

MIT SCHOOL OF ENGINEERING: CHEMICAL ENGINEERING MASTER'S PROGRAM

2-Year Graduate Curriculum for Advanced Chemical Engineering Practice

PROGRAM OVERVIEW

Program Structure: 4 Semesters (2 Academic Years) **Total Credits:** 66 credit hours

Format: Full-time, research-intensive program **Degree:** Master of Science in Chemical Engineering (M.S.Ch.E.)

SEMESTER-BY-SEMESTER OVERVIEW

First Year - First Semester (Fall): Advanced Mathematical Methods and Core Chemical Engineering Fundamentals

- Advanced Chemical Engineering Mathematics
- Thermodynamics of Chemical Processes
- Transport Phenomena I (Momentum Transfer)
- Chemical Reaction Engineering
- Research Methods and Safety

First Year - Second Semester (Spring): Transport Phenomena and Process Design

- Transport Phenomena II (Heat and Mass Transfer)
- Separation Processes
- Process Dynamics and Control
- Chemical Engineering Materials
- Statistical Methods and Data Analysis

Second Year - First Semester (Fall): Advanced Topics and Specialization

- Advanced Reaction Engineering
- Process Design and Economics
- Computational Methods in Chemical Engineering
- Specialized Elective I
- Master's Thesis Research I

Second Year - Second Semester (Spring): Research and Professional Development

- Advanced Separation Processes

- Process Safety and Environmental Engineering
 - Specialized Elective II
 - Professional Skills for Chemical Engineers
 - Master's Thesis Research II and Defense
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FIRST YEAR - FIRST SEMESTER (FALL)

Advanced Mathematical Methods and Core Chemical Engineering Fundamentals

Week 1: Mathematical Foundations for Chemical Engineering

Monday: Advanced Differential Equations

- Morning (4 hours):
 - Review of ordinary differential equations
 - Linear systems of ODEs
 - Eigenvalue problems in chemical engineering
 - Boundary value problems
- Afternoon (4 hours):
 - Applications to reaction kinetics
 - Heat and mass transfer problems
 - Problem-solving workshop
 - MATLAB/Python implementation

Tuesday: Partial Differential Equations

- Morning (4 hours):
 - Classification of PDEs
 - Heat equation and diffusion
 - Wave equation applications
 - Separation of variables
- Afternoon (4 hours):
 - Finite difference methods
 - Boundary conditions in chemical processes
 - Computer modeling exercises
 - Engineering applications

Wednesday: Linear Algebra and Matrix Methods

- Morning (4 hours):
 - Vector spaces and linear transformations
 - Eigenvalues and eigenvectors
 - Matrix decomposition methods

- Numerical linear algebra
- Afternoon (4 hours):
 - Applications to chemical process systems
 - Process optimization foundations
 - MATLAB/Python laboratory
 - Problem-solving workshop

Thursday: Complex Variables and Transform Methods

- Morning (4 hours):
 - Complex analysis fundamentals
 - Laplace transforms
 - Fourier transforms
 - Z-transforms for discrete systems
- Afternoon (4 hours):
 - Applications to process control
 - Signal processing in chemical engineering
 - Transfer function analysis
 - Computational exercises

Friday: Probability and Statistics for Engineers

- Morning (4 hours):
 - Probability theory review
 - Random variables and distributions
 - Hypothesis testing
 - Regression analysis
- Afternoon (4 hours):
 - Statistical process control
 - Design of experiments
 - Data analysis workshop
 - Week 1 assessment and review

Assessment for Week 1:

- Mathematical modeling assignment (15%)
- PDE solution problems (15%)
- Matrix methods application (10%)
- Statistical analysis project (10%)

Reading Materials:

- "Advanced Engineering Mathematics" (Erwin Kreyszig, Open Access Chapters)
- "Numerical Methods for Engineers" (Steven Chapra, MIT OCW)
- "Applied Statistics for Engineers" (Montgomery & Runger, OER version)
- "MATLAB for Chemical Engineers" (MIT OpenCourseWare)

Week 2: Thermodynamics of Chemical Processes I

Monday: Fundamental Principles of Thermodynamics

- Morning (4 hours):
 - First and second laws of thermodynamics
 - Thermodynamic properties and state functions
 - Equation of state for real gases
 - Cubic equations of state
- Afternoon (4 hours):
 - Property estimation methods
 - Corresponding states principle
 - Problem-solving workshop
 - Laboratory: PVT measurements

