Biochemical Engineering Curriculum

Final Report

Table of Content

Sections
1. BioChemcial Engineering ............................................................... 2
2. Graduates of the Curriculum ......................................................... 2
3. The Curriculum ............................................................................ 2
   3-A. Characteristics of the Curriculum ........................................... 2
   3-B. Curriculum Objectives for Each Year ..................................... 3
   3-C. Curriculum Content ............................................................. 3
   3-D. Explanation of the Courses ................................................... 8
   3-E. Distribution of Courses for University and ABET Requirements .... 6
4. Other Consideration ........................................................................
   4-A. Course Grade Requirements ....................................................
   4-B. Implementation Plan ............................................................
   4-C. Evaluation Plan ....................................................................
5. Resource Needed ............................................................................
   5-A. Faculty Resource ...................................................................
   5-B. Laboratories and Design Studio Resource ...............................  

Appendices
A. Engineering Laboratory and Design Courses ..............................
B. List of Courses for the University Core Requirement ....................
C. List of BioChemical Engineering Elective Courses ........................
D. Modified Schedule of Courses for Entering Class in Fall 2007 ............

Tables
1. Schedule of Courses for the BS in BioChemical Engineering Four-Year
   (Eight-semester) Degree Program ....................................................
2. Modified Schedule of Courses for the BS in BioChemical Engineering
   Four-Year (Eight-semester) Degree Program – Only for Class entering
   the program in Fall 2007 ...............................................................
3. EXCEL Spreadsheet of the BioChemical Engineering Degree Curriculum
   showing connections to the Profile of UGA Engineers and Academic
   Environment .................................................................................

BioChemical Engineering Curriculum Committee
James Anderson, Mark Eiteman, James Kastner and Brahm Verma (Chair)
Biochemical Engineering Curriculum

Final Report

June 7, 2007

Committee Members
James Anderson, K.C. Das, Mark Eiteman, James Kastner and Brahm Verma (Chair)

1. BIOCHEMICAL ENGINEERING (BCHE)
Biochemical Engineering requires integrated knowledge of governing principles of living systems, properties of biological materials and of engineering methodology. Processing of biological materials and processing using biological agents (such as cells, enzymes or antibodies) are the central domains of biochemical engineering.

2. GRADUATES OF THE CURRICULUM
Beyond strong preparation in sciences, mathematics, engineering sciences, and humanities, the UGA Biochemical Engineering curriculum emphasizes integration of foundational knowledge, creative conceptualization of innovating solutions, engineering analysis and synthesis, prototyping (and simulation) and testing. Students are prepared for careers devoted to the integration of discoveries from multiple fields to engineer biochemical processes yielding useful products. Some application domains of interest include biomedicine, pharmaceutical, biorefinery and bio-environmental systems. The graduates of the program are also provided solid foundation for advanced professional and graduate studies.

3. THE CURRICULUM
The following sections present the character and content of the curriculum.

3-A. Characteristics of the Curriculum
The curriculum is designed to have the following characteristics.

1. The overall character of the curriculum has been guided by the report of the UGA Engineer Think Tank and by the words of Ralph Waldo Emerson: "Skill to do comes of doing."

2. The following are the five core components intertwined in the curriculum and they are integrated into each year's program of study in the proposed four-year curriculum.

   a. Master Technical content [Tools1, Science Core2, and Foundational Subjects3]
   b. Acquire Social Intelligence [Humanities, Arts, Social and Economic Sciences]

---

1 Tools – Visualization, Graphic Representation, Algorithmic Logic and Programming Skills, Technical Writing
2 Science Core – Physics, Chemistry, Biology, Calculus
3 Foundational Subjects – Engineering Sciences, Mathematics, Modeling and Simulation, Technical subjects in biochemical engineering
c. **Build fluency across disciplines** [foundational disciplinary concepts and content] in “interdisciplinary” laboratories

d. **Integrate technical knowledge and social intelligence** in real-world design projects

e. **Connect with peers and professionals**

3. The key feature of the first two-year phase is to build mastery in foundational materials, and the second two-year phase is to concentrate on building competencies in biochemical engineering.

4. Engineering science is both **rigid** and **flexible**;

   - *rigid* in the required content and the mastery of it, but
   - *flexible* in the ways content is organized and learning modules are created to ease additional reorganizations for future changes

5. The depth and rigor of study in all five **core components** simultaneously advances each year in the four year program.

