

## Descriptions of Courses

### □ Undergraduate

#### CBE201 Molecular Engineering Laboratory

This course deals with basic experimental techniques and related principles required for understanding molecular engineering. This course covers various experimental techniques and theoretical principles for molecular reaction engineering, biochemical engineering, and polymer engineering.

#### CBE203 Industrial Organic Chemistry

Industrial organic chemistry will offer an extensive look at the special nature of carbon chemistry. Emphasis will be placed on structure, functional groups and nomenclature as well as important classes of industrial organic reactions.

#### CBE205 Engineering in Life Science & Chemistry

Main focus of the conventional chemical engineering was to design a process for a given chemical and bio-product. However, the new chemical and biomolecular engineering deals with chemical product design to meet the need of the market. This course explains how this new aspect of chemical and biomolecular engineering is implemented and gives brief introduction on the engineering science, chemistry and life science from the point of product and process design. High school level knowledge on chemistry and life science are assumed.

#### CBE221 Molecular Thermodynamics and Energy Systems

The main goal is for students to be more familiar with the basic principles of thermodynamics and apply these principles to the solution of a large variety of energy flow and equilibrium problems. In particular, molecular thermodynamics is emphasized to extend its applications to energy, environment, BT and NT.

#### CBE260 Biomolecular Engineering

Lecture about the basic biological principles necessary for the engineering application of biomolecular phenomena.

#### CBE261 Biochemical Engineering

This course deals with various engineering principles required for understanding and developing bioprocesses by using microbial, animal and plant cells, and enzymes.

#### CBE301 Chemical and Biomolecular Engineering Laboratory

This course deals with basic experimental techniques of chemical and biomolecular engineering and their implementations or applications into final products or processes. The scope of this course includes various key experimental technologies for reaction optimization, development of catalysts, molecular separation & analysis, polymer & nanomaterials, and biotechnology.

(Prerequisite course: CBE201)

#### CBE302 Chemical and Biomolecular Engineering LaboratoryII

This course deals with various experimental techniques of chemical and biomolecular engineering including fluid mechanics, reaction engineering, polymer engineering, biochemical engineering, and process control/analysis. (Prerequisite course: CBE301)

### CBE311 Molecular Reaction Engineering

Molecular reaction engineering deals with ideal reactor model and the kinetics of chemical and biological process. Estimation of kinetic parameters and reactor sizing are main topics in addition to the evaluation of the reactor performance.

### CBE321 Molecular and Bio Separation Technology

The separation technology becomes more important in the production of fine chemicals and bioproduct as well as the separation and purification of conventional petrochemicals. The goal of this lecture is to understand the principles of separation technology for various products in separation process. It covers equilibrium stage concept and cascade continuous molecular separation. Adsorption, chromatography, membrane separation, which are used widely in bioproduct separation, are also included.

### CBE331 Fluid Mechanics of Microsystems

This course is designed to provide an orderly treatment of the essentials of both macroscopic problems and detailed microscopic structure of fluid flows. Topics include continuum hypothesis, kinematics, body forces and surface forces, conservation laws, constitutive equations, one-dimensional flows, dimensional analysis, low Reynolds number flows, potential flows, boundary layer theory, turbulent flows and macroscopic balances. Prerequisites by topics are as follows: ordinary differential equations and partial differentiations, multiple integrals, Taylor series, basic elements of vector analysis, material and energy balances and elementary mechanics.

### CBE332 Heat and Molecular Transfer

Energy and mass conservation laws are applied to understand the heat and molecular transport phenomena. Tool developed in applied mathematics are frequently used to solve problems encountered in many field of science and technology. Students are encouraged to talk about the assumptions necessary to simplify the problem. (Prerequisite course: CBE331)

### CBE341 Process Simulation and Control

This course is designed to give juniors in chemical engineering an ability to design and analyze single loop feedback control systems.

