E526—Applied Math for Environmental Science—Syllabus
Section 9074—Fall 2002
School of Public and Environmental Affairs—Indiana University

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Lecture
11:15–12:30, SPEA 278
Lab (SPEA 273)
Section 9075: 12:20–2:15 pm F
Section 9076: 2:30–4:25 pm F

Office Hours: 2–3 Monday, 10:30–11:30 Wednesday, and by appointment at many other times. You are welcome to stop in at other times if my office door is open—I'll be happy to talk with you any time I'm free.

Associate instructor: Wendy Drake (wedrake@indiana.edu)
Office: SPEA 271. Office hours: M 4:30–5:30, T, W, Th 4–5.

Prerequisites:

This course assumes that you have studied calculus, with at least an introduction to both derivatives and integrals. If you haven't, please see Prof. Parkhurst right away.

Uses of mathematics in environmental science

Mathematics is an important tool in science, allowing a wide range of phenomena to be described precisely and, often, to be predicted fairly accurately. To list a few examples:

- Atmospheric scientists use math to model weather and climate, and rates of reactions of pollutant chemicals in the atmosphere.
- Conservation biologists and ecologists use math to model population growth and trophic interactions, and to perform probabilistic risk analyses of species extinction.
- Environmental chemists use math for tracking transport of materials, and rates of chemical reactions of chemicals, both within and between various media (*e.g.*, air, water, and soil).
- Hydrologists model flows of surface water and groundwater, and of materials dissolved or suspended in water.
- Limnologists use math to model transport, accumulation, and degradation of various substances in lakes and streams, to model absorption of light with depth, and for many other purposes.
- Risk analysts use math to estimate exposure of humans and other animals to pollutant chemicals, and to perform a wide range of probabilistic calculations.
- Toxicologists use math to model transport, accumulation, and degradation of chemicals between and within various compartments in the body.

If I've omitted your own area of interest, I'm sure you can think of applications that apply.

From 1993 to 1995, I worked for the New York City water supply at Kensico Reservoir. In that work, math modelling was used often. Some examples were:

- To track the movement of bacteria and other microorganisms into and through the reservoir.
- To determine how far into a reservoir chlorine concentration would remain undesirably high, if chlorine had to be used to kill zebra mussels in the aqueduct connecting two reservoirs.
- To estimate the longevity of coliform bacteria in a reservoir, and the numbers of bacteria contributed by Canada geese versus gulls

- To estimate how long it took water to flow to a reservoir outlet from various points in the watershed. (This was related to the supposed 60-day longevity of *Cryptosporidium* oocysts.)
- To understand the relationships between depth and volume of the numerous reservoirs in the City's system.
- To estimate whether enforcing "pooper-scooper" laws in communities in the watershed would help to reduce bacterial levels in the reservoir.
- To estimate phosphorus inputs into numerous reservoirs, based on various qualities of their watersheds

As these examples show, math is used in all areas of environmental science, and for making management decisions based on scientific information as well.

Course objectives:

In this course you should learn:

- How math is applied in various branches of environmental science, with emphasis on applications of calculus (plus a little trigonometry and linear algebra)
- How to solve problems numerically when analytic (symbolic) methods don't work

As a side-effect, the course is likely to refresh your skills in algebra.

Topic Outline:

Chapter	Topic	*Approximate* Start Date
1	Introduction to Applied Mathematics	Sep 3
2	Derivatives and Differentiation	Sep 10
3	Integration	Sep 19
4	Differential Equations	Oct 8
5	Further topics in ODEs	Oct 15
6	ODE Systems	Oct 17
7	Numerical solution of ODEs	Oct 29
8	Second-Order ODEs	Nov 5
9	Linear Algebraic Equations	Nov 14
10	Non-linear Equations	Nov 26
11	Partial Differential Equations	Dec 3

With all the above topics, I will emphasize conceptual understanding with the hope that in the future you can use what you've learned to fit new situations as well as ones like the examples we study.

For each major topic, we will follow a common pattern by discussing:

- What each mathematical concept is, and why it is useful.
- How to do any necessary calculations, analytically (symbolically) where possible, and otherwise numerically.
- How and why the concept works (simple theory).
- Examples from environmental science, from the viewpoint of both basic and applied science.

Course format and learning resources

We deal with complex but important ideas in E526, and some students will need to invest considerable effort in the course. We will help you as much as we can through:

- Lectures. Most days, about an hour of the class will be in lecture mode. Please interrupt and ask questions if you "lose the thread." I like questions!
- In-class problems. I will frequently pose problems for you to work, usually in small groups. We'll discuss these after you've had some time to attack them.
- Course notes. A set of notes developed specifically for E526 is available at a local copy shop (TBA). I will refer regularly to figures and equations in those notes, so you will most likely want to bring relevant sections to class each day.
- Textbook. You will probably want to have a calculus text available for reference throughout the semester, and for use during the open-book exams. Almost any calc text you may already have will do. If you don't have one, look under "texts" below.
- Labs. These Friday sessions allow time for you to work the exercises. We encourage you to work in groups, and to help each other out with these problems. The teaching assistant will be there to provide examples and to help with the assigned problems.
- Exercises. You will be provided with exercises for each topic to show how the principles under study apply in environmental science and management. Many of these problems are taken from past exams, so they give you practice solving the kinds of problems you can expect to see on the exams.

