Syllabus: PHYS 465/PHYS 665 Planetary Atmospheres and Ionospheres
Spring Semester 2022
Online via Blackboard - Zoom, Tuesdays, 4:30–7:10 p.m

1 Catalog description:

An interdisciplinary introduction to the fundamental physics and chemistry of the atmosphere-ionosphere system. The focus is on the governing equations of atmospheric and ionospheric dynamics with a systems (science) approach to the atmosphere-ionosphere coupling processes. Topics include observational and modeling techniques in Earth's upper atmosphere as well as recent progress in planetary atmospheres and ionospheres and planetary missions.

2 Introduction

This interdisciplinary course will provide a concise introduction to fundamental physical and chemical processes in planetary atmospheres and ionospheres. Topics include:

- Conservation laws
- Neutral planetary atmospheres
- Wave processes
- Ion-neutral coupling
- Chemical & ionization processes
- Global modeling
- Planetary Ionospheres

3 Instructor and contact information

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4 Specific course goals

To provide the students with:

(1.) an understanding of fundamental governing equations of planetary atmospheres and ionospheres and their application;

(2.) an overview of fundamental coupling processes in the planetary upper atmospheres;

(3.) recent progress in atmospheric and planetary science and missions.

5 Course format & activities

- **Lectures** presenting materials in the books by *Schunk and Nagy* [2009] and *Holton and Hakim* [2012];
- **Homework assignments** that help understand the material encountered in the lectures and readings;
- **Reading assignments** both from the texts and supplemental material;
- **Group discussion** to help develep further understanding of the learning material;
- **One small exam** during the semester
- **Active learning activities**
- **Term paper writing**

6 Required Assignments

6.1 Textbooks

The textbooks by:

(1.) *Schunk and Nagy* [2009]: Primarily a textbook that focuses on ionospheric physics and chemistry.

(2.) *Holton and Hakim* [2012]: A comprehensive book of atmospheric dynamics.

will be used. As basic literature the books by *Yiğit* [2015] and *Yiğit* [2018] are recommended as well.

Additional suggestions for reading are in section 10. The students are encouraged to follow the lectures and participate in discussions to develop a deeper understanding of the materials.

6.2 Tentative Weekly Schedule

Approximately, the following chapters will be covered weekly:

(Week 1.) Course introduction & introduction to atmospheric dynamics [*Holton and Hakim*, 2012, Chpt 1]

(Week 2.) Basic conservation laws [*Holton and Hakim*, 2012, Chpts 1,2]

(Week 3.) Elementary applications of the basic conservation equations [*Holton and Hakim*, 2012, Chpt 3]

(Week 4.) Atmospheric oscillations [*Holton and Hakim*, 2012, Chpt 5]

(Week 5.) General circulation [*Holton and Hakim*, 2012, Chpt 10]

(Week 6.) Atmosphere dynamics [*Holton and Hakim*, 2012, Chpt 12]

(Week 7.) Numerical modeling and prediction [*Holton and Hakim*, 2012, Chpt 13]

(Week 8.) Numerical modeling and prediction [*Holton and Hakim*, 2012, Chpt 13]

(Week 9.) Introduction to geospace environment [*Schunk and Nagy*, 2009, Chpts 1–2]

(Week 10.) Transport equations in planetary atmospheres [*Schunk and Nagy*, 2009, Chpts 3,5]

(Week 11.) Collisions and waves [*Schunk and Nagy*, 2009, Chpt 4]

(Week 12.) Chemical processes and Ionization [*Schunk and Nagy*, 2009, Chpt 8,9]

(Week 13.) Exam. Planetary atmospheres and ionospheres - Part 1 [*Schunk and Nagy*, 2009, Chpts 11–13]

(Week 14.) Planetary atmospheres and ionospheres - Part 2 [*Schunk and Nagy*, 2009, Chpts 11–13]

Depending on the performace of the class and other issues, this list could change slightly throughout the semester.