6. Integration of science core, foundational engineering sciences and mathematics is achieved through a sequence of “interdisciplinary” laboratories. These laboratory courses progressively make obvious the similitude and teach fluency across core engineering subjects. This aspect is especially important for biological processes.

7. The curriculum provides students flexibility to select advanced biochemical engineering subjects in any combination to create a concentration of their choosing and is not restricted by a set of prescribed areas of emphasis.

8. Integration of technical knowledge and social intelligence is learned in a sequence of design projects. Most importantly, the projects school students in the art of identifying and critically defining problems of significant social and economic importance. Furthermore, challenging creativity to conceptualize innovative solutions, assessing feasibility of solutions analytically, prototyping (or modeling *in-silico*) and testing viability of the solution builds confidence to lead professionally.

9. Participation in on-campus student-led organizations and professional societies, presentations at professional meetings, serving in leadership roles, engaging with students of other academic disciplines and other activities related with developing social intelligence is an integral part of the curriculum.

10. This is a four-year ABET accredited curriculum.

### 3-B. Curriculum Objectives for Each Year

**First Year** – To provide first-hand exciting engineering experience that integrates technical, humanistic and innovation for developing critical thinking, problem solving skills while simultaneously learning science core.

**Second Year** – To continue building mastering of science core, teach integrative and relational aspects of foundational engineering sciences, introduce concepts of system/process analysis and modeling and applying these elements to a project.
Third Year – To integrate sciences and mathematics and teach quantitative methods of describing processing of biological materials and use of biological agents for producing useful products; and to provide design and industry experience to highlight the context in which sustainable solutions are sought.

Fourth Year – To deepen ability to creatively integrate sciences, mathematics, best engineering practices and social intelligence for the innovation of sustainable design solutions, build/model/simulate proposed solutions, conduct quantitative analysis to assess feasibility and learn to make skillful oral and written presentations.

3-C. Curriculum Content

The curriculum is a 130 credit hour, four-year course of study that includes courses in basic sciences, engineering sciences, social sciences, humanities and arts and other supporting courses with experiential learning to develop skills important for the engineering profession. A sample example of the list of courses in a four-year (eight-semester) schedule is presented in Table 1.

3-D. Explanations of the Courses

* List of courses in which modifications are requested

- **Calculus I and II** are currently 4-hr. courses. We would like to change these to 3 hr courses and the 2-hr saved here should be used towards the 2-hr course in algorithmic logic and computer programming skills.

- **Engineering Lab I or “Engineering Visualization Lab”** – Engineering Graphics should be modified to include visualization jointly taught by a visual arts professor and an engineering professor. This is the first Engineering Lab course that includes art and science of visualization and graphics as applied to “processes,” devices, and systems, emphasizes the role and use of visualization and graphics for critical thinking, creativity, problem-solving, and communication.

- **Programming or “Algorithmic Logic and Programming”** – This course may focus on algorithmic logic and the fundamentals of programming of algorithm with the introduction to selected languages that will have dominant role in engineering courses.

- **Thermodynamics I** – This course may be similar to the current ENGR 3140 Thermodynamics course but its contents should be coordinated with the proposed new course in Equilibrium Thermodynamics and the new course in Statics and Fluid Mechanics. See also Engineering Lab III below.

- **Heat Transfer** – Steady and unsteady state heat transmission by conduction, convection and radiation in engineering solutions. See also Engineering Lab III below.

---

4 Generally courses in graphics may not include visualization and graphic representation of processes. Inclusion of topics that acquire this ability is critical to this program of study.
Mass Transfer – Mass transport and rate phenomena in the analysis of engineering problems. See also Engineering Lab III below.

Capstone Design I and II – This is a two-semester long design experience for innovative integration of technical knowledge, and social intelligence in solving a real-world problem and demonstrating the feasibility of the solution.

Biochemical Engineering I and II – Analysis of enzymatic and microbial reaction systems in the design of engineering solutions.

**New Courses proposed that will require development of content and faculty approval**

- **Engineering Design I, II and III** – These are project-based courses in which students will complete an engineering design solution for a problem assigned by the instructor. Progressively the degree of analysis will increase for justifying the feasibility and performance of the proposed design. In all courses there will be some element of prototyping and testing. They will also prepare a written report and make an oral presentation.

