# 155:201 Chemical Engineering Analysis I
# FALL 2005

**Meeting times:** Tuesday and Thursday, 3:20 a.m. – 4:40 p.m., SEC 203

**Instructor:**
Professor Yee C. Chiew, Ph.D.
Room C-150B Engineering
Tel: 732-445-0315; Email: ychiew@rci.rutgers.edu
Office hours: Wednesday, 1:30 p.m. – 3:00 p.m., C-150B

**Teaching Asst. (155:208):**
Amit Methorea; amitme@eden.rutgers.edu
Tel: 732 445 5058
Office hours: TBA

**Course Description:**

Chemical engineers encounter and solve a wide variety of problems in their work in the industry, government and academia. These problems may arise in the design, operation, or control of equipment or processes in diverse industries. Solution of most *real* problems involves the calculation and determination of the quantities and properties of various species present at different places of the process. Thus, material and energy balances are prerequisite to almost all chemical engineering problems.

Chemical engineers work in many industries besides chemical and petrochemical industries because their training and skills are easily portable to other industries including the pharmaceutical and biotechnology industries. One such skill is the systematic approach to solving problems, especially problems involving material and energy balances. Material and energy balances are also integral parts of most chemical engineering courses that are taken in the junior and senior years. Hence, mastery of the principles discussed in this course is a prerequisite for all other subsequent chemical engineering courses.

**Goals:** The objective of this course is to introduce students to the principles of material and energy balances as they apply to physical and chemical processes.

**Knowledge, Abilities, and Skills Students Should Gain From This Course:**

Upon successful completion of this course, a student should be able to:

1. develop systematic problem solving skills for physical and chemical processes
2. understand the principles of material and energy balance
3. apply the principles of material and energy balance to formulate and solve basic problems in process engineering
4. estimate and calculate the thermodynamic and phase equilibrium properties of ideal systems of gases and liquids
5. breakdown complex problems into component simpler problems
6. understand the relationship between various systems of units and be able to carry out calculations involving quantities and variables in different units

**Impact on Subsequent Courses in Curriculum:**
Material and energy balances and play an important role throughout chemical engineering. A student's ability to perform material and energy balances and estimate the thermodynamic properties of ideal systems of gases and liquids is necessary for subsequent courses such as *Thermodynamics, Transport Phenomena I & II, Unit Operations,* and *Reactor Design.*

**Course Outline:**

1. Basic concepts
2. Units and conversion of units
3. Calculations involving process variables
4. Material Balances
5. Thermodynamics of single phase fluids
6. Properties and phase equilibrium of ideal multi-phase systems
7. Energy and energy balances
8. Balances on non-reactive processes
9. Balances on reactive processes

**Required Text:** R. M. Felder and R. W. Rousseau, "Elementary Principles of Chemical Processes," 3rd Edition, Wiley, 2000.

**Evaluation Method:**

| | |
|---|---|
| Homework | 20% |
| Exam 1 | 25% |
| Exam 2 | 25% |
| Final exam | 30% |
| TOTAL | 100% |

**Important Dates:**
Exam #1: October 6, 2005
Exam #2: November 18, 2005
Final exam: during examination week (to be announced)

**Weekly Homework:** Homework problems will be handed out each Thursday and they will be collected on the following Thursday. Homework will be graded and solutions will be discussed and posted. Homework must be turned in promptly and late homework will not be graded.

## 155:208. Cemical Engineering Thermodynamics, Spring 2006

**Instructor:** Professor Fernando Muzzio
Office: C 126, Phone: 445-3357
Email: fjmuzzio@yahoo.com

**Co-Instructor:** Mr. Mobeen Faqih
Office: C111, Phone 445-5058
Email:mobeen17@yahoo.com

**Class Hours:** Tuesday & Friday, 12:00 - 1:30 p.m.
**Office hours:** Tuesday & Friday after class

**Objectives:**

The objective of this course is to introduce principles of thermodynamics, with a special focus on chemical engineering applications. The course seeks to build a necessary foundation for subsequent courses in reaction engineering, transport phenomena, and process design. To make the course user-friendly, we will follow closely the recommended textbook, but occasionally we will supplement it with additional reading material.

If you are prepared to work hard and consistently, you need not be afraid of the topic (or the instructor, for that matter). However, you need to be aware that Thermo is a subject matter not well suited for "cramming"; concepts need to be matured slowly, and it is much better to do a little bit of work every day (same principle as working out – can't get three months worth of exercise in just a week – and feel good afterwards).

You might have heard that the instructor is a busy guy (and the co-instructor too). This is true, but the door is wide open nonetheless – Please come see us after class as often as you need.

Only one warning: Cheating really makes us very angry. Do not even think about it.

**Required Textbook: Engineering and Chemical Thermodynamics (Milo Koretsky)**

**Grading:**

| | |
|---|---|
| Homework | 10% |
| Pop-quizzes (3) | 15% |
| Midterm | 30% |
| Final (Comprehensive) | 45% |

**Note: We will accept no Extra Credit Projects Whatsoever**

**Course Outline:**

| | |
|---|---|
| Introductory concepts | week 1 |
| Energy and the first law of Thermodynamics | weeks 2&3 |
| Entropy and the second law of Thermodynamics | weeks 3&4 |
| Equations of state | weeks 5&6 |
| Fundamental relationships | weeks 7&8 |
| Phase equilibria | weeks 9, 10, 11 &12 |
| Chemical Reaction equilibria | weeks 13&14 |

**Syllabus**
**155:303 Transport Phenomena I**
Fall 2005
Dr. Benjamin Glasser

***Introduction to fluid mechanics***
- General concepts
- Basic laws and physical properties
- Hydrostatics

***General conservation laws – Integral relationships***
- Mass balance
- Energy balance
- Bernoulli's equation

***Applications of Bernoulli's equation***
Momentum balances
Fluid flow in pipes
- Laminar flow
Shear stress models

***Differential Equations of Change***
- Viscous Flow
- Equations of motion
- Rectangular coordinates

***The Differential Equations of Change***

Equation of continuity for a single component

Equation of motion - Velocity and acceleration - Steady flows
Stress tensor
Stream Function

Boundary Conditions

***One-dimensional steady problems***

Falling film

Tube flow
Flow in and through an annulus
Adjacent flow of two immiscible fluids
Alternative solution using shell balances

***Flow in Pipes and Ducts***

Laminar flow

Piping and pumping problems
Friction factors
Pressure drop across pipe fittings

***Dimensional Analysis and Dimensionless Numbers***

Dimensions
Similarity
Pi Theorem
The equations of change in dimensionless form
Dimensionless numbers

***Advanced Topics***

Boundary Layer Theory

Turbulent Flow

## 155:304 Transport Phenomena II – Heat and Mass Transfer

**SPRING 2006**


**Instructor:** Prof. Silvina Tomassone
**Office:** ENG C234
**Telephone:** (732) 445-2972
**Email:** silvina@soemail.rutgers.edu


**Office Hours:** Mondays 2:00– 3:00p.m.; C234

**TA:** Nicole Plourde
**Office Hours:**

**Required Text:**
Stanley Middleman, "An Introduction to Mass and Heat transfer," John Wiley, New York (1998)

**Other Texts:**
Bird, R. B., Stewart, W. E., and Lightfoot, E. N., "Transport Phenomena," John Wiley, New York
Welty, J. R., Wicks, C. E., and Wilson, R. E., "Fundamentals of Momentum, Heat and Mass Transfer," John Wiley, New York (1998)
Mass Transfer, Fundamentals and Applications, Hines and Maddox

**Course Outline:**

**Fundamentals of Mass Transfer** Diffusion, Fick's Law; Definitions of Concentrations, Velocities, and Mass Fluxes

**Steady-State and Quasi Steady Mass Transfer** Mass Balance Equation; Shell Balances; External Boundary Conditions; Diffusion/Homogeneous Reaction; Convection/Diffusion

**Non Steady State Mass Transfer** Transient Diffusion Equation; Non Steady State Diffusion in Different Curvilinear Coordinates; Negligible Internal Mass Transfer Resistance

**Convective Mass Transfer** Preliminary Concepts; Boundary Layer Theory; Film Theory; Mass Transfer Coefficient; Correlations of Mass Transfer Data; Special Applications; Interphase Transport

**Fundamentals of Heat Transfer** Conduction; Fourier's Law; Thermal Conductivities; Thermal Properties of Matters

**Steady State and Transient Heat Conduction** Heat Balance Equation; Conducton in Simple and Complex Systems; Conduction with Heat Source; External Fins; Finite Difference; Transient Heat Conduction

**Convective Heat Transfer** Forced Convection; Correlations of Heat Transfer Coefficient; Buoyancy Induced Convection; Special Problems

**Special Topics** Radiation; Heat Exchangers; Evaporators and Condensers

**Grading Policy**
Exam 1 (25%), Exam 2 (25%), Final Exam (35%), Homework (15%)

**Examinations**
Exam 1 – March 2, 2006
Exam 2 – April 20, 2006
Final Exam – Refer to University schedule

**RUTGERS UNIVERSITY**
**Department of Chemical and Biochemical Engineering**

**155:307 CHEMICAL ENGINEERING ANALYSIS II** **FALL, 2005**

Professor: Dr. A. Constantinides (Dr. C)
Room: SOE C-203A
e-mail: constant@soemail.rutgers.edu
Telephone #: (732) 445-3678

Assistant: Miss Nicole Plourde
Room: SOE C-001 (basement)
nplourde@rci.rutgers.edu
(732) 445-5511

Class time: Monday & Thursday 10:20 to 11:40 a.m.
Location: EIT Lab (SOE D-110)
SERC-203 (exams only)

**Course description**
Introduction to modeling and simulation techniques in the analysis of chemical, and biochemical engineering systems. Application of numerical methods for the solution of complex process problems. Development and use of MATLAB software for the solution of engineering problems using personal computers.

**Course objectives**
- Introduce the concepts and methods of numerical analysis as applied to the solution of chemical and biochemical engineering problems.
- Provide the students with the awareness and the judgement to recognize the accuracy (or inaccuracy) and validity of numerical solutions.
- Familiarize the students with the strengths and weaknesses of various numerical methods, and give them some criteria for selecting methods to be used for solving of a particular problem.
- Introduce the students to the available computational tools in solving engineering problems.

**Contribution of course to meeting the professional component**
This course partially fulfills the requirement of 1½ years of engineering topics (engineering science and design) under professional component (Criterion 4) as required by ABET.

**Relationship of course to program objectives**
In this course, students learn how to apply knowledge of mathematics, science, and engineering to analyze and solve numerically problems encountered in chemical and biochemical engineering. The course gives the student the opportunity to analyze and interpret data, to identify, formulate, and solve engineering problems, and to use the techniques, skills, and modern engineering tools necessary for engineering practice. In addition, this course gives the student an understanding of professional and ethical responsibility

**Prerequisites**
440:127 Intro. to Computers for Engineering
155:201 Chemical Engineering Analysis I
640:244 Differential Equations for Engineering and Physics

**(A) Textbook (required for all students)**
A. Constantinides and N. Mostoufi, *Numerical Methods for Chemical Engineers with MATLAB Applications*, Prentice Hall PTR, Upper Saddle River, NJ, 1999.

