❒ Graduate

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.

CBE505 Chemical Process and Product Design
Problem solving strategy proposed by Fogler, Define-Generate-Decide-Implement-Evaluate, is introduced and applied to process and product design in chemical engineering. Patent and ethical issues are also discussed in connection with process and product design.

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.

CBE513 Catalysis for Renewables
Disruptive processes providing renewable chemical feedstocks and energy should be developed in order to establish sustainable development. Catalysis technology as well as the state-of-art of these processes will be discussed. Biomass conversion, clean hydrogen and solar fuel processes utilizing sunlight will be emphasized.

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 optoelectronicsmolecular 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. Develope 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 microstructured 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 programings, 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 Materials Engineering of Polymers
Polymers are very popular in various industries and daily life since they are light, cheap and easy to process. The relationship between structure and properties will be considered along with rheology, mixing, extrusion, injection molding, anisotropic properties during processing and related mechanical properties. In addition, functional characteristics of polymers such as electrical, optical and permeability will be included.

CBE554 Polymer Physics
This course is designed to be an introduction to the physical principles of polymers that govern the structures and properties of individual polymer chains and also physical properties and behavior of bulk polymer materials. The microstructural properties of polymer chains are crucial to determine the bulk properties 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 Protein Engineering
This course deals with general and advanced knowledge for Protein and Protein engineering. Basic principle of protein biosynthesis, structure, biochemical analysis tools and enzyme kinetics will be covered. Also, new techniques

and strategies of protein engineering and recent application of proteins to biochip will be covered with many recent reports.

CBE564 Bioprocess Engineering
Modelling of various fermentation and enzyme processes will be dealt with. Experimental approaches for the assessment 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. (Prerequisite course: CBE261, CBE311)

CBE566 Principles of Human Tissue Engineering
Human tissue engineering has been considered as an ultimate means of repairing damaged body parts because of natural aging, disease or accidents and congenital malfunctions. The textbook is 1300pages-long but the course will focus on the basis of growth and differentiation, in vitro control of tissue development, in vitro synthesis of tissues and organs, models of tissue engineering, biomaterials, transplantation, stem cells, gene therapy, applications to breast, cardiovascular system, gastrointestinal, hematopoietic system, kidney, musculoskeletal, respiratory and skin system.

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.

CBE569 Nucleic Acid Engineering
This course is focused on diverse DNA applications for most recently developed sequencing, SNP detection, gene expression, and new therapeutic discovery by fusion of bioorganic chemistry, nanotechnology, advanced genomic analytical technology.

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 dissussed as well as the application examples. (Prerequisite course: CBE260)

CBE601 Research Methodology for Chemical and Biomolecular Engineers
The course aims to discuss key elements in chemical and biomolecular engineering (CBE) graduate research. The class will review fundamental CBE principles and discuss how to implement them effectively and efficiently in a breadth of CBE problems. Ultimately, the course is expected to enable the students to independently design experiments for their own research projects using the CBE principles. In hands-on experimentation sessions, the first-year graduate students are given opportunities to implement their research ideas in experimental practice.

CBE602 Problem Solving in Chemical and Biomolecular Engineering

In this course, we study the approach to deal with problems in traditional chemical engineering including catalyst and energy processes and recent challenges in biotechnology, nano and polymer materials. To do this, we model representative chemical and biological engineering processes, based on understanding of transport phenomena, thermodynamics and reaction engineering.

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 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. (Prerequisite course: CBE203)

CBE613 Photocatalytic Reaction Engineering
This lecture discusses the basic principles of heterogeneous photocatalysis and applications of various types of photo-reactions are described. Problems related to the modeling and design of photocatalytic reactors are covered. Special focus will be made on the application of photocatalytic reaction for sustainable energy production and environmental clean-up by using photon.

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.

CBE623 Thin Film Nanotechnology
This class is an introductory course for basic thin film technologies. The class aims at the balanced understanding of thin film materials and processes. The class consists of 1) thin film processes, 2) thin film materials, 3) patterning processes, 4) surface chemistry, and 5) their applications to devices.

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. (Prerequisite course: CBE351)

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.

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 electrodialysis.

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 nanostrctured materials are also discussed.

CBE683 Electroactive Polymeric Materials and Devices
This class will cover methods in the synthesis of electroactive polymers including conjugated polymer synthesis (Suzuki and Stille coupling), and controlled radical polymerization. And the principles of electroactive polymers as well as their applications for polymer energy device (particularly in plastic solar cells) will be included. Rational design strategy to develop better organic electronics will be illustrated and discussed. (Prerequisite course: CBE351)

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, ELLS, 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. (Prerequisite course : CBE564)

CBE771 Advanced Electrochemical Engineering
Basic principles of electrochemistry including thermodynamic, electrochemical reaction, charge transport, and mass transport are to be explained. Based on understanding of these electrochemical principles, the design and analysis technologies for various electrochemical systems including sensors, fuel cells, secondary batteries, and capacitors are to be studied. (Prerequisite course : CBE371)

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.

CBE832 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

CBE841 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.

CBE851 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.

CBE861 Special Topics in Biochemical Engineering
The the most recent trend and topic(s) in the area of biochemical engineering are to be introduced.

CBE871 Recent Topics in Chemical & Biomolecular EngineeringⅡ
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.

CBE872 Recent Topics in Chemical & Biomolecular EngineeringⅢ
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.

CBE960 Thesis〈Master Student〉

CBE966 Seminar〈Master Student〉

CBE980 Thesis〈Ph.D. Student〉

CBE986 Seminar〈Ph.D. Student〉