336 Syllabus, Winter Quarter v1.2
Bioengineering Systems and Control

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Tuesday and Thursday 12.00 to 1.20 in MOR 220

If you own a laptop, bring it to class

Week 1:

- Introduction to Systems Theory
  - ◇ Systems
    - ▸ Open, Closed and Isolated Systems
    - ▸ Models of Systems
      - ○ What is a model?
      - ○ What is the purpose of a model?
      - ○ What is a good model?
    - ▸ Deterministic, Discrete, Stochastic, Continuous
      - ○ ODEs
    - ▸ Model Variables
    - ▸ Model Parameters
    - ▸ Dimensions, Units and Dimensional Analysis
    - ▸ Linear and Non-Linear Models
      - ○ Informal discussion, see Week 3 for a formal definition
    - ▸ Introduction to approximations including linearization, see Week 3 for discussion on linearization
    - ▸ Representing models using block diagrams
  - ◇ Electrical Models
    - ▸ Review of basic electricity:

        - Ohms Law
        - Kirchhoff's Laws
        - Capacitors
      - Averaging resistor circuit
      - Simple RC circuits
    - Electrical Analogs
      - OpAmps
      - Summers
      - Integrators
      - Constant Multipliers

Week 2:

- Model Behavior
  - Steady State
  - Transients
- Class Exercises
  - Fluid
    - Water tank models
  - Population Models
    - Predator prey model
  - Biochemical Models
    - Futile cycling in metabolism
  - Pharmokinetic Models
    - Intravenous feeding model

Week 3:

- The Mathematics of Continuous/Deterministic Systems

- ◇ Linear and Nonlinear Systems
  - ▶ Linearity, additivity and homogeneity
  - ▶ Time Invariance
  - ▶ LTI Systems
  - ▶ State Space Representation
  - ▶ Linearization
- ◇ Properties
  - ▶ Steady State
  - ▶ Stability
- ◇ Introduction to Laplace Transforms and Applications
  - ▶ Laplace Transforms
  - ▶ Transfer Functions
  - ▶ Transient Response

Week 4:

- Computer Modeling and Visualization Techniques
  - ◇ Numerical Integration of ODEs
    - ▶ Euler and RK methods
    - ▶ Stiff Systems
  - ◇ Computing steady state solutions (Newton-Raphson)
  - ◇ Software packages
    - ▶ Matlab
    - ▶ CVODE
    - ▶ Commercial Packages
  - ◇ Numerical Recipes by Press et al
  - ◇ The Behavior of Continuous/Deterministic Systems
    - ▶ Phase Portraits
    - ▶ Nullclines
    - ▶ Linearization and Stability Around Steady State

        - ▶ Bifurcation plots

Week 5:

- Introduction to Feedback Control
    - ◇ Open and Closed Loops
    - ◇ Set points
    - ◇ Error terms
    - ◇ Servos (Latin for slave) and Homeostasis
    - ◇ Sinusoidal Toolbox
    - ◇ Frequency Response
    - ◇ Bode Plots

Week 6:

- Introduction to Feedback Control
    - ◇ Proportional Control
    - ◇ Integral Control
    - ◇ Derivative Control
- Reverse Engineering Systems

Week 7:

- Biochemical Systems
    - ◇ Mathematical Representation
    - ◇ Modeling Biochemical Systems
    - ◇ State Space Representation
        - ▶ Transfer Functions for Networks
        - ▶ Frequency Response

- ▶ Sensitivity Analysis Interpretation

Week 8:

- Control in Biochemical Systems
  - ◇ Linear Chains
  - ◇ Branched Systems
  - ◇ Feedback Control
  - ◇ Feed-forward Control
  - ◇ Memory-less Switches (Ultrasensitivity)
  - ◇ Amplifiers

Week 9:

- Emergent Behavior in Systems
  - ◇ Oscillators and Bistable Switches
  - ◇ Conservation and Flux Laws
  - ◇ Unexpected Emergent Behavior

Week 10:

- Nonlinear Systems
  - ◇ Burst Kinetics
  - ◇ Chaotic Systems