  - **Engineering Design I** – Focus on concept development within the design process, and with a degree of analysis appropriate to the freshmen level. The course will include hands-on process experiences, measurement and statistics that utilize critical thinking, logic, brain-storming, and near-peer learning.

  - **Engineering Design II** – Focus on developing advanced concepts with the use of knowledge from the Engineering Visualization Lab and Design I, and analysis that appropriate for the sophomore-level knowledge of and use of science and engineering science core. The course will also include hands-on prototyping and testing.

  - **Engineering Design III** – Progressively the rigor and focus is increased from Design I and II on applying concepts of biochemical engineering in design and thoroughness of analysis using engineering science core. Prototyping and testing also required.

- **Freshmen and Senior Seminars** – Seminars format includes strong student participation and speakers invited to lead topics of special interest.

  - **Freshmen Seminar** – Include topics in which student experience the exciting work of an engineers and develop skills required for creating innovative engineering design solutions in a team environment. These topics should complement the work in the Design 1 project assignment.

  - **Senior Seminar** – Provides a glimpse of the future world through discussions led with faculty and invited speakers.

- **Biophysics** – Physical basis and description of life at the molecular level. Topics include allometry, animal locomotion, biological channels and receptors, signaling, electrophysiology, gravitational biology, muscle and contractility, photobiophysics, bioelectronics, sonar.
• **Thermodynamics II [Equilibrium Thermodynamics]** – Thermodynamics of chemical and biochemical reactions, equilibrium phenomena.

• **Statics and Fluid Mechanics** – Components of force systems in rigid structures and laws of fluids behaviors to evaluate forces and energies generated by fluids at rest and in motion. The course demonstrates analogies and common governing mathematical representation between the two systems. See also Engineering Lab III below.

• **Engineering Labs** – A series of four “interdisciplinary” laboratory (one each year) will demonstrate connectedness among topics in engineering core subjects and their application for the analysis of designed systems. Students may have the option to select a set number of labs from a list that most appropriately fitting their interest and degree program. The Labs will also expand the students' knowledge in specific engineering areas. They will be modular, with each single “lab” experience following a three-week cycle. A cycle will generally be composed of introduction lectures and discussion, conduct of “hands-on experiments”, discussion and analysis of results that may need modified experiments, and report writing.

  - **Engineering Lab I or “Engineering Visualization Lab”** – A modification of the current Engineering Graphics course is described above.

  - **Engineering Lab II or “Statics and Fluid Mechanics Lab”** – This laboratory will have assignments that integrate principles of force systems in rigid systems and fluids at rest and in motion and the analogies between the two systems.

  - **Engineering Lab III or “Heat, Mass and Thermodynamics Lab”** – This laboratory will have assignments that integrate topics in Thermodynamics I & II, Heat Transfer and Mass Transfer.

  - **Engineering Lab IV or “Biochemical Engineering Lab”** – This laboratory will have assignments that integrate topics from several courses including Kinetics/Reactor Design, Biochemical Engineering I & II and Biochemical Elective I & II.

• **Kinetics and Reactor Design** – tba

• **Bioprocess Quality Control [with Lab]** – tba

• **Bioprocess Electronics, Sensors and Controls** – Introduction to circuits, electronics, microprocessor and sensors for controlling bioprocessing devices and systems

• **Biochemical Engineering Elective** – Students will choose three courses from the courses listed in Appendix C
3-E. Distribution of Course Hours for University and ABET Requirements

The curriculum has 48 hrs in Basic Sciences, 59 hrs in Engineering Sciences and Design and 24 hrs in Social Sciences and Humanities courses distributed as the following:

- **Basic Sciences (48)**
  - Chem I & II (8), Organic Chem (4), Bio Chem (4) = Total (16)
  - Biology I & II (8), Microbiology (3) = Total (11)
  - Physics (4), Biophysics (4) = Total (8)
  - Calculus I & II & III (10), Diff Eqs (3) = Total (13)

- **Social Sciences and Humanities (24)**
  - Social Sciences (12)
  - Humanities and Arts (6)
  - English I & II (6)
  - Institutional requirement (?)

