ENVR 671
Principles of Environmental Physics I
Fall

1 General Information

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2 Grading Bases

The bases for assigning grades are as described in the following table; additional detail about these components is given in sections that follow.

Problem Sets:	25%
In Class Participation:	25%
Mid-Term Exam:	25%
Final Exam:	25%

3 Course Policies

Attendance of lectures is an essential part of this course due to the Socratic methods used in this course. For this reason, in-class participation is an important part of the grading evaluation. Late assignments and exams will not be accepted. The final exam plan for this course has been approved by the administration.

4 Introduction

This course is intended as an advanced undergraduate course or first graduate-level course in environmental physics. The name “environmental physics” is somewhat unusual. Books with these words in the title are rare and courses by this name are not taught in any other graduate program as far as we know. This seems somewhat strange. Environmental inorganic and organic chemistry, environmental microbiology, environmental policy, etc courses are quite common. Why not environmental physics? Is it that all the relevant physics needed for the study of the environment has been mastered at the undergraduate level? Or is it that the physics needed is so broad and specialized that it is taught in multiple specialized courses that bear different names, such as fluid mechanics, continuum mechanics, solid mechanics, transport phenomena, and process dynamics? If it is the latter, what fraction of the typical graduate student pool is exposed to the breadth of principles covered in this range of courses compared to what fraction of the students could benefit from education in physical principles? Another possibility is that the physical principles are so important that they are covered in many courses as a part of specialized study in a wide variety of areas. If this is the case, it would seem that we have an inefficient system of education.

Our view is that an essential element of environmental sciences and engineering education involves mastering a set of fundamental principles. This mastery should provide sufficient skill to apply these principles to a set of systems that could be encountered routinely. Additionally, this mastery should provide fundamental understanding that will provide a basis for addressing atypical problems or new issues that may develop throughout one's career. Most certainly, a set of physical principles exists that has widespread application in environmental systems. These principles involve methods ranging from analysis of environmental systems in terms of the simplest possible set of important variables to analysis in terms of continuum representations of conservation principles that provide mechanistic representations of environmental systems. This course, along with its sequel, is focused on (i) exposing participants to this broad set of principles; (ii) educating the student in their development and application; (iii) paving the way for more advanced and specialized study in a wide range of specialty areas; and (iv) cutting across and integrating the many areas of study collectively referred to as "environmental sciences and engineering."

5 Course Objectives

Specific objectives for students in this course are the following:

- to understand the broad scope of problems to which the principles of environmental physics can be applied and to appreciate the commonalities that exist among widely varying systems;
- to learn the principles and applications of non-dimensional analysis approaches;
- to master rudimentary mathematical concepts such as vectors, tensors, coordinate systems, time derivatives, transport and divergences theorems, and vector and tensor calculus necessary for continuum-scale modeling;
- to learn approaches necessary to derive microscale conservation and balance equations;

- to understand how the principles of mass conservation can be applied across a broad range of environmental systems;
- to learn principles and applications associated with conservation of momentum as applied to a broad range of environmental systems; and
- to appreciate classes of problems that are not tractable with the conservation principles covered in this course.

6 Background Required

The essential pre- or co-requisites for this course are the following:

- calculus through ordinary differential equations;
- partial differential equations;
- calculus-based physics;
- general chemistry; and
- computer literacy (e.g., programming in one or more languages, such as Matlab, Mathematica, C++, or FORTRAN).

Students who are deficient in one or more of these areas are not necessarily excluded from participation in this course and may be able to successfully complete the course. However, deficiencies in some areas will require additional commitment and effort to master the material in a way that will provide both intellectual satisfaction and a strong grade.

Because this is an advanced-undergraduate or beginning graduate-level course, it is expected that significant time will be required outside of lecture to master the material covered in the lectures and to complete the problem sets. If your background is average, you should plan on about three hours outside of class for each hour of class time. If your background is deficient, then more time will be required. Conversely, if your background is excellent, then you may need less time than average to master the material. However, despite these guidelines, it is important that the students understand that the course is intended to encourage intellectual growth. Such growth occurs only through immersion in a subject; it does not occur by compartmentalizing course topics to various hours of the day. Students are encouraged to try to integrate what they see in class to what they observe on the news, in experiences of rain storms, of runoff, of air quality, of water quality, of their environment. Those who become sensitive to their environment and come to understand environmental physics as a context for understanding system behavior will gain the most benefit from the course. In essence, participants are encouraged to make this course a part of their lifestyles!

