**CLEMSON UNIVERSITY**

**REQUESTING TO MODIFY AN EXISTING PROGRAM**

**Bachelor of Science**

**in**

**Chemical Engineering**

**Adding a concentration in Biomolecular Engineering**

***Submitted to the South Carolina Commission on Higher Education***

College of Engineering and Science
Clemson University

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Clemson University

## 1.0 Classification

The Department of Chemical and Biomolecular Engineering proposes a program modification to add a Biomolecular Engineering concentration to the 4-year B.S. degree in Chemical Engineering (CIP 14.0701). By definition, this concentration will *only* be available to those students within the Chemical and Biomolecular Engineering Department, and must be viewed as an academic concentration within the greater Chemical Engineering discipline. This concentration is not a complete University Major (course of study), but provides a focused learning experience beyond the core Chemical Engineering courses.

The proposed date of implementation for this program modification is Fall, 2007.

## 2.0 Justification

### 2.1 Purpose and Objectives of the Program

Chemical Engineers have had a long history of engagement with biological processes. In recent years, there has been an acknowledgement within the discipline that biology must be incorporated as a fourth enabling foundation science. At the undergraduate level, a fundamental understanding of biological molecules and biochemistry, for example, is now seen nationwide as a necessary requirement in the preparation of B.S. Chemical Engineers who are capable of solving problems and making contributions to their employers in the biopharmaceutical and biotechnology industries upon graduation. The proposed concentration will (1) enhance the academic experience of chemical engineering students and (2) allow Clemson B.S. Chemical Engineering graduates to compete nationally with other B.S. Chemical Engineering graduates.

### 2.2 Need for the Program in the State

The Biomolecular Engineering concentration is designed to enhance the academic experience and career opportunities of students selecting the existing Chemical Engineering major and degree at Clemson. There is no other program in the state that results in a B.S. degree in Chemical Engineering that incorporates a focused set of courses leading to a Biomolecular Engineering Concentration.

In developing the concentration in Biomolecular Engineering, the faculty members have solicited and incorporated input and justification from a wide range of sources as detailed below.

- A Curriculum Workshop, hosted by the department in 2004, noted that the companies that hire chemical engineers increasingly have a biological/life sciences focus, and recommended developing formal ways to incorporate these needs into the curriculum.
- At the Fall 2005 Advisory Board meeting, the board members encouraged the department to develop biology-based curriculum concentrations relevant to the Biotechnology industry.
- A series of workshops sponsored by the National Science Foundation and the Council for Chemical Research (CCR), and organized by Professor Bob Armstrong (Chair of Chemical Engineering at MIT), brought together both academics and industrial representatives to work on a revitalization of the Chemical Engineering

curriculum. Two key outcomes of this meeting were the recognition of biology as a necessary and enabling science for Chemical Engineering, and the observation that the discipline must respond to the industries (e.g. pharmaceutical, consumer products/personal care, and biotechnology) that are increasingly seeking our graduates at the B.S. level.

- The Sloan Career Cornerstone Center predicts large growth in research and development for biotechnology, and anticipates that, with regard to manufacturing industries, pharmaceuticals may have the best opportunities for ChEs.
- In a survey of our current undergraduate students, 45% list working in a bio-related field among their career goals.
- Approximately 5% of our graduates have gone on to Medical School over the past 15 years.
- Clemson faculty members in the Department of Chemical and Biomolecular Engineering have developed strong, competitively funded research programs in the bio area of Chemical Engineering. These research programs include: biodiesel, biopolymers, bioseparations, biosensors, and biomaterials. To enhance the undergraduate academic experience, these topics are increasingly being incorporated into core and elective courses within the department.
- The Department of Chemical and Biomolecular Engineering is the home department for the research program for Bioelectronics, Biosensors and Biochips (C3B). This research program, led by Professor Anthony (Tony) Guiseppi-Elie, has annual research expenditures of ~$1.2MM and 7 biotech industry partners.

## 2.3 Centrality of the Program to Clemson University's Mission

The proposed B.S. in Chemical Engineering with a concentration in Biomolecular Engineering will be a high-quality baccalaureate program built around a distinctive core curriculum, in this case the existing B.S. Chemical Engineering core curriculum. As a unique program in the state, the B.S. in Chemical Engineering with a concentration in Biomolecular Engineering will help the University to fulfill that part of its mission to attract a capable, dedicated and diverse student body. This program will share the University goal to develop students' communication and critical-thinking skills, ethical judgment, global awareness, and scientific and technological knowledge.

