AE 6050: Outline

This is a *tentative* outline of the material that will be covered and the appropriate chapter assignments from Vincenti and Kruger (plus optional parallel readings from Anderson). Class lectures will parallel and *expand upon* the coverage in the text.

		Reading **V&K** (Anderson)	~#Lectures @75 min
I.	**Introduction and Review**		3.5
	A. Ideal vs. High Temperature Gas Dynamics	(Ch. 9)	
	B. Ideal Gas Dynamics Review	any undergrad. text	
	1. Compressible Flow Overview, Mach number, Mach Angle		
	2. Governing Equations, Stagnation Temperature and Pressure		
	3. Quasi-1D Equations for tpg/cpg and Steady Isentropic Flow Behavior		
	4. Supersonic tpg/cpg Flow Adjustment to Boundary Conditions		
	a. Normal Shocks		
	b. Oblique Shocks		
	c. Prandtl-Meyer Flow		
	d. Example Applications, Wave Interactions and Wave Reflections		
	C. Statistical Mechanics Review (***on your own as necessary***)	**IV.1-13**(11.1-8)	
	1. Boltzmann's Relation and Boltzmann Distribution		
	2. Thermodynamic Properties from Partition Functions		
	3. Independent Energy Modes of Gases		
	4. State Relations and Specific Heats for Energy Modes		
	5. Equilibrium Constant from Partition Functions		
	D. Kinetic Theory Review (***on your own as necessary***)	**I.1-4,6; II.1-6**(Ch. 12)	
	1. Velocity Distributions and Gas Properties		
	2. Maxwellian Velocity and Speed Distributions		
	3. Bimolecular Collision Rates and Collision Frequencies		
II.	**Equilibrium Properties of Reacting Gas Mixtures**	**V.1-6**(11.9-14)	1.5
	A. Reacting Mixture Properties		
	B. High Temperature Air Example		
	C. Ideal Dissociating Gas		
	D. Ionization Equilibrium: Saha Equation		
III.	**Equilibrium and Frozen Flows**	**VI.1-3,5;VIII.5**(14.3-5,7)	4.5
	A. Steady Shocks		
	1. Equilibrium Normal Shocks		
	a. Equations and General (Numerical) Solution Approach		
	b. Shock Property Ratios and Ideal Dissociating Gas Expressions		
	c. Example: High Altitude Air and Hypersonic Flight Speeds		
	d. Example: High T Effects on Blunt Body/Bow Shock		
	2. Equilibrium Oblique Shocks		
	a. Equations		
	b. Example: High T Effects on Airfoil with Sharp Leading Edge		
	c. Maximum Turn Angle		

3. Equilibrium Flow and Frozen Flow Shocks

B. Steady Nozzle Flow
   1. Equations and Throat Condition
   2. Solution Approach
   3. Example: Rocket Nozzle

C. Prandtl Meyer Flow
   1. Turn Angle Expression and Flow Properties
   2. Equilibrium vs Frozen Expansions
   3. Example Numerical Solution Approach

D. Equilibrium Speed of Sound

IV. Nonequilibrium Processes **VII.1-4,6-8**(Ch. 13) 4.5

A. Vibrational Nonequilibrium
   1. V-T Rate Equations for Harmonic Oscillator
   2. Relaxation Time Constant (Landau-Teller, Millikan and White)
   3. V-V Effects and Anharmonic Pumping

B. Entropy Production due to (Vibrational) Nonequilibrium

C. Chemical Nonequilibrium
   1. Elementary Reactions and Rate Expressions
   2. Chemical Rate Constants and Characteristic Chemical Times
   3. Example: High Temperature Air
   4. Chemical Reactions with Thermal Nonequilibrium

V. Inviscid Nonequilibrium Flows **VIII.1-3,9,13,15,16**(15.1-5) 3.5

A. Equations (Inviscid)

B. Normal Shocks

C. Oblique Shocks

D. Nozzle Flows (quasi-1d)

E. Expansion Turns

F. Blunt Body Flow

VI. Translational Nonequilibrium–Nonequilibrium Kinetic Theory **IX.1-5** 4.5

A. Continuum vs. Molecular Conservation Equations
   1. Navier Stokes Equations
   2. Molecular Conservation/Transport Equations
   3. Molecular Interpretation of (Diffusive) Transport Terms

B. The Boltzmann Equation (BE)

C. Diffusive Transport Properties

D. Flows with Significant Translational Nonequilibrium

E. Nonequilibrium Plasmas

VII. Radiative Energy Transfer in Gases **XI.1-7**(18.1-2) 4

A. Radiation Equations
   1. Radiative Flux Vector and Intensity
   2. Equation of Radiative Transfer (Optically Thin and Thick Limits)

B. Radiative Properties of Gases
   1. Molecular Parameters – Einstein Coefficients
   2. Relationship to Absorption Coefficient

C. Molecular Spectra

1. Line Broadening
2. Multiple Transitions and Molecular Bands
3. Air Absorption
4. Line-by-Line and Band Models

D. Flows with Radiation
1. Uncoupled and Coupled Solutions
2. Shock and Reentry Flow Examples