Material and energy flow and transformation in engineered and natural systems

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www.bates.edu/~raustin (under construction)

Texts:

ES 203 Coursepack (Austin & Bohlen)

Recommended John Harte's 1988. *Consider a Spherical Cow*. University Science Books ISBN 0-935702-58-X

Course Objectives:

(1) Develop in students an understanding of how the laws of conservation of matter and energy can be used to examine environmental problems across many different scales.
(2) Expose students to environmental issues that span a wide range of temporal and spatial scales.
(3) Enable students to appreciate that environmental issues often span scales from the molecular to the global.
(4) Develop in students the critical thinking skills needed to evaluate scientific and technical arguments in environmental disputes.
(5) Develop in students an ability to estimate the approximate scale of environmental phenomena and to think "what order of magnitude am I dealing with here?" as a preliminary step to the evaluation of any environmental issue.
(6) To introduce students to tools for thinking quantitatively about environmental problems, and especially to introduce basic computer-based mathematical modeling using Excel and Stella.
(7) To introduce students to basic concepts of experimental design, statistical analysis, and numerical argument.
(8) To develop in students the ability to think critically about the complex role of science within environmental policy disputes.
(9) To instill in students an awareness of the scale of human impacts on the environment.

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Course Description:

The transport and transformation of matter and the generation and use of energy are key concepts that must frame any technical inquiry into the interactions of humans with the natural world. The intent of this course is to introduce you to the major conservation laws and their implications in an environmental context. We want to establish in your consciousness an awareness of these concepts, and provide you with a set of analytic tools that will allow you to ask questions about any process you are interested in – from eutrophication in the lakes of Maine to bioaccumulation of toxic mercury in the food chain.

To achieve these goals, we have designed an inquiry-based course that uses laboratory studies, mathematical modeling, and statistical analysis to examine a series of environmental questions. The course consists of six modules. The first module will introduce the course's major concepts and expose you to the computer-based modeling tools you will use throughout the remainder of the course. The five remaining modules will each focus on a particular topic, examining each for a period of two weeks. The lab will correspond to the classroom topic. In the first week of each lab module, you will be asked to develop simple mathematical models of the phenomena we will be studying and determine what data you will need to collect in order to test a key hypothesis in your models. In the second week, you will perform experiments and analyze their data to test the predictions of your models.

You will be introduced to the topics being explored in the classroom. The requisite scientific information needed to understand each subject will be presented. An additional recitation session will be scheduled (which half the class of students will attend each week) in which you will discuss a paper that links the module topic to a current policy issue. Throughout the course, we will use environmentally based estimation exercises to hone your ability to estimate the approximate scale or order of magnitude of environmental phenomena. These might include asking the class to estimate – based solely on information students already have – things like the total amount of water flowing through the Lewiston sewage treatment plant in a day, or the average concentration of mercury in the tissues of Maine freshwater fish.

The topics for each of the models have been selected so that they cover a wide range of spatial and temporal scales. Subjects covered in the course will range from the molecular to the global in scale. We have chosen to span a wide range of scales in order to encourage students to see the connections between these scales.

Course Modules

Module 1: Introduction to conservation laws, issues of scale – including the scale of humans' impacts on earth (Ecological footprint), computer modeling, and statistical analysis
Module 2: Urban hydrology, water supply and stormwater management
Module 3: Nutrient dynamics, nutrient processing and eutrophication
Module 4: Carbon cycle, photosynthesis, and greenhouse gasses
Module 5: Toxic metals in the environment – sources, distribution, transformation, and effects
Module 6: "Industrial Ecology" and material flow through the biosphere and economy

Assignments:

Problems from the textbook *Consider a Spherical Cow* will be assigned on a regular basis. They will be due at 5 pm on Friday every two weeks. The homework grade will be lowered by 10% for EACH day that an assignment is late. Your answers to these questions need to be neat and systematic.

In-class public hearings will be held three times during the semester. Each member of the class will have an opportunity to participate. These public hearings are designed to give you an opportunity to make, hear, and respond to quantitative arguments about selected environmental issues. You will need to prepare for the public hearing at least a week in advance of the scheduled meeting. You will be graded on the clarity of your presentation and your effective use of quantitative information in making and responding to arguments. It is expected that you will do some research to prepare for these presentations.

Extra Credit: You may attend any lecture that occurs at Bates, Bowdoin, Colby, or USM during the semester and write a one to two page summary of the talk and your response to it for extra credit. Your summary and response must be clearly and well written and typed for credit to be awarded.

Assigned Exercises

The numbers in the following table indicate certain chapters and sections in the textbook. You are to complete ALL exercises included the indicated chapters and sections.