7 Course policy and grading

7.1 Grading distribution

The final grade will result from performances in homework assignments, two exams, class participation, and a term paper.

7.1.1 Undergraduate and graduate grading

Homework	15%
One small exam	15%
Participation	20%
Term paper	50%

Please note that class **participation** is also graded. Class attendance, participation in discussions, bi-weekly presentation of progress with the term paper will all be assessed as a participation grade. **Homework** solutions must be submitted to me in a printed format by the beginning of the lecture. You have one week to work on them. Delayed submissions are not accepted. There may be additional homework problems for graduate students, which will be designated in homework assignments.

7.2 Numerical Grade Ranges

Grade range 0–100%:

A:	90-100%
B:	80-90%
C:	70-80%
D:	60-70%
F:	<60%

7.3 Tentative exam schedule

Exam: 19 April 2022 (Tuesday)

7.4 Term paper presentation

Terms papers are due by the beginning of the last lecture of the semester (28 April 2020).

8 Homeworks

In every assignment, 5% of your grade will be based on the following criteria:

- Clean and well organized solutions
- Each solution for a HW start on a new page.
- Number each page and indicate which problem you are working on.
- Incorporate additional guidelines and suggestions discussed in the lecture.
- Add some (brief) explanations in your derivations and problem solutions so that it is clear what your solution path is.
- Staple your sheets in the right order.

Successful solution of all problems will give you 95%. To get 100% you need solve all the problems and fulfill all the criteria above (+5%) in your submission. Depending on the performance and issues that can arise, this list may be updated during the semester.

Note that lack of clarity and organization in a given problem solution or derivation will lead to point subtractions even if the final solution is correct.

9 Term paper

A term paper is required in this course. Note that they will be graded differently for undergraduate and graduate students. The goal of the paper is to study a given solar system planet in detail. In the beginning of the semester, each student will be assigned a planet to focus on. Each paper must include an introduction to the basic properties of the planets and then should study some research topics associated with that planet. Below a number of topics in atmospheric, ionospheric and planetary science are suggested. Student are expected to give an update every two weeks in the class on the progress of their reasearch and writing. In the last lecture of the semester, the students will give a 20 minute presentation of their research paper.

9.1 Suggested term paper themes

- Atmosphere
  - Sudden Stratospheric warmings
  - Gravity waves
  - Solar tides
  - Thermospheric vertical winds
  - Gravity wave generation processes
- Ionospheres
  - Ionospheric variability and its sources
  - Joule heating
  - Thermosphere-ionosphere coupling
  - Geomagnetic storms and space weather
  - Transport of species
  - Thermosphere-ionosphere modeling
- Planetary atmospheres
  - Satellite missions
  - Rover missions
  - Dust storms on Mars
  - Jupiter's chaotic circulation and eddies
  - Planetary habitability
  - Manned mission to planets
  - Modeling of planetary atmospheres
  - Missions: New Horizons (Pluto); Mars Atmosphere and Volatile EvolutioN (MAVEN), Juno.

9.2 Term paper format

Abstract: A brief description of the paper, not to exceed 200 words.

Introduction: This section describes the the histocal background and context of the topic, citing the appropriate papers. Recent investigations related to the topic are summarized and the goals of the paper are clearly stated along with a brief statement of the main methodology of the research.

Main part: This part presents the main results of the investigation, putting the results in the context of published work.

Summary and Conlusions: Main results and conclusions of the paper are summarized.

References: List of cited work (American Geophysical Union style is recommended).

Format of the term paper: The paper must be typed, double-spaced, about 15–20 pages long (excluding figures), and have at least 4 figures with captions. All pages must be numbered. Use "Times" with 12pt script size. Section titles should be bold.

10 Additional recommended books

The books by *Andrews et al.* [1987]; *Chamberlain and Hunten* [1987]; *Rees* [1989]; *Hargreaves* [1992]; *Batchelor* [2000]; *Nappo* [2002]; *Prölss* [2004a,b]; *Vallis* [2006]; *Moldwin* [2008] can support your studies throughout this course.

