

# Parth Bhargava

+65 9121 7298 | Singapore | [bhargava.parth07@gmail.com](mailto:bhargava.parth07@gmail.com)  
[github.com/Vis-42](https://github.com/Vis-42) | [vis-42.github.io](https://vis-42.github.io) | [linkedin.com/in/parth-bhargava](https://www.linkedin.com/in/parth-bhargava)

## EDUCATION

### National University of Singapore

Aug 2024 – Present (Expected Graduation: May 2028)

Bachelor of Science in Physics (Honors, Distinction)

**GPA: 4.36**

### University of Texas at Austin

Aug 2026 – Dec 2026 (Upcoming)

Exchange Semester, Department of Physics

## SUMMARY

Year-2 physics undergraduate building toward research in complex systems and nonlinear dynamics. Hands-on experience across 15+ experiments spanning condensed matter, spectroscopy, plasma physics, biophysics, and ion-matter interactions. Computational modeling in Python, Julia, and MATLAB with focus on nonlinear dynamics and statistical methods. Seeking research opportunities that combine theoretical rigor with computational and experimental work.

## PROJECTS

### Chaotic Dynamics of a Driven Triple Pendulum

Jan 2026 – Apr 2026

*Computational Methods in Physics (PC3236) — MATLAB/Python*

- Derived Lagrangian equations of motion for three coupled pendulums with periodic driving torque
- Implemented custom **RK4 integrator** (validated against scipy RK45 to  $< 10^{-6}$  rad over 20 s); produced **phase portraits**, **Poincaré sections**, and **bifurcation diagrams** showing onset of chaos

### Quantum Wavepacket Visualization

Jan 2025 – Mar 2025

*Self-directed project — Python*

- Built a **3D simulation** of a quantum wavepacket traversing a potential barrier using finite-difference methods
- Visualized **quantum harmonic oscillator** energy eigenstates and time evolution

### ML Classification: Bank Term Deposit Prediction

Jan 2026 – Apr 2026

*Artificial Intelligence (IT1244) — Python, scikit-learn*

- Compared four classifiers (logistic regression, random forest, SVM, XGBoost) on 41k-record UCI dataset; applied SMOTE for class imbalance; identified top predictive features for pre-call targeting

## COURSEWORK

### Experimental Physics I (PC2193):

- Measured **carrier type**, **density**, and **mobility** in n- and p-type germanium via the **Hall effect**; cross-validated mobility by independent **magnetoresistance analysis** ( $R^2 > 0.99$ ); characterized the **extrinsic-to-intrinsic transition** at 106°C
- Determined **lattice constants** via **X-ray diffraction** using **Bragg's law**; achieved **sub-2% accuracy** for LiF and **0.24% deviation** for KBr identification through structural fingerprinting; extracted **Planck's constant** from bremsstrahlung cutoff analysis
- Calibrated **Helmholtz field constant** through five independent experimental methods with **3.3% uncertainty**; validated all **electromagnetic torque scaling laws** ( $R^2 > 0.997$ ); corrected mathematical model using **quadratic fitting** ( $T \propto d^2$  vs linear)
- Characterized **electron spin resonance** in paramagnetic systems; extracted **g-factors** from frequency-field data ( $R^2 = 0.9995$ ); analyzed **Zeeman splitting** and resonance conditions
- Measured **Gaussian beam propagation**; determined **beam waist** and **Rayleigh range** with **sub-1% agreement** to theory; characterized **beam quality factor** ( $R^2 > 0.998$ )

### Experimental Physics II (PC3193):

- Performed **X-ray fluorescence** spectroscopy for elemental identification and quantitative analysis of brass via **Gaussian deconvolution**; resolved the Cu  $K_\beta$  / Zn  $K_\alpha$  overlap; estimated Cu/Zn/Pb mass fractions over five trials
- Indexed **Laue diffraction** patterns for a LiF single crystal; identified Si (diamond-cubic,  $a = 5.430 \pm 0.002$  Å) and Mo (BCC,  $a = 3.140 \pm 0.004$  Å) via **powder X-ray crystallography**; derived the 8-atom diamond-cubic structure factor