Either (B) or (C) is required, depending on which category you will be in:

**(B) Software (required, if you will be using your own computer to do the homeworks)**
MATLAB Student Version with Simulink (Release 14), The Math Works.

**(C) Reference manual (required, if you do not own a computer and will be using Rutgers computers to do the homeworks)**
D. Hanselman & B. Littlefield, *Mastering MATLAB 7*, Prentice Hall PTR, Upper Saddle River, NJ, 2005.

**Numerical Methods software**
The textbook for this course contains a CD-ROM with Numerical Methods applications software written in the MATLAB language (for all three operating systems: Windows, Unix, and Macintosh). This software will be used in this course. Printing 1 of the textbook (published on 3/10/99) contained Version 1.00 of the software. Printing 2 and 3 contain version 2.00. Some modifications have been made to the software since printings 1 and 2. These changes are included in Version 3.00 of the software, which may be downloaded from the web page of the book:

http://sol.rutgers.edu/~constant

All students in this class who plan to use the Numerical Methods software on their own computers must download and install Version 3.00.

The students will be expected to become familiar with use of the MATLAB computing environment, the MATLAB language, and the Numerical Methods software. Most of the assigned homework in this course will require the writing of computer programs and/or the use of the Numerical Methods software for the solution of the problems.

MATLAB and the Numerical Methods software are installed on the computers in the Microlab of the Department (room C-233) and in the School of Engineering DSV Lab (rooms B-125/127) and EIT Lab (room D-110). If you have your own computer, you should purchase and install the MATLAB Student Version.

**Course outline**
The course will follow closely the contents of the text. The sections that have been marked with an asterisk (*) in the Contents of the book (pp. vii-xii) will not be covered this semester. A short introduction to MATLAB will be given at the beginning of the semester (Appendix A: Introduction to MATLAB and Mastering MATLAB 7). A week-by-week outline of the course is given on p.4 of this document.

**References and additional reading**
At the end of each chapter, there is a list of references pertaining to the particular topic of that chapter.

**Homework and grading policy**
Homework problems will be assigned, collected, and graded.
There will be one closed-book midterm examination and one closed-book final examination.
The course grade will be determined as follows:

| | |
|---|---|
| Class participation and attendance | 5% |
| Homework | 25% |
| Midterm exam | 25% |
| Final exam | 45% |
| | 100% |

Completion of assigned homeworks on time, and class participation and attendance are important. The instructor will read the class roster, periodically, to observe student attendance.

**Errata**
Corrections have been made to the text since the first printing of the book.
For your convenience, the list of errata for the 2nd and 3rd printings is attached to this outline.
If you own the 1st printing of the book, please obtain the errata list from our web site:

(http://sol.rutgers.edu/~constant)

**Please make these corrections to your copy of the textbook.**

## COURSE OUTLINE

| Week | Date | Topic | Chapter1 | Homework (due on dates shown)2 |
|---|---|---|---|---|
| 1 | Sept. 1 & 8 | Introduction to MATLAB, Algorithms, and Software | Appendix A, MATLAB text | |
| 2 | Sept. 12 | | | |
| | Sept. 15 | Solution of Nonlinear Equations | 1 | Homework #1: MATLAB Exercises |
| 3 | Sept. 19 | | | |
| | Sept. 22 | | | Homework #2: Newton-Raphson |
| 4 | Sept. 26 | Solution of Linear Algebraic Equations | 2 | Homework #3: Fanning Friction Factor |
| | Sept. 29 | | | 1.1, 1.2 1.4 |
| 5 | Oct. 3 | | | |
| | Oct. 6 | | | 2.1, 2.3 (a, b, c), 2.4 |
| 6 | Oct. 10 & 13 | Finite Difference Methods and Interpolation | 3 | |
| 7 | Oct. 17 | | | |
| | Oct. 20 | | | |
| 8 | Oct. 24 | | | 3.2, 3.3 |
| | Oct. 27 | Midterm Examination | Location: WL-AUD | |
| 9 | Oct. 31 | Midterm Examination Review | | |
| | Nov. 3 | Numerical Differentiation and Integration | 4 | |
| 10 | Nov. 7 | | | |
| | Nov. 10 | | | 4.1, 4.2, 4.3, 4.5, 4.8 |
| 11 | Nov. 14 & 17 | Solution of Ordinary Differential Equations | 5 | |
| 12 | Nov. 21 | | | |
| 13 | Nov. 28 | | | 5.3, 5.7, 5.8 |
| | Dec. 1 | Partial Differential Equations | 6 | |
| 14 | Dec. 5, & 8 | | | |
| 15 | Dec. 12 | | | Handout |
| | Dec. ?? | Final Examination 12:00 p.m. to 3:00 p.m. | Location: WL-AUD | |

1 The course will follow closely the contents of the text. The sections that have been marked with an asterisk (*) in the Contents of the book (pp. vii-xii) will not be covered this semester.

Additional homeworks may be assigned, as needed.

## Numerical Methods for Chemical Engineers with MATLAB Applications by Alkis Constantinides & Navid Mostoufi Prentice Hall PTR, 1999

These are the errata for the 2nd and 3rd printing of this book. Please make these corrections to your copy of the book.

| Page | Location | Correction |
|---|---|---|
| 50 | Line 13 | Change "TOL or TRACE" to "RHO or TOL" |
| 61 | Line 3 | Change "... water at 50°C ..." to "... water at 20°C..." |
| 62 | Line 4 | Change "Davidson, B. D." to "Davidson, B. Z." |
| 64 | Eq. (2.6) | Change " $V_i$ " to " $V_j$ " |
| 91 | Eq. (2.108) | Replace "$c_{ij}$" with "$c_i$" |
| 91 | Eq. (2.109) | Delete $\sum$ at the beginning of the equation |
| 122 | Line below Eq. (2.148) | Change "$(\mathbf{A}-\lambda\mathbf{x})$" to "$(\mathbf{A}-\lambda\mathbf{I})$" |
| 122 | Eq. (2.152) | Change " $-a_n$" to " $-a_n\mathbf{I}$ " |
| 147 | Eq. (3.14) | Change " $(h^3/3!)Dy(x)$ " to " $(h^3/3!)D^3y(x)$ " |
| 156 | Eq. (3.68) | Change " $\delta_{i+1}$ " to " $\delta y_{i+1}$ " |
| 157 | Eq. (3.70) | Change " $-y_{i-1/2}$ " to " $-10y_{i-1/2}$ " |
| 179 | Eq. (3.133) | Change " $p_k(x)$ " to " $p_k(x_i)$ " |
| 182 | Eq. (3.145) | Change " $y'_{i-1}$ " to " $y'_{i+1}$ " |
| 215 | After line 20 | Add: "options = optimset;" |
| 215 | Line 21 | Replace "phi = fzero(phifile,1,[ ], [ ], x0)" with "phi = fzero(phifile, 1, options, x0);" |
| 217 | Line 9 | Remove the command "break" |
| 222 | Line 16 | Change " (-dp-0*rhog*g) " to " (-dp-rhog*g) " |
| 222 | Lines 4-5 in deriv.m | Replace with:<br>% DERIV(Y) calculates the first-order derivative<br>% of each column of matrix Y by central finite<br>% differences,using unity as the independent<br>% variable interval. If Y is a row vector, then Y<br>% is converted to a column vector. |
| 223 | Line 26 | Change "(err ~= 2 \| err ~= 4)" to "(err = = 2 \| err = = 4)" |
| 227 | Line 12 | Change "... = 3.26% " to "... = 3.21% " |
| 231 | Figure 4.2 | Change the labels on the horizontal axis from " $x_1$ $x_0$ " to " $x_0$ $x_1$ " |
| 235 | Eq. (4.83) | Change upper limit on the two integrals from " $x_2$ " to " $x_3$ " |
| 243 | Eq. (4.93) | Move this equation one line down (below the line "For converting to ....") |
| 243 | Eq. (4.92) | This equation is missing:<br>$(x - a)/(b - a) = (z - c)/(d - c)$<br>Add it in the place previously occupied by Eq. (4.93): |

| | | |
|---|---|---|
| 251 | Middle of page | Delete " Initial value of " |
| 271 | Bottom line | Change " = $dy_3$ /dt " to " = $dy_3$ /dx " |
| 279 | Lines 5,6 | Enter " method =1; " between lines 5 and 6 |
| 279 | Line 12 | Delete " method =1; " at line 12 |
| 283 | Line 3 (bottom of page) | Change "The vector of dependent variable" to "The vector of independent variable" |
| 294 | Eq. (5.96) | Last term is " $9f(x_{i-3}, y_{i-3})]$ " |
| 294 | Eq. (5.97) | Last term is " $f(x_{i-2}, y_{i-2})]$ " |
| 295 | Line 3 | Change "value" to "values" |
| 301 | Line 6 | Change "F(X,P1,P2,...)" to "F(X,Y,P1,P2,...)" |
| 301 | Line 2 (bottom of page) | Change "F(X,P1,P2,...)" to "F(X,Y,P1,P2,...)" |
| 302 | Line 4 (bottom of page) | Change "F(X,P1,P2,...)" to "F(X,Y,P1,P2,...)" |
| 304 | Line 12 in Adams.m | Change "F(X,P1,P2,...)" to "F(X,Y,P1,P2,...)" |
| 305 | Line 13 in AdamsMoulton.m | Change "F(X,P1,P2,...)" to "F(X,Y,P1,P2,...)" |
| 314 | Line 1 (bottom of page) | Change "$t_1$=4.36" to "$t_1$=4.36e-2" |
| 315 | Eq. (2) | The term $\left(\frac{d\Phi}{d\eta}\right)$ in the denominator should be raised to the power of 2. |
| 315 | Eq. (3) | The term $y_1$ in the denominator should be raised to the power of 2. |
| 317 | Line 17 (bottom of page) | Change "Inside diameter" to "Inside radius" |
| 317 | Line 4 (bottom of page) | Change "/vmax" to "/vstar" |
| 318 | Line 13 | Change "lambda^2*y(1)" to "lambda^2*y(1)^2" |
| 320 | Middle of page | Change "Inside diameter" to "Inside radius" |
| 320 | Bottom of page | Change "Volumetric flow rate = 2.91" to "Volumetric flow rate = 8.00" |
| 320 | Line 2 (Discussion of Results) | Change "2.91 L/s" to "8.00 L/s" |
| 321 | Figure E5.4b | Has changed because of the above changes to the program. |
| 328 | Eq. (5.151a & b) | Change "j=0" to "i=0" under the summation signs |
| 334 | Line 4 (bottom of page) | Add: "options = optimset;" |
| 334 | Line 3 (bottom of page) | Replace "theta(k) = fzero(fth,30,1e-6,0, y(:,k),w)" with "theta(k) = fzero(fth,30,options, y(:,k),w)";" |
| 335 | Line 22 | Add: "options = optimset;" |
| 334-335 | | Example5_5.m and Ex5_5_func.m have changed. Please download the updated software and re-install. |
| 335 | Line 23 | Replace "theta = fzero(fth,30,1e-6,0, y,w)" with "theta = fzero(fth,30,options, y,w)";" |
| 345 | Middle of page | Change "implicit Euler" to "explicit Euler" |

| | | |
|---|---|---|
| | (above Eq. (5.189)) | |
| 350 | Eq. (5.223) | Change "$y_{n+2}$" to "$y_{n+1}$" on the left-hand-side |
| 356 | Line 1 (bottom of page) | Delete ".1" |
| 357 | Problem 5.7 Line 2 | Change "Lokta" to "Lotka" |
| 383 | Part (b) | Change the partial derivative in the 4th boundary condition to be with respect to y (not x) |
| 385-393 | | Example6_1.m and elliptic.m have been changed. Please go to http://sol.rutgers.edu/~constant to obtain software updates. |
| 407 | Line 10 | Change " DY = " to " DT = " |
| 413-416 | | Example6_3.m has been changed. Please go to http://sol.rutgers.edu/~constant to obtain software updates. |
| 416 | Line 15 from bottom | Change " by Crank-Nicolson implicit " to " by explicit (6.66) " |
| 469 | Line 1 | Change "in independent" to "is independent" |
| 477 | Eq. (7.114) | Move equation down one line (below the first line of item 2.) |
| 508 | Line 10 | Change " independent " to " dependent " (Note: The MATLAB script, Example7_1.m, should also be modified. You may make the change yourself or download the updated software from http://sol.rutgers.edu/~constant and re-install. |

