

PTYS/ATMO 544 – FALL 2026
Physics of the High Atmospheres

Instructor: Tommi Koskinen, Associate professor
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Office Hours: after class (or any time when I am in the office)

Course Description: The study of the high atmosphere is critical to our understanding of the long-term evolution and chemistry of the atmospheres of the Earth and other planets. High atmosphere processes such as photochemistry, ionization, and atmospheric escape can shape the atmosphere as a whole and alter its evolution. A robust understanding of the physics and chemistry of high atmospheres is also important to remote sensing planetary atmospheres. The goal of this course is to develop a grasp of the key concepts and physical mechanisms underlying the thermal structure, composition, and dynamics of middle and upper atmospheres of the Earth and other planets, required for further research in this area.

Time and location: Tuesday and Thursday, 2.00-3.15pm, Kuiper Space Sciences room 301

Course prerequisites and co-requisites: There are no formal pre-requisites for this course. I will assume familiarity with classical physics, including: mechanics, electricity and magnetism, and mathematical methods of calculus (vectors, tensors, differential equations, and numerical methods).

Course format and teaching methods: Live in person, lecture, regular homework assignments, in-class assignments, individual term project

Course objectives: During this course, students will explore the key physical processes of dynamics, photochemistry, radiative transfer, and energy balance that control the composition and temperatures of the middle and upper atmospheres of the Earth, the planets in the solar system, and extrasolar planets. They will learn how to apply related concepts and processes to solve problems and characterize planetary high atmospheres. They will communicate the key elements of high atmosphere science and the results of their personal research project in writing and in presentations aimed at a scientific audience.

Expected learning outcomes: At the conclusion of this course, the students will demonstrate practical knowledge required to investigate high atmosphere phenomena in greater depth and start developing and running models of the middle and upper atmosphere.

Required texts and materials: There is no required textbook for this course. Reading assignments will consist of journal articles. In preparing for this course, I have used the following textbooks, in addition to my personal notes:

- R. W. Schunk and A. F. Nagy, *Ionospheres: Physics, plasma physics and chemistry*, Cambridge University Press. A handbook-style book, which reviews many topics.

- M. H. Rees, *Physics and chemistry of the upper atmosphere*, Cambridge University Press. A detailed exploration of the theory of the terrestrial thermosphere and ionosphere.
- T. Gombosi, *Gaskinetic theory*, Cambridge University Press. Kinetic theory from first principles, one of the best textbooks that I have read.
- M. L. Salby, *Fundamentals of atmospheric physics*, Academic Press. A standard text for atmospheric physics, including the middle atmosphere.
- J. W. Chamberlain, D. M. Hunten, *Theory of planetary atmospheres: An introduction to their physics and chemistry*, Academic Press. A classic textbook that focuses on the high atmosphere and comparative planetology.

Schedule of topics and activities (approximate):

Week 1: Terminology and scope
08/25: Introductory problem

Week 2: High atmosphere composition, molecular and eddy diffusion
09/06: Term project topic due

Week 3: The ionosphere on the Earth

Week 4: The middle atmosphere of the Earth

Week 5: Magnetosphere and the aurora
09/27: Term project plan due

Week 6: High atmosphere energy balance and dynamics

Week 7: Venus and Mars

Week 8: Jupiter and Saturn

Week 9: Uranus, Neptune, Titan, Triton, and Pluto

Week 10: Thermal atmospheric escape

Week 11: Non-thermal atmospheric escape, solar system applications

Week 12: Exoplanet upper atmospheres

Week 13: Observations of upper atmospheres

Week 14: Observations of upper atmospheres

Week 15: Student presentations
12/06: Term project due

Week 16: Conclusion

Assessments: Homework will be assigned as necessary to improve the students' understanding of the course material. Homework assignments will be announced in class and supporting materials will be made available by the instructor. Homework assignments will focus on practical applications and/or derivations of key concepts related to in-class materials. Late homework will not be accepted without prior arrangement and a valid reason for extra time.

Each student is expected to complete a term project that focuses on a research question or literature review.

In-class participation will consist of class attendance and participation, presenting solutions to homework problems, and discussing journal articles. Journal articles will be assigned for reading throughout the course.

Your final grade will be based on your cumulative performance on homework, in-class participation, and the term project. The weighting of the assignments is as follows:

Homework assignments: 40%

In-class attendance and participation: 20%

Term project: 30%

Final examination (oral): 10%

Final Project: Each student must choose a topic for intense study during the semester. The instructor will provide a list of research questions that the students will choose to answer. The students may also propose their own research question for the instructor's consideration, as long as the topic clearly falls within the scope of the course. The students will hand in a term project report (due on 12/06) that answers the research question. The students will also deliver an in-class presentation to their fellow students and the instructor on their topic. The expected length of the report is 6 publication units (where one publication unit is 500 words or one figure/table) and the time allocated to the presentations is 10 minutes + 5 minutes for Q&A.

Final Examination: Each student will complete an oral examination on Monday 12/14/26 at a time assigned between 3.30 and 5.30pm. The examination is relatively brief and focuses on high-level concepts based on the course content. The instructor will provide guidance on the expected questions prior to the examination.

Grading scale: The grade will reflect your final overall average according to the following scale: (A) 90-100%, (B) 80-90%, (C) 65-80%, (D) 50-65%.

Safety on campus and in the classroom: For a list of emergency procedures for all types of incidents, please visit the website of the Critical Incident Response Team (CIRT):
<https://cirt.arizona.edu/case-emergency/overview>

Also watch the video available at

https://arizona.sabacloud.com/Saba/Web_spf/NA7P1PRD161/common/learningeventdetail/crtfy000000000003560

Nondiscrimination and anti-harassment policy: The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see: <http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy>

University policies: All university policies related to a syllabus are available at:
<https://catalog.arizona.edu/syllabus-policies>.

Graduate student resources: University of Arizona's Basic Needs Resources are available at:
<http://basicneeds.arizona.edu/index.html>

Information contained in the course syllabus, other than the grade and absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructor of this course.