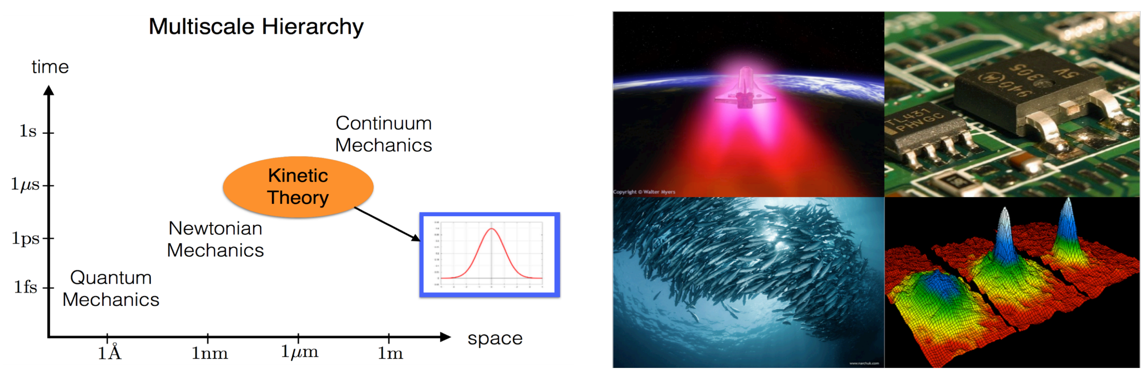
MA 69200 Topic Course in Applied Math (Spring 2018)
Introduction to Kinetic Theory (TTh 1:30-2:45pm, MATH 215)

Instructor: Jingwei Hu **Email:** jingweihu@purdue.edu **Phone:** (765) 496-0056
Instructor's Webpage: https://www.math.purdue.edu/~hu342/
Office: MATH 416 **Office Hours:** TBD

In multiscale modeling hierarchy, kinetic theory serves as a basic building block that bridges atomistic and continuum models. It describes the non-equilibrium dynamics of a gas or system comprised of a large number of particles using a probability density function. On one hand, kinetic descriptions are more efficient (requiring fewer degrees of freedom) than molecular dynamics; on the other hand, they provide rich information at the mesoscopic level when the well-known fluid mechanics laws of Navier-Stokes and Fourier become inadequate, and have proved to be reliable in many fields such as rarefied gas/plasma dynamics, radiative transfer, semiconductor modeling, or even social and biological sciences. This course will constitute an introduction to the kinetic theory with the focus on the Boltzmann equation and related kinetic models. We will discuss basic mathematical theory, numerical methods, and various applications.



Left: Multiscale modeling hierarchy. **Right:** Some applications of kinetic theory. Clockwise: space shuttle reentry; semiconductor modeling; Bose-Einstein condensate; swarming fish.

Specific topics will include: derivation and properties of the Boltzmann equation (collision integral, conservation laws, *H*-theorem, etc.), connection to molecular dynamics, connection to fluid equations, Chapman-Enskog expansion, moment closures, deterministic numerical methods (e.g., discrete-velocity methods, spectral methods, fast summation methods), stochastic numerical methods (e.g., direct simulation Monte Carlo methods), asymptotic-preserving schemes (multiscale methods coupling kinetic and fluid equations). Other possible topics depending on the interests of the audience: Vlasov and Fokker-Planck-Landau equations for plasmas, quantum Boltzmann equation for bosons and fermions, inelastic Boltzmann equation for granular media, multi-species Boltzmann equation for gaseous mixtures, semiconductor Boltzmann equation for electron transport, kinetic models for collective behavior of swarming and flocking, etc. No textbook is required. The material will be based on the lecture notes by the instructor, and some papers and book chapters. No exams. There might be some homework assignments. Students are expected to present course-related material in class or work on small research projects.

References:

- C. Cercignani. *The Boltzmann Equation and Its Applications*. Springer-Verlag, 1988.
- S. Chapman and T. Cowling. *The Mathematical Theory of Non-Uniform Gases*. Cambridge University Press, third edition, 1991.
- C. Cercignani, R. Illner, and M. Pulvirenti. *The Mathematical Theory of Dilute Gases*. Springer-Verlag, 1994.
- C. Cercignani. *Rarefied Gas Dynamics. From Basic Concepts to Actual Calculations*. Cambridge University Press, 2000.
- C. Villani. A review of mathematical topics in collisional kinetic theory. In S. Friedlander and D. Serre, editors, *Handbook of Mathematical Fluid Mechanics*, volume I, pages 71-305. North-Holland, 2002.
- S. Harris. *An Introduction to the Theory of the Boltzmann Equation*. Dover Publications, 2004.