditionally been used, it becomes increasingly ineffective at describing systems at larger scales and with more complex organization. Part of the reason for this is that as it has been applied so far, stochastic thermodynamics has ignored the numerous dynamical constraints on complex systems that restrict the evolution of such systems --- those constraints are expected to be the dominant reason for thermodynamic inefficiency in systems with many components and / or at larger scales than molecules. My research focuses on extending the framework of stochastic thermodynamics to analyze distributed computational systems above the nanoscale by accounting for the effect of these constraints on the possible CTMC. These restrictions on the dynamics dominate the physics whenever the system has the following characteristics: (1) It has spatially separated non-identical subsystems, which interact via a modular, hierarchical network, (2) It is not at thermodynamic equilibrium (and in general, not even in a stationary state); and (3) It has substantial thermodynamic costs of communication both among and within the subsystems.

Deriving thermodynamic speed limit theorems for composite stochastic processes *Dec. 2020 - Jul. 2021*
Using stochastic thermodynamics to tighten theoretical constraints on the speed of state transformation in composite processes based on the contributions to entropy production from each of the subsystems.

## PUBLICATIONS

Google Scholar - 141 citations as of 03/20/2022

*Published*

***Tasnim, F.**,* Wolpert, D. H. Thermodynamic speed limits for co-evolving systems. **2021.** https://arxiv.org/abs/2107.12471

Sun, T.*, ***Tasnim, F.****, McIntosh, R. T., Amiri, N., Solav, D., Anbarani, M. T., Sadat, D., Zhang, L., Gu, Y., Karami, M.A., Dagdeviren, C.†. Closed-loop conformable systems for spatiotemporal decoding of facial strains. *Nature Biomedical Engineering.* **2020**. https://doi.org/10.1038/s41551-020-00612-w

Obidin, N.*, ***Tasnim, F.****, Dagdeviren, C.†. The Future of Neuroimplantable Devices: A Materials Science and Regulatory Perspective. *Advanced Materials*, 1901482, **2019**. https://doi.org/10.1002/adma.201901482

***Tasnim, F.***, Sadraei, A., Datta, B., Khan, M., Choi, K. Y., Sahasrabudhe, A., Alfonso Vega Gálvez, T., Wicaksono, I., Rosello, O., Nunez-Lopez, C., Dagdeviren, C.†. Towards personalized medicine: the evolution of imperceptible health-care technologies. *Foresight*, 20(6), 589-601, **2018**. https://doi.org/10.1108/FS-08-2018-0075

Wang, L., Panaitescu, E., ***Tasnim, F.***, Fontana, E., and Menon, L.†. 2017. Iron Oxide Decorated Titania Nanotubes for Solar Energy Harvesting Applications. *Journal of Nanoscience and Nanotechnology* 17, 3, Article 7. **2017**. https://doi.org/10.1166/jnn.2017.12824

*In Preparation*

***Tasnim, F.**,* Wolpert, D. H. The fundamental thermodynamic costs of communication. **2023.** https://arxiv.org/abs/2302.04320

Pham, T., ***Tasnim, F.**, Korbel, J.,* Wolpert, D. H. Using stochastic thermodynamics to analyze non-thermodynamic properties of networked dynamical systems. **2023.**

***Tasnim, F.**,* Wolpert, D. H. Stochastic thermodynamics of composite systems. **2023.**

***Tasnim, F.**,* Korbel, J., Lynn, C., Wolpert, D. H., et. al. Stochastic thermodynamics: the key to understanding energetic costs in biological and artificial computers? **2023.**

*equal contribution

## CONFERENCES ORGANIZED

**Aug 15 - 17, 2022** — **Thermodynamics of Natural and Artificial Distributed Computational Systems**, hosted at the Santa Fe Institute. *Co-organizers: David H. Wolpert, Jan Korbel, Christopher W. Lynn, Joshua Grochow*

## FELLOWSHIPS, HONORS, & AWARDS

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|---|---|
| APS Shirley Chan DBIO Travel Grant (to present my work on thermodynamics of communication at the March Meeting 2022) | *Feb 2022* |
| Visiting Researcher at the Santa Fe Institute (SFI) | *Sep 2021 - now* |
| NCWIT Collegiate Award Winner ($10K) | *Apr. 2021* |
| Hertz Foundation Fellowship Finalist (top 48 out of > 900 applicants) | *Jan. 2021* |
| PD Soros Fellowship Finalist (top 77 out of > 2500 applicants) | *Dec. 2021* |
| Santa Fe Institute Complexity Interactive | *Sep. 2020* |
| MIT Burchard Scholar | *Feb. 2018* |
| Microsoft Scholarship Recipient ($2.5K) | *Apr. 2017* |
| HerCampus 22 Under 22 Most Inspiring College Women | *Aug. 2016* |
| NCWIT Collegiate Award Honorable Mention ($1.5K) | *May 2016* |
| Microsoft Scholarship Recipient ($10K) | *Apr. 2016* |
| Proton Onsite Energy Scholarship Winner ($36K) | *May 2015* |
| Georgia Regional STAR Student | *Apr. 2015* |
| FIRST Robotics Regionals, First Place Alliance Captain and Regional Winner | *Mar. 2015* |
| NCWIT Aspirations in Computing National Runner Up and State Winner | *Mar. 2015* |
| Research Science Institute (RSI) Scholar | *Jun. 2014* |

