BioEng 1102, Spring, 2000 12/1/99

Fundamentals of Bioengineering II.

MF 12:25 – 1:45 103 EMCB

Syllabus

Primary Instructor: Joe Andrade 2460 MEB Ph: 581-4379
joe.andrade@m.cc.utah.edu
Office Hours: TBA and by appointment

Discussion Sessions: Angela Yamauchi 1480 MEB Ph: 581-4549
angela.yamauchi@m.cc.utah.edu
Office Hours:

David Warren BPRB Ph: 581-
david.warren@m.cc.utah.edu
Office Hours:

Fundamentals of Bioengineering I & II (BIOEN 1101 & 1102) are designed to introduce students to the broad field of Biomedical Engineering and to some of the tools and techniques used in the profession. The material is organized around unified concepts of flux, transport and conservation in biological and engineered systems. Fundamental laws of physics and chemistry are applied to the analysis of biological systems and to the design of biomedical devices. Calculus and chemistry should be taken concurrently. Diffusion and molecular transport, electro-chemical gradients, heat and mass transport and related topics are used to explain the basic principles in cellular, organ, and systemic physiology. The same tools are also applied to design of biomedical devices.

Requisites: Concurrent with Chem 1210, Math 1250
Prerequisite: BioEng 1101 or consent of the instructor

Text: _The Biomedical Engineering Handbook_. Editor, Joseph D. Bronzino; CRC Press, 1995; ISBN 0-8493-8346-3. The handbook is very broad in scope and is intended to serve as a valuable referencefor many years. You will be held responsible only for the material in the assigned sections.

Reserve Books:
Medical Technology and Society: An Interdisciplinary Perspective, J.D. Bronzino, V.H. Smith, and M.L. Wade, eds, MIT Press, 1990 ISBN 0-262-02300-8
Introduction to Biomedical Engineering by J.M. Enderle, S.M. Blanchard, and J.D. Bronzino, Academic Press, 2000; ISBN 0-12-
E.R. Lewis, eds., Oxford Univ. Press, 1996 ISBN 0-19-856516X
Blood, L. Vroman, Natural History Press, 1966?. Out of print
The Second Law, P.W. Atkins, Scient American Lib., 1984
Maxwell's Demon, H.C. von Baeyer, Random House, 1998; ISBN 0-679-43342-2

Notes and handouts can be found on the web site: **http://webct.cc.utah.edu/**

Meeting Information:

Lecture:	Monday. 12:25-1:45 PM. 103 EMCB
Discussion Sessions:	Tuesday, Wednesday, and Thursday. (NEED TO SCHEDULE)
Guest or Demonstration:	Friday. 12:25-1:45 PM. 103 EMCB(SCHEDULE)

Grading and Evaluation:

Friday Lecture Participation	10%
Discussion Session Participation	10%
Homework	30%
Six quiz scores	50%

Seven quizzes will be given during the Monday or Friday lecture periods. Your six highest quiz scores will be used to compute your total quiz grade. If you are absent or miss a quiz for any reason, a score of zero will be assigned. Make-up quizzes will be given only under extenuating circumstances. We encourage students to study together and help one another with the material. Homework and answers on quizzes, however, must be your original work – copying is not allowed and may result in failure or expulsion. Late homework will not be accepted after solutions have been discussed in class or posted (usually the day after the homework is due).

General Organization.

The goal of the two semester sequence entitled "Fundamentals of Bioengineering I & II" is to introduce undergraduate students to a set of fundamental engineering principles and how they are applied to
i) solve practical biomedical design problems and
ii) answer scientific questions in biology and medicine.

The very nature of biomedical engineering requires an interdisciplinary approach which merges the life sciences with all fields of engineering. Biology does not exclude concepts traditionally identified with chemical engineering, computer science, electrical engineering, materials science or mechanical engineering. The course includes principles from all of these areas. As a unifying theme, the course is organized around fundamental flux and conservation laws of physics and chemistry but applied exclusively to biological systems and biomedical devices. The first semester (see outline below) covered mechanical and electrical systems as described by conservation of mass and conservation of electrons as well as the flux laws established by Darcy, Poisseuille, Hooke, Newton, Ohm, Kirchhoff and Coulomb. The second semester begins with conservation of molecules, Brownian motion and Fick's law, addressing diffusion in biology and diffusion-based medical devices. This is followed by heat flux and conservation of energy as described by Fourier and Carnot. The two-course sequence culminates by combining chemical and mechanical principles to arrive at Starling's law of membrane filtration, and by combining chemical and electrical principles to arrive at the Nernst-Planck relation – both of which are fundamental to physiology and to the function of numerous biomedical devices and sensors. The material is tied closely to guest lectures presented by biomedical engineers working in the field.

The course is designed for freshman undergraduate students. Calculus and chemistry should be taken concurrently. Flux and conservation equations will be written in finite difference or intergral forms that do not require knowledge of differential equations.

