# Building Models to Solve Engineering Problems

University Honors College

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M-F 9-12, 205 Civil Engineering

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## Overview of the Course

**Building models to solve engineering problems** explores major aspects of engineering through a series of hands-on modeling and design activities. Students learn about engineering design by building models to solve engineering problems using computer tools, including spreadsheets and expert systems. The entire course is problem-based, that is, the emphasis is on formulating and solving problems. Numerous problems will be selected from a variety of engineering contexts to help you learn engineering and modeling concepts, including: identification of variables and parameters, solution estimation, levels of representation, modeling resolution, the importance of purpose and context, time dependence, and many others.

## Course Objectives

- Reflect on and revise thoughts and attitudes about engineering and engineers
- Explore several aspects of engineering and design
- Recognize state-of-the-art engineering
- Experience the engineering design process
- Practice working in design teams
- Learn about formulating, modeling, and analyzing engineering problems
- Improve skills for using tools (computers) for modeling and problem solving
- Develop internet skills
- Have fun!

## Textbooks

Castro, Elizabeth. 1999. HTML 4 the World Wide Web. Peachpit Press.
Donaldson, Krista. 1999. *The engineering student survival guide*. New York: McGraw Hill.
Gottfried, Bryon S. 1998. *Spreadsheet tools for engineers.* New York: McGraw-Hill.
Starfield, A.M., Smith, K.A. & Bleloch, A.L. 1994. *How to model it: Problem solving for the computer age*. Edina, MN: Interaction.

## Software and Computer Use

Some of the assignments will involve the use of personal computers. *How to model It* is distributed with application software (*WinExp, CritPath*). Word processing, spreadsheet, equation solving, and other application software is available on the machines in Institute of Technology computing labs and other University labs. A World Wide Web site has been created for the course. The use of electronic mail (e-mail) is encouraged for communication among students and between students and faculty.

## Contacting Karl Smith and Vaughan Voller

Karl Smith is quite easy to contact outside of office hours if you persist. If you=re in the neighborhood, try knocking on the door (236 Civil Eng). If no answer, leave a message on the note pad and I'll phone. Try phoning me at 625-0305; if I don't answer (I=m either in conference, on the phone or out of my office), leave voice mail and I'll return your call. Send me e-mail (probably the most reliable way to reach me) and I'll respond. I read my e-mail regularly during the day and almost every evening at about 10:00 pm and I will reply promptly. If you want to meet in person and you're unable to meet during office hours, please contact me and make an appointment.

Vaughan Voller will be in 167 Civil Engineering. Phone 625-0765. BUT e-mail works best.

## Topics

Problems such as the 10 problems in the book *How to Model It* (ping-pong, purging a gas storage tank, the student's dilemma, tennis, etc.) will be given to introduce and help you learn engineering and modeling concepts, including

identification of variables and parameters
solution estimation
levels of representation
Occam's razor
modeling resolution
the importance of purpose and context
time dependence
bounds
lumped parameters
differences between deterministic and stochastic models
use of diagrams and schematics for formulation, solution, and explanation
identification and incorporation of constraints
the role of optimization
model verification and sensitivity analysis
how to compare models
representing and exploring trade-offs
qualitative and quantitative models
algorithm
heuristic
trade-offs
best change
state-of-the-art
rule of thumb
order of magnitude
factor of safety
resource allocation
risk control

## Basic Course Requirements

1. Attend all classes.
2. Read all assigned materials by the assigned time.
3. Actively participate in class discussions.
4. Satisfactorily complete all progress checks, projects, and assignments.
5. Participate fully in project groups (do your fair share of the work).
6. Submit all assignments on time and at an acceptable level of quality.
7. Contract for a grade of **A or S.**
8. Complete and submit a course evaluation.

## Grading

Grades will be determined on the basis of learning contracts. A specified minimum amount of work is expected of all students. The alternative learning contracts are:

**Grade S**: Meet minimum requirements (above)
Meet minimum criteria on all assignments

**Grade A**: Everything for Grade **S** plus
Complete an Individual Project (web site, poster, other?)

Project reports that do not meet the minimum criteria must be revised and resubmitted.

Final grades are based on a combination of Quantity and Quality of work. Quality is more important. All work must meet the standards of acceptable performance. On the final day of classes students must submit a written statement of the contract they are working to fulfill along with the required proof of meeting the contract.