11 Useful websites

Some atmospheric & space agencies:

- NASA `http://nasa.gov`
- ESA `http://www.esa.int`
- NOAA `http://www.noaa.gov`

Some international unions/organizations:

- COSPAR: `https://cosparhq.cnes.fr/`
- ICSU `http://icsu.org`
- IAGA `http://iaga.org`
- IUGG `http://iugg.org`
- AGU `http://agu.org`
- EGU `http://egu.eu`

12 Academic integrity

GMU is an Honor Code university; please see the University Catalog for a full description of the code and the honor committee process. The principle of academic integrity is taken very seriously and violations are treated gravely.

Academic integrity essentially means when you are responsible for a task, you will perform that task yourself. When you rely on someone else's work in an aspect of the performance of that task, you will give full credit in the proper, accepted form. In particular, when you are writing a paper, you must give credit to the works/sources that you have used directly.

Furthermore, extensive amount of discussion and debate are encouraged in this course, with the firm expectation that all aspects of the class activities will be performed with great respect toward differing ideas, perspectives, and traditions. The students are encouraged to seek guidance when they are in doubt (of any kind).

13 Students with disability

If you are a student with a disability and you need academic accommodations, please see me and contact the Office of Disability Resources at 703/993-2474

All academic accommodations must be arranged through that office.

14 Other useful university links

- The University catalogue http://catalog.gmu.edu/
- University policies http://universitypolicy.gmu.edu
- University library http://library.gmu.edu/
- Writing center http://writingcenter.gmu.edu/
- IT services http://itservices.gmu.edu

15 General philosophy

You should participate in all lectures and take your own notes. Listening to the lectures and participating in discussions will help you a lot.

For exam preparation, you should review your lecture notes, consider discussions during the lectures, and study your problem sheets extensively.

References

Andrews, D. G., J. R. Holton, and C. B. Leovy (1987), *Middle Atmosphere Dynamics*, *International geophysics series*, vol. 40, Academic press.

Batchelor, G. K. (2000), *Introduction to fluid dynamics*, Cambridge Mathematical Library Series, Cambridge university press.

Chamberlain, J. W., and D. M. Hunten (1987), *Theory of planetary atmospheres: An introduction to their physics and chemistry*, *International geophysics series*, vol. 36, Academic press.

Hargreaves, J. K. (1992), *The solar-terrestrial environment*, Cambridge Atmospheric and Space Science Series, Cambridge university press.

Holton, J. R., and G. J. Hakim (2012), *An Introduction to dynamic meteorology*, 5th ed., Academic Press.

Moldwin, M. (2008), *An introduction to space weather*, Cambridge University Press.

Nappo, C. J. (2002), *An introduction to atmospheric gravity waves*, *International geophysics series*, vol. 85, Academic Press.

Prölss, G. W. (2004a), *Physics of the Earth's space environment*, Springer.

Prölss, G. W. (2004b), *Space Weather effects in the upper atmosphere: Low and Middle Latitudes*, *Lecture notes in physics*, vol. 656, Springer, doi: 10.1007/b100037.

Rees, M. H. (1989), *Physics and chemistry of the upper atmosphere*, Cambridge atmospheric and space science series, Cambridge University Press.

Schunk, R. W., and A. F. Nagy (2009), *Ionospheres: Physics, plasma physics and chemistry*, Atmospheric and Space Science Series, Cambridge Univ. Press.

Vallis, G. (2006), *Atmospheric and oceanic fluid dynamics*, Cambridge University Press.

Yiğit, E. (2015), *Atmospheric and Space Sciences: Neutral Atmospheres VOLUME 1*, SpringerBriefs in Earth Sci., Springer, Netherlands, doi: 10.1007/978-3-319-21581-5.

Yiğit, E. (2018), *Atmospheric and Space Sciences: Ionospheres and Plasma Environments VOLUME 2*, SpringerBriefs in Earth Sci., Springer, Netherlands, doi: 10.1007/978-3-319-62006-0.