Tuesday: Phase Equilibria in Pure Components

- Morning (4 hours):
 - Clausius-Clapeyron equation
 - Antoine equation and vapor pressure
 - Phase diagrams and critical phenomena
 - Corresponding states correlations
- Afternoon (4 hours):
 - Property database usage
 - Computational thermodynamics
 - Case studies in phase behavior
 - Problem-solving workshop

Wednesday: Solution Thermodynamics

- Morning (4 hours):
 - Partial molar properties
 - Chemical potential
 - Activity and fugacity concepts
 - Gibbs-Duhem equation
- Afternoon (4 hours):
 - Ideal and non-ideal solutions
 - Mixing properties
 - Laboratory: Solution property measurements
 - Computational exercises

Thursday: Activity Models and Equations of State

- Morning (4 hours):
 - Activity coefficient models
 - UNIFAC and UNIQUAC methods
 - Equation of state mixing rules
 - Parameter estimation
- Afternoon (4 hours):
 - Process simulation software introduction
 - Model selection criteria

- Case studies
- Problem-solving workshop

Friday: Chemical Reaction Equilibria

- Morning (4 hours):
 - Reaction equilibrium constant
 - Temperature and pressure effects
 - Multiple reaction equilibria
 - Equilibrium calculations
- Afternoon (4 hours):
 - Industrial reaction equilibria
 - Computer-aided calculations
 - Case studies
 - Week 2 assessment and review

Assessment for Week 2:

- Thermodynamic property calculations (15%)
- Phase equilibrium problems (15%)
- Activity model application (15%)
- Reaction equilibrium project (10%)

Reading Materials:

- "Introduction to Chemical Engineering Thermodynamics" (Smith, Van Ness & Abbott, MIT OCW)
- "Molecular Thermodynamics of Fluid-Phase Equilibria" (Prausnitz et al., Open Access)
- "Chemical Process Design and Integration" (Robin Smith, OER chapters)
- "Process Systems Analysis and Control" (Coughanowr, Open Access)

Week 3: Thermodynamics of Chemical Processes II

Monday: Vapor-Liquid Equilibria

- Morning (4 hours):
 - Raoult's law and Henry's law
 - VLE calculations and bubble/dew points
 - Azeotropes and distillation boundaries
 - Non-ideal VLE behavior
- Afternoon (4 hours):
 - VLE measurement techniques
 - Laboratory: VLE experimental setup
 - Computer modeling of VLE
 - Process design applications

Tuesday: Liquid-Liquid and Solid-Liquid Equilibria

- Morning (4 hours):
 - LLE thermodynamics
 - Ternary diagrams
 - SLE and crystallization
 - Adsorption equilibria
- Afternoon (4 hours):
 - Extraction process design
 - Crystallization modeling
 - Laboratory: LLE measurements
 - Case studies

Wednesday: Thermodynamic Cycles and Energy Systems

- Morning (4 hours):
 - Power cycles and refrigeration
 - Heat pump analysis
 - Combined heat and power
 - Process integration
- Afternoon (4 hours):
 - Energy efficiency analysis
 - Pinch technology introduction
 - Case studies in energy systems
 - Problem-solving workshop

Thursday: Advanced Thermodynamic Applications

- Morning (4 hours):
 - Electrolyte solutions
 - High-pressure thermodynamics
 - Polymer thermodynamics
 - Biological systems
- Afternoon (4 hours):
 - Specialized applications
 - Research problem formulation
 - Literature review methods
 - Project work

Friday: Process Thermodynamics Integration

- Morning (4 hours):
 - Heat and material balances
 - Energy integration
 - Process synthesis considerations
 - Economic evaluation
- Afternoon (4 hours):
 - Case study: Complete process analysis
 - Team project presentations
 - Peer review
 - Week 3 comprehensive assessment

Assessment for Week 3:

- VLE calculation problems (15%)
- LLE and SLE analysis (15%)
- Energy system design project (15%)
- Comprehensive thermodynamics exam (20%)

Reading Materials:

- "Chemical, Biochemical, and Engineering Thermodynamics" (Sandler, MIT OCW)
- "Thermodynamics and Heat Transfer" (Koretsky, Open Access)
- "Process Design Principles" (Seider et al., OER chapters)
- "Separation Process Principles" (Seader & Henley, MIT OCW)