- **Engineering Sciences and Design (59)**
  - Basic Engineering Sciences = Total (18)
    [Statics and Fluids (3), Thermo I & II (4), Heat Transfer (2), Mass Transfer (2), Engineering Labs I & II & III (2, 2, & 3)]
  - Engineering Design = Total (10)
    [Design I & II & III & Capstone (2, 2, 2 & 4)]
  - Biochemical Engineering Course = Total (23)
    [Biochem Engr. I & II (4), Kinetics/Reactor Design (2), Bioproc Elec & Sensors (3), Bioproc Quality Control (3), Engineering Lab IV for Biochemical Engineering (2), Biochem Engr Elective I & II & III (9)]
  - Seminar, Programming = Total (7)
    [Seminars (1 & 1), Programming (2), Engr Decision (3)]

4. OTHER CONSIDERATIONS

4-A. Course Grade Requirements

- Meet the university requirements
- C or better grade in all core engineering courses

4-B. Implementation Plan

To be completed

4-C. Evaluation Plan

To be completed
5. RESOURCES NEEDED

This is a degree to be offered from the Faculty of Engineering. Currently the engineering faculty in BAE department is fully engaged in the program of the Department. They have provided support to advance comprehensive engineering at UGA over and above their already full load. For this reason faculty need to build sufficient capacity for offering this degree should be computed with the view that only a minimum support (nearly zero faculty) is currently available that could be redirected to this program.

5-A. Faculty Resource

An addition of seven (7) new faculty members in biochemical engineering is needed. This recommendation assumes that there will be faculty support available for engineering lab and design courses.

[The formula used for computing faculty numbers is: one full-time faculty for each two undergraduate biochemical engineering courses, NOT including engineering science core courses.]

Biochemical Engineering curriculum has 14 biochemical engineering courses taught in the third and fourth year of the program. This will require a total of seven faculty members in the Faculty of Engineering to support the program. Currently one-half faculty is in Faculty of Engineering and BAE faculty with expertise in this area are fully booked with the commitment in the BAE degree programs. A minimum of six and one-half faculty members should be added. This increase can incremental over the next three years; three in the first year, two in the second year and one and one-half in the third year.

Faculty support for engineering lab and design courses is imperative. Faculty with responsibilities for developing and maintaining labs and design studio for projects are needed. The total need in these categories can best be computed by the undergraduate and graduate coordinators.

5-B. Laboratories and Design Studio Resource

We have proposed “interdisciplinary” laboratory classes and they will need special labs facilities and faculty. A major effort on the part of faculty will be required to develop the labs and design project courses and then to teach them. Graduate Students will contribute to this effort however; several new faculty members are needed for these courses.

These classes will take physical space, and require investment in equipment for lab experiments, computer software for simulation/modeling, and technical personnel to support and maintain facilities. A deeper study by those who will be teaching these courses will be needed for developing a list of specific needs.

---

5 The following were important considerations in arriving at this formula. Each faculty has 65% research and 35% teaching appointment and they are required to develop a prominent research program that supports the undergraduate program and its direction. The faculty will likely teach two undergraduate courses and one graduate course each year. There will be other support available for offering laboratory courses. Finally, the calculations are based on a total of 60 students enrolled in the program. Increased student numbers will require more faculty.
### TABLE 1. Schedule of Courses for the B.S. in Biochemical Engineering Four-year (Eight-semester) Degree Program

#### A Sample Biochemical Engineering Curriculum (130 hrs)

* Modified course; ¥ - New course

<table>
<thead>
<tr>
<th>First Year</th>
<th>Second Year</th>
<th>Third Year</th>
<th>Fourth Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Calculus I (3)</td>
<td>Calculus II (3)</td>
<td>Calculus III (3)</td>
<td>Diff. Eq. (3)</td>
</tr>
<tr>
<td>Chemistry I (4)</td>
<td>Chemistry II (4)</td>
<td>Organic Chemistry (4)</td>
<td>* Thermo I (2)</td>
</tr>
<tr>
<td>* Programming (2)</td>
<td>Biology I (4)</td>
<td>Biology II (4)</td>
<td>* Thermo I (2)</td>
</tr>
<tr>
<td>Humanities I (3)</td>
<td>Social Sciences I (3)</td>
<td>English II (3)</td>
<td>Humanities II (3)</td>
</tr>
<tr>
<td>Recommended: PHIL 1500 - Logic and Critical Thinking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>¥ Engineering Design I (2)</td>
<td>¥ Engineering Design II (2)</td>
<td>¥ Engineering Design III (2)</td>
<td>¥ Engineering Design IV (2)</td>
</tr>
<tr>
<td>Freshman Seminar (1)</td>
<td>Prof. Org. Student-led Org. (0)</td>
<td>Prof. Org. Student-led Org. (0)</td>
<td>Leadership Prof. Meetings (0)</td>
</tr>
<tr>
<td>Total (16)</td>
<td>Total (17)</td>
<td>Total (17)</td>
<td>Total (16)</td>
</tr>
</tbody>
</table>