### CBE342 Chemical and Biological Product Design

The Basic concept of chemical and biological product design are introduced. Four steps of product design principles (need analysis, proposing alternative ideas, screening, and manufacturing and economic consideration) are discussed.

### CBE351 Introduction to Macromolecular Engineering

This course covers the general principles of synthesis, characterization, and physical behavior of polymers. It also deals with general methods of polymer processing. The course will emphasize understanding of the basic terminologies and concepts in polymer science and engineering.

### CBE362 Bioinformatics

This course will cover theories and practices of bioinformatics, which is an important subject in the era of high-throughput biology and biotechnology. Topics such as basics of modern biology including genomics, transcriptomics, proteomics and metabolic pathways will be discussed first. Then, various bioinformatic tools and databases will be introduced. Sequence analysis using BLAST and multiple alignment, database design and search, protein structure prediction, protein protein interaction, DNA microarray, proteome profiling, microbial genomics and systems biology/biotechnology are the major topics to be covered.

#### CBE404 Understanding of Molecules and Nanosystems

Quantum mechanical "language" to understand molecules and nano-scale materials are lectured. Introduction of Schrödinger equation, electron tunnelling, molecular structure of mono-, di- and poly-atoms, and origin of chemical bonding are discussed. Atomic spectroscopy, molecular spectroscopy, and X-ray crystallography that characterize nano-scale materials are introduced. Macromolecules and colloids are also briefly discussed.

#### CBE442 Optimal Design and Economics

Current trend in chemical and bio-related industry, accounting and balance of corporate, optimization, economic feasibility, process and product design method are lectured. Case studies of process and product design are also discussed.

#### CBE455 Nanochemical Technology

This course deals with theories and experimental methods for predicting the nanostructure-macroscopic property relations under equilibrium and nonequilibrium conditions. Nanofabrication methods considered in this course cover the conventional top-down lithographic techniques and the self-assembling bottom-up approaches. The building blocks for nanostructures include surfactant micelles, block copolymers, inorganic particles, liquid crystals, polymer latexes and biomolecules. Interactions between building blocks that govern the phase behavior of nanostructures will be discussed.

#### CBE471 Introduction to Environmental Engineering

This course introduces environmental issues both in global scale and in our immediate neighborhood to the students at senior and master level. Students can learn about technologies developed in biotechnology and chemical engineering and utilized to solve the environment problems. Issues related in water and wastewater treatment, solid waste disposal, and air pollution control are discussed.

#### CBE473 Microelectronics Processes

Unit Operations in micro-electronics processing such as chemical deposition, oxidation, ion implantation, metal sputtering, Sputtering, chemical deposition process are introduced and how these unit processes are integrated to produce semiconductor chips. Especially, chemical engineering principles are focused.

#### CBE481 Special Topics in Chemical and Biomolecular Engineering

Recent advances in chemical and biomolecular engineering are lectured. Details on the topics are available at the beginning of each semester.

#### CBE483 Engineering Principles of Human Physiology

Biotechnology for humans amounts to about 80% of biotechnology markets and the major areas for this contributions are drug delivery, tissue engineering, biochips and recombinant DNA products. Thus, there is need to help engineering students better understanding of engineering principles of human physiology. Mass and Energy balance of human body, respiratory system for oxygen exchange through membrane, blood circulation and blood coagulation, digestive bioreactor systems, filtration and urinary system. In addition, the recent development of artificial blood, diabetes and high blood pressure will be introduced with tissue engineering and gene therapy.

#### CBE490 Undergraduate Research in Chemical and Biomolecular Engineering

Various research topics ranging from the application to fundamental principles of chemical and biomolecular engineering are assigned by the thesis advisor. The final thesis should be submitted to the thesis committee.

#### CBE495 Individual Study

Special topics of personal interest is studied under the guidance of advisor. It includes laboratory work, literature survey, or computer simulation but is not limited to these activities.

