Emmanuel Hackman

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PERSONAL PROFILE

PhD student in Computational Science with research interests in Physics-Informed Neural Networks (PINNs), Neural Ordinary Differential Equations, scientific machine learning, scientific computing and high-performance computing, and numerical methods for PDEs. My research focuses on using PINNs and related machine-learning techniques to solve differential equations arising in computational mechanics, fluid dynamics (including the Navier–Stokes equations), medical imaging, Parkinson's disease modeling, and material science, alongside scalable algorithms for stiff dynamical systems. Experienced in high-performance numerical simulation, spectral methods, and machine learning for scientific discovery.

EDUCATION

University of Southern Mississippi (USM), *Hattiesburg, MS*
Computational Science (Mathematics) PhD *Aug. 2025 – Dec. 2030*
Expected

University of Southern Mississippi (USM), *Hattiesburg, MS*
Master of Science in Mathematics *Aug. 2023 – Aug. 2025*

University of Cape Coast (UCC), *Cape Coast, Ghana*
Bachelor of Science in Mathematics with Economics *Aug. 2018 – Nov. 2022*

RESEARCH INTEREST

- Physics-Informed Neural Networks (PINNs)
- Neural Ordinary Differential Equations
- Scientific Computing and High Performance Computing
- Scientific Machine Learning
- Numerical Methods for PDEs
- Computational Mechanics and Fluid Dynamics (Navier–Stokes Equations)
- Medical Imaging and Parkinson's Disease Modeling
- Material Science.

MANUSCRIPTS UNDER REVIEW

- **Emmanuel Hackman**, Michael Sakyi, and Huiqing Zhu, "Measurement-Aware Physics-Informed Neural Networks for Estimating Dopamine Diffusion and Uptake from Sparse Electrode Recordings," submitted to *Biomedical Signal Processing and Control* (Elsevier), October 2026. Code and data: doi:10.5281/zenodo.23518612.
- Jiu Ding, **Emmanuel Hackman**, and Huijian Zhu, "Difference Equations and Limits in Geometry," submitted to *The American Mathematical Monthly* (Taylor & Francis), September 2026.

CONFERENCE PRESENTATIONS

- **Emmanuel Hackman** and Huiqing Zhu, "Inverse Physics-Informed Neural Networks for Synaptic Dopamine Transport: Parameter Recovery at the Information Limit of Sparse, Noisy Data," poster, 11th SIAM Central States Section Annual Meeting, Jackson State University, Jackson, MS, October 10–11, 2026. Received the **Third Place Poster Award**. Travel supported by an NSF Travel Award administered by the SIAM Central States Section.
- **Emmanuel Hackman** and Huiqing Zhu, "When Inverse Physics-Informed Neural Networks Become Practically Identifiable: A Case Study in Synaptic Dopamine Transport," poster, Mississippi IDeA/EPSCoR Conference 2026 (MIEC26), Hattiesburg, MS, July 2026.

HONORS & AWARDS

- **Third Place Poster Award**, 11th SIAM Central States Section Annual Meeting, Jackson State University, Jackson, MS, October 2026. Awarded in recognition of an outstanding poster presentation.
- **NSF Travel Award**, administered by the SIAM Central States Section, to present at the 11th SIAM Central States Section Annual Meeting, October 2026.

QUANTITATIVE RESEARCH PROJECTS

Master's Thesis, *Scalable High-Resolution Simulation of the Prey-Predator Model, with a Non-local Consumption of Prey*
Accepted for publication — University of Southern Mississippi, The Aquila Digital Community *2025*

- Developed a scalable numerical solver for stiff, non-local prey-predator models using Krylov Subspace Spectral (KSS) methods, achieving up to **40× faster performance** than standard exponential integrators.
- Engineered high-resolution ecological simulations via Fourier spectral methods and adaptive polynomial interpolation, capturing complex patterns such as stationary patches and traveling waves.
- Benchmarked KSS against LEJA and Adaptive Krylov Projection (AKP) methods, demonstrating superior scalability and stability with relative errors consistently below 10^{-8} on grids up to $\mathbf{N = 8000}$.
- Formulated and analyzed biologically realistic non-local predator-prey partial differential equations with integral kernels to reflect spatially extended predator-prey interactions.
- Implemented advanced third-order exponential Rosenbrock integrators in MATLAB with matrix-free Jacobian approximations to handle large-scale stiff systems efficiently.