---

**Recommended:**

- PHIL 1500 - Logic and Critical Thinking
- Engineering Design I (2)
- Engineering Design II (2)
- Engineering Design III (2)
- Engineering Design IV (2)
- Capstone Design II (2)
- Organize UGA-wide activity (0)
- Senior Seminar (1)

---

**Total Hours:**

- First Year: 16
- Second Year: 17
- Third Year: 17
- Fourth Year: 16

---

**Total Credits:**

- First Year: 16
- Second Year: 17
- Third Year: 17
- Fourth Year: 16

---

**Total Credits (130 hrs):**

- First Year: 16
- Second Year: 17
- Third Year: 17
- Fourth Year: 16
Appendix – A. Engineering Laboratory and Design Courses

*Engineering laboratory* courses carry separate credit and a student will enroll in it in the same manner as s/he will for a classroom lecture course. Laboratory courses will be designed to integrate complementary concepts from several courses and disciplines. A single course (each year) on labs permits students to focus attention specifically on labs, heightens the significance placed on labs and communication skills, facilitates an appreciation for the linkage between areas of engineering. A lab assignment will defined with objectives, methods/protocols, data collection, analysis of data, results and conclusions. Student will provide a lab report that meets technical writing requirements.

Students complete engineering laboratory experiences during each year (spring of first three years, fall of last year). These courses build closely upon each other and integrate the science and engineering knowledge attained in lecture-based courses. Students will be able to select 5 from among several labs during the semester; e.g., Biochemical Engineering students may select different lab experiences than other students.

These labs will be delivered using a three-week format of, for example: one week of lecture focused on the lab and its engineering principles, a second week of conducting the lab, a third week to discuss the analysis and interpretation of results.

A period focused on labs permits University resources to be directed toward labs. During the first year, lab experiences will focus on device and process visualization, report writing, design of experiments, data analysis. During the second year, lab experiences will focus on development of statistical analysis skills, measurements, and basic engineering sciences courses of thermodynamics, statics and fluid mechanics. During the third year, the lab experiences will solidify core engineering knowledge and begin to develop knowledge in biochemical engineering. During the fourth year (fall semester), the lab experiences will solidify biochemical engineering experiences, relate engineering to advanced science. Focus on lab experiences in this way will also enhance the learning of data analysis and technical writing skills.

*Engineering Design* courses are project-based learning courses in which students learn to be creative, innovative and responsive to the integration of social and human aspects in the technical design solutions and skillful communicators.

Students complete engineering design experiences during each year (fall of first three years, both semesters of fourth year). These courses build closely upon each other and integrate the science and engineering knowledge with courses to build social intelligence attained in lecture-based courses.

During the first year, the focus will be on concept generation, creative thinking skills, report writing, and team building skills. During the second year, the focus will be on design methodology. During the third year, the focus will be on engineering and economic analysis of the design solutions. During the fourth year, students will have a year-long project. The focus of the Biochemical Engineering degree program is on process design, and therefore the design "problems" and capstone project will be process-based. During the fourth year, students may opt to engage in a two-semester biochemical engineering research project under the close mentoring of a faculty member.
Appendix – B

List of Courses for the University Core Requirement

The following is a list of selected courses that appear most appropriate to satisfy the university and degree requirements as well meet the overarching recommendations of the UGA Think Tank. Key words in each course description are highlighted to determine the desirability of it for the curriculum. Based on the description the following list ranks the desirability of courses with the number of star rating (four star is the highest rating), that is,

* Acceptable
** Desirable
*** Recommended
**** Highly recommended

NOTE: The University involved in these courses should be engaged in a discussion about this degree program BEFORE the curriculum is implemented. In this way they will gain appreciation of this program’s goals and the qualities we seek in a UGA Engineer. This will let us assess the true relevance/value of the course and know the potential of modification/enhancement possible for our goals.