BioEng 1102 (Spring, 2000) Topic Outline

Week Topic

1 Review and Fick's Law
Mechanical flux laws, conservation of mass, and conservation of charge.
Current flux laws and conservation of charge.
Molecular flux related to concentration gradient.
Conservation of molecules. Molecular transport.
Analogy to Ohm's and Darcy's laws.
Lab: Diffusion based drug delivery or hemodialysis device.

Chemical Concentrations and Potentials
Chemical Reactions and Equilibria; chemical thermodynamics.
Chemical reactions.
Lab: Concentration modulation of a chemical reaction .

3 Brownian motion—Maxwell's Demon.
Stochastic view of diffusion.
Stoke's flow and Stoke's radius.
Einstein's famous paper!.
Lab: Brownian motion of spores.

4. That Second Law – Entropy wins!
Engines, Explosives, and Entropy;
Temperature, the Third Law, and Biochemistry;
Lab: Temperature Modulation of a Biochemical Reaction.

5 Fourier's Law
Heat flux related to temperature gradient.
Conservation of heat.
Convection and Conduction.
Introduce equivalence of heat and work.
Lab: The wind chill factor.

6 Network models of heat conduction.
Analogy to electric networks.
Thermal resistance. Insulation.
Spreadsheet models.
Lab: Localized Hypothermia: microwave cancer treatment.

7 Carnot's Law.
Conservation of energy.
The second law of thermodynamics.
Control volume analysis of systems.
Lab: The heart as a pump.

9 Metabolism
Conservation of chemical energy.
Cells, organisms and the environment.
Photosynthesis and Respiration.
Lab: Bioluminescent Phytoplankton

Metabolism II: Biochemical Pathologies
Lab: Phenylalanine and PKU

11 Starling's Law.
Flux related to pressure and chemical gradients.
Combines Darcy's and Fick's laws.
Conservation of mass and molecules.
Osmotic pressure – Colligative Properties.
Lab: Osmotic pressure in cells.

12 Nernst-Planck Law.
Flux related to electrical and chemical gradients.
Combines Ohm's, Kirchhoff's and Fick's laws.
Conservation of charged molecules.
Lab: Electrophoresis with fluorescence/chemiluminescence.

13 Membrane potentials.
Single-ion Nernst potential.
Multiple ions.
Lab: The pH electrode; Nernst potential in mock cells.

14 Electrical excitability of cells.
Electrical excitability of muscle.
Electrical excitability of neurons.
Neuroprosthetics and functonal stimulation.
Lab: Frog muscle.

Your Future in Bioengineering

Detailed Schedule and Reading Assignments: TBA

Fundamentals of Bioengineering I BioEng 1101 (Fall, 1999) Topics

Week	Topic
1	Darcy's Law
	Mass flux related to transmembrane pressure gradient.
	Mechanical filtration by biological and engineered membranes.
	Conservation of mass. Control volume methods.
	Series and parallel membranes.
	Lab: Pressure drop and flow through membrane systems.
2	Newton's Fluid Law
	Mass flux related to longitudinal pressure gradient.
	Viscous Poiseuille flow in tubes and arteries.
	Gravitational potential energy and power dissipation. Heat.
	Series and parallel tubes. Ideal dashpots.
	Lab: Build physical model of a vascular network.
3	Hook's Law
	Mechanical displacement related to force.
	Bulk modulus, shear modulus, and the modulus of elasticity.
	Elastic potential energy.
	Series and parallel springs. Ideal springs.
	Lab: Stiffness of blood vessels and vascular grafts.
5	Ohm's Law
	Current related to voltage gradient.
	Ideal resistors. Resistance vs. dimensions.
	Analogy to viscous flow in tubes.
	Electric potential energy, power and energy. Heat.
	Lab: Resistance of materials and biological tissues.
6	Kirchhoff's Law
	Conservaton of electrons. Analogy to mass conservation.
	Series and parallel resistors. Analogy to pipe networks
	DC networks -- loop and node equations.
	Introduce impedance via equivalent circuits.
	Lab: Voltage/current dividers using resistors and tissues.
7	DC network models of biological systems.
	Spreadsheet models.
	Passive extracellular electric fields.
	Lab: Build model of vascular network using resistors.
9	Coulomb's Law
	Conservation of charge. Analogy to deformable mechanical volume.
	Ideal capacitors. Response to sinusoidal voltage and current.
	Representation of amplitude and phase using complex numbers.
	Impedance -- amplitude and phase as a function of frequency.

Lab: Ideal capacitors and resistors. Scope.

10 AC networks
The RC network. Review Kirchhoff's Law.
Impedance. Input-output gain and phase vs. frequency.
Tissues and cells as RC networks
Lab: Impedance of tissues and cells.

11 Filters and analog to digital conversion
Gain and phase of active and passive filters.
Digital sampling. The Nyquist frequency.
Lab: Filters and A/D.

13-14 Bioelectric Potentials
Ideal Operational Amplifiers
Differential Bioamplifiers
Lab: EKG.