Knowledge Expectations for METR 3213
Physical Meteorology I: Thermodynamics

Purpose: This document describes the principal concepts, technical skills, and fundamental understanding that all students are expected to possess upon completing METR 3213, Physical Meteorology I: Thermodynamics. Individual instructors may deviate somewhat from the specific topics and order listed here.

Pre-requisites: Grade of C or better in MATH 2443, PHYS 2524, METR 2024 (or 2413).

Students should have a basic understanding of functions of several variables, partial derivatives, differentials of multivariate functions, line and surface integrals, the basics of state variables such as temperature, pressure, density, and volume, and basic energy concepts prior to starting this course.

Goal of the Course: This course introduces the physical processes associated with atmospheric composition, basic radiation and energy concepts, the equation of state, the zeroth, first, and second law of thermodynamics, the thermodynamics of dry and moist atmospheres, thermodynamic diagrams, statics, and atmospheric stability.

Topical Knowledge Expectations

I. Basic Radiation Principles.

- Understand the basic physical concepts of radiative transfer of energy, including radiation characteristics, quantities and units.
- Understand the concepts of emission, absorption, and scattering of radiation.
- For solar (short-wave) radiation, understand the definition of the albedo and know typical values for different surfaces. Understand the dominant causes of absorption and scattering of solar radiation in the atmosphere.
- For long-wave radiation in the atmosphere, understand the important constituents (greenhouse gases) and processes affecting emission and absorption.
- Be familiar and work problems using Wien's Law, Stefan Boltzmann's Law, and the Inverse Square Law.

II. Atmospheric composition

- Be able to describe the vertical structure of the atmosphere in terms of its constituents, as well as the behavior of these constituents in the presence of solar and terrestrial radiation.
- Be able to describe the vertical structure of the atmosphere in terms of temperature, pressure, density, and moisture content.

III. Fundamental Physical Concepts (integrated with IV. Fundamental Physical Laws)

- Define, understand, and apply the concepts of kinetic energy, potential energy, and internal energy.
- Define and understand the concept of geopotential.
- Define, understand, and apply the concepts of work and heat.
- Understand the concepts of sensible heat, specific heat, and latent heat.
- Define and understand the concept of absolute zero.
- Understand the concepts of heat transfer via conduction, convection, and radiation.
- Understand the concepts of thermal, mechanical and chemical equilibrium.

- Understand the concepts of entropy and enthalpy.
- Understand the concepts of adiabatic and diabatic.
- Understand the concept of virtual temperature
- Understand the concept of potential temperature and isentropic processes.
- Understand the concept of equivalent potential temperature and pseudo-adiabatic processes.
- Understand how moisture is measured and presented, including mixing ratio, saturation mixing ratio, vapor pressure, saturation vapor pressure, relative humidity, and specific humidity.
- Understand phase transformations of water and the associated phase diagrams.
- Understand reversible and irreversible processes.
- Understand the Carnot Cycle.

IV. Fundamental Physical Laws.

- Be able to understand the Kinetic Theory of Gases.
- Be able to understand the Zeroth Law of Thermodynamics.
- Be familiar with Boyle's (Marriott's) Law, Charles (Gay-Lussac) Law, and Joule's Law
- Be able to derive and understand the Ideal Gas Law (Equation of State) for both dry and moist air.
- Be able to derive the Law of Conservation of Energy (First Law of Thermodynamics) from Newton's Second Law.
- Be able to derive and apply the Dry Adiabatic Lapse Rate and Moist Adiabatic Lapse Rates.
- Be able to derive and apply the Hydrostatic Equation
- Be able to derive and apply the Hypsometric Equation.
- Be able to derive and apply Poisson's equation for isothermal, isobaric, and isochoric processes.
- Be able to derive and apply the Second Law of Thermodynamics
- Be able to understand the Clausius Inequality.
- Be able to derive and apply the Clausius-Clapeyron Equation.
- Be able to derive and apply thermodynamic functions such as the Gibbs, Helmholtz, and Maxwell relations.

V. Thermodynamic Diagrams.

- Be able to perform the equal area transformations necessary to derive the emagram, tephigram, and Skew-T Log P diagram.
- Be able to interpret and apply the Skew T Log P diagram, including the ability to determine stability, inversions, and unreported meteorological parameters such as lifting condensation level, convective condensation level, convective temperature, wet-bulb temperature, equilibrium level, freezing level, and tropopause level.
- Be able to determine stability parameters such as lifted index, best lifted index, Showalter index, K-index, total totals index, sweat index, dynamic index, convective available potential energy, and convective inhibition.