#### CBE496 Seminar for Undergraduate Students

This course is intended to give chemical engineering undergraduates opportunities to contact currently important chemical engineering topics. Speakers are invited from a wide spectrum of fields such as institutions, government, and so forth.

### □ Graduate

#### CBE501 Chemical & Biomolecular Engineering Experimentation and Research Method

This lecture discussed how to set the goals and objectives of experiments how to minimize the amount of experiments by electronic search, and how to design experiments, measure, and analyze data. Safety rules in chemical and biomolecular engineering laboratory are also emphasized.

#### CBE502 Engineering Applied Mathematics

To obtain analytical solutions of various mathematical models related to chemical engineering, solution methods for the linear partial differential equations are introduced. Nonlinearity of the differential equations are taken into account by asymptotic analysis, perturbation method, WKB theory. This course also deals with both classical and modern methods for analyzing nonlinear ordinary and partial differential equations appearing in chemical engineering problems.

#### CBE503 Numerical Methods for Chemical Engineers

The goals of CBE503 are two fold. First, computational methods are presented for solving many of the differential equations that model physical phenomena arising in chemical engineering. Second, the presentations of these techniques will be organized in a way so that the common strands of numerical analysis are exposed and so that they form the foundations necessary for the more advanced studies required to solve problems arising at the forefront of research.

#### CBE511 Design of Reaction Systems

Design and analysis of reaction systems related to chemical and biomolecular engineering will be introduced. The lecture covers the chemical reaction kinetics, experimental planning, multiple reaction, introduction of ideal reactors, interaction of heat and mass transfer with chemical reaction, residence time distribution, design of nonideal reactors, and stability analysis of reaction systems.

#### CBE512 Introduction to Catalysis Engineering

The Basic concept of heterogeneous catalysis including the catalytic activity and selective adsorption, kinetic models, catalyst preparation and experimental evaluation will be explained. Typical catalytic systems of industrial importance will be discussed ; metal supported catalysts, acid and zeolites, catalytic oxidation, and energy and environmental catalysis.

#### CBE522 Introduction to Interfacial Engineering

The aim of this course is to introduce and motivate the research of surface and nano-surface science and chemistry for first year graduate students. The basic structure consists of three parts ; surface structure and energy, molecular alignment at surface, and electrical and dispersive interaction at interface. Covered at this course were the concepts of surface energy, curvature effect, quantum-size effect, molecular interaction, surface force measurement, surfactant, detergency, micelles and aggregation, adsorption in solution, contact

angle, wetting, monolayer, organic thin film, LB film, hydrogels and liquid crystals, emulsion and dispersions.

#### CBE523 Rate-controlled Separation Processes

The goal of this lecture is to learn the principles of the rate-controlled separation process, mechanical separation process and bioseparation process, and theoretical background and practical application of the separation with adsorption, membrane, and crystallization. Also, it covers the application of the special separation process such as chromatography, permeation, and the basic design of equipment.

#### CBE525 Molecular Electronics

This course covers molecular electronic in organic materials, molecular methodologies, biooptoelectronics and molecular electronic logic and architecture. Detailed topics includes molecular scale electronics in nano-science, Foundations and theories of molecular electronics, properties and ordering of materials, piezoelectric and pyroelectric materials, molecular magnets, molecular nonlinear optics, photochromism, conducting polymers, charge transfer complex, OLED, liquid crystals and devices, self-assembly, Langmuir-Blodgett films, organic molecular beam epitaxy, molecules at surface, biological membrane, biosensors, biomolecular optoelectronic molecular imaging, molecular electronic logic and architecture

#### CBE531 Multiphase Reactor Engineering

To understand basic theory and phenomenon in various chemical reactors such as fixed bed, bubble column, and fluidized bed. Develop ability to analyze multi-phase flow reactors in chemical processes and to design chemical reactors associated with fluidized bed and multi-phase flow reactors

#### CBE532 Mass Transfer

Fundamentals and mechanisms of mass transfer at steady and transient state are explained with diffusion theory and mass transfer coefficients. Also, the convective mass transfers in laminar and turbulent flow are studied. This course covers the application for the separation process, where mass transfer phenomena is crucial, such as interface contactor and membrane separation.

