AE 3450 Thermodynamics and Compressible Flow (3-0-3)


Course Coordinator: Prof. J. Seitzman

Learning Objectives:
1. Define basic thermodynamic properties (e.g., temperature, pressure, density, internal energy, enthalpy, and entropy), and show how to use state equation relationships to calculate one property based on other properties;
2. Introduce the basic theorems of Thermodynamics in the form of the First and Second Laws, and their application to both closed and open systems;
3. Develop and describe the properties of compressible flows, especially in contrast to the properties of incompressible flows;
4. Analyze quasi-one-dimensional compressible flows, including: converging-diverging nozzles, supersonic flows over and around simple bodies, shock tube flows, and channels with friction or heat transfer.

Expected Outcomes: Students will be able to: a) calculate equilibrium thermodynamic properties of gases (and liquids) based on state relationships; b) use the conservation and transport equations to analyze thermodynamic property changes for closed and open fluid systems, and identify possible and impossible processes; c) calculate and use stagnation properties of flows; d) analyze quasi 1d compressible flows – including flows within nozzles and diffusers; e) analyze simple, 1d and 2d steady flows with shocks and expansions, including flows over simple bodies; f) perform preliminary design calculations for a simple supersonic windtunnel, supersonic engine inlet, or supersonic nozzle; and g) analyze 1d flows with friction or heat transfer – including choking.

Prerequisites: Phys 2212

Topics:
1. **Basic Thermodynamic Concepts**: Systems; Energy and its transfer by work and heat; Equilibrium, Properties of Substances
2. **Mass Conservation** for Closed Systems and Open Systems (integral and differential forms); Flow rates and fluxes
3. **Energy Conservation** (1\textsuperscript{st} Law) for Closed Systems (including friction, latent heat and cycles), and for Open Systems (integral and differential forms); Stagnation temperature and enthalpy

4. **Entropy** (2\textsuperscript{nd} Law): Characteristics of entropy; reversible vs. irreversible processes; entropy transfer; 2\textsuperscript{nd} Law for closed systems; entropy state equations (including stagnation pressure); Entropy conservation/transport equation for open systems

5. **Isentropic Compressible Flows**: Wave propagation and sound speed; steady, quasi-1d flow equations; steady flow with area change (Mach relations and sonic throats); Isentropic nozzle analysis (converging and converging-diverging) and back pressure

6. **Shock Waves**: Formation; Normal Shocks - Mach number relations, Moving and Reflected shocks, Shocks in C-D nozzles, Starting problem for supersonic windtunnels; Oblique Shocks - Mach number relations, strong, weak and detached shocks, supersonic inlets/diffusers

7. **Prandtl Meyer Expansions and Compressions**: Equations; Maximum turning angle; Continuous turns

8. **Reflected Waves**: Compression and expansion reflections – boundary conditions; Application to under- and over-expanded nozzles; Plug and aerospike nozzles

9. **Flows with Friction and Heat Transfer**: generalized 1-d Mach relations; Fanno Flow; Rayleigh Flow