PRINCIPLES OF ENVIRONMENTAL SCIENCE
Environmental Science and Policy 110 (ESP 110)
CRN 23858
Winter 2008

Principles of Environmental Science (4) Lecture--3 hours; discussion--1 hour. Prerequisite: Physics 1A or 5A, Mathematics 16B or 21B, and Biological Sciences 1A. Application of physical and chemical principles, ecological concepts, and systems approach to policy analysis of atmospheric environments, freshwater and marine environments, land use, energy supplies and technology, and other resources.

I. Instructors & Schedules

John Largier, Professor
Office Hours: Thursday 3-4pm and Friday 12-1pm,
Wickson 2120J
jlargier@ucdavis.edu

Adrian Bell, Teaching Assistant
Office Hours: Wed 4-6pm, Wickson 3148
avbell@ucdavis.edu

Lectures:
Thursday 4:40pm-6:00pm, Hutchison 115
Friday 10:30am-11:50am, Hart 1130

Discussion:
Wickson 2120J
Monday 11:00-11:50am, 2:10-3:00pm, or 3:10-4:00pm

Homework Assignments:
Weekly homework problems assigned in Friday lecture (posted on SmartSite).
Homework answers will be posted on SmartSite as a way to check your work.
Homework to be submitted by 4:30pm on following Thursday
(box in ESP front office, Wickson).
Solutions will be posted on SmartSite on weekend or following Monday.

Project:
Project title & 1-paragraph description due Wednesday 6 February
Draft for review (voluntary) on or before Friday 22 February
Completed project due Wednesday 12 March

Mid-terms:
Friday 15 February, 10:30am (regular lecture time, regular location)

Finals:
Saturday 22 March, 6:00pm-8:00pm, Haring 2016

II. Text

Gilbert M. Masters and Wendell P. Ela. 2008
Introduction to Environmental Engineering and Science
Third Edition. Prentice Hall.

Additional texts that may be useful:
- John Harte. 1988. *Consider a Spherical Cow – A Course in Environmental Problem Solving.* University Science Books.
- John Harte. 2001. *Consider a Cylindrical Cow – More Adventures in Environmental Problem Solving.* University Science Books.

III. Objectives

- To improve your quantitative analytical skills.
- To introduce you to physical/chemical environmental sciences.
- To develop your ability to understand systems.

Quantitative analysis is a fundamental part of understanding and managing environmental systems. The question is not whether to pollute or not to pollute, but how much of a pollutant do we need to remove to achieve some desirable outcome, such as reducing the mortality of fish (or humans) to an acceptable level. We need to compare the performance of alternative plans in order to find a cost-effective solution to the problem. The main tactic for solving management problems consists of making a model of the physical, chemical, biological, and socio-economic processes involved and using it as a tool to solve the problem. Further, constructing these models often provides deep insight to the problem. We want you to come out of the course with the skills necessary to set up and solve basic models of environmental processes and problems.

Knowledge of the ***physical/chemical environmental sciences*** is essential for environmental professionals. Organisms, including people, live in environments where they are buffeted by winds and currents, exposed to nutrient and toxic chemicals, and heated and cooled by radiative transfers of energy. Further, the activities of organisms change the physical/chemical environment, which in turn affects other organisms. Thus, virtually all environmental problems that you will meet in your careers will have a physical/chemical dimension. Some of these problems are relatively simple, while some of them are awesomely complex.

Modern science involves a lot of specialization – and this has become true also in environmental science. It is surprisingly how few people include several components and processes in their analysis of the environment. A system consists of multiple linked processes and components. Simple models are effective ways to address the bulk characteristics and functions of a complex system. So, rather than focusing in on one aspect, a ***systems approach*** works to zoom out and see how the whole system functions – or to see all the aspects of a given environmental issue. This involves a cognizance and integration of the physical, chemical, biological and social aspects.

