AE 2010/2011 Outline

This is a *tentative* outline of the material that will be covered and the appropriate chapter assignments from the textbooks (**T** = Turns' Thermodynamics text, 1st ed., **A** = Anderson's Aerodynamics text, 6th ed.) for readings that complement the lecture material (note: class lectures *expand upon* the coverage in the text, and are not derived from the textbooks).

Students in AE 2011 will be responsible for the sections identified with the symbol ⇒ (with the assumption that they have are already mastered the other material which may be considered fundamental to understanding the material covered in the marked sections).

	Reading	# Hours
⇒ **I. Introduction and Overview**	A1.2, 7.1; T1.1,1.2	**1.5**
A. Thermodynamics		
B. Fluids		
C. Compressible Flow		
D. Units, Significant Figures and Precision	A1.4.1; 1.6	
II. Basic Concepts		**4**
⇒ A. How to Think of Matter	A1.10.1, 2.3.3	
1. Macroscopic vs microscopic viewpoints of matter		
2. Continuum vs rarefied viewpoints of fluids		
B. Thermodynamic Concepts and Definitions	T1.3, 1.5, 2.2a	
1. Systems		
2. Energy and its Transfer by Work and Heat		
3. Equilibrium and Properties Example: Work as Path Function		
⇒ C. Flow Field Concepts and Definitions	A1.4, 2.3-2.3.2, 2.11	
1. Velocity		
2. Reference frames		
3. Fluid elements: Eulerian and Lagrangian approaches		
4. Visualizing velocity fields: streamlines, streaklines and pathlines		
III. Properties of Substances		**7.5**
A. Extensive and Intensive (Thermodynamic) Properties	T2.1	
1. Definitions		
2. Converting extensive to intensive property		
3. Creating new properties: enthalpy (and stagnation enthalpy)		
B. The State Postulate and State Equations	T2.3a-b, 2.5	
1. Independent TD properties: how many?		
2. Equations of state (EOS) and *p-v-T* examples		
3. Generalized compressibility and compressibility factor		
C. Ideal/Thermally Perfect Gas State Equations	T2.4-2.4d	
1. Ideal Gas Law		
2. Caloric equations of state		
3. Example: TPG state equations		
D. Incompressible Substances (Liquids/Solids)	T2.7-2.8	
E. Two-phase mixtures: Equilibrium Diagrams and Saturated Liquid/Vapor Systems	T2.6-2.6a	
1. Phase transitions, phase diagrams and supercritical fluids		
2. Mixed phases: quality and saturated liquid-vapor mixture properties		
3. Example problems and use of data tables		

⇒ F. Transport Properties A1.4, 1.10-11, 1.8, 15.3

1. Diffusion and diffusivities
   a. Heat conduction and thermal conductivity
   b. Shear stress and viscosity
   c. Temperature and pressure dependence
2. Introduction to boundary layers: momentum and thermal
3. Similarity parameters: Prandtl number, Reynolds number, Mach number

IV. Conservation Equations **16**

A. Mass Conservation T 3.1-3.3; A2.4, 2.9 2.5

1. Closed Systems (Control Mass Approach)
2. Open Systems (Control Volume Approach)
   a. Integral forms
   ⇒ b. Differential forms and material derivatives

⇒ B. Reynolds Transport Theorem 0.5

⇒ C. Conservation of Linear Momentum A2.5,1.9, 2.6, 3.2 4.5

1. Derivation of differential and integral forms
   a. Control mass integral from and wing pressure example
   b. Control volume integral form
   c. Control volume differential form
2. Example applications
   a. Hydrostatics: atmospheric pressure
   b. Aerodynamic forces from velocity profiles: airfoil lift and drag (and coefficients)
   c. Propulsion: engine nozzle force
3. Bernoulli equation
   a. Derivation from streamline momentum conservation
   b. Dynamic and stagnation pressure
   b. Application examples: low speed wind tunnel; Pitot-static probes
4. Differential form for quasi-1D steady flows

D. 1^{st} Law - Conservation of Energy T5.1-5.2a, 5.3 4

1. Control mass (integral and differential forms)
2. Examples
   a. Constant volume heat addition
   b. Constant pressure heating
   c. Impact of friction on constant pressure process
   d. Latent heat of vaporization
   e. Shaft work
3. Control volume analysis (integral form)
4. Examples
   a. High speed nozzle and stagnation temperature
   b. Adiabatic mixing
   c. Compressor
5. Cycles and cycle efficiency
6. Differential form for quasi-1D steady flows

E. 2^{nd} Law - "Conservation" of Entropy T6.1-2;6.3a,d;6.5-6 4.5

1. Entropy basics and 2^{nd} Law for an isolated system
   a. Limitations of the 1^{st} Law, work and molecular chaos
   b. Characteristics of entropy
   c. Entropy production and the 2nd Law for isolated systems
   d. Reversible and irreversible processes

e. Entropy transfer through heat transfer
2. Development of 2^{nd} Law for a control mass (modern approach)
(classical approach - not included in lecture)
3. Analysis of 2^{nd} Law for CM
a. Entropy change and isentropic processes
b. Maximum/minimum work conditions
c. Carnot cycle and limiting cycle efficiency
4. Entropy state relations
a. The Gibbs equation
b. General substances, saturated mixtures, incompressible substances
c. Ideal (thermally perfect) gases and mixtures
⇒ d. Stagnation pressure, relation to Bernoulli equation
⇒5. 2^{nd} Law for control volumes and examples

⇒ **V. Compressible Flows** **21**

A. Fundamentals 2
1. Wave Propagation in Compressible Substances
a. Speed of Sound A8.3
b. Mach Angle and Mach Number A9.1 (pp. 604-606)
2. Stagnation Properties and Mach Number A7.5 (pp. 535-537)
3. Steady, Quasi-1D Flow Equations A10.2 (pp. 672-677)

B. Isentropic Compressible Flows 3
1. Steady Isentropic Flow with Area Change A10.2-3 (pp. 678-682)
a. Conservations Equations - Mach Relations
b. Sonic Throat Condition and Choking
2. Isentropic Nozzle Analysis and Back Pressure A10.3 (pp. 683-686)
a. Converging Nozzle Analysis
b. Converging-Diverging Nozzle Analysis

C. Shock Waves A8.1 7.5
1. Formation of Shock Waves - Compression
2. Normal Shock Waves
a. Mach Number Relations A8.2, 8.6
b. Moving Normal Shocks
c. Reflected Normal Shocks
d. Normal Shocks in Converging-Diverging Nozzles A10.3 (pp.687-688)
e. Starting Problem - Supersonic Windtunnels A10.5
3. Oblique Shock Waves A9.1-2
a. Mach Number Relations
b. Strong, Weak and Detached Shocks
c. Application to Supersonic Inlets (Diffusers)

D. Prandtl Meyer Expansions and Compressions A9.6 1.5
1. Flow Equations - Mach Relations
2. Maximum Turning Angle
3. Continuous Expansions and Compressions

E. Reflected Waves A9.4 2
1. Reflections of Compression and Expansion Waves
2. Application to Under & Overexpanded Supersonic Nozzles
3. Plug and Aerospike Nozzles

F. Lift and Drag on Simple Supersonic Airfoil Geometries A9.7 2
1. Thin flat plate
2. Diamond airfoil

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