## 2.4 Relationship with Other Programs at Clemson University

The continually evolving face of Chemical Engineering has led to changes in (1) the public profile of the discipline; (2) the demands of companies that recruit our students; (3) the career goals and aspirations of B.S. graduates; and (4) the research activities of the faculty in response to the interests of funding agencies and corporate partners.

To better serve all of its constituents, the department proposes adding this concentration in Biomolecular Engineering to the B.S. degree in Chemical Engineering. Given the specific context within the existing Chemical Engineering discipline, this concentration does not duplicate any other majors that are available on campus or across the state. We contend that this concentration is evolutionary, as it builds upon the traditional foundation of the Chemical Engineering curriculum, and represents one of the primary directions in which the discipline is moving at the national level.

## 2.5 Comparison with Related Programs

The discipline of Chemical Engineering is one of the core, founder society, engineering disciplines (along with mechanical, electrical and civil engineering), and has historically been built upon a foundation of mathematics, chemistry and physics. Chemical Engineering, unlike the other founder engineering disciplines, focuses on molecular phenomena that manifests on scales that range from individual molecules to their large-scale production. In recent years, paralleling the growth in the molecular basis of biology, there has been an acknowledgement within the discipline that biology must be incorporated as a fourth enabling foundation. This has been confirmed through national workshops sponsored by the National Science Foundation and the Council for Chemical Research. This need is a manifestation of the demand for B.S. Chemical Engineers from a wide range of industries. No longer do petrochemical companies hire 70-80% of our undergraduates. Rather, graduates are pursuing careers as chemical engineers within pharmaceutical, biotechnology and consumer products companies that expect their new employees to apply Chemical Engineering core competencies to a range of applications with biological, chemical and life sciences implications. In addition, Chemical Engineering is nationally viewed as a rigorous, professional, preparatory degree for undergraduates matriculating to pharmacy and medical schools.

For these reasons, in early 2005, the Clemson Board of Trustees approved, and the Commission on Higher Education was notified of, a name change for the Department of Chemical Engineering to the Department of Chemical and Biomolecular Engineering. This name change is consistent with many other institutions nationwide (and worldwide), and reflects the fact that the skills traditionally taught and applied to Chemical Engineering problems increasingly require a knowledge of biological processes on a molecular scale. The current proposal codifies and gives substance to this approved name change.

# 3.0 Enrollment

The admissions criteria are those for the B.S. in Chemical Engineering. There are no additional admissions criteria for the proposed concentration.

Table 1 summarizes the projected total student enrollment for the first 5 years. These estimates were made based on historical data of the average size of the graduating class in the B.S. Chemical Engineering program (37 graduates/year over the last 10 years) and recent poll data. In a poll of undergraduate students currently enrolled in Chemical Engineering, 49% of freshman and 38% of sophomores stated that they have a career goal to work in the biotech, pharmaceutical or life sciences industries. The same cohort of students was also asked if their decision to enroll in the University was influenced by the fact that our Department has biomolecular engineering as an area of emphasis. 9% said that this emphasis was a factor in their decision. The results of that poll serve as the reference for the estimated number of new students to the University that will result from this program modification, shown in Table 2.

Thus, it is anticipated during the first 5 years that 18-26 students annually will choose to pursue the B.S. degree in Chemical Engineering with a Concentration in Biomolecular Engineering. While this number is based upon the interests of the current B.S. Chemical Engineering students, employment trends for Chemical Engineers within the biotechnology, pharmaceutical and life sciences related chemical industries suggest that

these percentages are reasonable to expect. The American Institute of Chemical Engineers Department of Career Services reported in its most recent report (Dec. 2003) that 13% of BS chemical engineers had initial placement in the biotechnology and related industries, up from 10.3% in 2001-2002. And, as we highlighted in Section 2.2, the pharmaceutical industry is likely to have the best opportunities for ChEs interested in careers in manufacturing. As with the AIChE data, we expect to see a gradual increase in the number of students who choose the Biomolecular Engineering Concentration in Chemical Engineering.

