Atmospheric Sciences 5950 (Atmospheric Thermodynamics) Course Syllabus

Class Meetings: MWF 3:00-3:55 PM
Classroom: Derby Hall 0080

Instructor: Dr. Rachel Mauk
Office: Room 1055 Derby Hall
Office hours: MW 4:00 – 5:00 PM; by appointment
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Course Prerequisites: Math 153 or 1152.
Not open to students with credit for Atmospheric Sciences 631.

Course Objectives

The basic objective of this course is to provide students with knowledge of the fundamentals of atmospheric thermodynamics. Thermodynamics deals with the processes that transfer energy and thermodynamic processes help to create and change atmospheric systems. Knowledge of the basic principles of thermodynamics and their interactions will facilitate students' comprehension of meteorological processes that determine the weather and climate of the Earth. Understanding thermodynamic processes is critical to accurate assessment of the current state of the atmosphere and to accurate evaluation of the output from numerical models of weather and climate.

The four specific scientific objectives of this course are to:
(1) Understand the basic principles of thermodynamics as they apply to dry air (i.e. air with no water vapor);
(2) Understand the effects of the different phases of water on thermodynamic processes;
(3) Determine how thermodynamic processes generate the observed structure of the atmosphere;
(4) Examine how thermodynamic processes affect the stability of portions of the atmosphere.

In addition to the scientific objectives, students will receive an introduction to basic principles and best practices of scientific programming. Upon completing this course, students will be able to translate thermodynamic problems into working code, and interpret the meaning of code samples.

Course Structure

The class will meet three days per week for 55 minutes each day. Lectures during the classes will present material on thermodynamic processes and their application to atmospheric situations. Important equations will be derived and the implications of assumptions will be discussed. Examples of meteorological problems will be discussed. Homework problems that involve the application of material introduced in class will also be assigned and discussed in class. Homework problems, quizzes, and examinations are designed to test students' comprehension and ability to apply the principles of thermodynamics to "real world" atmospheric situations. Programming exercises are designed to introduce students to meteorological data analysis and plotting.

Textbook

There is no appropriate thermodynamic textbook that covers and supplements all of the topics that are discussed during this course. All content will be covered during lecture and in handouts on Carmen. The following books have sections on thermodynamics that relate to the topics presented in this course and you may choose to use them to supplement the lectures.

Petty, G.W., 2008: *A First Course in Atmospheric Thermodynamics*, Sundog Publishing.

Tsonis, A.A., 2002: *An Introduction to Atmospheric Thermodynamics*, Cambridge.

Bohren, C.F. and B.A. Albrecht, 1998: *Atmospheric Thermodynamics*, Oxford.

Wallace, J.M. and P.V. Hobbs, 1977: *Atmospheric Science: An Introductory Survey*, Academic Press.

Curry, J.A. and P.J. Webster, 1999: *Thermodynamics of Atmospheres & Oceans*, Academic Press.

Course Requirements

The grade for this course will be determined by the following components:

1. The **first examination** will occur in class on **Wednesday Sept. 28, 2016** [15%].

2. The **second examination** will occur in class on **Wednesday Nov. 2, 2016** [20%].

3. The **final examination** will occur at 12:00-1:45 PM on **Friday Dec. 9, 2016** [25%]. *This time is set by the registrar.*

4. **Sets of problems** assigned in class [25%].

5. **Programming assignments** assigned in class [10%].

6. **Online quizzes** (to be completed between lectures) posted on the course's Carmen page [5%]. The highest 17 quiz grades out of 20 quizzes will be counted for this component.

The OSU standard scheme will be used:

A ≥ 93.00%	A- 90.00 – 92.99%	
B+ 87.00 - 89.99%	B 83.00 – 86.99%	B- 80.00 – 82.99%
C+ 77.00 - 79.99%	C 73.00 – 76.99%	C- 70.00 – 72.99%
D+ 67.00 - 69.99%	D 60.00 – 66.99%	E < 60.00%

Detailed Requirements

Examination format: Each examination will begin with a series of terms to define in one or two sentences. You will have a choice of terms to define. The remainder of the examination will consist of short essay questions and calculations like the problems that will be assigned as homework. The examinations are designed to test your comprehension of the material, as well as your ability to recall basic thermodynamic principles. Programming syntax and interpretation questions will also appear on examinations. Students are expected to bring a scientific or graphing calculator (cell phone calculators are not acceptable) with sufficient batteries and a pen or pencil with eraser. Paper will be provided.