**RUTGERS UNIVERSITY**
**Department of Chemical and Biochemical Engineering**

**155:324 DESIGN OF SEPARATION PROCESSES** **SPRING 2006**


| | | |
|---|---|---|
| Professor: | Dr. A. Constantinides (Dr. C) | Assistant: Hong Yang |
| Room: | SOE C-203A | SOE C-156 |
| e-mail: | constant@soemail.rutgers.edu | hongya@eden.rutgers.edu |
| Telephone: | 732-445-3678 | 732-445-7061 |


Class time: Monday & Thursday 10:20 to 11:40 a.m. Class location: WL-AUD

**TEXTBOOK (required)**

P. C. Wankat, Separations in Chemical Engineering: Equilibrium Staged Operations, Prentice Hall, New York, NY (1988).

**TEXTBOOK (recommended)**

J. D. Seader and E. J. Henley, Separation Process Principles, $2^{nd}$ ed., John Wiley & Sons, Inc., (2006).

## SOFTWARE

Interactive Computer Modules for IBM-PC: Separations. These modules are on all the personal computers in the Microcomputer Laboratory of the Department (room C233). To access the modules, log in to one of the computers and double click on the "Shortcut to MODULES" icon on the desktop. This will open the folder C:\Modules. Double click on the BAT file that has the name of the module you want to execute, and follow instructions on the screen. The four modules which are relevant to this course are:

| | |
|---|---|
| BASIS: | Introduction to separation processes. |
| MCCABE: | Binary distillation. |
| CASCADES: | Liquid-liquid extraction. |
| ABSORP: | Absorption tower design. |

These modules will be assigned during the semester. Students will be given further instructions on the assignment, and on how to access these programs.

CHEMCAD: This is a steady-state process simulator for chemical engineering design. This program performs material and energy balances, calculates sizes and estimates costs of equipment, and draws process flow diagrams. It has an extensive thermodynamic property data base. It is installed on all computers in the Microcomputer Laboratory (room C-233), in the EIT Laboratory (room D-110), and the DSV Laboratory (room B-127). To access this program, log in to one of the computers and execute the program from the CHEMCAD icon (or from Start/Programs/ CHEMCAD/CHEMCAD).

It is also possible for you to obtain a copy of CHEMCAD that you may install on your own computer. A procedure for doing this will be provided to you later.

## REFERENCES AND ADDITIONAL READING

C. J. Geankoplis, Transport Processes and Separation Process Principles, Prentice Hall, Upper Saddle River, NJ (2003).

R. E. Treybal, Mass-Transfer Operations, 3rd Edition, McGraw-Hill Book Company, New York (1980).

## HOMEWORK AND GRADING POLICY

Homework problems will be assigned, collected, and graded. There will be one midterm exam, and a design project. No final examination. The course grade will be determined as follows:

| | |
|---|---|
| Homework | 33.3% |
| Midterm examination | 33.3% |
| Design project | 33.3% |
| | 100.0% |

Class participation and attendance are important. The professor will read the class roster, periodically, to observe student attendance.

## ERRATA OF TEXTBOOK

Page 4 of this document is a partial list of errata for your textbook: P. C. Wankat, Separations in Chemical Engineering: Equilibrium Staged Operations. Your copy of the book may not have all these errors, depending on which printing of the book you own. Please make whatever corrections are applicable to your copy of the book. If you find any other errors in the textbook, please bring them to my attention.

## COURSE OUTLINE

The course will follow closely the contents of the text. Some chapters will not be covered. Additional material will be distributed as handouts. A week-by-week schedule of the course, showing topics and reading assignments, is on p. 3.

# COURSE SCHEDULE

| Week | Topic | Reading |
|---|---|---|
| 1, 2 | Introduction:<br>General discussion of separation processes<br>Review of vapor-liquid equilibria<br>Bubble-point and dew-point calculations | Chapters 1, 2 |
| 2, 3 | Single-stage distillation:<br>Boilers<br>Flash distillation<br>Sizing flash drums<br>Introduction to CHEMCAD | Chapter 3<br><br><br>Handouts |
| 4 | Multistage distillation:<br>Cascades<br>Towers | Chapter 4 |
| 4, 5 | Binary systems:<br>McCabe-Thiele method<br>Shortcut methods using CHEMCAD | Chapters 5, 6 |
| 6, 7 | Multicomponent systems:<br>Short-cut methods (Fenske/Underwood/Gilliland)<br>Rigorous methods (Holland's theta,<br>Lewis-Matheson, Thiele-Geddes)<br>Rigorous methods using CHEMCAD | Chapters 7, 8, 9 |
| 8 | Midterm examination | |
| 9 | Staged column design<br>Design Project assignment | Chapter 12<br>Handouts |
| 10, 11 | Mass transfer analysis for packed columns | Chapter 19 |
| 12 | Absorption and stripping | Chapter 15 |
| 13 | Liquid-liquid extraction | Chapters 16, 18 |
| 14 | Packed column design | Chapter 13 |
| | Design project due on day of scheduled final exam | |

# EQUILIBRIUM STAGED SEPARATIONS by P. C. Wankat

## PARTIAL LIST OF ERRATA

| Page | Paragraph | Line | Correction |
|---|---|---|---|
| 26 | Table 2-4 | 15 | n-Nonane -255,104 is wrong (probably -2,551,040) |
| 29 | 3 | 8 | procedure |
| 57 | last equation | 3(bottom) | $\frac{(0.3-1)(0.45)}{1+(0.3-1)(0.1)}$ |
| 58 | 2 | 6(bottom) | = -4.631 |
| 59 | 2 | 4 | $y_1 = \ldots = (0.7)(0.0739)$ |
| 63 | 3 | 6 | Note that |
| 68 | 4 | 4 | minimum cross sectional area |
| 73 | Eq. 5 | 1 | $V(MW_V)$ |
| 73 | Eq. 5 | 4 | $mL/ft^3$ |
| 81 | D12 | 3 | ethylene, 0.05 |
| 102 | | 6(bottom) | and then Eq. (4-3) |
| 104 | D | 3 | = 6670 kg/hr |
| 119 | 1 | 1 | liquid leaving the stage |
| 155 | 1 | 7 | Problems 3-D5 |
| 155 | E2 | 10 | Problem 3-D5 |
| 165 | Figure 6-4 | | $z_2 = 0.4$ |
| 216 | Figure 7-1 | | $Q_R$ (at reboiler) |
| 219 | figure | | $z_{C5} = 0.482$ |
| 221 | 1 | 6 | from Eqs. (7-5b), |
| 234 | 1 | 5 | $\overline{V} = V - (1 - q)F$ |
| 246 | D | 2 | $K_{C4} = 2.87$ |
| 247 | Stage 2 | 4 | $x_{C5,2} = 0.225$ |
| 281 | Figure 9-2 | | $y_{i,j+1}$ |
| 313 | Figure 10-5 | | is partially miscible |
| 421 | Figure 13-4 | | $G'^2$... (on vertical scale) |
| 421 | Figure 13-4 | | L'/G'... (on horizontal scale) |
| 479 | Figure 15-3 | | Horizontal scale should be:<br>0 .0002 .0006 .0010 .0014 |
| 483 | Figure 15-5 | | $X_0$ (not $X_D$ ) |
| 486 | 1 | 8 | Figure 15-3 for absorbers and like Figure 15-5 for strippers |
| 502 | 2 | 2 | noxious chemicals |

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# 155:409:*Chemical Systems Safety and Health Engineering Management*
# Fall 2005

**Place, Time, Day, Credits:** SEC-210, Second Period: 10:20 A.M. – 11:40 A.M.; Wednesday; 1.5 credits (80 minutes per week).

**Instructor:** Prof. Burton Z. Davidson, P.E.
School of Engineering Building, Room C-232, Busch Campus
Phone: 445-2203 or 445-2228 (Undergraduate Assistant, Lynn DeCaprio)
E-Mail: burtond@soemail.rutgers.edu

## Course Description:

Prerequisite or co-requisite is 14:155:441 or permission of instructor.

The course covers modern principles and practices of chemical systems analyses of engineering safety and health problems in the industrial, government and public sectors of society. Emphases are on engineering management duties and responsibilities, particularly as related to codes and standards of OSHA, EPA, the Consumer Product Safety Commission, ANSI, ASTM, DOT, NFPA, The National Electric Code, etc. Cognate examples of documented case studies of chemical safety and health mishaps will be presented, including legal aspects of engineering design negligence and methods of accident prevention. The course encompasses both product and process safety engineering concepts and practices.

## Learning Objectives

Upon completion of this course, students should:

- Be cognizant of the extra burden and responsibility to protect chemical plants and chemicals in storage and transportation from post 9/11/01 dangers.
- Understand the hazards of chemical substances and be able to characterize the hazards of any given material and combinations of materials.
- Be aware of the hazards posed by various products and unit operations and be able to specify necessary engineering control measures for each of these hazards.

- Be able to recognize human error possibilities inherent in process unit operations and maintenance and handling of materials.
- Be able to utilize appropriate analytical techniques to identify hazards in the design and operation of chemical process systems, like HAZOP techniques.
- Be able to utilize the voluntary and government mandatory health and safety standards which govern chemical products and process systems (e.g. OSHA, ANSI, NFPA, D.O.T., EPA, etc.)
- Be able to utilize Risk Assessment Methodology to the extent that various chemical process and product risks can be quantified and this information used in the risk decision making.
- Be able to apply occupational hazard control measures such as ventilation, materials substitution, process modification, process enclosure, wet methods, and warnings-and-instructions.
- Be able to apply Process Safety Management (PSM) concepts to yourself in the laboratories, and elsewhere, and become familiar with MCA's principles of **responsible care** and **product stewardship**.
- Be able to use the appropriate reference sources to locate safety information on chemicals and chemical processes.
- Be thoroughly cognizant of ethical responsibilities to protect employees, the environment, and the public through safe design, operation, maintenance, and commissioning of chemical processes, facilities, and products.

## Textbooks:

### Required

*Chemical Process Safety: Fundamentals with Applications*
by D. A. Crowl and J. F. Louvar, Prentice-Hall, second edition, 2002.

### Useful Companion Reference Materials

*Occupational Safety Management and Engineering*
By Willie Hammer, Prentice-Hall, Third Edition, 1985.

