EAS 3603: Thermodynamics – Earth Systems
Fall Semester, 2012

T Th, 4:35pm-5:55pm, ES&T L1125

Instructor:
Professor Nga Lee Ng
Office: ES&T 2222
Email: ng@chbe.gatech.edu
Office hours: T and Th 3:30 – 4:30pm

Teaching Assistant:
James Hite
Email: jhite6@gatech.edu
Office hours: TBA

Textbook: Thermodynamics of Atmospheres and Oceans by Curry and Webster, Academic Press, 1999.

Web: Course materials, announcements, homework assignments, and grades will be posted on T-square (http://www.t-square.gatech.edu). Check the website regularly.

Grading scheme:

Homework	25%
Exams (3)	45%
Final Exam (1)	30%

Exam 1: 9/27 (Th)
Exam 2: 10/30 (T)
Exam 3: 11/20 (Th)
Final Exam: 12/13 (Th) 2:50pm - 5:40pm

Class polices:

Honor Code

Students are required to abide all terms of the Academic Honor Code regarding course materials, homework, and exams. Unauthorized use of any previous semester course materials (e.g., tests, homework, and other coursework) is prohibited in this course. Collaboration on the homework is allowed, but each student must turn in their own solutions. Anyone who copies homework solutions will automatically receive a zero grade.

Homework

1. No late homework will be accepted for any reason. Homework is due at the beginning of the class on the due date.
2. Homework must be hand-written on 8 ½” X 11” pages. No pages torn out of spiral notebooks or computer printout sheets (except for problems involving computation). Print neatly.
3. Number the pages and staple all pages together.
4. List all assumptions made, reference additional information used and show all work performed to obtain the solution. Box the solution.

Exams

All exams are closed book. You are allowed to bring one 8 ½” X 11” sheet of personal notes with any information you want on it. These notes must be yours and may not be copied from others. All necessary information relating to conversion factors and component properties (e.g., molecular weight or density) will be given on exams. Scientific calculators are allowed in exams but graphing calculators and wireless devices are forbidden.

Others:

Cell phones and laptop computers are prohibited during class.

Materials to cover:

PART 1: INTRODUCTION

Introduction

- What is thermodynamics? Why study thermodynamics of the Earth system?
- Thermodynamic systems: composition and state; system vs the environment; open or closed or isolated; boundaries of a system and the environment,
- Thermodynamic state of a system: state variables (intensive and extensive); thermodynamic properties; equation of state
- State variables: pressure, temperature, volume/density; units

Composition and structure of components of the earth system

- Composition: atmosphere, ocean, solid earth
- Pressure: units; vertical variations in the atmosphere, ocean, solid earth; space/time variability
- Density (specific volume): units; vertical variations in the atmosphere, ocean, solid earth
- Temperature: units; vertical variations in the atmosphere, ocean, and solid earth; space/time variability
- Hydrostatic equation: application to ocean and hypothetical constant density atmosphere; solid earth

Equation of state

- Ideal gas law
- Kinetic-molecular model of the ideal gas
- Equation of state for air: Dalton's law of partial pressures; virtual temperature
- Hypsometric equation (atmosphere)
- Equation of state for real gases, liquids, and solids
- Equation of state for seawater

PART 2: FRAMEWORK

First Law of thermodynamics

- Basic concepts
- Mathematical review: differentials and derivatives, exact differentials
- Work; expansion work
- Heat: heat capacity, basics of heat transfer mechanisms
- First law of thermodynamics: internal energy, enthalpy, specific heats, heat capacity.
- Applications of first law to ideal gases: Poisson's relations

Entropy and the 2nd law

- Entropy: reversible and irreversible processes; Clausius inequality; Boltzmann-Gibbs statistical picture of entropy
- 2^{nd} Law of thermodynamics
- First and second laws combined: Legendre transformations: Gibbs and Helmholtz functions; thermodynamic equilibrium
- Thermodynamic relations: Maxwell relations; relations involving specific heats
- Adiabatic processes in the dry atmosphere, ocean, and mantle and core
- Static stability
- Entropy and diffusive processes (heat conduction, viscosity, etc)
- Entropy, heat, and the 3^{rd} law

Phase Equilibria

- Gibbs phase rule: thermodynamic degrees of freedom, phases and components
- Energy in phase changes and chemical reactions
- Phase equilibria: chemical potential and multicomponent systems (Gibbs-Duhem); latent heat; Clapeyron equation (first latent heat law) and Kirchoff's equation (second latent heat law)
- Application to water (single component system): phase diagram; Clausius-Clapeyron equation;
- Binary phase diagrams (water solution): simple eutectics, lever rule
- Crystallization in binary systems: equilibrium crystallization, fractional crystallization, melting

PART 3: APPLICATIONS

Moist thermodynamic processes in the atmosphere

- Humidity variables
- Isobaric cooling: dew point and frost point; radiation fog
- Cooling and moistening by evaporation of water: wetbulb temperature; prefrontal rain fog
- Saturation by adiabatic, isobaric mixing: steam fog and jet contrails
- Saturated adiabatic cooling: equivalent potential temperature; saturated adiabatic lapse rate, adiabatic liquid water content; convective cloud formation
- Aerological diagrams

Physical chemistry of water solutions – solution thermodynamics

- Fugacity and activity
- Ideal solutions
- Colligative properties
- (Real solutions: variation of activities)
- Aerosols (deliquescence-efflourescence; surface energy-Kelvin effect;)