## Group Project Reports

The format for most of the project reports will be formal, that is, they must be typewritten or computer generated and printed. Recommended formal report format is given below. All group reports must meet the following criteria:

1. One report from each group.
2. Every group member must indicate that he or she agrees with the group's report and understands the material by signing the group's report.
3. Make sure all group members are involved in formulating and solving the problem and in producing the report.
4. Assist all group members in understanding the material; every member of the group is responsible for the quality of the report.
5. As you will be required to do in professional practice, in this course you will be responsible to detailed time estimates and time tracking. At the beginning of each group project assignment each individual must record an *estimate of the total time necessary (for both individual work alone and time spent with the group)*. After the report is completed, record the actual time and effort required. Time estimates and

time tracking should be recorded to the nearest 15 minutes (3 hour).

The format for some of the reports will be electronic (via e-mail) and a few will be informal, that is, they may be handwritten as long as the handwriting is legible. Further details on the format will be provided with each project. A typical engineering report format is as follows:

Executive Summary (One page or less summary of the problem, formulation, model, method, results, and conclusion)
Table of contents
Problem -- Description of the problem
    Formulation -- assumptions
Method -- Description of the method
    Limitations, assumptions
Results -- Tables or Figures (Use graphs liberally)
Discussion of results
    Effect of assumptions & method of formulation on solution (sensitivity of solution to assumptions)
    Implications for other problems
References
Appendix (Computer output, Tables)

## Individual Project

**Web Presentation** (A Project)

**Web Hosted Review or Application paper:** Write either a (1) review paper on some aspect of the course--modeling, engineering, problem solving [a book review (See reference list for examples)] or review of some approach to modeling--linear programming {Chapter 7} or expert systems {Chapter 10}], or (2) a practical application paper describing a application of modeling [choose a problem you're interested in and build a model {mathematical, computer, physical, etc]. This paper should be at least 1000 words (about 5 double-spaced pages long). Review and application papers must include external references, for example, journal articles, an interview, etc. Examples of web hosted review or applications papers are available on the web.

**Web Hosted Poster (or Slide Show)**: Prepare a poster reviewing some aspect of engineering or design. Examples of poster slide-shows from a first-year engineering class available on the Web. Posters must conform to the guidelines and be supported with a short paper. Papers should be about 1000 words (5 double-spaced pages) with less than one-half graphics and charts and must include external references; for example, journal articles, interviews, surveys, etc. Posters will be presented on the last day of class. The purpose of the poster is to demonstrate one of your major learnings from the course.

### Books in Course Library

Adams, James L. 1991. **Flying buttresses, entropy, and o-rings: The world of an engineer.** Cambridge: Harvard University Press.

Bucciarelli, Louis, L. 1996. **Designing engineers**. Cambridge, MA: MIT Press.

Petroski, Henry. 1996. **Invention by design: How engineers get from thought to thing**. Cambridge: Harvard University Press.

Dym, Clive L. 1994. **Engineering design: A synthesis of views.** Cambridge: Cambridge University Press.

Eide, Arvid R., Jenison, Roland D., Mashaw, Lane H., & Northup, Larry L. 1998. **Introduction to Engineering Design.** New York: McGraw Hill

Ferguson, Eugene S. 1992. **Engineering and the mind's eye.** Cambridge, MA: MIT Press.

Florman, Samuel. 1996. **The introspective engineer.** New York: St. Martins.

Hapgood, Fred. 1992. **Up the infinite corridor: MIT and the technical imagination.** Reading, MA: Addison-Wesley.

Hornstein, Mark. 1998. **Engineering design: A day in the life of four engineers.** Upper Saddle River, NJ: Prentice Hall.

Kidder, Tracy. 1981. **The soul of a new machine.** New York: Little-Brown.

Landis, Raymond B. 1995. **Studying engineering: A road map to a rewarding career.** Burbank, CA: Discovery Press.

Roadstrum, W.H. 1988. **Being successful as an engineer.** San Jose, CA: Engineering Press.

Schon, Donald. 1987. **Educating the reflective practitioner: Toward a new design for teaching and learning in the professions.** San Francisco: Jossey Bass.

Simon, Herbert. 1996. **The sciences of the artificial.** Cambridge, MA: MIT Press.

Ullman, Ellen. 1997. **Close to the machine: Technophilia and its discontents.** San Francisco: City Lights.