*Industrial Safety and Health Management*
By C. Ray Asfahl, Prentice-Hall, 1984.

*Product Safety Management and Engineering*
By Willie Hammer, Prentice-Hall, 1980.

*Handbook of Chemical Industry Labeling*
By O'Connor and Lirtzman, Noyes, 1984

*Dangerous Properties of Industrial Materials*
By N.I. Sax, Van Nostrand-Reinhold Co., Sixth Edition, 1984.

*Fire Protection Guide on Hazardous Materials*
NFPA, Seventh Edition, Sixth Printing, 1983.

*Industrial Hygiene Aspects of Plant Operations: Volumes I and II*
By Cralley and Cralley, MacMillian & Co., 1982.

*Accidental Explosions: Volumes I and II*
By L.A. Medard, Ellis Horwood, Ltd., Halstead Press, 1989.

*Accident and Emergency Management*
By L. Theodore, J.P. Reynolds, and F.B. Taylor, Wiley, 1989.

*What Went Wrong – Case Histories of Process Plant Disasters*
By T.A. Kletz, Gulf, Second Edition, 1988.

*Major Industrial Hazards*
By J. Withers, Halsted Press, 1988.

*Fire Protection Handbook*
By A.E. Cote and J.L. Linville, NFPA, Tenth Edition, 1986.

*Human Factors in Engineering and Design*
By M.S. Sanders and E.J. McCormick, McGraw-Hill, Sixth Edition, 1987.

*Products Liability, Design and Manufacturing Defects*
By L. Bass, McGraw-Hill, 1986.

*The Sigma-Aldrich Library of Regulatory and Safety Data: Volumes I, II, and III*
Milwaukee, WI, 1993.

*29 CFR 1910*
OSHA, particulary sections 1910.119, 1910.1200, and 1910.1450.

*Department's Guidelines for Laboratory Health & Safety, Fall 2005 Edition.V.*

## Course Outline

| Weeks | Topics |
|---|---|
| 1, 2, 3 | Overview; Principles of Chemical Systems Safety and Health Engineering Management (duties, responsibilities, ethics, fault-tree analysis, utility-risk assessment, HAZOP, warnings-and-instructions, legal aspects, etc.); Review of OSHA 29 CFR 1910. (Homework will be assigned in class). |
| 4, 5, 6 | Dangerous properties of engineering materials (e.g., toxicity, flammability, explosivity, and environmental impact). (Homework will be assigned in class). |
| 7, 8, 9 | Dangerous properties of products and processes (human factors, exothermicity, transients, fail-unsafe and fail-safe modes, etc.). (Homework will be assigned in class). **Midterm Examination.** |
| 10, 11 | Introduction to government and industry codes and standards for products and processes (OSHA, EPA, ASTM, UL, ANSI, D.O.T., CPSC, etc.). (Homework will be assigned in class). |
| 12, 13, 14 | Case histories of product-process safety mishaps in the real world (e.g., asbestos, PVCR-VCM, deflagrations with flammable vapors and dusts, chemical reactor explosions, etc.). |
| 15 | **Final Examination.** |

## Grading Policy

| | |
|---|---|
| Class Attendance | 10% |
| Graded Homework | 20% |
| Midterm Examination | 30% |
| Final Examination | 40% |
| | 100% |

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# 155:411: *Introduction to Biochemical Engineering*

Fall 2005

**Instructor:** Shaw S. Wang
Office C-226
445-3360
shaww@sol.rutgers.edu

**Meeting/Credits:** M,W 5th period (3:20-4:40pm)
C-115
3 credits

**Textbook:** *Bioprocess Engineering: Basic Concepts* by Shuler & Kargi
2nd edition, 2002, Prentice Hall

| Week | Topic |
|---|---|
| 1 | Introduction: Does Biochemical Engineering include tissue engineering and controlled drug release? |
| 2 | The basics of biology: an engineer's perspective. Do cells have membranes? |
| 3 | Enzymes: are all enzymes protein in nature? Chiral drugs manufacturing. |
| 4 | How cells work: are biochemical engineers interested in tissues and organs, in addition to cells? |
| 5 | Major metabolic pathways: where do genomics, proteomics and bioinformatics fit into this? |
| 6 | How cells grow: application of chemical engineering kinetics and reactor design to a biological system. Are we interested in how to grow tissues and organs also? |
| 7 | Stoichiometry of microbial growth and product formation: application of the first principle in chemical engineering, "mass balances." |
| **8** | **Midterm Exam** |
| 9 | Operating considerations for bioreactors for suspension and immobilized cultures. |
| 10 | Selection, scale-up, operation and control of bioreactors. |
| 11 | How cellular information is altered: the new biotechnology. |
| 12 | Utilizing genetically engineered organisms. |
| 13 | Animal cell and plant cell cultures. |
| 14 | Tissue engineering, stem cells and therapeutic cloning, bio-nanotechnology and bio-chips. |
| **15** | **Final Exam** |

**Grading:**

| | |
|---|---|
| Homework | 20% |
| Midterm Exam | 30% |
| Final Exam | 30% |
| In-class performances (Q&A and quiz) | 20% |

155:415 Process Engineering Laboratory



# General Information



## Fall 2005

The chemical and biochemical engineering process laboratory is a two-semester course that provides an introduction to various unit operations that are characteristic of the chemical and biochemical process industries. The course includes a one hour recitation section and an extended time period that allows for hands-on operation in a modern pilot-scale setting.

As an instructional laboratory, research projects are not envisioned. Instead, the laboratory introduces new perspectives on material learned or first seen in the classroom as well as an opportunity to become familiar with those things that practicing engineers are expected to know.

### Course Requirements

Students work in groups of 3-4 carrying out two of the eight experiments each semester. The groups change each semester and the experimental plan is guided by a group-initiated specification of objectives. Experimental planning and design, analysis of results, presentations (both oral and poster), adherence to safety protocols and guidelines that includes satifying all REHS requirements, and active participation in the laboartory exercises are required of all students. Grades are based on the group's performance.

### Course Objectives

Feisel and Rosa (2005; J. Eng. Educ., 94:121) have recently presented a summary of rational laboratory objectives for engineering based on a workshop involving some 50 engineering educators. We have adopted these with some modification here. In particular, by completing the laboratory, students will be able to (1) apply appropriate sensors, instrumentation and software tools to measurements of physical quantities; (2) identify strengths and limitations of theoretical models as predictors of real-world behaviors; (3) devise an experimental approach to meet self-defined objectives and interpret the experimental data to characterize the system and assess relevant physico-chemical parameters; (4) demonstrate the ability to collect, analyze and interpret data, and to form and support conclusions. Make order of magnitude udgements and use appropriate units and their conversions; (5) devlop SOPs and P&IDs for the supporting equipment and procedures; (6) propose solutions to unsuccessful outcomes; (7) demonstrate creativity and sound judgement; (8) identify health and safety concerns and follow all requirements related to safe and responsible laboratory practice; (9) communicate effectively about the work in writing and in oral presentations; (10) work effectively in the team structure and meet deadlines, monitor progress and integrate individual contributions into a coherent outcome; and (11) behave ethically and interact with integrity.

**Pipe Flow** **Liquid-Liquid Extraction**

This experiment utilizes an array of pipes, valves and fittings to demostrate head loss relationships in the context of the Bernoulli equation.

Friction factor calculations (Excel with macros)

**Gas Absorption**

This experiment uses a custom-built packed column to absorb carbon dioxide from a gas (air) phase into water in a counter-current arrangement.

Henry's law information, CO2/water
Fyrite analyzer manual

**Wiped Film Evaporator**

Operation of a wiped-film evaporator is carried out to demonstrate methods for concentrating labile, viscous solutions. Sugar/water mixtures are used.

vacuum pump manual

A butanol-water system is
in an agitated, counter-cu
driven pumps and pneum
regulate flows of various i

Acetic acid analysis by titi
Phase diagram overview;

**Fermentation**

The growth of a recombin
synthesizing a green fluor
investigated from molecu
scale fermentation.

GFP transformation proto

**Level Control**

A two-tank level control e
demonstrate control strat
levels in tanks. Pressure-
acquisition with process c

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**155: 422** **Process Simulation and Control** **Spring 2006**

Web page: http://sakai.rutgers.edu
Lectures: Mon, Wed 2:50-4:10pm, SEC 209
Instructor: Henrik Pedersen: 5-2568, email: hpederse@rutgers
Engineering C-226, by arrangement
Teaching Assistant: Natalia Rodriguez-Pinto, Office hours: Tue 4-5:30pm, Thu 4-5pm
email: rodrinat@eden.rutgers.edu, Office Rm #: C138

**Course Description**: The course is an introductory presentation of the basic principles of automatic process control. Applications to processes of general interest to chemical engineers are emphasized. Elements of mathematical simulation of process dynamics for open-and-closed loop operations are presented for both linear and non-linear systems. Concepts of feedback, feedforward, and cascade control of processes using popular control algorithms are covered, including aspects of stability, controller tuning, and safety.

**Course Objectives**: Equip the student with necessary fundamental control theory tools in order to answer questions of the following type:

- Why is automated process control necessary and how is it done?
- What are the differences between "open" and "closed" loop system dynamics?
- What are the elements of a "closed-loop" automated control system?
- When, where, and why does a closed loop automated control system become unstable and how can a control engineer correct instability?

**Textbook**: ***Process Dynamics and Control, 2nd Edition***
Dale E. Seborg, Thomas F. Edgar, and Duncan A. Mellichamp
Published by John Wiley & Sons, 2004.

**Software**: *Matlab/Simulink*: This is an interactive environment for system simulation and design. Utilizing a block diagram interface, it can be used to model, simulate, and analyze systems described by differential and algebraic equations for process control and to understand system dynamics. It is installed on all PCs in the Microcomputer Lab (room C233). *MAPLE* can also be used for many of these problems. *EXCEL* may also be useful.

**Class Participation**: Students are expected to participate in classroom discussions and in interactive sessions with their fellow classmates. This does not include *completion* of assignments (although discussion of assignments is appropriate) and exams, of course. The student honor code is expected to be followed.

