Mathematical Modeling
Fall 2013
MATH 471.01 (3 credits), M_W_F, 11:00AM-11:50AM, Wickersham 101

Prerequisites: A grade of C- or better in MATH 365 (*Ordinary Differential Equations*) is the prerequisite for this course.

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Textbook: *An Introduction to Mathematical Modeling*, Edward A. Bender, Dover Publishing Company, Mineola, New York 2000, ISBN: 978-0486411804.

This is a reprint of the 1978 John Wiley & Sons edition. This textbook may be supplemented by other instructor-provided materials.

Objectives:

- To introduce mathematics students to real–world problems.
- To introduce students to problems in disciplines outside of mathematics in which "example", "existence", and "realism" may be more important than "calculation" or "proof".
- To introduce students to the use of the computer as a tool for exploration, simulation, visualization, and presentation of problem solutions.
- To impress upon students the need to acquire the vocabulary and methods of expression found in disciplines outside mathematics, in order to communicate mathematical solutions and treatments of problems to non–mathematicians.
- To give students the opportunity to use skills learned throughout their mathematics and science coursework.

Course Contents:

The content of the course can be viewed either as a set of applied mathematics case studies and mathematical modeling problems and projects or as a set of underlying mathematical modeling techniques which are applicable to a wide variety of real–world problems. Changes in technology, the business climate, and research initiatives of industry and academia may provoke changes in the mathematical modeling topics studied in this course. The topics listed below are merely examples of the topics which may be covered in this course. If a greater need for, expertise in, or applicability of other topics can be found, instructors should feel free to include other topics. The list of topics below does not imply that all of these topics will be covered. The instructor's own background, expertise, and interests coupled with the students' background and interests should guide the selection of topics presented and the amount of detail and sophistication placed in the modeling effort.

1. Mathematical modeling topics

(a) Allometry, shape, and form
    i. Organ sizes and body weights of animals
    ii. Geometry of blood vessels
    iii. Design of blades in cutting tools
(b) Pharmacokinetic modeling
    i. One compartment linear models
    ii. Two compartment linear models
    iii. Non–linear Michaelis-Menten processes
    iv. Physiologically–based modeling
(c) Chemical reaction dynamics
(d) Population biology and mathematical ecology
    i. Cleaning pollution from a lake
    ii. Mutual competition between two species
    iii. Predator–prey interactions
    iv. Pioneer–climax interactions
(e) Traffic dynamics
    i. Paths of turning and towed vehicles
    ii. Braking to avoid collisions
    iii. Driving in tunnels
    iv. Shocks and rarefactions in traffic flow
(f) Optimal control and utility
    i. Energy allocation in plants
    ii. Energy consumption during animal migration
    iii. Employment levels in a company
    iv. Harvesting and stocking strategies
    v. Temperature control in reptiles
(g) Elections and voting
(h) Games and chance and skill
(i) Birth and death
    i. Branching processes
    ii. Inventory control
    iii. Traffic junctions and turn lanes
    iv. Justification for pedestrian crossings

2. Mathematical modeling techniques
(a) Axiomatic systems
(b) Geometry and trigonometry
(c) One, two, and three–dimensional ordinary differential equations
(d) Numerical solution of ordinary differential equations
(e) Parameter estimation and curve fitting
(f) Graph theory

(g) Planar dynamical systems
    i. Isoclines
    ii. Equilibria
    iii. ω–limit sets
    iv. Vector fields
(h) One–dimensional partial differential equations and fluid flow
(i) Conservation laws
(j) Control theory
(k) Elementary probability
(l) Development of computer–based simulations

Each of these topics is rich enough to justify at least one complete mathematics course. This course will not attempt to cover all the detail necessary for a deep understanding of these topics, but instead will introduce the key ideas from these topics necessary to build and analyze simple mathematical models. Depending on the backgrounds and academic and career interests of the students and the instructor, topics other than those listed here may be included in this course. One component of the course will be the use of calculators, computers and mathematical software such as *Mathematica* for the creation of simulations, development of visualizations of model behavior, and numerical solution of equations.

At the end of this course, successful students will be able to develop mathematical models to describe various real–world problems and will be better able to tap the expertise and knowledge base of people in other disciplines when a mathematical modeling effort is required in an unfamiliar area. The students will have some experience creating written reports describing their models in language suitable for consumption by non–mathematicians. They will also have experience developing and giving oral presentations geared for a mixed audience of mathematicians and non–mathematicians.

Attendance: Students are expected to attend all class meetings. If you must be absent from class you are expected to complete class requirements (tests and/or homework assignments) prior to the absence. Students who miss the deadline for an assignment should provide a valid excuse, otherwise they will not be allowed to make up the assignment. Assignments should be made up within one week of their scheduled deadline.

Homework: Homework assignments will consist of a mixture of pencil and paper, calculator and/or computer assignments. Students are expected to do their homework and participate in class. Students should submit all homework by the date due. Late homework will not be accepted without valid excuse. Discussion and collaboration between students on homework assignments is encouraged, but homework submitted for grading should be written up separately. Submitted written homework and programming assignments should not be merely identical copies of other students' work.

Grades: Course grade will be calculated as follows.

Class Participation	33%
Homework	34%
Final/Project Presentation and Report	33%

I keep a record of students' assignment scores. Students should also keep a record of graded assignments and other materials. The course letter grades will be calculated as follows.

90-92	A−	93-100	A		
80-82	B−	83-86	B	87-89	B+
70-72	C−	73-76	C	77-79	C+
60-62	D−	63-66	D	67-69	D+
		0-59	F		

Course Repeat Policy An undergraduate student may not take an undergraduate course of record more than three times. A course of record is defined as a course in which a student receives a grade of A, B, C, D, (including + and −) F, U, Z or W. The academic department offering a course may drop a student from a course if the student attempts to take a course more than three times.[1]

Inclement Weather Policy: If we should miss a class day due to a school closing because of weather, any activities planned for that missed day will take place the next time the class meets. For example, if a test is scheduled for a day that class is canceled on account of snow, the test will be given the next time the class meets.

Cell Phones: Silence (or better yet, turn off) all cellular telephones upon entering the classroom. Leaving class to initiate or receive a telephone call will not be tolerated and students doing so will not be re-admitted to the classroom until the following class meeting. Texting or tweeting during class interferes with the learning process. Students distracted by their cell phones are not engaged in class and will find, over the course of the semester, that learning and course grade will suffer.

Final Word: Math is not a spectator sport. What you learn from this course and your final grade depend mainly on the amount of work you put forth. Daily contact with the material through homework assignments and review of notes taken during lectures is extremely important. Organizing and conducting regular study sessions with other students in this class will help you to understand the material better.

No one can guarantee you success in this course. Your responsibilities and the instructor's expectation are outlined above. There will be no second chances, "do-overs", or extra credit assignments.

[1] Memorandum to mathematics faculty from Dr. Charles G. Denlinger, Assistant Chair, Department of Mathematics, August 30, 2004.