BIOLOGICAL SYSTEMS ENGINEERING 244
George Meyer

“Thermodynamics of Living Systems"

Syllabus - Spring 2001
University of Nebraska-Lincoln

Course Description:

This course is an introduction to the laws of thermodynamics and their application to biological and environmental systems. Topics include zeroth, first, second, and third laws, open and closed systems, enthalpy and specific heat, Gibb’s free energy and chemical potential for biological and environmental systems. Applications include biochemical potentials, water potential, adsorption, osmosis, radiation, membranes, surface tension, and fugacity. Also discussed are thermodynamic cycles as they apply to living systems.

Course Objectives:

Having successfully completed this course, students will be able to:

- Apply the first law to energy flow in biological and environmental systems.
- Understand the second law and that energy in different forms has different utility.
- Understand the Carnot Cycle in broader terms of heat engines and heat production in biological systems.
- Use psychrometrics to calculate changes in sensible and latent heat between living organisms and their environment.
- Explain water movement in the soil-plant-atmosphere continuum from Gibb’s free energy.
- Explain movement of materials influenced by membranes and their surroundings in biological-environmental systems.

Prerequisites: MATH 208; BIOS 101 or BIOS 201; PHYS 211; and CHEM 110 or 114.

Format: 3 credit hours, 3 hours of lecture per week (3 hours of Engineering Science)

<u>Meeting Times</u>:

<u>Lectures</u>: Monday/Wednesday/Friday - 3:00 - 3:50 p.m., Room 148 L.W. Chase

<u>Textbook and Supporting Materials</u>:

Cengel, Y.A. and M.A. Boles, 1999. Selected chapters from *Thermodynamics, An Engineering Approach* (Third Edition), McGraw-Hill. ISBN 0-07-238-577-4. (Available from Campus and Nebraska bookstores.)

Students must have e-mail addressess and be familiar with use of NETSCAPE or EXPLORER for surfing the World Wide Web. If you do not have an e-mail address, there are several free Internet providers in the area, or obtain a BIG RED account at 103 Miller Hall. Each student will have his/her own course account on UNL BLACKBOARD <u>blackboard.unl.edu</u>. Your initial password is your social security number, which you should change at first logon. Be sure to check that your e-mail address is correctly listed in BLACKBOARD. During the semester, announcements, web site links, supplemental handouts (Adobe PDF) will be available to students. To open PDF files at home, you must have Adobe Reader 4.0, which is free from <u>www.adobe.com.</u> Handouts will include additional detailed subject matter on biological and environmental applications of thermodynamics. Sample problem exercises and solutions will be also available.

Solutions to problems must be submitted on either standard engineering paper or done by computer. Students may use MATHCAD or MATLAB to solve computer homework problems. **However, all solutions must be carefully documented using a standard engineering solution outline and SI units.** The problem solution outline consists of what information is given, what information is sought, assumptions used, a detailed analysis using the appropriate equations, a unit analysis, and a clearly marked final answer. Do not crowd your work. **Points will be deducted for messy, erased, and unreadable work.**

Both MATHCAD and MATLAB are available on the BSEDOM network. If you do not have a BSEDOM account, you will need to fill out an application form. Student editions of MATHCAD 2001 are available through Nebraska Bookstore, or from MATHSOFT, Inc., Box 870, Buffalo, New York 14207-0870, www.mathsoft.com or call 1-800-289-5075. (Be aware that MATHCAD 2001 files cannot be loaded with previous versions of MATHCAD, so you will need to *save as* to the older version when transferring your files.)

Academic Integrity:

Academic conduct must conform to all UNL regulations on academic dishonesty as stated in the "Code Of Student Conduct." Violations are listed as follows:

"A student shall be guilty of a violation of academic integrity if he or she:

- represents the work of others as his or her own.
- obtains assistance in any academic work from another individual in a situation in which the student is expected to perform independently;
- gives assistance to another individual in a situation in which that individual is expected to perform independently;
- offers false data in support of laboratory or field work."

All violations will be handled according to University Guidelines. It is the instructor's understanding and expectation that the student's signature on any test, quiz, or assignment means that the student has completed the work by himself or herself.

Students With Disabilities:

If you have a disability that may affect your participation in this class, please notify the instructor so that any necessary adjustments can be made.