**Assessment**: Homework*: 20%*, Exams*: 80% (20:20:40-mid1:mid2:final)*

**Course Content**

| Week | Date | Topic | Chapter |
|---|---|---|---|
| 1 | Jan. 18 | Course Organization-Introduction to Process Control | 1 |
| 2 | Jan. 23 | Introduction to Process Dynamics and Simulations | 2 |
| | Jan. 25 | Introduction to Process Dynamics and Simulations (Simulink, MATLAB, Maple) | 2 |
| 3 | Jan. 30 | Laplace Transforms | 3 |
| | Feb. 1 | Laplace Transforms | 3 |
| 4 | Feb. 6 | Transfer Functions and State Space Models | 4 |
| | Feb. 8 | Transfer Functions and State Space Models | 4 |
| 5 | Feb. 13 | Dynamic Response of First and Second Order Systems | 5 |
| | Feb. 15 | Dynamic Response of First and Second Order Systems | 5 |
| **6** | **Feb. 20** | **First Exam** | |
| | Feb. 22 | Dynamic Response of More Complicated Processes | 6 |
| 7 | Feb. 27 | Model Reduction | 6 |
| | Mar. 1 | Empirical Models, Process Identification | 7 |
| 8 | Mar. 6 | Discrete Time Dynamic Models | 7 |
| | Mar. 8 | Feedback Controllers | 8 |
| **9** | **Mar. 13,15** | **Spring Break** | |
| 10 | Mar. 20 | Control System Instrumentation and Design | 9,10 |
| | Mar. 22 | Closed Loop Control Systems | 11 |
| 11 | Mar. 27 | Closed Loop Control Systems | 11 |
| | Mar. 29 | PID Controller Design | 12 |
| **12** | **Apr. 3** | **Second Exam** | |
| | Apr. 5 | Direct synthesis, IMC, Tuning models | 12 |
| 13 | Apr. 10 | Feedforward Control | 15 |
| | Apr. 12 | Lead-lag Systems | 15 |
| 14 | Apr. 17 | Enhanced Single Loop Control Strategies | 16 |
| | Apr. 19 | Digital Sampling, Z-transforms | 17.1-3 |
| 15 | Apr. 24 | Multiloop and Multivariable Control | 18.1-2 |
| | Apr. 26 | Examples, Review | |
| **16** | **May. 1** | **Review** | |

*14:155:427/428 Chemical and Biochemical Engineering Design & Economics I and II*

**Instructors:**

September 1 – October 19, 2005 – Dr. Shaw S. Wang (Office: C-226)
October 24 – December 12, 2005 – Dr. Alkis Constantinides (Office: C-203A)
January 18 – March 8 , 2006 – Dr. Alkis Constantinides
March 22 – May 1, 2006 – Dr. Shaw S. Wang

**Teaching Assistant:**

Jeng-Shiou Chen
Office: SOE C-120, e-mail: jengshiou@hotmail.com, tel. # 732-445-5057

**Class Time and Place:**

Mondays and Wednesdays, 1:40 – 3:00 pm, SEC. room 207

**Contribution of course to meeting the professional component:**

This course partially fulfills the requirement of one and one-half years of engineering topics (engineering science and design) under professional component (Criterion 4) as required by ABET.

**Course Description:**

Chemical and Biochemical Engineering Design & Economics is a two-semester course (155:427, and 428) that covers the principles of product design, process design, and economic considerations for building and operating chemical or biochemical plants. Reflecting recent advances in chemical engineering education, we are integrating product design and process design in this sequence of capstone courses. Specifically, starting from identifications of marketable products, we proceed to develop ideas of making the products, select workable methods and then design the best processes for both up-stream (reactor design and batch, semi-batch, or continuous operation) and down-stream processing (separations and purifications) to produce the said product profitably.

The material of the two courses, 427 and 428, is divided into three parts:

**Part One**, the first seven weeks of 427 (Sept. 1 – Oct. 19, 2005), covers the rate-based separation methods, (equilibrium based separations were covered in 155:324) such as sedimentation, centrifugation, membrane separations, and various chromatographic methods. These methods are used for biochemical and specialty chemical separations and purifications.

**Part Two** covers the design and economics of production of bulk chemicals or petrochemicals. The second half of 427 (Oct 24 – Dec. 12, 2005), and the first half of 428 (Jan. 18 – March 8, 2006), will be devoted to this part of the course.

Its specific objectives are:

- Chemical engineering fundamentals, i.e., material and energy balances, transport phenomena, thermodynamics, kinetics, separations, unit operations, control and safety, are integrated into the design and operation of chemical plants.
- Introduces the concepts and methods of plant design and economic evaluation: planning, cost estimation, fixed capital investments, working capital, production costs, depreciation, rate of return, profitability analysis, discounted cash flow analysis.
- Raises awareness of the students to the concepts of supply and demand of raw materials, commodity and specialty chemicals.
- Introduces the students to the available computational tools for process flow design and economic evaluation.
- Stresses the importance of professional ethics, honesty and integrity.

**Part Three** of this course (Mar 22 – May 1, 2006) covers the design of batch processes that are used for the production of specialty chemicals. Here, the same chemical engineering fundamentals are integrated in the design and operations of chemical and biochemical plants to produce specialty chemicals and biochemicals in batch processes. Topics include batch process design, scheduling, and batch-process simulations. The principles of product design, i.e., marketability, idea generations, selections of ideas and designs of up-stream and downstream processing to produce the products, are stressed.

**Design Projects:**

There will be two design projects in this sequence of courses. The first project will be the design, cost estimation, and profitability analysis of a complete chemical process plant. The second project will involve the design of a product by utilizing the general principles of product design (marketability, generations of ideas, selections of ideas, and design of a process based on the selected idea to make the product). These projects will be described later in the course.

For these projects, students will be placed in groups of three to work jointly, including the final design reports. Each group must select a group leader who will be responsible in coordinating the work of the group, meeting deadlines, and producing deliverables. The following are critical to your success in this course:

1. <u>Begin early:</u> The case study is very time-consuming with no room for procrastination.

2. <u>Attend all lectures:</u> Assignments will be handed out at lectures with full discussion of the current problem at that time. If you miss the discussion, you may have difficulty with the assignment.

3. <u>Cooperate with partners:</u> Share the load, but understand that all partners need to know all the design material. If you find inter-personal problems hindering the teamwork, bring them to the attention of the professors immediately. Do not wait until the end of the semester.

4. <u>Use every resource:</u> Utilize the textbook, the handouts, the library, the computer, and the professor as sources of information for this project.

5. <u>Complete assignments thoroughly and timely:</u> Several assignments will be completed during the design projects. These assignments will be collected and graded.

**Required Textbooks (427 and 428):**

R. G. Harrison, P. W. Todd, S. R. Rudge, and D. Petrides, Bioseparations Science and Engineering, Oxford University Press US, New York (2003).

M.S. Peters, K.D. Timmerhaus, and R.N. West. Plant Design and Economics for Chemical Engineers, 5th. Edition, McGraw-Hill Book Company, New York (2003) (Referenced below as P, T, & W).

**Recommnended (but not required) Textbooks:**

W. D. Seider, J. D. Seader, and D. R. Lewin, Product and Process Design Principles. John Wiley and Sons, New York (2004).

E. L. Cussler and G. D. Moggridge, Chemical Product Design, Cambridge University Press, Cambridge, UK (2001).

**Pre-requisites:**

155:324 Design of Separation Processes

155:441 Chemical Engineering Kinetics (concurrent)

**Course Outline – Part One (Sept 1- Oct. 19, 2005 – 7 weeks):**

| Week | Subject | Reading Assignment |
|---|---|---|
| 1 | Product and process design<br>Overview | Handout I<br>Ch. 1, HW I (H.T.R.P)* |
| 2 | Comparison of rate-based versus<br>equilibrium-based separations<br>and bioseparations | Handout II<br>Ch. 2 and 6 HW II (H.T.R.P)* |
| 3 | Filtration<br>Conventional filtration<br>Membrane filtration (UF, MF, RO)<br>Scale-up and design | Ch. 4, HW III (H.T.R.P)* |
| 4 | Sedimentation<br>Equation of motion<br>Production centrifuges<br>Ultracentrifugation<br>Inclined sedimentation<br>Scale up criteria | Ch. 5, HW IV (H.T.R.P)* |
| 5 & 6 | Liquid Chromatography and Adsorption<br>Adsorption column dynamics<br>Chromatography column dynamics<br>Equipment and scale up | Ch. 7, HW V (H.T.R.P)* |
| 7 | Review and mid-term exam | |

**Course Outline – Part Two (Oct. 24 – Dec. 12, 2005. Weeks 8 – 14)**
**(Jan. 18 – March 8, 2006. Weeks 15 – 22):**

| Week | Subject | Reading Assignment |
|---|---|---|
| 8 | Introduction to plant design and economic evaluation | Ch. 1 (P, T & W) |
| | General design considerations | Ch. 2 (P, T & W) |
| | Start of plant design project | Handouts and References |
| | Definition of project | |
| | Engineering ethics | Handout |
| 9 | Process design development | Ch. 3 (P, T & W) |
| | Plant design project | Handouts and References |
| | Establishment of design basis | |
| | Physical properties needed | |
| 10 | Reactor design | Handouts and References |
| | Cracking ethane to produce ethylene | |
| | Derivation of reactor model | |
| | Discussion of reactor conditions | |
| | Discussion of reactor limitations | |
| | Simulation of reactor model | |
| 11 | Computer-aided design | Ch. 5 (P, T, & W) |
| | Essential flow diagram | Handouts |
| | Block flow diagrams (BFD) | |
| | Process flow diagrams (PFD) | |
| | Piping and instrumentation diagrams (P & ID) | |
| | Equipment descriptions and standard notation | |
| 12 | General Design Factors and Specifications | Handouts |
| | Rules of thumb in design | |
| | Materials of construction (Guest speaker) | Ch. 10 (P, T & W) |
| 13-14 | Design and Cost Estimating | |
| | Materials handling equipment (pumps, compressors) | Ch. 12 (P,T & W)<br>Handouts |
| | Heat transfer equipment (heat exchangers) | Ch. 14 (P, T & W)<br>Handouts |
| | Liquid-vapor separators (flash drums) | Wankat, pp 68-70<br>Handouts |
| 15 | Analysis of cost estimation | Ch. 6 (P, T & W) |
| | Cash flow | |
| | Capital investments | |
| | Fixed capital and working capital | |
| | Types of capital cost estimates | |

| | | |
|---|---|---|
| | Direct and indirect costs<br>Cost indices; Cost scaling factors<br>Ratio factors | |
| 16 | Production Costs<br>Raw materials; Utilities; Operation costs<br>Overhead expenses; Fixed charges<br>Administrative and marketing expenses | Ch. 6 (P, T & W) |
| 17 | Interest and Investment Costs<br>Simple, compound, continuous interest<br>Present worth, future worth | Ch. 7 (P,T & W) |
| | Taxes and Insurance | Ch. 7 (P,T & W) |
| | Depreciation Methods<br>Straight-line method and declining-balance<br>Method | Ch. 7 (P, T & W) |
| 18 | Profitability Analysis<br>Rate of return on investment<br>Discounted cash flow rate of return<br>Net present worth<br>Payout period | Ch. 8 (P, T & W) |
| 19 | Introduction to CHEMCOST<br>Problem assignment to use CHEMCOST | Manual and notes |
| 20 | Design and Cost Estimating | |
| | Refrigeration systems | Thermodynamics book and References |
| | Mass transfer and reactor equipment | Ch. 16 (P, T & W)<br>Handouts |
| 21 | Safety in Design<br>Process Plant Layout | Handouts |
| 22 | The Design Report<br>Contents; flow diagrams; equipment lists<br>Investment and production costs<br>Profitability analysis | Ch. 11 (P, T & W) |

**Design project is due on March 8, 2006.**

**Course Outline for Part Three (Mar. 22 – May 1, 2006 – Weeks 23-29):**

| | | |
|---|---|---|
| 23 & 24 | Chemical product design | Handouts |
| | General principles of idea | |
| | Selections | Ch. 4 (C.M.)* |
| | Molecular structure design | Ch. 2 (S.S. L.)* |
| | Micro-structured products | Ch. 5 (C.M.)* |
| | Specialty chemical manufacture | Ch. 6 (C.M.)* |
| | Combinatorial chemistry and | |
| | High through put experimentation | Handouts |
| 25 & 26 | Batch process design | Ch. 11 (H.T.R.P.)* |
| | Batch size, batch time, scheduling, | |
| | Process simulators, illustrative | |
| | Examples | |
| 27 & 28 | Finishing Operations | Chs. 8, 9, 10 (H.T.R.P.)* |
| | Precipitation, crystallization, | |
| | Drying, scale up | |
| 29 | Integrated Product and Process Design | |
| | Hemodialysis machine, etc. | |

***Notes:**

S.S. L.: Seider, Seader, and Lewin, <u>Product and Process Design Principles</u>, Wiley, 2004.
C.M.: Cussler and Moggridge. <u>Chemical Product Design</u>, Cambridge, 2001.
H.T.R.P.: Harrison, Todd, Rudge, and Petrides. <u>Bioseparations Science and Engineering</u>, Oxford, 2003

**Product Design Projects:**

Three students in a group are required to select a project for the design of a product by utilizing the general principles of product design. (Marketability, generations of ideas, selections of ideas, and design a process based on the selected idea to make the product). Groups (and projects intended) are required to be formed at the end of the 9th week.

