MET 305 – ATMOSPHERIC THERMODYNAMICS

COURSE PARTICULARS

Course Code: MET 305
Course Title: Atmospheric Thermodynamics
No. of Units: 3
Course Duration: Two hours of theory, two times per week for 15 weeks.
Status: Compulsory
Course Email Address:
Course Webpage:
Prerequisite: MET 204

COURSE INSTRUCTORS

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COURSE DESCRIPTION

Atmopheric thermodynamics is one of the outcomes of classical physics. It has applications not only in physics, chemistry, and the Earth sciences, but in subjects as diverse as biology and economics. Applied to the atmosphere, Thermodynamics plays an important role in our quantitative understanding of atmospheric phenomena involving phase changes that lead to latent heat releases and cloud formation. The purpose of this course is to introduce some fundamental ideas and relationships which, together with other physical conservation principles, form the basis for daily weather and climate prediction. Topics to be covered include the applications of the *ideal gas equation*, the *first and second laws of thermodynamics* to the atmosphere as well as the concept of *entropy* used to obtain crucial conditions for cloud formation. Finally, thermodynamic diagrams are introduced together with their uses. Practical exercises are given at each stage of the course.

COURSE OBJECTIVES

The objectives of this course are to:

- Provide basic understanding of the foundational mathematical and physical principles of atmospheric thermal processes;
- Impart the ability to apply the conceptual understanding of the principles to solve problems relating to cloud formation processes and the types and intensity of such clouds

COURSE LEARNING OUTCOMES / COMPETENCIES

Upon successful completion of this course, the student will be able to:
(Knowledge based)

- Differentiate between moisture/humidity variables and explain the principle and working of the Psychrometer.

- Explain the difference bewteen the various lapse rates, interprete the concept of hydrostatic balance, geopotential (height), and virtual temperature and its importance.

- Recognise and understand the first law of thermodynamics as a statement of conservation of energy, and appreciate the importance of atmospheric stability and associated criteria in vertical motions of an air parcel and thus cloud development, types and intensity.

- Understand the principles of the T-ϕ (tephigram) and how it can be used to make daily weather forecasts of clouds, thunderstorm and, hence, rainfall.

(Skills) :
Plotting of real time meteorological data on the tephigram, from which the following can be determined:
Potential temperature (θ), the Normand's theorem and Lifting Condensation Level (LCL) which is the cloud base, Level of Free Convection (LFC), equivalent potential temperature (θ_e), wet-bulb potential temperature (θ_w), among others. Cloud base and cloud top. Analysis and use of the Convective Available Potential Energy (CAPE) to determine cloud updraft velocities, and consequently, the type and vertical extent of a cloud.

- The major skill expected to be gained by students at the end of this course is nowcasting/forecasting with the tephigram.

GRADING SYSTEM FOR THE COURSE

This course will be graded as follows:

Assignments	25%
Test(s)	15%
Final Examination	60%
TOTAL	**100%**

GENERAL INSTRUCTIONS

Attendance: It is expected that every student will be in class at least 10 minutes before lecture commences and also participate in all assignments and practical exercises. **Extant University regulation of 65 percent attendance at lectures as qualification to write semester exams will be strictly enforced.** Therefore, in cases of illness or other unavoidable causes of absence, the student must communicate as soon as possible with any of the instructors or the HOD, indicating the reason for the absence.

Academic Integrity: Violations of academic integrity, including dishonesty in assignments, examinations, or other academic performances are prohibited. You are not allowed to make copies of another person's work and submit it as your own; that is plagiarism. All cases of academic dishonesty will be reported to the University Management for appropriate sanctions in accordance with the guidelines for handling students' misconduct as spelt out in the Students' Handbook.

Assignments and Group Work: Students are expected to submit assignments as scheduled. Failure to submit an assignment as at when due will earn him/her zero for that assignment. Only under extenuating circumstances, for which a student has notified any of the instructors in advance, will late submission of assignments be permitted.

Code of Conduct in Lecture Rooms and Laboratories: Students should turn off their cell phones during lectures. Students are prohibited from engaging in other activities (such as texting, watching videos, *etc*.) during lectures. Food and drinks are not permitted in the laboratories.