**Table 1.** Projected total enrollment in the B.S. Chemical Engineering with a concentration in Biomolecular Engineering.

| **PROJECTED TOTAL ENROLLMENT** | | | | | | |
|---|---|---|---|---|---|---|
| **YEAR** | **FALL** | | **SPRING** | | **SUMMER** | |
| | Headcount | Credit Hours | Headcount | Credit Hours | Headcount | Credit Hours |
| 2007 – 08 | 10 | 160 | 10 | 160 | N/A | N/A |
| 2008 – 09 | 28 | 448 | 28 | 448 | N/A | N/A |
| 2009 – 10 | 44 | 704 | 44 | 704 | N/A | N/A |
| 2010 – 11 | 45 | 720 | 45 | 720 | N/A | N/A |
| 2011 – 12 | 46 | 736 | 46 | 736 | N/A | N/A |

**Table 2.** Projected new enrollment in the University as a result of the program modification for a B.S. Chemical Engineering with a concentration in Biomolecular Engineering.

| **PROJECTED NEW ENROLLMENT** | | | | | | |
|---|---|---|---|---|---|---|
| **YEAR** | **FALL** | | **SPRING** | | **SUMMER** | |
| | Headcount | Credit Hours | Headcount | Credit Hours | Headcount | Credit Hours |
| 2007 – 08 | 6 | 96 | 6 | 96 | N/A | N/A |
| 2008 – 09 | 7 | 112 | 7 | 112 | N/A | N/A |
| 2009 – 10 | 8 | 128 | 8 | 128 | N/A | N/A |
| 2010 – 11 | 9 | 144 | 9 | 144 | N/A | N/A |
| 2011 – 12 | 10 | 160 | 10 | 160 | N/A | N/A |

## 4.0 Curriculum

### 4.1 Sample Curriculum

The curriculum for the B.S. Chemical Engineering with a concentration in Biomolecular Engineering is shown on the next page. Courses that have been removed from the standard B.S. Chemical Engineering program are listed below the curriculum under the heading 'OUT'. Courses that have been added are listed under the heading 'IN' and are shown in boldface within the curriculum.

### 4.2 New Courses to be Added to the Undergraduate Catalog in the Next 5 Years

**BMOLE 403, 603 Biotransport phenomena 3(3,0)** Analysis of single and multidimensional steady-state and transient problems in momentum, energy, and mass transfer in biological systems. Mathematical similarities and differences in these mechanisms are stressed, and mathematical descriptions of physiological and engineering systems are formulated.

**BMOLE 423, 623 Bioseparations 3(3,0)** Study of principal methods of separation and purification of bioproducts, such as proteins, amino acids, and pharmaceuticals. Topics include analytical bioseparations, membrane separations, sedimentation, cell disruption, extraction, adsorption, chromatography, precipitation, crystallization, and drying.

**BMOLE 425, 625 Biomolecular Eng 3(3,0)** Introduction to basic principles of biomolecular engineering, the purposeful manipulation of biological molecules and processes, applied to problems and issues in the life sciences, biotechnology, and medicine. Topics include carbohydrates, proteins, nucleic acids, and lipids, with emphasis on their structure-property-function relations; molecular recognition; biochemical pathway engineering; and cell growth.

**BMOLE 426, 626 Biosensors and Bioelectronic Devices 3(3,0)** Development of the methodologies used in the design, fabrication and application of biosensors and bioelectronic devices to monitoring problems in the environmental, medical and chemicals industries. Application of the fundamentals of measurement science to optical, electrochemical, mass and thermal means of signal transduction. Use of the fundamentals of surface science to interpret bio-immobilization, biofouling and non-specific interactions of enzymes, antibodies and DNA at surfaces.