-----------------------------------------------------------------------------

AREA A – Essential Skills (9 hours)

Two courses in English and one in math.

AREA B – Institutional Options (4-5 hours)

AREA C – Humanities/Fine Arts (Select 6 hours)

**ARTS 2000. Art Appreciation.** 3 hours. - Oasis Title: ART APPREC.
Understanding painting, sculpture, architecture, and design to enhance aesthetic appreciation.
Non-traditional format: This course is also offered through University System of Georgia Independent Study (USGIS).
Offered fall and spring semesters every year.

**DRAM 2000. Appreciation of Dramatic Art.** 3 hours. 2 hours lecture and 2 hours lab per week.
Oasis Title: APPREC OF DRAM ART.
Aesthetics and craft of the theatrical experience on stage, screen, and television. Discussions and analyses of all aspects of the theatrical arts; critical viewing of performances both in and out of class with written analyses. May not be used for credit towards the drama major.
Non-traditional format: This course is also offered through (USGIS).
Offered fall, spring, and summer semesters every year.

**MUSI 2020. Introduction to Music.** 3 hours. - Oasis Title: INTRO TO MUSIC.
The art of music listening involving study of the evolution of a wide range of musical styles from both western and non-western traditions. The course's approach is substantially chronological with elements of music also being covered.
Non-traditional format: This course is also offered through (USGIS).
Offered fall and summer semesters every year.

*****PHIL 1500. Logic and Critical Thinking.** 3 hours. 2 hours lecture and 1 hour lab per week.
Oasis Title: LOGIC & CRIT THINK.
Not open to students with credit in PHIL 1500H.
The principles and standards for thinking and communicating clearly and effectively. Topics include
theories of meaning, uses of language, common causes of confusion and error in thought and argument, and evaluation of arguments.
Non-traditional format: This course is also offered through (USGIS).
Offered fall, spring, and summer semesters every year.

****PHIL 2200. Introduction to Ethics. 3 hours. 2 hours lecture and 1 hour lab per week. -
Oasis Title: INTRO TO ETHICS.
Not open to students with credit in PHIL 2200H.
The major philosophical positions concerning right and wrong, ethical values, and moral responsibility. The relevance of moral philosophy to current issues of personal and social ethics.
Non-traditional format: This course is also offered through (USGIS).
Offered fall and spring semesters every year.

PHIL 2400. Philosophy, Science, and Nature. 3 hours. 2 hours lecture and 1 hour lab per week.
Oasis Title: PHIL SCIENCE & NAT.
The philosophy of science and the philosophy of nature, including such issues as standards governing scientific reasoning and the philosophical implications of contemporary and past scientific theories.
Offered every year.

AREA D – Science, Mathematics and Technology (10-11 hours)

Our curriculum should meet this requirement easily

AREA E – Social Sciences (12 Hours)

**AFAM 2000. Introduction to African American Studies. 3 hours. - Oasis Title: INTRO AFRI AMER ST.
Cultural, social, and historical movements among Americans of African descent.
Offered fall and spring semesters every year.

***ANTH)CLAS 2000. Introduction to Classical Archaeology. 3 hours. - Oasis Title: CLASSICAL ARCHAEO.
Concepts and principles of archaeology, including site formation, survey and excavation techniques, artifact retrieval and analysis, chronology, archaeological theory, and contemporary issues such as "ownership" of the past; focus on sites from Greek and Roman antiquity.
Offered spring semester every odd-numbered year.

*****CLAS 2110. Reacting to the Past: Athens and China. 3 hours. - Oasis Title: REACT ATHENS/CHINA.
In "Athens, Greece, 403 BCE" students, as Athenians, reestablish the polis after war and tyranny, debating amnesty, citizenry, education, foreign policy. In "China, 1587" students, as Chinese scholars, apply Confucian precepts to a dynasty in peril and confront a crisis in succession raised by the Wanli Emperor's break with tradition.
Non-traditional format: Through role-playing, students investigate large questions of historical causation. The class is constructed as a set of games that unfold unpredictably. Students run all game sessions; instructors advise factions and grade oral and written work. At the end of each game portion, in a series of post-mortem explorations, instructors set forth what did happen historically and compare "real" history to what happened in the classroom version.