7 Problem Sets

Problem sets will be assigned during the course to expose students to problem solving for a range of topics. Generally two weeks will be given to complete these problem sets. It is important that this not be understood to mean that a student can rest for a couple of weeks before making a concerted effort to complete an assignment. Work on an assignment should begin when the material is assigned so that difficulties encountered can be opportunities for learning rather than just obstacles that prevent knowledgeable completion of an assignment. Any reference materials, software, or individuals available to the student can be used to complete these problem sets. Discussions and cooperative efforts among class members are encouraged. However, each write-up must be the product of the student submitting the work. Any work handed in must reflect the understanding of the author of the document. Key ideas contributed by others, key references, as well as the names of individuals with whom the work was discussed should be acknowledged in the write-up. Problem sets should be typed and organized, reflecting the ability of the student to prepare a document in a professional manner. The objective of the homework is to facilitate the learning of each student. Therefore, work handed in should reflect what the individual has learned and understands, not what others have learned. Random questioning of students about homework assignments may be used as a learning tool.

8 Exams

A mid-term and a final exam will be given in this course. Both of these exams will be given in take-home form to allow stimulating questions to be posed without unreasonable time constraints. These exams will be open book but must be individual work. Thus these exams should not be discussed with others before they are turned in. You will be asked to write and sign the honor pledge to affirm that you have neither given nor received aid on the exam.

9 Course Text and References

The material covered in this course does not map to any available book, so no book is required. Course notes will be prepared and posted on Sakai. References will be suggested in addition to the notes. Books on tensor calculus, fluid mechanics, transport phenomena, continuum mechanics, process dynamics, and a high-level programming language will be of some use. There are many available. Students are asked to notify the instructors of any particularly helpful references they encounter that provide either details or context for this course including journal articles, text books, and popular media.

10 Lecture Outline

The formal in-class portion of this course will consist of 28 lectures. These lectures will address many aspects of environmental physics. They will not follow any book specifically, but readings will be suggested. The topics to be covered along with the reference numbers for the lectures on each topic are detailed below:

1. Introduction to Environmental Physics (1–2)
   (a) Scope of environmental problems
   (b) Need for fundamental approaches
   (c) Scales of concern
   (d) Quantitative approaches
   (e) Mechanistic models
2. Mathematical Tools (3–6)
   (a) Scalars, vectors, and tensors
   (b) Tensor algebra
   (c) Tensor calculus
   (d) Time derivatives
   (e) Eulerian and Lagrangian perspectives
   (f) Gradient and divergence operators
3. Dimensional Analysis (7–9)
   (a) Units and dimensions
   (b) Dimensional homogeneity
   (c) Buckingham-Pi theorem
   (d) Non-dimensionalizing mechanistic models
4. Overview of Conservation Principles (10–11)
   (a) Source of conservation laws
   (b) Description of a continuum
   (c) Importance of scale
   (d) General law
5. Conservation of Mass (12–22)

(a) Species equation formulation for a volume
(b) Phase equation formulation for a volume
(c) Interphase transfer processes
(d) Reaction processes
(e) Point form species mass conservation equation for a phase
(f) Point form mass conservation for a phase
(g) Interface jump condition
(h) Macroscale point equation
(i) Multiscale conservation of mass

6. Conservation of Momentum (23–28)

(a) Conservation of momentum for a phase
(b) Stress tensor
(c) Body forces
(d) Newton's law of viscosity
(e) Stress tensor for a Newtonian fluid
(f) Navier-Stokes equations
(g) Euler Equations
(h) Stokes Flow
(i) Taylor Dispersion
(j) Non-Newtonian fluids
(k) Frames of Reference