# PROPOSED B.S. CHEMICAL ENGINEERING CURRICULUM WITH A BIOMOLECULAR ENGINEERING CONCENTRATION

## Freshman Year

| | | | | | |
|---|---|---|---|---|---|
| CH 101 | General Chemistry | 4 | CH 102 | General Chemistry | 4 |
| MTHSC 106 | Calculus of One Variable I | 4 | MTHSC 108 | Calculus of One Variable II | 4 |
| ENGL 103 | English Composition | 3 | PHYS 122 | Physics with Calculus I | 3 |
| CES 102 | Engineering Disciplines & Skills | 2 | CH E 130 | Chemical Engineering Tools | 3 |
| Humanities/Social Science[1] | | 3 | Humanities/Social Science[1] | | 3 |
| *Semester Totals:* | | ***16*** | | | ***17*** |

## Sophomore Year

| | | | | | |
|---|---|---|---|---|---|
| CH 223 | Organic Chemistry | 3 | CH 224 | Organic Chemistry | 3 |
| MTHSC 206 | Calculus of Several Variables | 4 | CH 229 | Organic Chemistry Lab | 1 |
| CH E 211 | Intro. to Chemical Engineering | 4 | BIOCH 301 | General Biochemistry | 3 |
| PHYS 221 | Physics with Calculus II | 3 | **BIOCH 302** | **Molecular Biology Lab** | **1** |
| Literature Requirement[2] | | 3 | ChE 220 | Chemical Engr. Thermodynamics I | 3 |
| | | | ChE 230 | Fluids/Heat Transfer | 4 |
| *Semester Totals:* | | ***17*** | | | ***15*** |

## Junior Year

| | | | | | |
|---|---|---|---|---|---|
| CH E 319 | Engineering Materials | 3 | CH E 321 | Chemical Engr. Thermodynamics II | 3 |
| ChE 307 | Unit Operations Lab. I | 3 | CH E 330 | Mass Transfer & Separations | 4 |
| MTHSC 208 | Intro to Ord. Diff. Equations | 4 | **BIOCH 431** | **Physical Approach to Bioch.** | **3** |
| **BIOL 103/105** | **General Biology I/Lab** | **4** | Humanities/Social Science[1] | | 3 |
| Humanities/Social Science[1] | | 3 | **ENGINEERING REQUIREMENT** | | **3** |
| *Semester Totals:* | | ***17*** | | | ***16*** |

## Senior Year

| | | | | | |
|---|---|---|---|---|---|
| CH E 407 | Unit Operations Lab. II | 3 | CH E 353 | Process Dynamics and Control | 3 |
| CH E 431 | Process Dev. & Design | 3 | CH E 433 | Process Design II | 3 |
| CH E 443 | Chem. Engr. Senior Seminar I | 1 | CH E 444 | Chem. Engr. Senior Seminar II | 1 |
| CH E 450 | Chemical Reaction Engineering | 3 | MICRO 413 | Industrial Microbiology | 3 |
| **BMOLE 403** | **BioTransport Phenomena** | **3** | **ENGINEERING REQUIREMENT** | | **3** |
| **BIOE 302** | **Biomaterials** | **3** | Humanities/Social Science[1] | | 3 |
| *Semester Totals:* | | ***16*** | | | ***16*** |

**Total =130 hrs.**

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| **OUT** | | | **IN** | | |
|---|---|---|---|---|---|
| ECE 307/309 | Basic Elect. Engr & Lab | 3 | BIOCH 302 | Molecular Biology Lab | 1 |
| CH 339 | Physical Chemistry Lab | 1 | BIOE 302 | Biomaterials | 3 |
| CH 332 | Physical Chemistry | 3 | BIOL 103 | General Biology I | 4 |
| CH 340 | Physical Chemistry Lab | 1 | BIOCH 421 | Physical Approach to Bioch. | 3 |
| Emphasis Area | | 9 | BioTransport Phenomena | | 3 |
| **Total** | | **17** | ENGINEERING REQUIREMENT | | 6 |
| | | | **Total** | | **20** |

**ENGINEERING REQUIREMENTS LIST (2 courses)**

| | |
|---|---|
| **CH E 428** | **Biochemical Engineering** |
| **BMOLE 423** | **Bioseparations** |
| **BMOLE 425** | **Biomolecular Engineering** |
| **BMOLE 426** | **Biosensors and Bioelectronic Devices** |

## 5.0 Faculty

### 5.1 Rank and Academic Qualifications

Table 3 summarizes the rank and qualifications of the faculty who will be involved in the Biomolecular Engineering Concentration. Table 4 on the next page shows the number and full-time equivalent of faculty, administrators, and staff to be used in the new program. At Clemson, full-time equivalent is defined as 12 credits.