Grading Schedule:

	Points	Percent of Total
15 Homework Assignments (20 points each)	300	50
8 Quizzes (25 points each)	200	33
Final Exam (Open Book)	100	17
TOTAL POINTS	600	100

Weekly homework usually consists of 5 - 15 problems, depending on the length, scope, and complexity of the problems. Homework will be due no later than 5:00 p.m. on the day posted. **Homework received after the due date may be reviewed, but will receive *zero* points.** Quizzes will be closed book and approximately 20 minutes in length. Prior to each quiz, students will have an opportunity to review past homework problems and discuss the material covered. The final exam will be comprehensive, covering the entire course, and will be open book.

Individual numerical grades will be tabulated and made available to each student using UNL BLACKBOARD. Letter grades are then derived at the end of the semester from the student's numerical TOTAL POINTS score. A one-half point letter increase (+) will be awarded according to his/her semester running numerical average. At least 372 points must be earned to obtain a letter grade of *D*, 432 for a *C*, 492 for a *B*, and 540 for an *A*.

Attendance: Attendance is expected and will be taken at all lectures, unless prior arrangements are made. More than THREE unexcused absences will result in a 5-point reduction per additional unexcused absence. *If you have an excused absence planned, please notify the instructor prior to the absence.*

Instructor:

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Office Hours: 1:00 - 3:00 p.m. *(Tuesdays by appointment only)* or by electronic mail anytime.

Background of the Instructor:

George E. Meyer is a Professor of Biological Systems Engineering, University of Nebraska (40% teaching, 60% research). He specializes in machine vision, plant growth modeling, and electronic instrumented research. He is co-author of the soybean crop computer simulation model SOYMOD. Dr. Meyer is currently working with modeling plant stress response and machine vision for identifying and enumerating plants. During the period 1987-1994, he coordinated Nebraska's first major greenhouse projects with Dr. Jay Fitzgerald, Horticulture. Dr. Meyer has received major Federal funding for many areas of research and teaching. He recently received grants for machine vision and intermittent spraying of weeds. He received an NSF undergraduate equipment teaching grant which has been used to develop the Environmental Monitoring Laboratory for this course. Dr. Meyer team-taught the course "Environmental Factors Affecting Biological Systems" with Dr. Jim DeShazer (now Department head at Idaho) from 1978-1991. He also team-taught the AG*SAT course "Engineering Plant and Animal Systems" during the falls of 1992 and 1993 with Dr. Jim DeShazer of Idaho and Dr. Lou Albright of Cornell University. He is generally considered an expert on distance education and has been invited to teach short courses at ASAE National meetings. Dr. Meyer has been an organizer of ten Society of Photo-Illumination Engineering (SPIE) "Optics in Agriculture," held in conjunction with Photonics East in Boston. Dr. Meyer has taught "Instrumentation and Controls" since 1987. Dr. Meyer has received several teaching recognitions, including Nebraska Alumni Teaching Awards and 1999 College Teaching Professor of the Year. He will be assisted by a graduate teaching assistant.

Background of the Course:

Biological Systems Engineers need to understand and utilize various sources of free energy in their designs and applications, along with dynamic and non-equilibrium considerations. Biological and environmental applications use the laws of classical thermodynamics, but must go beyond thermostatics. This is not entirely a new concept at the undergraduate engineering level, since chemical engineering thermodynamics and physical chemistry probe into their respective application areas. Applications and energy cycles, involving biological and environmental systems have been addressed by prominent scientists and engineers in many literature sources over the last fifty years. It is now time to introduce this material at the undergraduate level in an efficient, but single introductory course.

"Thermodynamics of Living Systems" is, therefore, a required subject for Biological Systems Engineering. Plants and animals require a continual input of free energy. If sources of free energy are removed, organisms and other related biological processes drive toward equilibrium or consequent cessation of life. In order to understand biological and environmental processes, students need to apply the Gibb's free energy function, which is the combination of the first and second laws of thermodynamics. Most classical treatments of thermodynamics are better-named "thermostatics." Those concepts are usually covered in only a few weeks. However, in most biological and environmental problems, non-equilibrium and dynamic conditions require an understanding of not only thermal, but also chemical and diffusion potentials, as well.