IV. Approach

The course is in the style of an engineering course in environmental science. Engineers have a very useful set of tools that are used in practicing their art of building practical quantitative models to solve problems. One typically starts with a simple model of a system, including only the key components and processes. For example, a "black-box" approach is often used in which one identifies inputs and outputs without resolving the complexities of the processes in the box. Such simple models allow one to do back-of-the-envelope calculations and obtain very useful answers that may either solve the problem or provide very valuable insight on where to look next. The idea is to boil down (reduce) a complex problem to obtain the essence.

While there is a place for complex models in environmental science, such models are extra-ordinarily expensive to build and use and they often predict poorly because they are "overfit" (when available data are too limited and noisy relative to a complex model, the model tries to fit to the noise in the data as well as the real patterns). The complex model will "predict" the noisy data all too well, but it will badly fit the next lot of data from the same system because the fit was bamboozled by the noise in the original data. The art of modeling is to match the model to the problem, the available data, the time available and the level of solution/understanding required.

In this course we will explore the use of simple quantitative models in the analysis of environmental systems and issues (even when we know the problem has much more complexity than the model captures). This approach requires some judgment on what to include and what to leave out – in other words, one needs to make some simplifying assumptions. At times this means that one has to loosen up and be ready to ignore all sorts of possible objections to get to some kind of model you can solve to get some kind of answer (any kind of answer). Then you turn the crank on this machine and see what sort of answer pops out. Again, then, you need judgment – is this answer reasonable given the data and theory/understanding that you have at hand. If not, take another cut. In most cases you soon work out a model that is credible and an answer that is useful.

This answer may only be right to an order of magnitude (within a factor of ten) –

often that is all you need to know, at least for the moment. For example, pollution associated with a new project may be well under a threshold of damage (no action needed) or it may be well over the threshold (project cannot proceed without a new design). Only if it is in the vicinity of the threshold does one need to get fancy with complex models and detailed field data. Even if you do no more than discover that a more complex analysis is needed, you often gain a lot of insight into the problem working on the back of the envelope. And, when you do make a complex model, you will do a lot of back-of-the-envelope calculations to check that the complex model is working right under simplifying assumptions. Thus, paradoxically, simple models are one of the most important tools to analyze complex problems.

In this course we stress the art of the back-of-the-envelope calculation in this course – "art" because no surefire recipe exists to pick the right simple model to apply to a complex problem. You use all the knowledge you have about the system, add a bit of creative thinking, and try out some different model approaches. In the "real world", we often monitor systems and then take new cuts at modeling as the new data accumulates. These adaptive approaches are becoming more common.

The homework problem sets are designed to give you lots of hands-on experience solving problems. The text and the problems in it are quite reflective of real-world situations. *The hard part is not doing the math, but using your insight and conceptual understanding to set the problem up in a way that lets you get away with a simple calculation—the "art".* The project requirement is designed to give you experience reviewing how others think about a problem of your own choice, and trying your hand at setting up your own calculations.

This course is designed to put marketable skills in your hands. Biological ecologists with good practical quantitative skills and some knowledge of the physical environmental sciences are not common, nor are engineers with a good knowledge of ecology. You will be able to solve many problems that would ordinarily take an engineer. Of course, when you come to solve real problems on the job you'll have to read deeper, but I hope that this course will give you a running start on most problems you'll run into. When problems do get too complex for your physical/chemical expertise, you'll be in a position to make a timely, persuasive, recommendation to hire an expert. Often environmental professionals work in multi-disciplinary teams. Successful teams have members that appreciate each other's strengths and weaknesses and can communicate easily. Your level of knowledge of environmental science and engineering will allow you to talk fluently and work effectively with engineers and physical scientists. As your career advances, you will likely acquire management responsibilities. The more you know about the disciplines of the members of your team the better team leader you can be. Part of the motivation for the project assignment is to give you a sample of work you can show to potential employers and graduate and professional school admissions committees. Some of you will find this course rather challenging. We hope that you will remember the expected future payoffs to learning this material when the going gets tough!