Exercises	**Due Date**
1:4 1:5 (exercises 1, 3, 4, and 5) 1:6	January 23 (Urban Hydrology)
2:1 2:2 2:9 (exercises 1 and 2) 2:17	February 6 (Hydrology)
2:6 (exercises 1 and 2) 2:7 (exercises 1-4) 2:8 (exercises (1-3)	February 27 (Nutrients)
2:3 2:19	March 12 (Carbon)
2:10 2:11	March 26 (Metals)
2:4 2:5 2:12	April 9 (Urban Ecology)

Tentative Course Schedule

Module 1: Introduction to the Course

Week 1

Monday, Jan. 12	Lecture	Course Intro
Wednesday, Jan. 14	Lecture	Stocks and Flows
	Lab	Introduction to EXCEL and STELLA
Thursday, Jan. 15	Discussion	Review of Math Skills Needed for Course
	Lab	Introduction to EXCEL and STELLA
Friday, Jan. 16	Lecture	What is Environmental Science? Issues of scale

Week 2

Monday, Jan. 19		MLK DAY
Wednesday January 21	Lecture	Population and Economic Growth, Intro to Footprints
	Lab	Personal Footprint and Ecological Footprint of Bates Colle
Thursday January 22	Lab	Personal Footprint and Ecological Footprint of Bates Colle
Friday January 23	Lecture	Ecological Footprints and primary Productivity

Module 2: Urban Hydrology and the Water Cycle

Week 3

Monday Jan 26	Lecture	The Water Cycle and Mass Balance
Wednesday January 28	Lecture	Experimental Design, Sampling, and Estimation
	Lab	Estimating Water Stored in the Snow Pack: Study Design
Thursday January 29	Lab	Estimating Water Stored in the Snow Pack: Study Design
Friday January 30	Lecture	Effects of Urbanization on Surface Water and Streams

Week 4

Monday, Feb 2	Lecture	Water Quality Impacts of Stormwater
Wednesday, Feb 4	Lecture	Stormwater Management - General
	lab	Estimating Water Stored in the Snow Pack: Data Collectio
Thursday, Feb 5	lab	Estimating Water Stored in the Snow Pack: Data Collectio
Friday, Feb 6	Lecture	Stormwater Management – Local Examples

Module 3: Nutrient Dynamics in Lakes

Week 5

Monday, Feb. 9	Lecture	Public Hearing: A New Walmart in Lewiston?
Wednesday, Feb. 11	Lecture	Introduction to Limnology: Lakes, Heat, and Oxygen
	Lab	Oxygen and Temperature in Winter Lakes
Thursday, Feb. 12	Lab	Oxygen and Temperature in Winter Lakes
Friday, Feb. 13	Lecture	The Concept of Nutrients: Building blocks of living tissues

FEBRUARY BREAK

Week 6

Monday, Feb. 23	Lecture	Major Nutrients in Lakes: N, P, C
Wednesday, Feb. 25	Lecture	Sources and Sinks of Major Nutrients in Lakes
	Lab	Oxygen and Temperature in Winter Lakes: Field
Thursday, Feb. 26	Lab	Oxygen and Temperature in Winter Lakes: Field
Friday, Feb. 27	Lecture	What Limits Primary Production in Lakes?

Module 4: Global Carbon Cycle: Carbon Mitigation

Week 7

Monday, March 1	Lecture	Introduction to the Carbon Cycle - Compartments and Flow Climate
Wednesday, March 3	Lecture	Carbon cycle continued
	Lab	Photosynthesis and Iron in Marine Systems
Thursday, March 4		EXAM
Thursday, March 4	Lab	Photosynthesis and Iron in Marine Systems
Friday, March 5	Lecture	Carbon Cycle and Conservation

Week 8

Monday, Mar. 8	Lecture	Carbon Sinks
Wednesday, Mar.10	Lecture	Carbon Sequestration
	Lab	Photosynthesis and Iron in Marine Systems
Thursday, Mar.11	Lab	Photosynthesis and Iron in Marine Systems
Friday, Mar.12	Lecture	Public hearing: Iron Seeding in the Gulf of Maine?

Module 5: Toxic Metals

Week 9

Monday, Mar. 15	Lecture	An introduction to Toxicity and Humans
Wednesday, Mar. 17	Lecture	Environmental Risk and Analytical Thought
	Lab	Lead in the Environment: Planning
Thursday, Mar. 18	presentation	ES seniors doing research on lead
Thursday, Mar. 18	Lab	Lead in the Environment: Planning
Friday, Mar. 19	Lecture	Risk Assessment - the EPA model

Week 10

Monday, Mar. 22	Lecture	The Speciation and Distribution of Lead in the Environmer
Wednesday, Mar. 24	Lecture	The risk lead poses…
	Lab	Lead in the Environment: Finish
Thursday, Mar. 25	Lab	Lead in the Environment: Finish
Friday, Mar. 26	Lecture	The risk lead poses…

Module 6: Economic and Engineered Systems

Week 11

Monday, Mar. 29	Lecture	Example - Aquaculture
Wednesday, March 31	Lecture	Example - Aquaculture
	Lab	College-wide audit- finish up
Thursday, Apr. 1	EXAM	
Thursday, Apr. 1	Lab	College-wide audit- finish up
Friday, Apr. 2	Lecture	Public Hearing: Environmental Stewardship at Bates

Wrap Up and Review

Week 12

Monday April 5	Lecture	Wrap up: Material and Energy Flow as Unifying themes ir
Wednesday April 7	Lecture	Review for Final
Friday April 9	presentation	Presentation of lab results