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THERMODYNAMICS OF LIVING SYSTEMS
TENTATIVE COURSE OUTLINE

Topic No.	Lecture Date	Topic*	Reading Assignments	Problems (TBA)	Due (TBA)
1	January 8	**Introduction and Course Objectives**	Course Syllabus		
2	January 10	Thermodynamics and Energy	Cengel 1-1 thru 1-5		
3	January 12	Closed and Open Systems	Cengel 1-6 thru 1-7		
	January 15	**Martin Luther King Day**			
4	January 17	Processes and Cycles	Cengel 1-8 thru 1-9		
5	January 19	**Summary - Quiz 1**	–		
6	January 22	Pressure and Temperature	Cengel 1-10 thru 1-12		
7	January 24	Pure Substances	Cengel 2-1 thru 2-3		
8	January 26	Property Diagrams	Cengel 2-4 thru 2-6		
9	January 29	Equations of State	Cengel 2-7 thru 2-9		
10	January 31	Ideal Gas Law	Cengel 2-7 thru 2-9		
11	February 2	**Summary - Quiz 2**	–		
12	February 5	Heat Transfer	Cengel 3-1 thru 3-3		
13	February 7	Concept of Work	Cengel 3-4 thru 3-5		

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Topic No.	Lecture Date	Topic*	Reading Assignments	Problems (TBA)	Due (TBA)
14	February 9	First Law	Cengel 3-6 thru 3-7		
15	February 12	Enthalpy	Cengel 3-8 thru 3-9		
16	February 14	Refrigeration	Cengel 3-10 thru 3-11		
17	February 16	**Summary - Quiz 3**	–		
18	February 19	Psychrometric Properties	Handout		
19	February 21	Psychrometric Process I	Handout		
20	February 23	Psychrometric Process II	Handout		
21	February 26	Thermodynamic Analysis of Control Volumes	Cengel 4-1 thru 4-2		
22	February 28	Steady-Flow Processes	Cengel 4-3 thru 4-4		
23	March 2	**Summary - Quiz 4**	–		
24	March 5	Steady-State Flow	Cengel 4-4		
25	March 7	Non-Steady-State Flow	Cengel 4-5		
26	March 9	**Summary - Quiz 5**	–		
	March 11 - March 18	**Spring Break**			

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Topic No.	Lecture Date	Topic*	Reading Assignments	Problems (TBA)	Due (TBA)
27	March 19	Second Law of Thermodynamics	Cengel 5-1 thru 5-3		
28	March 21	Heat Engines/Animal Calorimetry	Cengel 5-4 thru 5-6; Handout		
29	March 23	Reversible and Irreversible Process	Cengel 5-7 thru 5-9		
30	March 26	Carnot Cycles and Photochemical Cycles	Cengel 5-10; Handout		
31	March 28	Refrigeration and Heat Pumps	Cengel 5-11 thru 5-13		
32	March 30	**Summary - Quiz 6**	–		
33	April 2	Entropy Production and Removal	Cengel 6-1 thru 6-3		
34	April 4	Isentropic Processes	Cengel 6-4 thru 6-7		
35	April 6	**Summary - Quiz 7**	–		
36	April 9	Combination of First and Second Laws	Handout		
37	April 11	Gibbs Free Energy	Handout		
38	April 13	Chemical Potential and Water Potentials	Handout		
39	April 16	Matric and Osmotic Potentials	Handout		

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Topic No.	Lecture Date	Topic*	Reading Assignments	Problems (TBA)	Due (TBA)
40	April 18	Gravitational and Pressure Potentials	Handout		
41	April 20	**Summary - Quiz 8**	–		
42	April 23	Free Energy in the Environment I	Handout		
43	April 25	Free Energy in the Environment II	Handout		
44	April 27	**Final Review**	–		

* Based on 15 weeks (three lectures per week). Homework is due at 5:00 p.m. on the due date.

Final exam is scheduled for Monday, April 30, 3:30 - 5:30 p.m.

References: (The Cengel and Boles text will be supplemented with sample problems prepared by the instructor.)

Kondepudi, D. and I. Prigogine. 1998. Modern Thermodynamics—From Heat Engines to Dissipative Structures. John Wiley & Sons, New York. 485 pp.

Merva, G.E. 1995. Physical Principles of the Plant Biosystem. ASAE—The Society for Engineering in Agricultural, Food, and Biological Systems. St. Joseph, MI. 272 pp.

Valsaraj, K.T. 1995. Elements of Environmental Engineering—Thermodynamics and Kinetics. Lewis Publishers, New York. 649 pp.

Fluck, R.C. and C.D. Baird. 1984. Agricultural Energetics. AVI Publishing Co., Wesport, CN. 192 pp.