## SKILLS

*Electrical* — Circuit design (analog, digital, mixed signal, wireless), simulation (LTSpice), and layout (Altium, Kicad) for rigid or flex PCBs; SMD soldering, reflow, and rework; Custom embedded systems design; Test equipment and automation (VSCode)

*Mechanical* — Mechanical design and modeling (AutoCAD, Solidworks, PTC Creo, Autodesk Inventor),

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|---|---|
| | Machine shop usage (mill, lathe, waterjet, laser cutter, 3D printer, drill press, bandsaw) |
| *Software* | Basic algorithms (e.g. KNN-DTW) and machine learning (e.g. Reinforcement Learning); Image processing; Research automation; Data collection, analysis, and plotting. Languages: Python, C, MATLAB, Java, HTML, Javascript |
| *System Design & Research* | Closed-loop conformable device design, fabrication, and testing; Feedback control systems design, implementation, and analysis, Microfabrication techniques in cleanroom (fabrication steps design, mask design, deposition, photolithography, etching, spin coating, transfer printing; electrical, mechanical, and vibrational characterization) |
| *Teaching* | Workshop design and implementation, Course design and implementation, Teaching assistantship (2 graduate & 6 undergraduate courses at MIT), Mentoring undergraduates in research (6 in the past year) |

## INDUSTRY WORK EXPERIENCE ----------------------------------------

### Electrical/Energy/Fashion Engineering Intern, Microsoft Research

*Jun. 2017 - Jan. 2018*

I developed body energy harvesting solutions in order to reduce form factor and energy needs of wearables, and created a novel electronic outfit that harvests energy via a knee energy harvester and powers a stunning peacock display created out of completely recycled materials.

### Electrical Engineering Intern, Microsoft Hololens

*Jun. 2016 - Aug. 2016*

I developed a flexible PCB for the bring-up and testing of internal Hololens motherboards. The project involved digital circuitry design, PCB layout, system integration.

### Electrical/Energy Engineering Intern, Intel Corporation, New Devices Group

*Jun. 2015 - Sep. 2015*

I created PCB's, firmware, and an integrated product to harvest and analyze natural sources of energy from action sports to power sensors without batteries, which reduces form factor, maintenance, and market advantage.

## M.S. RESEARCH PROJECTS ----------------------------------------

**Closed-loop conformable systems for high dynamic range strain sensing *in vivo*** *Jul. 2019 - Jun. 2020*
Existing systems for biomedical strain sensing either have low bandwidth or require bulky hardware, limiting applicability to flat, low-strain regions of the body. I designed a novel conformable system which can intimately couple to any curvilinear region of the body and simultaneously capture accurate quantitative patterns of deformation with high dynamic range (high bandwidth and high sensitivity). The closed-loop system will be tested both *in vitro* on custom-built actuated mock knees and *in vivo* on patients with neuromuscular disorders, such as Parkinson's disease. Mentored 5 undergraduates for this project.

**Closed-loop conformable systems for spatiotemporal decoding of facial strains** *Aug. 2018 - Jun. 2020*
Existing nonverbal communication systems typically result in high uncertainties, cumbersome response time, or are bulky and unsuitable for use on curvilinear regions of the body, such as the face. We introduce skin-like, conformable devices together with non-contact optical methods for full-field strain mapping and rigorous theoretical models to offer a system capable of predictable, spatiotemporal, biokinematic assessment of the face. The enabling advances in engineering science include mass-manufacturable microfabrication of soft, piezoelectric interfaces to the skin; three-dimensional reconstruction of soft-tissue surfaces in vivo under dynamic deformation conditions; extensive theoretical modeling of complex epidermis-device mechanical

interactions; and algorithms for real-time detection and classification of distinct epidermal deformation signatures. Preliminary studies on healthy and amyotrophic lateral sclerosis subjects demonstrate reliable performance that establishes potential viability for use in clinically-realizable nonverbal communication technologies. Mentored 2 undergraduates for this project.