The final report of this design project is due on May 9, 2006.

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DEPARTMENT OF CHEMICAL AND BIOCHEMICAL ENGINEERING

| | | |
|---|---|---|
| 14:155:441:01 | **Chemical Engineering Kinetics** | Fall 2005 |
| 3 Credits | | Fully Graded |

| | | |
|---|---|---|
| Tuesday | 1:40 pm to 3:00 pm | SEC-206 |
| Thursday | 1:40 pm to 3:00 pm | SEC-206 |

***Course Objectives:***
This course presents the fundamental design procedures for chemical reactors found in industrial processes throughout the breadth of the chemical industries. The application of principles of stoichiometry, mass and energy balances, and transport phenomena to reactors for homogeneous and heterogeneous systems is emphasized. The relationship of reaction mechanisms to rate laws is investigated.

***Instructor:***
J. L. Rankin, Assistant Dean
Office of Academic Affairs, EN-B100, Busch Campus
732-445-2212
jerankin@rci.rutgers.edu
Office Hours: By Arrangement

***Textbook (Required):***
Fogler, H. Scott, Elements of Chemical Reaction Engineering, 3rd Edition, Prentice Hall, Upper Saddle River, NJ, 1999.

***Grading Policy:***
Your final grade will consist of a combination of examination, homework, and quiz scores as indicated below. Midterm examinations will be given during the regular class time. The final examination will be held during the three hour block assigned by the Scheduling Office as indicated on the attached class schedule. Homework problem solutions are VERY IMPORTANT in successfully completing the course. Those that fail to spend adequate time on homework assignments will typically do poorly on scheduled examinations. Each assignment will be due at the beginning of class on the date stated. The assignments will be equally weighted in the final grade calculation. Late assignments will received a maximum of 50% of credit unless cleared with the instructor previously. Working in small groups on homework assignments is encouraged, but each student in the group must learn how to solve every problem assigned. If emergencies arise which preclude your attendance at lectures or examinations, let me know as soon as possible. I will attempt to be reasonable and fair in working out arrangements to our mutual satisfaction.

***Design Project:***
A computer-oriented reactor design project will be required of each student. It will be weighted in the final grade as indicated. However, no student may pass the course without handing in this project. It will be due at the time of the final examination. This project will be done in groups of 2 to 3 students. Please begin thinking about with whom you wish to work so you will be prepared when asked. More details will follow shortly.

***Grade Calculation:***

| | | |
|---|---|---|
| | Homework Assignments | 15% |
| | Design Project | 10% |
| | Midterm Examination #1 | 25% |
| | Midterm Examination #2 | 25% |
| | Final Examination | 25% |

The course will be fully distributed, i.e., there will be grades from A to F (if necessary).

***Academic Integrity:***
A simple direct statement should suffice. NO CHEATING OF ANY KIND WILL BE TOLERATED. Any student who violates university integrity policy will be reported and prosecuted. Let us all remember that this is an upper level division course in the professional program of Chemical and Biochemical Engineering and we ought to act as true professionals as we study together. Any student who observes dishonesty in others should feel deeply the responsibility to converse with the instructor about the problem confidentially as an equal partner in protecting the study environment in the course.

***Homework Format:***
All homework assignments are to be submitted on 8 1/2" x 11" engineering computation paper. This paper is available at the Rutgers Bookstore and other office supply stores in the area (Staples, OfficeDepot, OfficeMax, etc.) Each page of the assignment should be numbered at the top along with your name. Problems should be done neatly and presented logically with all final answers boxed for easy identification. Practice the good habit of presenting your work so that others can follow your reasoning and understand your ideas.

***Additional References:***

*Elementary:*


1. Levenspiel, O., The Chemical Reactor Minibook, OSU Book Stores, Inc, Corvallis, OR, 1979.
2. Levenspiel, O., Chemical Reaction Engineering, 2nd Edition, John Wiley and Sons, New York, NY, 1972.
3. Fogler, H. S., The Elements of Chemical Kinetics and Reactor Calculations: A Self-Paced Approach, Prentice-Hall Inc, Englewood Cliffs, NJ, 1974.
4. Butt, J. B., Reaction Kinetics and Reactor Design, Prentice-Hall Inc, Englewood Cliffs, NJ, 1980.
5. Smith, J. M., Chemical Engineering Kinetics, 3rd Edition, McGraw-Hill Book Co, New York, NY, 1981.
6. Walas, S. M., Reaction Kinetics for Chemical Engineers, Butterworths, Boston, MA, 1989.
7. Boudart, M., Kinetics of Chemical Processes, Butterworth-Heinemann, Boston, MA, 1991.
8. Schmidt, L. D., The Engineering of Chemical Reactions, 2nd Edition, Oxford University Press, New York, NY, 2005.


*Advanced:*


1. Aris, R., Elementary Chemical Reactor Analysis, Butterworths, Boston, MA, 1989.
2. Froment, G. F., and K. B. Bischoff, Chemical Reactor Analysis and Design, John Wiley and Sons, New York, NY, 1979.
3. Laidler, K. J., Chemical Kinetics, 3rd Edition, Harper and Row Publishers, New York, NY, 1987.
4. Richardson, J. T., Principles of Catalyst Development, Plenum Press, New York, NY, 1989.
5. Sadana, A., Biocatalysis: Fundamentals of Enzyme Deactivation Kinetics, Prentice Hall, Englewood Cliffs, NJ, 1991.
6. Tarhan, M. O., Catalytic Reactor Design, McGraw-Hill Book Co, New York, NY, 1983.
7. Campbell, I. M., Catalysis at Surfaces, Chapman and Hall, New York, NY, 1988.
8. White, M. G., Heterogeneous Catalysis, Prentice-Hall, Englewood Cliffs, NJ, 1989.
9. Petersen, E. E., and A. T. Bell, eds, Catalyst Deactivation, Marcel Dekker Inc, New York, NY, 1987.
10. Weller, S., ed, Standardization of Catalyst Test Methods, AIChE Symposium Series, Volume 70, Number 143, AIChE, New York, NY, 1974.
11. Lee, H. H., Heterogeneous Reactor Design, Butterworth Publishers, Boston, MA, 1985.
12. Satterfield, C. N., Heterogeneous Catalysis in Practice, McGraw-Hill Book Co, New York, NY, 1980.
13. Thomas, J. M., and W. J. Thomas, Principles and Practice of Heterogenous Catalysis, VCH Publishers Inc, New York, NY, 1996.
14. Gianetto, A., and P. J. Silveston, eds, Multiphase Chemical Reactors: Theory, Design, Scale-Up, Hemisphere Publishing Co, New York, NY, 1986.
15. Somorjai, G. A., Introduction to Surface Chemistry and Catalysis, John Wiley and Sons, New York, NY, 1994.
16. Masel, R. I., Principles of Adsorption and Reaction on Solid Surfaces, John Wiley and Sons, New York, NY, 1996.

**COURSE SCHEDULE**

| Date | Topic | Reading | Assignment Due |
|---|---|---|---|
| Sep 1 | Course Introduction | 1.1 | ----- |
| Sep 6 | Reaction Stoichiometry | 2.1, 2.5, 3.3-3.5 | ----- |
| Sep 8 | Mechanism and Rate | 3.1, 7.1-7.5 | ----- |
| Sep 13 | Mechanism and Rate | 10.1-10.8 | ----- |
| Sep 15 | Mechanism and Rate | ----- | #1 |
| Sep 20 | Temperature Dependence of Rate | ----- | ----- |
| Sep 22 | Single Ideal Reactors | 1.2-1.5, 2.2-2.3, 3.2 | ----- |
| Sep 27 | Single Ideal Reactors | ----- | ----- |
| Sep 29 | Analysis of Rate Data | 5.1-5.7 | #2 |
| Oct 4 | Analysis of Rate Data | ----- | ----- |
| Oct 6 | Isothermal Reactor Design | 2.4, 4.1-4.8 | ----- |
| Oct 11 | Isothermal Reactor Design | ----- | ----- |
| Oct 13 | Isothermal Reactor Design | ----- | #3 |
| Oct 18 | MIDTERM EXAMINATION #1 | | |
| Oct 20 | Nonisothermal Reactor Design | 8.1-8.6, 9.1-9.4, 9.6 | ----- |
| Oct 25 | Nonisothermal Reactor Design | ----- | ----- |
| Oct 27 | Multiple Reactor Systems | 6.1-6.6, 8.7, 9.5 | ----- |
| Nov 1 | Multiple Reactor Systems | ----- | ----- |
| Nov 3 | External Transport Effects | 11.1-11.5 | #4 |
| Nov 8 | NO CLASS | ----- | ----- |
| Nov 10 | NO CLASS | ----- | ----- |
| Nov 15 | External Transport Effects | ----- | ----- |
| Nov 17 | MIDTERM EXAMINATION #2 | | |
| Nov 22 | NO CLASS (Wednesday Classes) | ----- | ----- |
| Nov 24 | NO CLASS (Thanksgiving) | ----- | ----- |
| Nov 29 | Internal Transport Effects | 12.1-12.11 | ----- |
| Dec 1 | Internal Transport Effects | ----- | #5 |
| Dec 6 | Internal Transport Effects | ----- | ----- |
| Dec 8 | Design Case Study Help | ----- | ----- |
| Dec 13 | Design Case Study Help | ----- | #6 |

FINAL EXAMINATION - Tuesday, December 20, 8:00 am to 11:00 am, at SEC-206

GROUP DESIGN PROJECT DUE AT TIME OF FINAL EXAMINATION

## ENGINEERING ORIENTATION LECTURES

14:440:100 | 1 Credit | Pass/Fail

Fall 2005

Meeting Times and Locations:

| | | | |
|---|---|---|---|
| Section 01 | M | 10:20 am to 11:40 am | HLL-116 |
| Section 02 | M | 10:20 am to 11:40 am | PH-111 |
| Section 03 | F | 3:20 pm to 4:40 pm | SEC-209 |
| Section 04 | F | 3:20 pm to 4:40 pm | EN-B120 |

*Requirements*

Each first-year student (except for those in the Honors Program taking 440:191) must register for and complete the Engineering Orientation Lecture series. The course is graded on attendance. **EACH STUDENT SHOULD PLAN TO ATTEND *EVERY* LECTURE OF THE COURSE.**

Attendance will be monitored by the assigned lecturers. Except for the first meeting of the class on September 16th and September 19th, each student will turn in a weekly worksheet based on in-class activity to the instructor. The completed worksheets will be collected by the instructor at the end of the lecture and serve as the ***only*** evidence of attendance.