V. Course Requirements

A. ***Exams.***

There are midterm and final exams, worth 15% and 30% of your grade, respectively. The exams will test your comprehension of the concepts and principles outlined in the reading and lectures. The exams will also have some quantitative problems to solve.

B. ***Homework problem sets.***

The homework problem sets will be worth 25% of your grade. The primary aim of these problem sets is to develop your skills and practice them. Feel free to seminar with other students about how to do a problem, but *you must do your own work*. Problem sets turned in late will be docked 10% per day. Problem sets submitted after solutions posted (typically over the weekend) will receive a zero grade. Please let us know if you can't get your homework in on time – we can usually make a plan.

C. ***Term project.***

This will be worth 25% of your grade. Choose a problem that interests you – it must have a physical/chemical environmental science component and be amenable to quantitative analysis. Your task is to write a technical briefing paper on your problem (imagine you have been hired as a consultant or delegated by your employer to solve the problem, or at least recommend the next step in its solution). The paper should describe the problem, present a review of the scientific principles involved, outline a simple model, and use the model to solve the problem or recommend the next steps in solving the problem. The aim is to think the problem through, distilling the essence of the problem, which can then be handled with a back-of-the-envelope small set of calculations. Be sure that your model is integrated into the text description of your project. Motivate the model, describe how it works and interpret the results, using these results to underpin your conclusions. In technical prose, about half your persuasive power rests on your words and about half on your numbers, and everything depends upon making the two work together. You may find Excel (or other more sophisticated programming tools) useful when problems get a bit more complex than those in the problem sets. If others have done a more complex quantitative analysis, critique it. Suggest what further data collection or modeling is required. You can pick a big problem like the effect of anthropogenic CO_2 on global climate change or a small one, such as how to grow a good lawn without allowing excess nitrogen fertilizer to run off or leach downwards. You should submit a proposal for your project by Wednesday 6 February. As you develop a draft, please ask for comments – this you can do via email. If your project gets out of hand, it may be possible to arrange for 198-credit (perhaps in Spring Quarter) to give you credit for going further with this than is required.

D. ***Attendance and Participation.***

Your level of attendance and participation in lectures and specifically at the weekly discussion sections will constitute 5% of your final grade. By putting in time at discussion and office hours, your quantitative skills will improve more rapidly and with less effort as you benefit from the interactions with others.

E. ***Discussion Section***.

The discussions serve two purposes. First, they give you an opportunity to ask questions about the scientific concepts and principles reviewed in the text. Second, the TA will review the methods for handling the problems, including difficulties experienced by many students. We are committed to helping you get your problem solving skills honed to the highest level you can in one quarter. He will use the discussion session to introduce some analyses that are a little more imaginative than those in the text. These are intended to be a halfway house between the text problems and your project. If you need extra help with some of the problems please take advantage of our office hours.

VII. Grading Policy

In the past, students in this course have differed widely in background and skills. Our objective is to raise everyone's skill level as far as possible, whatever level you enter with. We will put extra effort into helping those with weaker backgrounds achieve a decent level of proficiency, if you similarly put in an extra effort. We are also keen to help skilled students who want to push the envelope of their skills, say to produce a really outstanding project. In grading, we will give a lot of consideration to students who show improvement relative to their entry skills. We think that any student who tries hard should be able to get at least a B in this course; and we would be happy to hand out any number of A+'s to skilled students who do elegant projects. In the past, more skilled students have often acted as informal mentors for the novices. Not only does one learn through teaching, but we will also count this as a positive contribution to the class.

VII. Course Outline

Week 1. *Materials Balance.*
Week 2. *Energy Balance.*
Week 3. *Environmental Chemistry*.
Week 4. *Climate Change.*
Week 5. *Resources and Populations.*
Week 6. *Mid-term Exam.*
Week 7. *Risk Assessment.*
Week 8. *Water Pollution.*
Week 9. *Air Pollution.*

Week 10. *Air Pollution & Projects due.*
Week 11. *Final Exam.*