  Study hint: We will provide answers for most problems, but we strongly recommend that you not look at those answers until you have worked the problem yourself. You will learn a thousand times more (give or take a little) by working a problem through yourself than by looking at a prepared solution and convincing yourself that you understand it. Remember that in your future work you will have to solve problems yourself, not just understand someone else's solutions, and the same is true in exams.

  If you help other students with a problem, you can do them the most good not by working it for them, but rather by either (a) working some similar problem for them, or (b) finding out where they are "stuck," and asking leading questions that will get them on the right track. If you go to the effort to help others in these ways, you will likely learn a lot yourself in the process. See the Course Ethics section (p. 5) regarding working with others on the required homework.
- Matlab exercises. I will provide you with exercises you can use to learn computer software called Matlab, a powerful tool for performing both symbolic and numerical mathematics. You should keep up with these, as one exam may include a take-home part that involves use of Matlab, and there may also be questions about using this software on the final exam.
- Homework: Between three and five homework assignments (depending on complexity) spread through the semester will give you practice in using Matlab to solve problems.

  The homework will take the form of group assignments, for two reasons. First, education research shows that most students can learn better by working with their peers than by just listening to a professor and then working alone. Second, agencies and firms that hire students often tell us that people generally work together in the "real world," and for that reason they encourage us to give students experience in working with others.

For these assignments, you must participate fairly in your group's work —if you do not, you will receive a reduced grade for that assignment. (I will be asking each person to rate the participation of group members for each group assignment.)

Required homework must be handed in by the deadline to receive credit. Because computer systems and printers occasionally fail, you should plan to complete your work before the due date (*e.g.,* a day early), to allow for such problems.

Your average homework grade will contribute 10% of your final course grade.

- Exams. As a student, I learned a great deal from the process of wrestling with ideas while taking exams, and I try to write questions that will give you that same benefit. This means that most questions will test your knowledge of underlying concepts, and not only your ability to "spit back" standard recipes. Questions will be similar in general form and difficulty to the assigned exercises and to those on past exams, some of which I will make available to you as study aids. Except for the final, exams will be held in the Friday section. All exams will be open book and open notes.
- A course web site. Go to www.indiana.edu/~e526math You must have an IU network account to use this site. If you find you don't have access, please let me know by email. HTML, the standard formatting system for the web, is not very good at displaying mathematical formulas. For that reason, some of the material at the site is in Adobe's "portable document format," *i.e.*, provided as PDF files. To read those, you need to have Adobe's Acrobat Reader installed as a helper to your web browser. If you find you need to obtain it to read these files, you can get it free from www.adobe.com. I think it is also available on the IUWare CD you can get for $5 (with much other software) at the IU bookstore.
- E-mail. Each day at the end of class, I will ask part of the class to write out a brief note about (a) what you found most interesting that day, (b) what you understood least that day, and (c) any specific questions you might have.. I try within a day or two to provide answers to questions, via e-mail that I send to everyone in the class. PLEASE READ THESE MESSAGES—I view the information they provide as supplements to lecture, and will assume you have that information when I write exam questions.
- Office hours: Both Prof. Parkhurst and the associate instructor hold regular office hours, and will be happy to help you when you can't work a problem or don't understand some concept. See Dr. Parkhurst after class or send e-mail to make appointments for other times.

Texts:

- *Introduction to Applied Math for Environmental Science (Notes for E526)*, by D. Parkhurst. Listen for an announcement about availability.
- Goldstein, Lay, and Schneider, *Calculus and Its Applications*. There are different versions of this book—the one with the chapter on differential equations is preferable for this course. Otherwise, which edition you have is not important. The edition in press is the 10^{th}(?), but if you can obtain a used copy of an earlier edition, that would be fine. (If you have a different edition, you may need to check the current edition from time to time to ensure that you are working with reading and problems comparable to what I suggest.)

  If you have a different calculus text, you don't need to buy this one. You may benefit from having *some* calculus text with you for the exams, which are open book. Please note that sharing books or calculators during exams is not permitted.

- You will also need a pocket calculator with logarithmic, exponential, and trigonometric (sine, cosine, tangent, etc.) functions. Calculators with several internal memories can help you avoid writing down intermediate results, which saves time and reduces the chance for errors. A single storage register is acceptable, however. Statistical functions like summation, regression, and the like will be useful for other classes, but are not required for E526. You don't need a graphing calculator, although those are acceptable.

Exams:

The first mid-term exam will be given during the Friday lab period on October 4.

The second mid-term may be a combination of in-class and take-home parts, with the latter (if assigned) involving the use of Matlab. This will take place around November 9. I will try to combine the two lab sections for the in-class exams—we'll discuss this as the exam approaches. The official final exam time is 8–10 am on Tuesday, December 17. I will consult with the class and try to extend this to a three-hour period for those who may want more time.