Homework assignments: Homework assignments are designed to accomplish two goals. The first goal is to give students some experience solving basic thermodynamic problems using concepts introduced in class. The second goal is to make students think about the thermodynamic processes that occur in certain atmospheric phenomena. More challenging problems may require students to combine thermodynamic principles in order to arrive at the solution to the problem. Some problems will be similar to the tasks require of operational meteorologists. Other problems will deal with fundamental principles and calculations that are used to develop meteorological models and software. Each student must turn in his or her own work.

Programming assignments: Programming assignments will primarily build on problem sets. These exercises will be assigned throughout the term to give students an opportunity to practice data analysis and plotting procedures. The American Meteorological Society (AMS) calls competency in scientific computing "essential" for undergraduates[1]. This course will use R (www.r-project.org). R can be downloaded for free to a personal machine, or accessed through the computer labs.

Students may work solo or in pairs on programming assignments. If students work in pairs, then only one solution (with **both** names) should be submitted. In this case, each student in the pair will receive the same grade. Students will submit code for grading through Carmen. All material needed to complete the programming assignments will be posted on Carmen as PDF handouts. If students use code from an online source, then they must include the source of that code (complete web address to the exact page with the date accessed*)* in an appropriately formatted comment within the submitted code file. Using code from other sources without attribution is considered *academic misconduct*.

Online quizzes: Quiz content will primarily come from the prior 1-2 lectures. Quizzes are intended to emphasize important concepts and equations from lecture. However, some questions will incorporate relevant general meteorological concepts and R programming. Quizzes are open-note. Quizzes will be available for at least 36 hours, and will close 1 hour prior to the next lecture (2:00 PM EDT/EST). Once a quiz is started on Carmen, it must be completed within 30 minutes. Once online quizzes have closed, they will not be made available again. *Use the three dropped quizzes wisely.* Students are expected to complete quizzes on their own without classmates.

[1] https://www.ametsoc.org/ams/index.cfm/about-ams/ams-statements/statements-of-the-ams-in-force/bachelor-s-degree-in-atmospheric-science/ . Accessed 27 July 2016.

Other Policies

Units: Numerical answers are incomplete unless they are accompanied by the correct simplified units. Students will lose points on examinations and homework assignments if the units are incorrect, unsimplified, or missing.

Late policy: Problem sets and programming assignments are due on the stated date. Assignments will be accepted for grading until they have been returned to the rest of the class (generally within one week).

Academic misconduct: All quiz answers, examination answers, and homework assignments are expected to be the work of the student whose name appears on them. [For programming assignments only, two students who have worked together on the assignment may submit one solution with both students' names.] Copying another student's work is *plagiarism* and is considered to be *academic misconduct.*

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term *academic misconduct* includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the Committee (Faculty Rule 3335-5-847). For additional information, see the Code of Student Conduct (http://studentaffairs.osu.edu/csc/).

Disability services: Students with disabilities that have been certified by the Office for Disability Services will be appropriately accommodated, and should inform the instructor as soon as possible of their needs. The Office for Disability Services is located in 150 Pomerene Hall, 1760 Neil Avenue; telephone 614-292-3307, VRS 614-429-1334; http://www.ods.ohio-state.edu/.

Outline of Topics

Part I: **Review of basic concepts and systems (1.0 week)**

a. Systems
b. State variables, functions, and ideal gases
c. Atmospheric composition

Part II: **The first law of thermodynamics (2.0 weeks)**

a. Internal energy and work
b. The first law of thermodynamics
c. Dry adiabatic processes

Part III: **The second law of thermodynamics (1.0 weeks)**

a. Entropy
b. Statements of the second law of thermodynamics
c. Implications of the second law of thermodynamics

Part IV: **Thermodynamics of moist air (2.5 weeks)**

a. Saturation
b. Phase changes of water
c. Clausius-Clapeyron equation
d. Humidity variables
e. Saturated adiabatic processes

Part V: **Thermodynamic diagrams (2.0 weeks)**

a. Properties of an ideal thermodynamic diagram
b. Simple thermodynamic diagrams
c. Tephigram
d. Skew T-Log P diagram

Part VI: **Atmospheric statics (2.0 weeks)**

a. Geopotential
b. The hydrostatic approximation
c. Integration of the hydrostatic equation
d. Reduction of pressure to sea level

Part VII: **Mixing in the atmosphere (1.5 weeks)**

a. Horizontal mixing
b. Vertical mixing
c. The Mixing Condensation Level

Part VIII: **Atmospheric Stability (2.0 weeks)**

a. The parcel method
b. Stability indices
c. Entrainment
d. Lifting layers of air
e. Conditional Instability