#### CBE533 Fundamentals of Microstructured Fluid Flow

This course deals with flows of complex imcrostructured fluids in continua emphasizing the microscopic behavior. Continuum hypothesis and its consequences, equations of motion, continuity equation, transport equations of heat and mass will be covered for the systems of complex fluids. Examples of flowing systems to be considered include Brownian motions, particulate suspensions and heat and mass transfer at low Reynolds numbers.

#### CBE541 Advanced Process Control I

The course treats formulation, analysis, and design of industrial control systems. Advanced control techniques will be covered which include feedforward control, ratio control, cascade control, and multi-loop control. Recent issues such as distributed control system, z-transform and digital control algorithm, model predictive control will be introduced, too.

#### CBE542 Process Optimization

The course covers basic concept of process optimization, application to chemical and biomolecular process industry, formulation of optimization problems, selection of optimization techniques, emerging LP and LNP techniques, dynamic programming, integer and mixed integer programmings, and recent trend of optimization researches.

#### CBE551 Polymer Rheology

Constitutive equations are needed to describe the flow behaviors of polymeric liquids. Differential and integral

types of constitutive equations are derived using the continuum theory and the non-equilibrium thermodynamics. They are applied to the flow system of fluid.

#### CBE552 Polymer Processing

It covers several different processes related to the fabrication parts from polymeric materials and relevant mathematical modeling. Extrusion, injection and elongational processes are main concerns along with heat and mass transfer problem in these processes.

\* Prerequisites : CBE451 (Polymer Structure and Bulk Properties)

#### CBE554 Polymer Physics

This course intends to provide a solid base for the understanding of polymeric materials. The microstructure of the chain molecule, the physical behavior and state of polymers are treated in this course. The emphasis of this course lies on fundamental physical concepts, terminology, and an overview of the phenomenology of polymer materials.

#### CBE555 Biopolymer

Introduction and classification of the biopolymers, their chemical and physical structures are studied. The application of biopolymers in biomedical, sensor, drug delivery, etc. are also studied.

#### CBE556 Structure and Properties of Macromolecules

The effects of the polymer structure (chemical structure, molecular weight, intermolecular structure and morphology) on physical, mechanical and electrical properties are studied. The property estimation scheme originating from the structure-property correlation is also studied.

#### CBE563 Enzyme Process Engineering

This course will cover bioprocesses involving enzymes. Basics of enzyme including enzyme nomenclature, enzyme characteristics, and enzymekinetics will be covered. Furthermore, bioprocesses developed using enzymes will be discussed to help understand various processes for the production of a wide range of products. Recent advances in directed evolution and protein engineering strategies will be covered to help understand ways of designing and improving enzymes and biocatalysis using them. Further coverage includes multi-step enzymatic reactions and the processes

#### CBE564 Fermentation Process Engineering

Modelling of various bioprocesses will be dealt with. Experimental approaches for the identification and improvement of oxygen transfer in bioreactors will be discussed. Topics relating to bioreactor design, bioreactor monitoring, stability analysis, bioprocess economics will be also dealt with in a comprehensive way.

#### CBE565 Bioprocess Experiment

Basic experimental skills in microbial cultivation, microbial screening, DNA manipulation, protein analysis will be introduced. Sterilization experiments and fermentations in 2~5 L-scale and 50~300 L-scale bioreactors will be performed by the students. Membrane separation experiment, bioprocess modeling, oxygen transfer coefficient measurement will be also carried out.

#### CBE566 Introduction to Molecular Biomedical Engineering

Human body can be examined from chemical, biological, mechanical, electro-information systemic viewpoints. This course deals with macroscopic mass and heat balances of human body, covers renal physiology in depth along with cardiac and pulmonary physiology. Special topics include diabetes, controlled drug delivery, biomaterials and artificial organs.