Vincenti, Walter. 1990. **What engineers know and how they know it: Analytical studies from aeronautical history.** Baltimore: Johns Hopkins University Press.

Weingardt, Richard. 1998. **Forks in the road: Impacting the world around us.** Denver: Palamar.

## References

### Engineering

Adams, James L. 1991. **Flying buttresses, entropy, and o-rings: The world of an engineer**. Cambridge: Harvard University Press.

Bucciarelli, Louis, L. 1996. **Designing engineers**. Cambridge, MA: MIT Press.

Ferguson, Eugene S. 1992. **Engineering and the mind's eye**. Cambridge, MA: MIT Press.

Florman, Samuel. 1996. **The introspective engineer**. New York: St. Martins.

Hapgood, Fred. 1992. **Up the infinite corridor: MIT and the technical imagination**. Reading, MA: Addison-Wesley.

Koen, Billy V. 1985. **Definition of the engineering method**. Washington: American Society for Engineering Education.

Papanek, Victor. 1995. **The green imperative: Natural design for the real world**. New York: Thames and Hudson.

Petroski, Henry. 1985. **To engineer is human: The role of failure in successful design.** New York: St. Martins Press.

Pool, Robert. 1997. **Beyond engineering: How society shapes technology.** New York: Oxford University Press.

Simon, Herbert. 1996. **The sciences of the artificial**. Cambridge, MA: MIT Press.

**Modeling**

Aris, Rutherford, 1994. **Mathematical modeling techniques**. New York: Dover.

Casti, John L. 1992. **Reality rules: Picturing the world in mathematics (Volume I: The fundamentals)**. New York: Wiley.

Casti, John L. 1992. **Reality rules: Picturing the world in mathematics (Volume II: The frontier)**. New York: Wiley.

Friedman, R. 1991. **Problem solving for engineers and scientists**. New York: Van Nostrand.

Morrison, F. 1991. **The art of modeling dynamic systems: Forecasting for chaos, randomness, and determinism**. New York: Wiley.

Papalambros, Panos Y. and Wilde, Douglass J. 1988. **Principles of optimal design: Modeling and computation**. Cambridge, England: Cambridge University Press.

Starfield, Anthony M., and Bleloch, Andrew L. 1991. **Building models for conservation and wildlife management,** Second Edition. Edina, MN: Bellweather Press. [Burgess International Group, 7110 Ohms Lane, Edina, MN 55435-9831 Telephone 612-831-1344]

Swetz, Frank and Hartzler, J.S. 1991. **Mathematical modeling in the secondary school curriculum**. Reston, VA: National Council of Teachers of Mathematics. [NCTM, 1906 Association Drive, Reston, VA 22091]

# Grading Contract
# Summer Honors College

(Contract is tentative and subject to modification)

Name_______________________________________________________

Please fill out this contract and return it with the completed course requirements.

I have contracted for a **grade** of______.

**Requirements for Grade S:**

____ Attended class and actively participated.

____ Completed, submitted, and met minimum criteria on all group project reports.

____ Completed and submitted all individual assignments.

**Additional Requirements for Grade A:**

____ Completed, submitted and met requirement on an individual project.

Signature______________________________ Date____________________

# Student Information Sheet
# Summer Honors College

**Name**________________________________________________________

**Phone Number**_____________________________ **E-Mail**____________________________

**Engineering, Science & Math Experience (describe briefly):**

**Computing Experience (list hardware and software used):**

**Motivation for taking this course:**

**Expectations from the course:**

**Any special learning needs that we should be aware of:**

Part III: Engineering Problem-Solving with MATLAB, which utilizes this critical tool for modeling. Each of the chapters in this part corresponds to an earlier chapter using MATLAB to implement programs for examples from that chapter. Clear, methodical, and uniquely focused on real-world engineering practice, Introduction to Engineering; is a solid course that will quickly acquaint you with engineering concepts, build your problem-solving skills, and prepare you to meet the challenges of designing systems as a professional engineer in any field. Many, many models to memorize. Useless for new problems. Fastest way to solve old problems.Â  12 Add springs 1 more variation in model building blocks Each piston problem could now be with or without springs (insulated or not) Now 3x2x6=36 complete models Add possibility of piston kinetic energy 1 more variation in model building blocks Piston problems now insulated (or not), with spring (or not), with KE (or not) =.