Physics-Informed Neural Networks for Synaptic Dopamine Transport, *Measurement-Aware Physics-Informed Neural Networks for Estimating Dopamine Diffusion and Uptake from Sparse Electrode Recordings*
Hackman, Sakyi & Zhu, 2026 — submitted to Biomedical Signal Processing and Control (Elsevier), October 2026; poster presented at the Mississippi IDeA/EPSCoR Conference 2026 (MIEC26), Hattiesburg, MS, and at the SIAM Central States Section Annual Meeting 2026, Jackson, MS (Third Place Poster Award) *2026*

- Developed a measurement-aware inverse physics-informed neural network (JAX, Flax NNX, Optax) that estimates the diffusion coefficient D and uptake rate k of a 2D reaction-diffusion model of dopamine release by passing the network output through a model of the electrode: tip averaging, response lag, whitening of correlated noise, and removal of a baseline offset.
- Recovered D and k within about **2%** on a single noisy recording; over 20 noise realizations the network matched classical least squares on the true model, with errors of **8.9%** and **6.3%** against Cramér–Rao bounds of 7.5% and 5.9%.
- Showed that ignoring the sensor biases the estimates (a 2-ms response lag more than doubles the estimated D) and makes uncertainty intervals overconfident, and that modelling the sensor with a short pre-stimulus baseline restores unbiased estimates with close to nominal coverage.
- Used the Cramér–Rao bound and 50 noise realizations per design to derive electrode design rules (k from one electrode; D needs a site near the release site or two sites), and released the code and data as an open archive on Zenodo.

Difference Equations and Limits in Geometry, *Difference Equations and Limits in Geometry*
Ding, Hackman & Zhu, 2026 — submitted to The American Mathematical Monthly, September 2026 *2026*

- Solved the convergence problem for sequences of vectors in Euclidean space generated by a fixed weighted-average recursion, and obtained an explicit expression for the limit.
- Reduced the geometric limit problem to an initial value problem for a linear difference equation with constant coefficients, giving a shorter and more elementary derivation than matrix diagonalization or the Perron–Frobenius power-limit method.
- Connected difference equations, characteristic polynomials, and the Perron–Frobenius theorem in a self-contained treatment that extends to other limit problems of this type.

DATA ANALYSIS PROJECTS

Adaptive Actuarial Exam Prep Platform, *github.com/Hachero98/actuarialprep — live at actuarialprep.vercel.app*
Full-stack adaptive learning platform for SOA actuarial exams (P, FM, FAM, ALTAM, ASTAM, SRM, PA) *2026*

- Built and deployed a full-stack adaptive learning platform (FastAPI, Next.js/TypeScript, PostgreSQL, Redis) with question banks for seven SOA exams, adaptive practice, mock exams, and personalized study plans.
- Implemented a three-parameter logistic Item Response Theory model with Bayesian ability estimation, Bayesian Knowledge Tracing for per-topic mastery, and Fisher-information-based item selection to target the next-best question in real time.
- Containerized the backend and frontend with Docker and Docker Compose, with the frontend deployed on Vercel.

PhD Command Center, *github.com/Hachero98/phd-command-center — live at phdcommandcenter.com*
Research management web application for STEM PhD candidates *2026*

- Built a web application (Next.js, TypeScript, PostgreSQL, Prisma) that links research questions, hypotheses, experiments, results, literature, advisor meetings, publications, and dissertation chapters in one relational data model.
- Implemented rule-based engines for next-step recommendations, gap analysis, dissertation readiness, and defense preparation, covered by a Vitest unit-test suite; deployed on Vercel with PostgreSQL on Railway.

ClassCheck, *classroom attendance and exam check-in platform*
Multi-instructor attendance system for university courses, starting with College Algebra (MAT 101) *2026*

- Built a multi-instructor attendance platform (Next.js, TypeScript, PostgreSQL, Prisma, Auth.js) with Excel/CSV roster import, QR self-check-in using a rotating anti-proxy classroom code, and a live dashboard over Server-Sent Events.
- Added an exam mode with a mobile QR scanner, TA/LA staff roles with per-course authorization, an append-only audit log, and Excel/CSV export, backed by unit and integration tests.

TEACHING EXPERIENCE

USM, *Hattiesburg, MS*
Instructor (Graduate Assistant) *Aug. 2023 – Present*

- **Fall 2026:** MAT 101 College Algebra (2 sections).
- **Spring 2026:** MAT 102 Brief Applied Calculus.
- **Fall 2025:** MAT 101S College Algebra Supplement.
- **Spring 2025:** MAT 103 Plane Trigonometry (2 sections).
- **Fall 2024:** MAT 101 College Algebra (2 sections).
- **Fall 2023:** MAT 101 College Algebra (Teaching Assistant).

UCC, *Cape Coast, Ghana*
Teaching Assistant(TA) *Nov. 2022 – Aug. 2023*

- Assisted with research in econometrics and financial analysis, focusing on monetary policy and fiscal models.
- Conducted literature reviews and data analysis for economic forecasting models, providing insights into macroeconomic trends and financial risks.
- Developed predictive models using Stata and R for economic research, which are directly applicable to financial markets analysis.

TECHNICAL COMPETENCIES

Leadership, critical thinking, attention to detail, teamwork, and written/verbal communication.

SKILLS & OTHERS

Mathematics: Econometrics, Probability Theory, Optimization, Stochastic Calculus and Monte Carlo Simulation,
Machine Learning: Generalized Linear Models, Neural Networks.
Computer: Excellent in Python, and LATEX. Proficient in R, Stata, SQL, Excel, and MATLAB.
Interests: Strategy Games, Music, Adventure Sports