- Used **Raman spectroscopy** to characterize carbon allotropes (graphite, HOPG, nanotubes, diamond); estimated graphene layer count from 2D/G intensity ratios; identified an unknown wafer as crystalline Si from its  $521\text{ cm}^{-1}$  mode
- Measured **Paschen curves** for air at three pressures; extracted the **second Townsend coefficient** ( $\gamma = 0.0017 \pm 0.0003$ ); identified the transition from avalanche to streamer breakdown at high  $pd$
- Ran **TRIM Monte Carlo simulations** of ion transport across six applied problems (nuclear microscopy, semiconductor implantation, sputtering, proton therapy); analyzed range, straggling, damage, and sputter yields

### Biophysics II (PC3267):

- Monitored **protein unfolding** in BSA and lysozyme via **fluorescence spectroscopy** (280 nm excitation); observed a 24% intensity drop and 19 nm blue shift in BSA; correlated structural differences with disulfide-bond count
- Used **circular dichroism** to track secondary-structure loss under acid denaturation; BSA showed 21% ellipticity reduction versus less than 1% for lysozyme, consistent with lysozyme's four stabilizing disulfide bonds
- Imaged plant and animal cells via **fluorescence microscopy** with Hoechst nuclear staining; compared brightfield and epi-illumination contrast

### Theory & Computation:

- **Mechanics:** Lagrangian and Hamiltonian formulations, coupled ODEs, variational principles, phase space dynamics
- **Electromagnetism:** Maxwell's equations, boundary-value problems, vector calculus, gauge theory
- **Quantum Mechanics:** Schrödinger equation, operator methods, eigenvalue problems, perturbation theory
- **Thermodynamics & Statistical Mechanics:** Entropy, Gibbs free energy, Boltzmann factor, equipartition, boson/fermion statistics, photon gases, Carnot engines
- **Mathematical Methods:** Linear algebra, ODEs/PDEs, Fourier analysis, complex analysis, special functions
- **Computation:** Python, Julia, MATLAB; numerical methods (Runge-Kutta, Newton-Raphson, Gaussian quadrature, Monte Carlo, finite differences); ODE/PDE solvers (wave, heat, Laplace, Schrödinger equations); data analysis, visualization
- **Artificial Intelligence:** Supervised learning (KNN, regression, neural networks), unsupervised learning (clustering), deep learning foundations, AI ethics
- **Biophysics:** Biomolecular electrostatics, reaction kinetics, self-assembly, molecular dynamics, protein structure prediction, motor proteins
- **Experimental Methods:** Statistical analysis, uncertainty propagation, calibration, regression, error budgets

## RESEARCH INTERESTS

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- **Complex Systems & Nonlinear Dynamics:** How deterministic rules produce effectively unpredictable behavior. Chaos theory, bifurcation analysis, and the geometry of attractors in phase space. Interested in systems where local interactions build global structure and the transition between ordered and chaotic regimes can be mapped and visualized.
- **Biophysics & Biological Complexity:** How physical principles govern biological systems at the molecular and cellular scale. Protein stability, conformational transitions, and the statistical mechanics of self-assembly. Drawn to problems where physical measurement (spectroscopy, diffraction, microscopy) makes biological mechanism legible.
- **Network Science & Information Theory:** How topology shapes dynamics. Information flow through network structures, feedback and robustness in coupled systems, and the connections between graph theory, statistical mechanics, and emergent collective behavior.
- **Computational Modeling & Geometric Visualization:** Building simulations that respect the mathematical structure of physical systems and using geometric tools (phase portraits, Poincaré sections, bifurcation diagrams) to make abstract dynamics concrete and interrogable. Bridging numerical methods with physical intuition.
- **Emergence & Statistical Reasoning:** The boundary between genuine collective phenomena and accumulated correlation. How macroscopic behavior arises from microscopic rules through statistical mechanics, and how to distinguish structure from noise in complex datasets. Interested in physics-informed machine learning as a tool at this boundary.

## ACHIEVEMENTS

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- **Silver Medal**, International Aerospace Olympiad 2024
- **JEE Mains: 99.14 percentile** (Top 1% of 1.47 million candidates)
- **JEE Advanced Rank: 9112**
- **IISER Aptitude Test Rank: 357**
- **BITSAT: 321/390**