*****CLAS 2113. Reacting to the Past: Athens and Revolution in France. 3 hours. - Oasis Title: REACT ATHENS/FRANCE.
In "Athens, Greece, 403 BCE" students, as Athenians, reestablish the polis after war and tyranny, debating amnesty, citizenry, education and foreign policy. In "France, 1791" students, as members of the parliament, formulate a constitution that redistributes power differently from the ancien regime, determining the direction of the revolution in progress.
Non-traditional format: Through role-playing, students investigate large questions of historical causation. The class is constructed as a set of games that unfold unpredictably. Students run all game sessions; instructors advise factions and grade oral and written work. At the end of each game portion, in a series of post-mortem explorations, instructors set forth what did happen historically and compare "real" history to what happened in the classroom version.
*GEOG 1101. Human Geography: People, Places, and Cultures. 3 hours. - Oasis Title: HUMAN GEOGRAPHY.
Not open to students with credit in GEOG 2010H-2010D.
Global patterns of resources, population, culture, and economic systems. Factors contributing to these patterns and distinctions between the technologically advanced and less advanced regions of the world. Non-traditional format: This course is also offered through (USGIS).
Offered fall, spring, and summer semesters every year.

**HIST(AFST) 2052. Multiculturalism in Modern America. 3 hours. - Oasis Title: MULTICULTUR MOD AM.
United States history since 1865 from a multicultural and multiethnic perspective. The course will emphasize social, cultural, and political dimensions of the American experience, paying particular attention to issues of race and ethnicity. Highlights the contributions of the many different peoples who make up America.
Offered every year.

***HIST 2302. History of Western Society Since 1500. 3 hours. - Oasis Title: WEST SOC SINCE 1500.
Western society from the Renaissance to the present day, emphasizing ideas, culture, and social change. Non-traditional format: This course is also offered through (USGIS).
Offered every year.

****HIST 2702. World Civilizations II. 3 hours. - Oasis Title: WORLD CIV II.
The human community from A.D. 1500 to the present, focusing on the interrelations of societies and cultures and comparing the experiences of peoples and civilizations with one another.
Offered every year.

**POLS 1101. American Government. 3 hours. - Oasis Title: AMERICAN GOVERNMENT.
Not open to students with credit in POLS 1105H.
Government and politics in the United States, including the philosophical and constitutional foundations, political institutions such as Congress and the presidency, political practices such as voting, and civil rights and liberties.
Non-traditional format: This course is also offered through (USGIS).
Offered fall, spring, and summer semesters every year.

****PSYC 1101. Elementary Psychology. 3 hours. - Oasis Title: ELEM PSYCHOLOGY.
Not open to students with credit in PSYC 1030H.
The phenomena, laws, theories, and history of psychology. Topics include animal and human learning, motivation, perception, individual differences, social behavior, and biopsychology. Emphasis is on fundamental principles rather than on application. Students are given the opportunity to participate in ongoing research.
Non-traditional format: This course is also offered through (USGIS).
Offered fall, spring, and summer semesters every year.

****SOCI 2600. Social Problems. 3 hours. - Oasis Title: SOCIAL PROBLEMS.
Not open to students with credit in SOCI 1600.
The causes, consequences, and social construction of American social problems, including poverty, crime and delinquency, environmental degradation, and race and ethnic relations.
Non-traditional format: This course is also offered through dy (USGIS).
Offered fall and spring semesters every year.

**WMST 2010. Introduction to Women's Studies. 3 hours. - Oasis Title: INTRO WOMEN STUDIES.
Not open to students with credit in WMST 2010H.
The study of women of diverse racial, ethnic, and class backgrounds. Topics include contemporary concerns within women's studies: labor markets, health, reproduction, socialization, language, media representations, law, and public policy.
Non-traditional format: This course is also offered through study (USGIS).
Offered fall, spring, and summer semesters every year.

AREA F - Courses related to the Program of Study
Appendix – C

List of Biochemical Engineering Electives Courses

- **Applied Pharmacokinetics and Toxicokinetics** - Dispersion and distribution of substances throughout bodily tissues.