It is your responsibility to arrange employment requirements, job interviews, airplane flights, and the like so they do not conflict with any of the scheduled exams.

Grading:

Many exam questions involve a sequence of calculations and logical steps. When we find an error in such a question, we try to count off once for that error, and then to grade the rest of the question starting from that point. That is, we try not to let a small error at the start of the problem cause you to lose too many points overall.

After each exam, I will give you the conversion from scores to grades, so you know right away the contribution of that exam to your course grade. I decide on the conversions by the following sequence of reasoning. First, I treat each score as a percentage of the points available, and assign grades on a scale where 90% = lowest A-, 80% = lowest B-, 70% = lowest C-, etc. If an exam is particularly challenging, I sometimes boost the distribution, usually with a conversion of the form $\text{Grade} = a + b \times \text{Score}$ where *a* and *b* are appropriate constants.

At the end of the year, your course grade will consist of a weighted average, with your homework average counting 10% and the three exam grades weighted as 27%, 29%, and 34%, respectively. The scale for the course grade will be more or less the same as that above, except that 89–91, 79–81, 69–71, etc., will be borderline areas within which I may grade up or down depending on improvement, attendance, class participation, and the like.

Course ethics:

Many of my colleagues share with me the frustration that a few students seem increasingly not to know the difference between intellectual honesty and dishonesty. Cheating on tests is obvious enough, but issues involving out-of-class assignments (like the homework for this class) seem less clear. These difficulties are increased by my hope that you will work together—**to a point**— but that you (or your group, for group work) will turn in work that is your own. Computers add another source of ambiguity. The following discussion is intended to help clarify my expectations about the homework. Please ask if you want further guidance.

Here is a statement (modified from one provided by Prof. D. Willard) that I use in my undergraduate classes:

> **ACADEMIC MISCONDUCT.** Academic dishonesty is not common, but **is** serious and intolerable. Please familiarize yourself with the Student Handbook guidelines. I assume that you all know and understand what plagiarism and cheating are; if you don't, find out. The rules are simple. Do your own work. Don't copy or even seem to copy from others. Allowing someone else to use your work as if it were their own is as serious as using someone else's work without full written acknowledgment in whatever you turn in. If you make legitimate use of work done by others, always document your sources.
>
> **Please be fully aware—If I determine that a student has cheated in this course[1], then that student will be dropped from the course and will receive a failing course grade. As required, I will also report such infractions to SPEA's Graduate Program Director and to the Dean of Students.**

For E538 homework, I hope that you **will** work together in the following acceptable ways:

[1] I don't expect to see this in a graduate course, but it does seem to happen on average about once a semester in medium to large undergraduate courses. I have occasionally had indications of cheating even in graduate classes.

- Verbally discuss the purposes of an assignment. What is the point of an analysis like this? Why might we want to know the results being asked for? What assumptions are required for a particular kind of analysis? Why are these methods useful? In what ways is the exercise like something you have done in the past, or might have to do in the future? What would the results mean if they came out in various ways?
- You may also discuss the general ways of dealing with the types of calculation required for the exercise. If you know how to do the calculation, and want to help a classmate who hasn't figured it out yet, I would be pleased if you did that. Indeed, probably the best way to learn well how to do something is to show someone else how to do it— such cooperation should help both you and the person you are helping. However, do this by making up a similar set of data and showing your classmate how to analyze the made-up data. Then, **leave them to analyze the real homework exercise themselves**. (Of course, for group assignments you may work with others in your group on the actual exercise.)
- Similarly, if you are helping someone learn to perform mathematical analyses (for example, with Matlab), show them the general ideas, but do not leave a computer file in a state such that they can enter the homework data into a ready-made template that you have prepared. (Again, if working in an assigned group, you may exchange computer files **with others in your specific group**.)

Here are some examples of what is **NOT** permissible, for individual assignments or with others outside your group for group assignments:

- Copying from another student's written answers, even if you make substantial changes to the wording. Also, as noted above, it is just as unacceptable to provide your answers to another student as it is for them to use your answers.
- Analyzing the data in a computer file, then allowing someone else to use or modify that file (or a copy of it) in any way.
- Giving a copy of **any** computer file related to the homework assignment to any other student in the class, except one in your own group, of course.

If you are uncertain about what is fair and what is not, please err on the careful side, then ask for clarification later.

Policy on “Incompletes”:

The University policy on grades of "incomplete" includes the following statement:
CIRCUMSTANCES PERMITTING INCOMPLETES
The grade of Incomplete used on the final grade reports indicates that the work is satisfactory as of the end of the semester but has not been completed. The grade of Incomplete may be given ONLY when the completed portion of a student's work in the course is of passing quality. Instructors may award the grade of Incomplete upon a showing of such hardship to a student as would render it unjust to hold the student to the time limits previously fixed for the completion of his or her work.

Based on discussion of this statement with my colleagues, I believe that the "hardship" referred to does not include poor preparation or planning, an overloaded schedule, or similar factors. Rather, it refers to serious illness, family emergencies, and the like. Any incompletes granted in E538 will be based on this University policy.