#### CBE567 Metabolic Engineering

This course will cover topics related to how to analyse the metabolic pathways qualitatively and quantitatively, how to use molecular biological and related techniques for engineering metabolic pathways, and how to design strategies for the metabolic engineering of the organisms for the production of various bioproducts including primary and secondary metabolites and proteins.

#### CBE568 Nanobiotechnology for Biochemical Engineers

This course deals with principles and key technologies of nanobiotechnology including DNA chip, protein chip, and Lab-on-a-Chip. The scope of this course also includes various nanostructure-based strategies for biotechnology.

#### CBE571 Energy Engineering

To study on the general energy engineering principles, the current status of alternative energy development and the overall coal energy utilization (pyrolysis, combustion, gasification, liquefaction) processes in this course.

#### CBE572 Inorganic Materials Processing

This course deals with process-property relationship while the main focus of conventional materials science and engineering is to understand structure-property relationship. Chemical synthesis of powder, fiber and monolith form of inorganic materials are discussed. Especially, gas and liquid phase chemical processes are explained.

#### CBE573 Fuel Cell Processes and Materials

Unit process analysis and materials design for fuel cell core technology will be discussed. State-of art fuel cell unit process and computer simulation will be understood. Optimal design of MEA preparation, cathode and anode materials, electrolytes, stack, bipolar plate, and diffusion layer will be introduced. Recent trends of primary fuel cell technology will be included.

#### CBE581 Micro-Chemical and Biomolecular Systems

The microfabrication principles for micro chemical and biomolecular systems composed of microfluidic reactors, lab-on-chip and nanometer and micron scale devices are discussed as well as the application examples.

#### CBE611 Theory of Catalysis

Geometrical theory, electronic theory, semiconductor theory, which are classic theories of catalysis phenomena are introduced. Theoretical considerations of catalysis phenomena will be given applying molecular orbital theory now in progress. The correlation of catalytic properties such as activity and selectivity with the performance of catalyst is discussed. The instrumental methods to analyze the reaction intermediate and structure of catalyst are introduced. This course also covers the theoretical interpretation of both homogeneous catalyst and of the heterogeneous catalyst.

#### CBE612 Design of Catalysis

The procedures of catalyst selection for specific chemical reactions include theoretical utilization of potential information and experimental evaluation. Design parameters for both homogeneous and heterogeneous catalysis are to be discussed. The concept of catalyst design, activity patterns of active components, selection of secondary components and supports, catalyst preparation and experimental testing are to be discussed. Some examples of catalyst design are to be introduced for important chemical reactions.

#### CBE621 Phase Equilibria and Physical Properties

The phase equilibria is broadly introduced for extending the insights of molecular thermodynamics towards useful applications in chemical engineering. Students are expected to gain some experience in phase-equilibria while working their projects. The scope and type of the projects will be discussed in class.

#### CBE622 Mixing Technology in Chemical Engineering

To understand fluid mixing phenomena in homogeneous and non-homogeneous systems. To study power consumption for mixing of various fluids and to understand heat and mass transfer characteristics in various mixing processes. With the studied knowledge, the mixing systems will be designed.

#### CBE631 Microfluidics

As microfluidics plays an important role in biotechnology and nanotechnology, the goals of this course can be set as; firstly, understanding of physical phenomena in fluid flow of microfluidics, and secondly, obtaining the insight for the analysis, optimization or design of microfluidic system based on fundamental understanding. Also, various fabrication technology for microfluidic systems and applications of microfluidic system in engineering and science will be introduced.

#### CBE632 Colloids and Surface Chemistry

The aim of this course is to establish the fundamental concepts on the colloid and biocolloid for industrial and pharmaceutical applications. Following Introduction to interfacial engineering, this course is designed to understand in depth and art-of-state knowledge of electrical phenomena, surface modification and adhesion, stabilization of emulsion, foam, and particle dispersion, microcapsules and their industrial applications. Special attentions are paid to pharmaceutical and biomedical applications throughout the topics including sophisticated drug delivery systems.

