

# HAORAN QI

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## Education

- *Ph.D. in Mathematics*, The Pennsylvania State University. *Aug 2020 - Jun 2026 (expected)*  
◇ Advisor: Prof. Anna Mazzucato  
◇ Research interest: Microlocal Analysis, Partial Differential Equations, Numerical Analysis
- *B.S. in Mathematics (with Honor)*, Xi'an Jiaotong University. *Aug 2016 - Jul 2020*  
◇ Thesis: *The Analysis of Elliptic Hemivariational Inequalities with Discontinuous Galerkin Method* (in Chinese). Thesis Advisor: Prof. Fei Wang.

## Publications

2. (With A. Mazzucato) *Microlocal Analysis of Hyperbolic Viscoelastic Equation with Non-smooth Coefficients*, in progress.
1. (With F. Wang) *Discontinuous Galerkin Method of an Elliptic Hemivariational Inequality*, **Applied Mathematics Letters**, 109(2020), pp. 1-8.

## Awards & Scholarships

- Mary Lister McCammon Award Honorable Mention for Distinguished Undergraduate Teaching. *Apr 3, 2025.*  
"For exemplary teaching of undergraduate (freshman/sophomore) mathematics courses at Penn State."
- Dr. John Randall Shuman Troxell Memorial Scholarship in Mathematics. *Spring 2023*

## Academic Activities

3. SIAM Conference on Analysis of Partial Differential Equations (PD25), Pittsburgh, PA, USA. *Nov 2025*
2. Microlocal Analysis and Quantum Dynamics 2024, Northwestern University, Evanston, IL, USA. *Jun 2024*
1. Second Drexel Waves Workshop, Drexel University, Philadelphia, PA, USA. *Mar 2023*

## Teaching Experience at Penn State

- **Instructor**, MATH 140, *Calculus I* (2 sections). *Spring 2025*
- **Instructor**, MATH 251, *Ordinary and Partial Differential Equations* (4 sections). *Fall 2024, Fall 2023*
- **Instructor**, MATH 22, *College Algebra II* (1 section). *Spring 2022*
- **Graders** for the following courses: MATH 311W (Concepts of Discrete Mathematics), MATH 513 (Partial Differential Equations I), MATH 555 (Mathematical Optimization).

## Research Experience

### **Project: Analysis of Singularity Propagation in Viscoelastic Equations**

*Jan 2023 – Present*

- Developed a novel microlocal analysis framework to decouple second-order viscoelastic equations with nonsmooth coefficients into first-order systems involving fractional memory terms. This work provides the first general method for such a decoupling, resolving a key technical barrier in the field.
- Proved a foundational theorem demonstrating that the wave front set for homogeneous evolution equations with fractional memory is identical to the non-memory case, clarifying a fundamental aspect of singularity propagation dynamics.
- Discovered and characterized a periodic “echoing” phenomenon where singularities are regenerated over time due to interactions between the initial conditions and a memory kernel with multiple singularities.
- Extended classical results on the well-posedness of hyperbolic equations and the formation of caustics to systems incorporating memory effects, broadening the applicability of existing theory.

### **Project: Numerical Analysis of Advective Cahn-Hilliard Equations**

*Jun 2025 – Aug 2025*

- Provided essential numerical and computational support for an ongoing research project analyzing advective Cahn-Hilliard equations.
- Designed and implemented simulations in the Julia programming language using an adaptive-order, semi-implicit spectral method to generate numerical examples that validate and guide theoretical analysis.

### **Project: PennSim Reservoir Simulation Software**

*Aug 2021 – Nov 2022*

- Served as a key developer for PennSim, a high-performance reservoir simulation software written in C++ and used in petroleum engineering research.
- Co-designed and implemented an adaptive solver that dynamically switches between the Fully Implicit Method (FIM) and an improved Implicit Pressure, Explicit Saturation (IMPES) method to optimize computational stability and efficiency.
- Validated software performance against standard industry benchmarks from the Society of Petroleum Engineers (SPE), confirming the accuracy, efficiency, and stability of the numerical solutions.

## Technical Skills

- **Programming Languages:** Python, MATLAB, C/C++, Julia
- **Software:** LaTeX, Mathematica