**BEFORE EACH LECTURE,** the student must access the course webpage and do the preparatory work if indicated. Then also print the appropriate worksheet form corresponding to the department presenting the upcoming lecture. If you do not have the worksheet at the time of class meeting, you will be unable to fully participate in that day's lecture. **PLEASE COME TO CLASS PREPARED WITH YOUR BLANK WORKSHEET AND HOMEWORK ASSIGNMENT.** Besides the worksheet, other helpful information about engineering careers and curricula will be posted on the web pages from time to time.

The course web page address is ***www.soe.rutgers.edu/oaa/440100.php*** (we will inform you if this link should change in the future). Go each week to the web site and print off the worksheet corresponding the next upcoming lecture in your section.

*Objectives*

The lectures are designed to give each student general knowledge of the activities of professional engineers in each of the fields represented by departmental instruction and research at Rutgers University. This is perhaps the best way to gather information that will serve as a basis for the official Declaration of Major each year. Please feel free to seek additional insights and information from the professors who are involved in the lectures by asking questions of them or any other representative located at the individual department offices.

In addition, students will be briefly introduced to some other important subject areas such as ***the nature of the Engineering community*** and workplace and ***engineers as designers*** and creators.

*Recommended Text*

Dunn, S., J. Rankin, and H. Crawford (eds.), Entering the Engineering Community, McGraw-Hill, 2004.
(Available at the Rutgers Bookstore)

Note: This text is to serve as a reference for EXCEL applications in your future coursework.

*Questions or Problems*

Address all questions, problems, absence requests, etc. to Dean Rankin, Room B100, Phone number 445-2212. Dean Rankin coordinates the course and assigns all final grades. In particular, any absences must be officially verified and, if appropriate, excused by Dean Rankin at the Office of Academic Affairs.

8/05

***ENGINEERING ORIENTATION LECTURES***
***Fall 2005***

| DATE | Section 01 *(M2 @ HLL-116)* | DATE | Section 02 *(M2 @ PH-111)* | DATE | Section 03 *(F5 @ SEC-209)* | DATE | Section 04 *(F5 @ EN-B120)* |
|---|---|---|---|---|---|---|---|
| Sep 12 | *No Class* | Sep 12 | *No Class* | Sep 2 | *No Class* | Sep 2 | *No Class* |
| Sep 19 | Introduction (Rankin) | Sep 19 | Introduction (Bernath) | Sep 9 | *No Class* | Sep 9 | *No Class* |
| Sep 26 | Chemical/Biochemical Eng'g | Sep 26 | Industrial Eng'g | Sep 16 | Introduction (Rankin) | Sep 16 | Introduction (Bernath) |
| Oct 3 | Civil/Environmental Eng'g | Oct 3 | Mechanical/Aerospace Eng'g | Sep 23 | Biomedical Eng'g | Sep 23 | Electrical/Computer Eng'g |
| Oct 10 | Electrical/Computer Eng'g | Oct 10 | Biomedical Eng'g | Sep 30 | Bioresource Eng'g | Sep 30 | Industrial Eng'g |
| Oct 17 | Industrial Eng'g | Oct 17 | Bioresource Eng'g | Oct 7 | Materials Eng'g | Oct 7 | Mechanical/Aerospace Eng'g |
| Oct 24 | Mechanical/Aerospace Eng'g | Oct 24 | Materials Eng'g | Oct 14 | Chemical/Biochemical Eng'g | Oct 14 | Biomedical Eng'g |
| Oct 31 | Biomedical Eng'g | Oct 31 | Chemical/Biochemical Eng'g | Oct 21 | Civil/Environmental Eng'g | Oct 21 | Bioresource Eng'g |
| Nov 7 | Bioresource Eng'g | Nov 7 | Civil/Environmental Eng'g | Oct 28 | Electrical/Computer Eng'g | Oct 28 | Materials Eng'g |
| Nov 14 | Materials Eng'g | Nov 14 | Electrical/Computer Eng'g | Nov 4 | Industrial Eng'g | Nov 4 | Chemical/Biochemical Eng'g |
| Nov 21 | *No Class* | Nov 21 | *No Class* | Nov 11 | Mechanical/Aerospace Eng'g | Nov 11 | Civil/Environmental Eng'g |
| Nov 28 | Professionalism (Rankin) | Nov 28 | Packaging Eng'g | Nov 18 | Professionalism (Rankin) | Nov 18 | Packaging Eng'g |
| Dec 5 | Packaging Eng'g | Dec 5 | Professionalism (Rankin) | Dec 2 | Packaging Eng'g | Dec 2 | Professionalism (Rankin) |
| Dec 12 | *No Class* | Dec 12 | *No Class* | Dec 9 | *No Class* | Dec 9 | *No Class* |

# 440:127 Introduction to Computing for Engineers
# Spring 2006

**This syllabus is subject to change. Please consult the class website for updates and announcements.**

**Dr. Holly Crawford (Associate Dean for Engineering Continuing Education and Outreach)**
hcrawfor@rci.rutgers.edu
**Office: B-215; Phone: 732-445-4549**

**Teaching Assistants:** Josh Finch (jwfinch@eden.rutgers.edu); Alex Wu (ricqui@rci.rutgers.edu); Mahesh Mahadevan (mahadevs@rci.rutgers.edu) Mingliang Wang (mlwang@eden.rutgers.edu)

**Textbooks:** There are three required textbooks for the class and they come in one package. You must purchase the current textbooks! The package contains: ***Just Enough UNIX, 5th Edition*** by Paul K. Andersen; ***C Programming for Engineering and Computer Science, Abridged*** by H.H.Tan and T.B. D'Orazio; and ***Introduction to Matlab 7 for Engineers***, Abridged by William J. Palm, III.

**Course Website:** http://coewww.rutgers.edu/classes/gen/gen127

**Matlab Software Location:** ARC Computing Center (Open 7/24).

**Matlab Software Purchase:** Matlab 7 (Release 14). This software is available in the aforementioned computer labs. Students may buy a student license directly from Mathworks. Please visit the following website for further information:
http://www.mathworks.com/web_downloads/

**C and UNIX Software:** You will use your Eden account for your C and UNIX work. ***All students must have an Eden account.***
http://rucs.rutgers.edu

**QUESTIONS AND CONCERNS**
If you have questions or concerns, don't be shy. **Please contact your TA** via email or attend office hours immediately. There is no such thing as a dumb question. Remember, don't let a problem sit on the back burner—**talk to your TA**!!

**COURSE OBJECTIVES**
This course is designed to provide students with an introduction to and overview of UNIX (a reliable and flexible operating system used on Rutgers University mainframe computers), Matlab (a powerful programming package for engineers and scientists), and C (a stable and robust structured programming language). Students will learn

- The fundamentals of UNIX, Matlab and C
- How to write programs using Matlab and C
- How to solve engineering problems using both Matlab and C programming techniques

***Course content is introduced in the weekly lectures. Homework will be discussed in the weekly recitations.***

**GRADING POLICY**
Students are graded based on their performance on weekly homework assignments (10%), 4 unannounced quizzes (20%--5% for each quiz; two will be given in lecture and two will be given in recitation), a midterm examination (30%), and a final examination (40%). Students must turn homework (in person) into their Teaching Assistant at the start of weekly recitation. ***Late***

***homework assignments will not be accepted and will earn a grade of 0 (zero).*** If, due to extraordinary circumstances (e.g. verifiable family death, verifiable student illness—must be verified with Dr. Jeffrey Rankin who is located in the Engineering Building, Room B-100), the student cannot attend recitation and turn his or her homework in, ***it is the responsibility of the student*** to contact his or her Teaching Assistant by e-mail ***prior*** to the start of recitation. Once the extraordinary circumstances have been verified, the student and the TA will then work out a schedule for make-up assignments.

Homework is graded in the following manner. Starting with the written homework due February 9 and 10, the TAs will grade 2 problems at random for each problem set turned in by a student. The remaining problems will be reviewed to ascertain a student's overall effort. The final grade for each problem set will be based on a combination of the correctness of the two problems in tandem with the level of effort made to complete the entire problem set.

**Midterm Examination:** The midterm will be given during the March 23 and 24 recitation periods. Please go to your regular recitation classroom on those days.

**Final Examination:** Friday, May 5, 2006 in the Livingston Campus Gym from 4:00 p.m. to 7:00 p.m. ***Please be on time! Latecomers will not be admitted into the examination room after 4:00 p.m.*** **If you have an exam conflict (we are blocked with Group J Biology) or if you need an accommodation exam, you MUST contact Dr. Crawford by April 5, 2006 via e-mail so that a make-up exam can be scheduled.**

**GRADING SCALE**
***Note: Curving is not used in this class***
A: 92-100
B+: 87-91
B: 82-86
C+: 77-81
C: 72-76
D: 60-71
F: 59 and below

**CHEATING AND PLAGIARISM POLICY**
Cheating and plagiarism **will not be tolerated** in the class. All students should review the Rutgers University policy on these matters. This policy is located at http://teachx.rutgers.edu/integrity/policy.html

**ELECTRONIC DEVICES AND GENERAL COMPORTMENT POLICY**
Students will have their cell phones and pagers **turned off at all times** during lecture and recitation. Recording devices **are not allowed** in lecture and recitation. Students may not leave lecture or recitation prior to either's conclusion unless they have to use the restroom. Talking during lecture or recitation (unless it is for the purposes of class participation) is disrespectful. Please refrain from doing so. Food and drink **are not allowed** in the ARC computer lab.