#### CBE641 Advanced Process Design

Hierarchical decision making for process synthesis and systematic procedures for process improvement are studied. Computer aided synthesis of optimized chemical process is also covered.

#### CBE651 Multicomponent Polymer Materials

The synthesis, morphology, properties and application of the multi-component polymer materials are studied. Block and graft copolymer, polymer alloy and interpenetrating polymer networks (IPN) are studied as the multi-component polymer materials.

#### CBE652 Polymer Characterization

Theories and experimental method for the characterization of polymer materials are studied. Theories on molecular conformation, osmometry, X-ray, light scattering, rheometry, gel permeation chromatography are also studied.

#### CBE653 Mechanical Properties of Polymers

The equations to describe the elasticity and viscoelasticity of polymer solid are derived by using the continuum and statistical theories. They are applied to the analyses of isotropic and anisotropic polymers. The theories are compared with the experimental results of polymers with linear and nonlinear viscoelasticities. The yield and fracture behaviors of polymers are also studied.

#### CBE661 Cell Culture Engineering

This course is designed to provide graduate students with various techniques necessary for working animal plant cell cultures and their application for producing high-valued biochemicals. Special topics include: taxol production by plant cell culture, antibody production by high density cell culture, cell culture bioreactors and

downstream processing.

#### CBE662 Bioseparation Processes Engineering

This course will cover theories and practices of separating rather fragile bioproducts. Primary separation processes including cell harvest, cell disruption and removal of insolubles will be covered as centrifugation, filtration, sonication, bead milling, french pressing and other methods are discussed. Major separation processes including chromatography, adsorption, extraction, electrophoresis and ultrafiltration will be covered in relation to bioproducts of interest. Integrated bioseparation process development will also be discussed.

#### CBE664 Process for Recombinant Microorganisms

This course will cover topics related to the production of various bioproducts ranging from primary to secondary metabolites as well as recombinant proteins by employing genetically engineered microorganisms. Brief introduction to molecular biology, microbiology and biochemistry will be given before covering gene cloning and strain development. Biochemical engineering strategies of employing recombinant microorganisms will also be covered.

#### CBE672 Air Pollution Control

Chemical reactions in atmosphere, origin, measurement techniques of air pollutants, fluid dynamics of particles and designing of air pollution control equipments will be covered in this course.

#### CBE673 Water Pollution Control

Wastewater treatment by physico-chemical and biological methods are discussed. Also taught in the lecture are technologies involved in degradation of recalcitrants, removal of nitrogen and phosphorous, small packaged system for treatment of sewage and wastewater treatment, and sludge treatment and disposal. Students are expected to present a term paper on the recent development on different technologies.

#### CBE680 Membrane Technology

Membrane technology starts with introducing the competitiveness of membrane separation with other separation processes. Membrane materials, processing and characterization; transport in membranes, concept of concentration polarization and fouling, modules are covered. Special topics include desalination by reverse osmosis, ethanol purification using pervaporation, microfiltration in wastewater treatment, fuel cell and electro dialysis.

#### CBE682 Organic Nano-Structured Materials

This lecture includes: non-crystal, crystals, liquid crystals, imperfections in ordered media, and finally nano-structure. Because the properties of nanomaterials are structure-sensitive, numerous associations in this class will be made to establish structure-property relations for advanced organic materials using very useful experimental techniques, in particular, diffraction and microscopy. Applications to IT and BT devices using nanostructured materials are also discussed.

#### CBE711 Advanced Reaction Engineering

Adsorption dynamics, surface reaction, interaction between diffusion and reaction inside the catalyst particle, and catalyst deactivation will be discussed. Modelling concept for heterogeneous catalyst systems is to be analyzed in depth by accommodating the heat and mass transfer and the parametric sensitivity.