**Table 3.** Rank and qualifications of each faculty member who will be involved in the program.

| Faculty by Rank | Highest Degree Earned | Field of Study | Teaching in Field (Yes/No) |
|---|---|---|---|
| Professor #1 | PhD | Heterogeneous Catalysis and Kinetics, Biofuels | Yes |
| Professor #2 | PhD | Biotechnical Polymers, Biosensors, and Biochips | Yes |
| Associate Professor #1 | PhD | Biofuels, Molecular Modeling of Biodegradable Polymers | Yes |
| Associate Professor #2 | PhD | Polymer Surface Engineering | Yes |
| Associate Professor #3 | PhD | Bioseparations, Biointerfacial Engineering | Yes |
| Associate Professor #4 | PhD | Non-Newtonian Fluid Mechanics and Renewable Resource Polymers | Yes |
| Assistant Professor #1 | PhD | Photopolymerizations, Degradable Biomaterials, Protein Delivery | Yes |

### 5.2 Enumeration and Discussion of New Faculty and Staff Qualifications

The new faculty hires in 2008-09 and 2010-11 will be either due to replacing retiring faculty or due to enrollment growth in the Department as a result of this new concentration. The qualifications of these new faculty hires will be 1) a PhD degree in an engineering or science discipline and 2) teaching and/or research experience in a field of study related to biomolecular engineering.

### 5.3 Explanation of Proposed Changes in Faculty Assignment

The Department of Chemical and Biomolecular Engineering will assign courses in this Program as part of normal faculty teaching loads. New teaching requirements in this Program will be balanced by a shift in students from the standard chemical engineering courses, which will require less effort due to smaller class size or fewer sections.

### 5.4 Institutional Plan for Faculty Development Related to the Program

Faculty teaching in this Program, by and large, already have existing research in this area. The Department will support travel of faculty involved to workshops and conferences on the development of biomolecular engineering courses in chemical engineering. Some release time will be provided for course development and curriculum issues.

**Table 4.** Number and full-time equivalent of faculty, administrators and staff to be used in the program.

| UNIT ADMINISTRATION/FACULTY/STAFF SUPPORT | | | | | | |
|---|---|---|---|---|---|---|
| **YEAR** | **NEW** | | **EXISTING** | | **TOTAL** | |
| | Headcount | FTE | Headcount | FTE | Headcount | FTE |
| **Administration** | | | | | | |
| 2007 – 08 | N/A | N/A | 1 | 0.1 | 1 | 0.1 |
| 2008 – 09 | N/A | N/A | 1 | 0.1 | 1 | 0.1 |
| 2009 – 10 | N/A | N/A | 1 | 0.1 | 1 | 0.1 |
| 2010 – 11 | N/A | N/A | 1 | 0.1 | 1 | 0.1 |
| 2011 – 12 | N/A | N/A | 1 | 0.1 | 1 | 0.1 |
| **Faculty** | | | | | | |
| 2007 – 08 | N/A | N/A | 7 | 0.5 | 7 | 0.5 |
| 2008 – 09 | 1 | 0.25 | 7 | 0.75 | 7 | 1.0 |
| 2009 – 10 | N/A | N/A | 7 | 1.25 | 7 | 1.25 |
| 2010 – 11 | 1 | 0.25 | 7 | 1.25 | 7 | 1.5 |
| 2011 – 12 | N/A | N/A | 8 | 2.0 | 8 | 2 |
| **Staff** | | | | | | |
| 2007 – 08 | N/A | N/A | 1 | 0.1 | 1 | 0.1 |
| 2008 – 09 | N/A | N/A | 1 | 0.1 | 1 | 0.1 |
| 2009 – 10 | N/A | N/A | 1 | 0.1 | 1 | 0.1 |
| 2010 – 11 | N/A | N/A | 1 | 0.1 | 1 | 0.1 |
| 2011 – 12 | N/A | N/A | 1 | 0.1 | 1 | 0.1 |

## 6.0 Physical Plant

The physical plant is adequate to provide space for the program for at least the first 5 years.

## 7.0 Equipment

One major equipment item will be needed in the next 5 years for a new undergraduate laboratory experiment focused on Biomolecular Engineering in the senior year Unit Operations Laboratory II course. The item is an ÄKTApurifier™ (GE Healthcare Life Sciences) protein chromatography system, which will be used for a bioseparations laboratory experiment.

