Engineering Faculty Document No. 23-04
March 1, 2005

TO: Engineering Faculty
FROM: The Faculty of Agricultural and Biological Engineering
RE: New Undergraduate Level Course

The faculty of the Department of Agricultural and Biological Engineering has approved the following new undergraduate level course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ABE 301 - Modeling and Computational Tools in Biological Engineering

Sem. 2, Class 3, cr. 3

Prerequisites: MA 265 and MA 266 or MA 262 and ABE 202

Description:
Introduction to principles of analysis, setup, and modeling of biological systems using fundamental principles of engineering. Development of algebraic and differential models of steady state and transient processes involving material and energy balances, elementary thermodynamic, transport, and kinetic reaction principles, and economics in biological engineering systems.

Reasons:
While undergraduate engineering students take a wide range of mathematics courses and learn to apply these to previously developed models, they have relatively little direct education on how to develop quantitative models. The purpose of this course is to provide students with knowledge and skills needed to develop quantitative models from physical/industrial phenomena and the use of appropriate numerical methods for obtaining solutions to such models, as needed.

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Suggested reference and/or textbooks:
Applied Numerical Methods with Matlab for Engineers and Scientists by Steven C. Chapra (2005) McGraw Hill.

Course Learning Objectives:

In this course the student will learn numerical modeling skills for interpolation, cubic splines, finding roots, statistical regression modeling, and numerical solution of differential equations. Emphasis is placed on the use of computational tools for modeling and solution of problems. Engineering problem solving skills will be developed via MathCad/Matlab software programming.

At the end of the course the student will be able to:

1. understand principles of mathematics and computation used to develop numerical models of food and biological phenomena,

2. understand the modeling limitations related to computational accuracy/error and statistical precision,

3. gain an understanding of principles and techniques of data modeling, numerical approximation, maxima/minima determination, solutions of linear algebraic systems, IV/BDV ODE/PDE systems, and non-linear dynamic systems,

4. develop skills to create numerical models from natural/biological systems using fundamental physical and chemical phenomena, such as reaction kinetics, transport phenomena, and thermodynamics, and

5. develop skills for creating computational tools to quantify numerical models.

Topics

Week 1-2 What are models and why are they useful?
Empirical vs. Theoretical
Algebraic vs. Calculus/Differential
Linear vs. Nonlinear
Simulation vs. Optimization
Numerical Modeling
- Computational, graphical

Numerical Accuracy/Precision/Error
Principles for developing models from physical phenomena
Numerical Computational Tools (MathCad/MatLab)

Week 3-4 Introduction to Concepts of Biological Engineering
Thermodynamics
- Material balances/Energy balances
- Chemical Potential/Vapor-Liquid Equilibrium

Reaction Kinetics
- Batch, Mixed Flow, Plug Flow reactors

Separations
- Chromatography
- Vapor-Liquid Equilibria

Economics

Week 5-6 Data Modeling
Water Vapor Pressure Modeling
- Approximation methods using tabular data
  - Interpolation
  - Differentiation
  - Integration
- Steam tables

Empirical modeling of data
- Statistical regression
  - Linear, polynomial
  - Antoine's equation, production economics, pharmaceutical quality control
- Non-statistical
  - Cubic splines
  - Chromatographic separations,

Computational Tools Development

Week 7 Optimization
Gibbs Energy Minimization/Equilibrium
Finding Roots
- Newton method
- Bisection/false position

Derivative slope methods

Computational Tools Development

Week 8 Linear systems
Biomass Separation Processes

Distillation/Vapor-Liquid Equilibria; Binary mixture separations

Substitution, Gaussian elimination, matrix algebra

Linear Programming/Optimization

Computational Tools Development

Week 9-10 Unsteady State Biological Processes
Enzyme/Biochemical Reactions
Fermentation Kinetics

Conductive/Convective Heat Transfer in Cooking Foods

Ordinary Differential Equations

Initial value/boundary conditions

Euler

Runge-Kutta

Computational Tools Development

Week 11-12 Unsteady State Biological Processes
Diffusion of Moisture in Biological Materials

Finite Element

Difference equations

Multidimensional elements

Computational Tools Development

Week 13-15 Dynamic Biological Processes
Microbial Population Dynamics, Metabolic Cycles, Imaging

Introduction to Non-Linear Dynamic systems

Fractal graphics

Prey-Predator models

Attractors

Bifurcation/Stability

Computational Tools Development

Prerequisite knowledge:

Calculus/differential equations

Mass/energy balances

Basic descriptive statistics

Concurrent with transport phenomena

Grading Policy	**%**
Homework	40
Quizzes	10
Exams	30
Semester project	20

Notes:

Examples from biological and food process systems

Teach basic concepts in unsteady state transport phenomena, reaction kinetics