#### CBE712 Surface Phenomena

The fundamental principles and the application of surface science are lectured to understand the phenomena at the level of molecules of the surface of catalyst, polymer and inorganic materials. The most widely used surface science instruments such as XPS, AUGER, ISS, UPS, SIMS, LEED, EELS, SEXAFS, RHEED, work

function measurement, TDS will be discussed to understand the principles, operating components and the application to the real samples.

#### CBE731 Polymer Fluid Dynamics

Molecular approaches for the understanding of flows in the polymeric systems are the main issues here and rheo-optical experiments are also dealt to study the relationship between microstructure and properties of these system.

#### CBE741 Advanced Process Control II

This course gives introduction to the state of the art in process control area.

#### CBE751 Advanced Rheology of Polymer

Probability theories for the Rouse motion, hydrodynamic interaction and conformation of polymer are introduced to derive the diffusion equations and constitutive equation. The constitutive equations derived using phase-space and reptation theories are used to calculate the rheological properties of flexible and liquid crystalline polymers in dilute, concentrated or melt state.

#### CBE761 Bioprocess Analysis and Control

Topics relating to bioprocess monitoring and control are to be dealt with. Biosensor systems for the on-line monitoring of bioreactors will be introduced. Various techniques for the indirect estimation of nonmeasurable quantities will be also discussed. Algorithms for the optimization of batch and fed-batch cultures will be introduced. Stability analysis and control of continuous bioreactors will be discussed.

#### CBE771 Electrochemical Engineering

Basic principles of electrochemistry are to be explained. The interactions between the electric current distribution and heat/mass transfer are to be analyzed, and their effects on electrochemical reactions are to be discussed.

#### CBE773 Recent Topics in Chemical & Biomolecular Engineering

This course offers opportunities to understand new theory and applications of chemical and biomolecular engineering. Details of the topics are announced at the beginning of the semester.

#### CBE811 Special Topics in Chemical Reaction Engineering

Application of reaction engineering principle ranges from environmental cleaning to semiconductor processing. New area of application of reaction engineering principle is introduced. Details of lecture topics are announced at the beginning of the semester.

#### CBE821 Special Topics in Chemical Engineering Thermodynamics

Chemical engineering thermodynamics is now in a state of transition. Classical thermodynamics is becoming increasingly replaced by new tools from applied statistical thermodynamics and molecular simulation. Students are expected to gain some experience in the newly appeared thermodynamics needed to energy and environmental systems while working their projects. The scope and type of the projects will be discussed in class.

#### CBE831 Special Topics in Transport Phenomena

Selected topics of current transport phenomena will be studied in depth. Examples are transport phenomena in fluid flow in porous medium, stability of fluid flow, heat and mass transfer in turbulent flow, Taylor dispersion in chromatography, crystallization and dissolution.

#### CBE 832 Special Topics in Separation Processes

This course covers the designs, operations and equipments for the various separation processes such as column process, chromatography, membrane separation and electrophoretic separation. In order to solve the problem related with column operation, it includes the details about design, scaleup, startup, shutdown and operation

#### CBE 841 Special Topics in Process Engineering

The course covers application of dynamic simulation, fault diagnosis, process safety, and artificial intelligence to process industry. It also treats selected topics in process engineering such as novel technologies in process control.

#### CBE 851 Special Topics in Polymer Engineering

This course deals with recent trends of the properties of polymers, such as solution properties, solid properties, electrical properties, optical properties and mechanical properties. Recent topics on polymer characterization methods are also discussed.

#### CBE 861 Special Topics in Biochemical Engineering

The the most recent trend and topic(s) in the area of biochemical engineering are to be introduced.

CBE 960 Thesis <Master Student>

CBE 966 Seminar <Master Student>

CBE 980 Thesis <Ph.D. Student>

CBE 986 Seminar <Ph.D. Student>