MAE236
Nonequilibrium Gas Dynamics
Winter 2021

This is a course for students interested in the molecular foundation of gaseous flows, real-gas effects in flows with very high acceleration or shocks, flow in rarefied gases, or micro gas flows. The course will relate continuum-scale behavior for flowing gases to phenomena at the molecular level. The conservation equations and the Navier-Stokes equations will be derived from the study of molecular behavior. Constitutive relations for viscous stress, conductive heat flux and diffusive mass flux will be determined based on first principles on molecular motion. Shock structure will be analyzed. Chemical nonequilibrium and vibrational nonequilibrium in rapidly accelerating (or decelerating) flows, wave motion, and relaxation in flows (e.g., aft of shocks) will be studied. Flows with scales comparable to the molecular mean-free path (e.g., flight in the outer atmosphere or micro-fluidics) will be discussed.

Instructor: Feng Liu, fliu@uci.edu, Telephone: 824-1750, EG3201.
Lectures: 9:30-10:50am, M.W.
Zoom Lecture link: https://uci.zoom.us/j/96403289490
Meeting ID: 964 0328 9490
Passcode: 3975

Office Hours/Discussions: on line and TBD.
Course Grading: Homework: 35%, Midterm: 30%, Final: 35%

Textbook and References:
1. Vincenti, W.G. and Kruger, C.H., *Introduction to Physical Gas Dynamics*, Krieger (1982).
2. Williams, F.A., *Combustion Theory*, Benjamin-Cummins (1985).
3. Hirschfelder, J.O., Curticss, C.F. and Bird, R.B., *Molecular Theory of Gases and Liquids*, John Wiley (1954).
4. Anderson, J.D, Hypersonic and High-Temperature Gas Dynamics, 2nd ed., AIAA 2006.

Course Contents:
Fundamentals of Kinetic Theory (3 weeks)
- Basic Concepts of Kinetic Theory
- Introduction of Nonequilibrium Kinetic Theory
- Molecular Derivation of Conservation Equations

Transport Phenomena in Gases (3 weeks) |
- Chapman-Enskog Expansion
- Derivation of Navier-Stokes Equations
- Transport Properties (viscosity, heat and mass diffusivity)

Flows with Translational, Vibrational and Chemical Nonequilibrium (4 weeks)
- Shock Structure Review of Chemical and Vibrational Rate Processes
- One-Dimensional Steady Flow (Nozzle Flow and Shock Relaxation)
- Linearized Wave Phenomena (Acoustic Equations and Slender Body Theory)