READING LIST

[4] Tsonis, A. A., (2007): An Introduction to Atmospheric Thermodynamics. Second edition. Cambridge University Press, New York. 199p.

[2] Wallace, J. M., and P. V. Hobbs, (2006): Atmospheric Science: An introductory Survey. Second Edition. Academic Press, New York, 467p.

[2] Riegel, C. A., and A. F. C. Bridger, (1992): Fundamentals of Atmospheric Dynamics and Thermodynamics. World Scientific Publishing. 502p.

Legend

1- Available in the University Library
2- Available in Departmental/School Libraries
3- Available on the Internet.
4- Available as Personal Collection.

COURSE OUTLINE

Week	Topic	Remarks
1	Course Introduction; Atmospheric Composition.	During the first class, the students are made to know the importance of the course as one of the five courses that must be taken and passed to **be recognized as a Meteorologist** by World Meteorological Organisation (WMO). Students are tested (given class work) on their prerequisite knowledge on this topic.
2	State Variables and Functions; thermodynamic variables. Equation of state for gases.	Thermodynamic variables and atmospheric variables are linked at this stage. Students will be taught the equations of state that define the behaviour of ideal gases in the atmosphere: for dry air, water vapour and the mixture of both; significance of Boyle's, Charles', Dalton's, Avogadro's laws. Students will be given assignments to test and deepen their understanding of the subject so far.
3	Moisture/Humidity variables; paths leading to saturation. The Psychrometer equation. virtual temperature.	The lecturer teaches the various ways by which the moisture content of the air (humidity) are measured, and their mathematical representations. The physical principle of the psychrometer operation is explained to the students. Students are given class assignments on their prerequisite knowledge on this topic. Equation for Virtual temperature. Uses and special imporatnce in the Tropical atmosphere.
4.	The first law of thermodynamics; concepts of work, internal energy and specific heats. The Poisson equation and Potential temperature.	Students are made to know that the 1st law is of fundamental importance in atmospheric thermodynamics and is central to many atmospheric processes: the Poisson equation, hence the potential temperature equation. Importance of the potential temperature in the atmosphere. Students are tested (given class work) on their prerequisite knowledge on this topic.

5.	Lapse Rate: adiabatic process, Dry and Saturated adiabatic lapse rates.	applications of adiabatic process and lapse rates. Derivation of the dry and saturated adiabatic lapse rate. Home work assignments are given on the topics
6	MID-SEMESTER TEST	
7 & 8	The hydrostatic equation, The geopotential and geopotential height, Enthalpy (Dry Static Energy),	The hydrostatic equation will be derived. The relevance of the hydrostatic equation in the atmosphere will be given. Definition of expression for, and application of geopotential and enthalpy Students are tested (given class work) on their prerequisite knowledge on this topic.
9 & 10	Atmospheric statics and stability: Stability and Clouds (from fair weather cumulus to cumulonimbus and thunderstorms). Vertical (updrafts and downdrafts) motions in clouds.	Application of the parcel method in atmospheric stability. This will be used to explain in detail how clouds are formed and what type of cloud to expect. Various stability criteria and buoyancy of an air parcel. Usefulness of the adiabatic lapse rates in assessing the stability of atmospheric layers. Students will be given home work assignments on this topic.
11 & 12	Concept of Entropy. Entropy and 2nd Law of Thermodynamics. Equivalent Potential Temperature, Θ_e. Moist Static Energy, MSE.	The second law of thermodynamics is introduced with respect to the Carnot cycle and the concept of entropy. Entropy as the basis of the tephigram. Equivalent potential temperature and moist static energy are introduced as very important parameters for atmospheric stability. **Their importance in Tropical research and prediction.** Students are tested (given class work) on their prerequisite knowledge on this topic.
13 & 14	The T – φgram (Tephigram) and its uses.	Practical sessions on the uses and applications of the tephigram: Estimation of Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), vertical velocity (ω) in clouds, convective cloud tops, etc. Importance and role of CAPE, CIN, and ω in Tropical thunderstorms and line squalls development and intensity Students will be given T- φgram charts and real-time upper air data for practical exercises on the above.

15	REVISION	This week preceeds the Semester Examinations. At this time, an evaluation will be done to assess how far the students' expectations of the course have been met.