- **Biocatalysis and Protein Engineering** - Homogeneous and heterogeneous biocatalysis and applications in a variety of industries. Applied enzymology, protein design, structure-activity relationships, biosensor technology, microbial transformations.

- **Bioinformatics and Systems Biology** – Introduction to bioinformatics, nature of bio-molecular level measurements and mathematical, computational, statistical methods to gain insights in the bio-functions. Also, introduce biology in context to a system that provides and understanding that biological systems have boundaries, elements, interconnectedness of the elements, flow of energy and mass and network.

- **Biomaterials** – Chemical, mechanical and thermal properties of biomaterials and their used in bioprocessing systems.

- **Biorefinery Engineering** - The design of sustainable processes for the conversion of biomass into fuels and chemicals. This course presents various aspects of biomass conversion to energy, chemical, and bioproducts. The presentations are linked to introduce the student to opportunities in the emerging bio-economy. Topics include biomass types and characteristics, technologies, systems analysis, economics, and environmental aspects of biorefineries.

- **Drug Formulation and Delivery**

- **Engineering Life Cycle Analysis** - Principles of life cycle analysis (cradle-to-grave) approaches, mass and energy balances, inventory (resources & emissions) analysis, impact assessment, allocations and interpretations, applications to engineering processes and products, hybrid LCA approaches.

- **Facility Design and Biocontainment** - Design of facilities for GMP manufacturing, including current regulations covering such facilities.

- **Introduction to Systems and Modeling** – Introduction to systems thinking, methods of systems representation, principles of computer-based modeling and discrete event modeling. Class project will require modeling an element of a biochemical system.

- **Tissue Engineering** - Introduction to tissue engineering and biological scaffolds. This course presents the fundamentals of science and engineering design related to replacement organs and tissues.
Appendix – D.  Only for Class entering the program in the Fall 2007.

**TABLE 2. Modified Schedule of Courses for the B.S. in Biochemical Engineering Four-year (Eight-semester) Degree Program**

**A Sample Biochemical Engineering Curriculum (130 hrs)**  
[* Modified course; ¥ - New course]

“First Year schedule of courses is modified because of the inability of offer Design I class in the Fall 2007”

<table>
<thead>
<tr>
<th>First Year</th>
<th>Second Year</th>
<th>Third Year</th>
<th>Fourth Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Calculus I (4)</td>
<td>Calculus II (3)</td>
<td>Calculus III (3)</td>
<td>* Biochem Engr I (2)</td>
</tr>
<tr>
<td>Chemistry I (4)</td>
<td>Chemistry II (4)</td>
<td>* Thermo I (2)</td>
<td>* Biochem Engr II (2)</td>
</tr>
<tr>
<td>Biology I (4)</td>
<td>* Programming (2)</td>
<td>* Heat Transfer (2)</td>
<td>¥ Thermo II (2)</td>
</tr>
<tr>
<td>Physics I (4)</td>
<td>¥ Biophysics (4)</td>
<td>¥ Statics &amp; Fluid Mechanics (3)</td>
<td>¥ Biochem Engr Elective I (3)</td>
</tr>
<tr>
<td>Humanities I (3)</td>
<td>Social Sciences I (3)</td>
<td>English II (3)</td>
<td>¥ Biochem Engr Elective II (3)</td>
</tr>
<tr>
<td>* Engineering Design I (2)</td>
<td>¥ Engineering Lab II (2)</td>
<td>¥ Engineering Design III (2)</td>
<td>¥ Biochem Engr Elective III (3)</td>
</tr>
<tr>
<td>Engineering Lab I – * Visualization (2)</td>
<td></td>
<td>¥ Engineering Lab III (3)</td>
<td>¥ BioProc. Elec. &amp; Sensors (3)</td>
</tr>
<tr>
<td>Freshman Seminar (1)</td>
<td>Prof. Org. Student-ld Org. (0)</td>
<td>* Capstone Design II (2)</td>
<td>¥ BioProc Quality Control w/Lab (3)</td>
</tr>
<tr>
<td>Total (16)</td>
<td>Total (16)</td>
<td>Total (17)</td>
<td>Total (18)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total (16)</td>
<td>Total (15)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total (16)</td>
<td>Total (15)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total (15)</td>
<td>Total (15)</td>
</tr>
</tbody>
</table>

*Only for Class entering the program in the Fall 2007.*