Designing a laboratory experiment that uses this protein chromatography system is important since the majority of costs in a bioprocess are associated with product purification, and oftentimes the purification method of choice is chromatography. This experiment will improve instruction by giving students hands-on experience with elements of bioseparations.

## 8.0 Library Resources

This proposal is for a program modification to add a Biomolecular Engineering concentration to the 4-year B.S. degree in Chemical Engineering. As shown in the proposed curriculum, all but 9 hours of coursework (Biotransport phenomena, 3; Engineering requirement, 6) in the program are existing courses taught at Clemson, for which current library holdings have been deemed to be sufficient by the various College and University Curriculum Committees that have approved them.

Library holdings for the four newly proposed BMOLE courses listed in Section 4.0 are also sufficient. Table 5 summarizes current holdings relevant to these courses. *Importantly*, the books and journals given in Table 5 represent only specialized holdings. There are many other general library holdings are pertinent to these courses. For example, there are 26 journals in separation science and engineering, and most of these publish articles on bioseparations.

**Table 5.** Pertinent library holdings for the newly proposed BMOLE courses.

| COURSE | # OF BOOKS | JOURNALS |
|---|---|---|
| BMOLE 403 | 12 | Biorheology, Clinical Hemorheology, Microcirculation |
| BMOLE 423 | 13 | Bioseparation |
| BMOLE 425 | 16 | Biomolecular Engineering; Genetic Analysis, Biomolecular Engineering |
| BMOLE 426 | 56 | Biosensors and Bioelectronics; Advances in Biosensors |

## 9.0 Accreditation

The concentration will be offered under the broader Chemical Engineering discipline, will be based upon and be derived from the core chemical engineering curriculum and will therefore be subject to accreditation as a Chemical Engineering degree by ABET.

## 10.0 Estimated Cost

Table 6 summarizes the new costs to the institution and the sources of financing for this program. No "unique costs" or other special state appropriations will be required or requested.

**Table 6.** New costs to the institution and the sources of financing for this program.

| ESTIMATED COSTS BY YEAR | | | | | | |
|---|---|---|---|---|---|---|
| **CATEGORY** | **1st** | **2nd** | **3rd** | **4th** | **5th** | **TOTAL** |
| Program Administration | $0 | $0 | $0 | $0 | $0 | $0 |
| Faculty Salaries | $0 | $0 | $25,000 | $26,000 | $27,000 | $78,000 |
| Graduate Assistants | $0 | $0 | $10,000 | $25,000 | $25,000 | $60,000 |
| Clerical/Support Personnel | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplies and Materials | $2,000 | $5,000 | $10,000 | $10,000 | $10,000 | $37,000 |
| Library Resources | N/A | N/A | N/A | N/A | N/A | N/A |
| Equipment | $0 | $60,000 | $10,000 | $10,000 | $10,000 | $90,000 |
| Facilities | N/A | N/A | N/A | N/A | N/A | N/A |
| Other (Identify) | $0 | $0 | $0 | $0 | $0 | $0 |
| **TOTALS** | $2,000 | $65,000 | $55,000 | $71,000 | $72,000 | $265,000 |
| **SOURCES OF FINANCING BY YEAR** | | | | | | |
| Estimated FTE Revenue Generated from the State | $0 | $0 | $0 | $0 | $0 | $0 |
| Tuition Funding (New students only) | $40,278 | $46,991 | $53,704 | $60,417 | $67,130 | $268,233 |
| Other State Funding (Legislative Approp.) | $0 | $0 | $0 | $0 | $0 | $0 |
| Reallocation of Existing Funds | $0 | $0 | $0 | $0 | $0 | $0 |
| Federal Funding | $0 | $0 | $0 | $0 | $0 | $0 |
| Other Funding (Endowment, Auxiliary etc.) | $0 | $0 | $0 | $0 | $0 | $0 |
| **TOTALS** | $40,278 | $46,991 | $53,704 | $60,417 | $67,130 | $268,233 |

## 11.0 Institutional Approval

| Title of internal institutional body approving this concentration | Approval date |
|---|---|
| • Department of Chemical and Biomolecular Engineering | 09/21/2005 |
| • Clemson University Board of Trustees | 10/19/2006 |
| • College of Engineering and Science Curriculum Committee | 03/02/2007 |
| • University Curriculum Committee | 05/04/2007 |