1 Review of Fundamental Laws and Constitutive Equations

1.1 Fundamental laws governing continuum flow, expressed in terms of (i) material volumes (closed systems) and (ii) control volumes.

1.2 Mass conservation equation; integral and differential forms.

1.3 The equation of motion in terms of the stress tensor. Integral and differential forms. Stress tensor for a Newtonian fluid. The Navier–Stokes equation.

1.4 The energy equation (First Law) in integral and differential forms. The equations for the kinetic, potential, and internal energies. Physical significance of the various terms. The viscous dissipation function.

1.5 The Second Law of thermodynamics.

1.6 The equation for entropy production (Gibbs' equation). The Second Law as a statement that the viscous dissipation function is greater than or equal to zero.

1.7 The thermodynamic equations of state: differential expressions for all the thermodynamic properties of a fluid in terms of three measurable properties which are functions of pressure and temperature–the coefficient of thermal expansion, the isothermal compressibility, and the specific heat at constant pressure.

1.8 The differential equation for temperature and heat flux. Example: thermal effects due to viscous heating in Couette flow.

1.9 Some low–speed approximations: (i) "incompressible flow," (ii) the neglect of the isentropic compression term in the temperature equation. Criteria for validity.

1.10 The conservation equation for a molecular species. Mass transfer.

1.11 Introduction to the molecular basis of viscosity, heat conduction and diffusion in terms of a simplified kinetic theory of gases. (This serves as an important but relatively simple analogy for the random–walk transport that also occurs in turbulence.)

References:

Sec. 1.1–1.4: Sonin. *Fundamental Laws of Motion: Particles, Material Volumes*,

And Control Volumes. Sonin. *The Equation of Motion for Viscous Fluids.* available at http://web.mit.edu/2.25/www/ ; White.*Viscous Fluid Flow*, 2nd ed. (1991): 59–89, 96–100; Pope. Ch. 2; or other books.

Secs 1.4 – 1.6: Class notes plus summaries handed out by Sonin.
For Sec. 1.7–1.8: Handout: Sonin."The Thermodynamic Constitutive Equations and the Equation for Temperature."

Sec. 1.10: Class notes.

Sec. 1.11: See for example Bird, Curtis, and Hirschfelder. *Molecular Theory of Gases and Liquid,* (1954): 8–16, or Vincenti & Kruger. *Introduction to Physical Gas Dynamics.* 1965:15–20.