BEE 453/MAE 453. Computer-Aided Engineering: Applications to Biomedical Processes
Spring Semester 2007

Credit: 3 hours

Catalogue description:
Introduction to simulation-based design as an alternative to prototype-based design. Analysis and optimization of complex real-life processes using physics-based computational software. Biomedical applications of heat and mass transfer are covered that includes drug delivery and thermal therapy such as laser heating and cryosurgery. Computational topics introduce the finite-element method, pre- and post-processing, and pitfalls of using computational software. Students choose their own term project, which is the major component of the course (no final exam).

Required or Elective: Elective

Prerequisite(s): Heat and Mass Transfer [BEE 350 (Biological and Environmental Transport Processes), ChemE 324 (Heat and Mass Transfer), MAE 324 (Heat Transfer) or equivalent].

Textbook(s) and/or other required material:

Course objectives:
Upon completion of this course, students should:

1. Be able to identify and formulate engineering problems that involve heat and mass transfer, from the real world into a computer model.
2. Be comfortable in thinking of computer simulation as an important practical tool in design and research projects in industry and academia. Should be able to solve less complex problems on his/her own and can work with a group of experts in solving problems of increasing complexity.
3. Know the essential components of a typical computer prototyping software and has realistic ideas about the advantages and pitfalls of such a software.
4. Be able to integrate engineering analysis with biomedical processes.
5. Learn about several biomedical processes in drug delivery and thermal therapy.

Topics covered:
Introduction to Design and Computer Prototyping
Problem Formulation
- Fundamentals of Problem Formulation
- Governing Equations for Continuity, Flow, Species Mass Balance and Energy
- Boundary Conditions
- Material property and Other Input Parameters
- Source Terms in Heat and Mass Transfer

Numerical Methods
- Finite Element Method
- Solving the Linear Set of Equations
- Linearization of Non-Linear Equations, Solving Multiple Sets of Equations
- Errors in Numerical Solutions, Convergence
- Accuracy in Transient Calculations

Software for Fluid Dynamics, Heat Transfer, Mass Transfer and Mechanics
- Components of a Typical Software Package
- Computer implementation of problem: COMSOL Software Instruction

Validation, Sensitivity Analysis and Debugging
Case Studies of Design and Optimization of Biomedical Processes
- Rectal protection during prostate cryosurgery
- Thermal burns and cooling therapy
- RF heating for hyperthermia treatment of tumor
- Laser eye surgery
- Detection of breast cancer from surface temperature
- Drug delivery in brain
- Uncertainty analysis of temperature calculations in cryosurgery

**Class/laboratory schedule, i.e., number of sessions each week and duration of each session:**
Two 50-minute lectures and one 50-minute lab each week (averaged over the semester).

**Contribution of course to meeting the professional component:**
This course partially fulfills the requirement to complete a Field Approved Elective in the Biological Engineering Concentration. For students opting to do a Minor in Biomedical Engineering, the course can be used in one of the categories of the minor program.

**Course outcomes and their relation to ABET program outcomes a-m:**
Upon completion of this course, students should:
1. Be able to formulate a real world engineering problem that involves heat and mass transfer and/or fluid flow in terms of a computer model. Be able to apply this modeling concept to biomedical processes. (a, c, g, k, l-b)
2. Be comfortable in thinking of computer simulation as an important practical tool in biomedical design and research. Should be able to solve less complex problems on his/her own and can work effectively with experts in solving problems of increasing complexity. (a, e, i, k)
3. Know the essentials of computing methodology and their implementations in a typical computer prototyping software. Have realistic ideas about the advantages and pitfalls of such software. (k)
4. Learn about several biomedical processes in the areas of drug delivery and thermal therapy. (a, e, l-b)

**Outcome Assessment:**
In the two written exams, questions test understanding in 1) Ability to formulate a mathematical problem from a biological one; 2) Organization of a typical computer-aided engineering software; and 3) Subject matter (biomedical process modeling, numerical methods). Group projects (worth 50% of course grade) are assessed through formal presentation and a final report.

**Ethical Behavior Statement**
Reference to Cornell University Code of Academic Integrity is made explicitly in the course syllabus and during the first day of classes. Other detail of the academic integrity that is required of the students is also described in the Syllabus that is handed out on the first day.

**Course Webpage**

**Person(s) who prepared this description and date of preparation:**
Ashim Datta, 4/27/07