## LECTURE, READING, AND HOMEWORK ASSIGNMENT SCHEDULE

***Homework not turned in at the start of recitation will receive a grade of 0 (zero). Graded homework will be turned back to the students one week after the homework has been turned in to the Teaching Assistant. For example, homework turned in by the student on February 9 will be turned back to the student by the Teaching Assistant on February 16.***

| | |
|---|---|
| **Week 1 (Jan. 18):** | **Course Overview**<br>**Read** Andersen, pp. 1-33; 69-101 |
| **Week 2 (Jan. 25):** | **Introduction to UNIX**<br>**Read** Andersen, pp. 155-158; 293-304<br>and browse http://www.openssh.com/<br>**HW (Due Feb. 2/3)** Familiarize yourself with the various functions included with your Eden account.<br>Also, download SSH<br>http://www.nbcs.rutgers.edu/ssh/index.php3<br>and familiarize yourself with that application. Please note that the SSH client is also located on university lab computers. |
| **Week 3 (Feb. 1):** | **UNIX**<br>**Read** Andersen, pp. 241-250; pp. 491-505; pp. 533-536<br>**HW (Due Feb. 9/10)** Prob. 6 (p.33); Prob. 2 (p. 101); Prob. 2 (p. 158) and do the following task in your Eden home directory: create a new file called **engineer.** Also create a new directory called **127spring**. Copy the file **engineer** into the directory **127spring**. Print a list of your home directory and the **127spring** directory (make sure the list shows everything) to demonstrate that the file **engineer** resides in both directories. |
| **Week 4 (Feb. 8):** | **UNIX/Introduction to C Programming**<br>**Program Structure, Printing, Comments**<br>**Read** Chapter 2 (Tan)<br>**HW (Due Feb. 16/17)** Prob. 2 (p. 250) and Unix problems on worksheet posted on class website |
| **Week 5 (Feb. 15):** | **The Basics of C: Variables, Arithmetic Operations, Math Functions, and Input/Output**<br>**Read** Chapter 3 (Tan)<br>**HW (Due Feb. 23/24)** Problems 1, 3, 5, 7, 9, 10 (Tan, Chapter 2) pp. 72-74. |
| **Week 6 (Feb. 22):** | **Beginning Decision Making and Looping in C**<br>**Read** Chapter 4 (Tan)<br>**HW (Due Mar. 2/3)** Problems 3.3, 3.4, 3.6, 3.8, 3.10, 3.11 (Tan, Chapter 3) pp.161-168. |
| **Week 7 (Mar. 1):** | **Functions in C**<br>**Read** Chapter 5 (Tan)<br>**HW (Due Mar. 9/10)** Problems 4.8, 4.12, 4.13, 4.14, 4.17, 4.19 (Tan, Chapter 4) pp. 260-264. |

| | |
|---|---|
| **Week 8 (Mar. 8):** | **Numeric Arrays in C**<br>**Read** Chapter 6 (Tan)<br>**HW (Due Mar. 23/24)** Problems 3, 19, 20, 23, 24, 25 (Tan, Chapter 5) pp. 338-347 |
| **Week 9 (Mar. 15):** | **Spring Break—No Classes** |
| **Week 10 (Mar. 22):** | **Matlab and Problem Solving**<br>**Read** Chapter 1 (Palm)<br>**HW (Due Mar. 30/31)** Problems 1, 2, 3, 6, 9, 10 (Tan, Chapter 6) pp. 438-442<br>***Note: The midterm will be held during the Mar. 23/24 recitation periods. Please go to your regular recitation meeting on these dates.*** |
| **Week 11 (Mar. 29):** | **Array and Matrix Operations in Matlab**<br>**Read** Chapter 2 (Palm)<br>**HW (Due Apr. 6/7)** Problems 12, 17, 27, 30, 36, 42 (Palm, Chapter 1) pp. 61-67. |
| **Week 12 (Apr. 5):** | **Files, Functions, and Data Structures in Matlab**<br>**Read** Chapter 3 (Palm)<br>**HW (Due Apr. 13/14)** Problems 6, 10, 17, 19, 24, 44 (Palm, Chapter 2) pp. 125-139. |
| **Week 13 (Apr. 12):** | **Programming with Matlab**<br>**Read** Chapter 4 (Palm)<br>**HW (Due Apr. 20/21)** Problems 6, 8, 11, 14, 18, 24 (Palm, Chapter 3) pp. 177-181. |
| **Week 14 (Apr. 19):** | **Plotting and Model Building in Matlab**<br>**Read** Chapter 5, pp. 258-311 (Palm)<br>**HW (Due Apr. 27/28)** Problems 9, 14, 17, 20, 33, 37 (Palm, Chapter 4) pp. 241-257. |
| **Week 15 (Apr. 26):** | **Review**<br>**HW (Due by 5:00 pm EDT via e-mail to your TA on Tuesday, May 2)** Problems 4, 11, 19, 24, 33, 34. (Palm, Chapter 5) pp. 340-357. |

***Final Examination: Friday, May 5, 2006, 4:00 p.m. to 7:00 p.m. in the Livingston College Gym. Latecomers will not be admitted to the examination room. This exam is blocked with Group J Biology.***

Homework & Solutions

## General
## 14:440:221 Engineering Mechanics: Statics (3)
## Prerequisites: 01:640:151;01:750:123

**Instructors:**
**Dr. Frank Pavlovich, Phone: 732-445-0429, Office: B-224**
**Dr. George J. Weng, Phone: 732-445-2223, Office: B-218**

**T.A.:**
**Elan Borenstein, Phone: 732-445-1401, Office: D-150**
**Pamela Carabetta, Phone: 732-445-1401, Office: D-150**
**Pedro Romero, Phone: 732-445-0267, Office: D-106**

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Course syllabus (pdf)

| Lecture | Sections | Topics | Homework |
|---|---|---|---|
| 1 | 1.1 – 1.8 | Introduction, vectors | 1/3, 5, 9 |
| 2 | 2.1 – 2.3 | 2-D forces | 2/3, 15, 17 |
| 3 | 2.4 – 2.6 | 2-D moments, couples | 2/37, 71, 85 |
| 4 | 2.7 – 2.8 | 3-D forces, moments | 2/99, 111 |
| 5 | 2.8 – 2.9 | 3-D moments, resultants | 2/115, 119 |
| 6 | 3.1 – 3.3 | Equilibrium, free-body diagram | 3/7, 9, 11 |
| 7 | 3.3 | 2-D equilibrium | 3/17, 23, 27 |
| 8 | 3.4 | 3-D equilibrium | 3/61, 65 |
| 9 | 3.4 | 3-D equilibrium | 3/69, 81 |
| 10 | 4.1 – 4.3 | Truss, method of joints | 4/3, 11, 13 |

| | | | |
|---|---|---|---|
| 11 | 4.4 | Method of sections | 4/29, 35, 39 |
| 12 | 4.6 | Frames and machines | 4/65, 67, 69 |
| 13 | 5.1 – 5.3 | Center of mass, centroids | 5/9, 15, 27 |
| 14 | 5.4 | Centroids of composites | 5/47, 55, 59 |
| 15 | | Review | |
| | | **Mid-Term Examination** | |
| 17 | 5.5 | Theorems of Pappus | 5/71, 73, 83 |
| 18 | 5.6 | Beams | 5/93, 95, 97 |
| 19 | 5.7 | Shear force & bending moment in beams | 5/115, |
| 121 | | | |
| 20 | 5.7 | Shear force & bending moment in beams | 5/123, |
| 129 | | | |
| 21 | 5.8 | Parabolic & catenary cables | 5/139, 141, 143 |
| 22 | 6.1 – 6.3 | Friction | 6/13, 23, 31 |
| 23 | 6.8 | Flexible belts | 6/87, 91, 99 |
| 24 | 7.1 – 7.3 | Virtual work | 7/7, 9, 15 |
| 25 | 7.4 | Potential energy and stability | 7/35, 39, |
| 41 | | | |
| 26-27 | | Review | |

# Grading

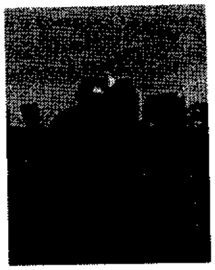
Attendance 10%
Homework 10%
Quizes (6) 20%
Mid-term exam 25%
Final exam 35%

# Office Hours:

Pavlovich (M 2pm-3pm),
Carabetta (Tu 10:20am-11:40am),
Borenstein (W 2pm-3pm),
Romero (Th 1:30pm-2:30pm),
Weng (F 3pm-4pm)

# Textbook:

*Engineering Mechanics Statics* ***Fifth Edition***, John Wiley, By J.L. Meriam & L.G. Kraige.
ISBN: 0-471-40646-5



**Academic Integrity Policy**
Please review the RU Academic Honesty Policy

Rutgers University
School of Engineering

14:440:407 (02)
Fall 2005

# MECHANICAL PROPERTIES OF MATERIALS

**LECTURER**: Prof. Jerry Scheinbeim
Room C-164 (School of Engineering)
e-mail: jis@rci.rutgers.edu
tel: 732-445-3669

**LECTURE ROOM**: SEC 205

**TIME**:

Lecture Wed. 12:00 - 1:20 p.m.
Fri. 1:40.- 3:00 p.m.

Office hours Wed. 2:00 p.m. – 3:30 p.m.
Fri. 10:00 a.m. – 11:30 a.m.

## COURSE OUTLINE

I. Introduction:

Micromechanics (Material Science Approach)

II. Cohesion in Solids:

Thermodynamics, Equilibrium State of Matter, Kinetics
Atomic Structure
Bonding (ionic, covalent, metallic, van der Waals, hydrogen bonds)
Crystal Structures (crystal systems, Miller indices)

III. Structure of Engineering Materials:

Metals (HCP, FCC, BCC structures, alloys, phase diagrams)
Ceramics (crystalline ceramics, glass)
Polymers (semi-crystalline polymers, amorphous polymers, elastomers, thermoplastic elastomers)
Composites (fibrous composites, laminated composites)

IV. Static Mechanical Properties of Materials:

Tensile Properties (stress, strain, stress-stain curves, tensile parameters)

V. <u>Elasticity of Materials</u>:

- Elastic Properties of Crystalline Materials
- Elastic Properties of Composites
- Rubber Elasticity

VI. <u>Plasticity of Materials</u>:

- Plastic Deformation of Crystalline Materials
- Strengthening Mechanisms
- Plastic Deformation of Polymers

VII. <u>Fracture of Materials</u>

- Brittle/Ductile Fracture

VIII. <u>Corrosion of Materials</u>

**TEXTBOOK: "The Science and Engineering of Materials"** by Donald R. Askaland and Pradeep P. Phillips, Fifth Edition.

**GRADING**: First Exam: 30%
Second Exam: 30%
Final Exam: 40%

Rutgers University
School of Engineering

14:440:407 (02)
Spring 2006

# MECHANICAL PROPERTIES OF MATERIALS

**LECTURER:** Prof. Jerry Scheinbeim
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**TIME:**

Lecture: Mon. 5:00 - 6:20 p.m.
Wed. 5:00.- 6:20 p.m.

Office hours: Mon.. 4:00 p.m. – 5:00 p.m.
Wed.. 4:00 p.m. – 6:00 p.m.

**LECTURE ROOM:** SEC 205

## COURSE OUTLINE

I. Introduction:

Micromechanics (Material Science Approach)
Structure/Properties Relationships in Materials

II. Cohesion in Solids:

Thermodynamics, Equilibrium State of Matter, Kinetics, Metastable States
Atomic Structure
Bonding (Primary-ionic, covalent, metallic) (secondary- dipole-dipole, dipole-induced dipole, van der Waals, hydrogen bonds)
Crystal Structures (crystal systems, Miller indices)

III. Structure of Engineering Materials:

Metals (HCP, FCC, BCC structures, alloys, phase diagrams)
Ceramics (crystalline ceramics, glass)
Polymers (semi-crystalline polymers, amorphous polymers, elastomers, thermoplastic elastomers)
Composites (particulate composites,fibrous composites, laminated composites, woven composites nano-composites)

IV. Static Mechanical Properties of Materials:

Tensile Properties (stress, strain, stress-stain curves, tensile parameters)

V. Elasticity of Materials:

- Elastic Properties of Crystalline Materials
- Elastic properties of non-crystalline and semi-cystalline materials
- Elastic Properties of Composites
- Rubber Elasticity

VI. Plasticity of Materials:

- Plastic Deformation of Crystalline Materials
- Strengthening Mechanisms
- Plastic Deformation of Polymers

VII. Fracture of Materials

- Brittle/Ductile Fracture

VIII. Corrosion of Materials

**SUPPLEMENTAL TEXTBOOK: "The Science and Engineering of Materials"** by Donald R. Askaland and Pradeep P. Phillips, Fifth Edition.

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**EXAM MATERIAL** WILL COME FROM CLASS NOTES AND DISCUSSIONS !!