Week 4: Transport Phenomena I - Momentum Transfer

Monday: Fundamentals of Fluid Mechanics

- Morning (4 hours):
 - Continuum hypothesis and fluid properties
 - Stress tensor and Newton's law of viscosity
 - Non-Newtonian fluids
 - Dimensional analysis and scaling
- Afternoon (4 hours):
 - Viscosity measurement techniques
 - Laboratory: Rheological characterization
 - Non-Newtonian flow behavior
 - Problem-solving workshop

Tuesday: Shell Momentum Balances

- Morning (4 hours):
 - Momentum balance approach
 - Flow between parallel plates
 - Flow in circular tubes
 - Flow around spheres
- Afternoon (4 hours):
 - Analytical solutions
 - Boundary condition applications
 - Flow profile development
 - Computational verification

Wednesday: Equations of Change

- Morning (4 hours):
 - Equation of continuity
 - Navier-Stokes equations
 - Stream function and vorticity
 - Simplified forms and applications

- Afternoon (4 hours):
 - Creeping flow solutions
 - Lubrication theory
 - Computational fluid dynamics introduction
 - Problem-solving workshop

Thursday: Turbulent Flow and Mixing

- Morning (4 hours):
 - Reynolds number and flow regimes
 - Turbulence characteristics
 - Time-averaged equations
 - Mixing length theory
- Afternoon (4 hours):
 - Turbulent flow in pipes
 - Boundary layer theory
 - Laboratory: Flow regime identification
 - Engineering applications

Friday: Flow Measurement and Instrumentation

- Morning (4 hours):
 - Flow measurement principles
 - Pressure drop calculations
 - Pump and compressor basics
 - Flow control systems
- Afternoon (4 hours):
 - Laboratory: Flow measurement techniques
 - Pump characteristic curves
 - System design considerations
 - Week 4 assessment

Assessment for Week 4:

- Shell balance problems (15%)
- Navier-Stokes applications (15%)
- Turbulent flow analysis (15%)
- Flow measurement lab report (10%)

Reading Materials:

- "Transport Phenomena" (Bird, Stewart & Lightfoot, MIT OCW)
- "Fluid Mechanics for Chemical Engineers" (de Nevers, Open Access)
- "Introduction to Fluid Mechanics" (Fox & McDonald, OER version)
- "Computational Fluid Dynamics" (Anderson, MIT OCW)

Week 5: Chemical Reaction Engineering I

Monday: Reaction Kinetics and Mechanisms

- Morning (4 hours):
 - Elementary and non-elementary reactions
 - Rate laws and rate constants
 - Arrhenius equation and temperature effects
 - Collision theory and transition state theory
- Afternoon (4 hours):
 - Experimental kinetics methods
 - Parameter estimation techniques
 - Laboratory: Reaction rate measurement
 - Data analysis workshop

Tuesday: Reactor Design Fundamentals

- Morning (4 hours):
 - Reactor classification and selection
 - Batch reactor design
 - Continuous stirred tank reactor (CSTR)
 - Plug flow reactor (PFR)
- Afternoon (4 hours):
 - Reactor performance comparison
 - Residence time distributions
 - Laboratory: Reactor characterization
 - Design calculations

Wednesday: Multiple Reactions and Selectivity

- Morning (4 hours):
 - Parallel and series reactions
 - Selectivity and yield
 - Reactor choice for optimal selectivity
 - Competitive reaction analysis
- Afternoon (4 hours):
 - Case studies in selectivity
 - Industrial reactor examples
 - Optimization strategies
 - Problem-solving workshop

Thursday: Non-Ideal Flow Patterns

- Morning (4 hours):
 - Residence time distribution theory
 - Tracer techniques
 - Segregated flow models
 - Maximum mixedness models
- Afternoon (4 hours):
 - RTD measurement techniques
 - Laboratory: RTD experiments
 - Model parameter estimation
 - Real reactor analysis

Friday: Heterogeneous Catalysis Fundamentals

- Morning (4 hours):
 - Catalysis principles
 - Adsorption isotherms
 - Surface reaction mechanisms
 - Langmuir-Hinshelwood kinetics
- Afternoon (4 hours):
 - Catalyst characterization
 - Laboratory: Catalytic activity testing
 - Industrial catalytic processes
 - Week 5 assessment

Assessment for Week 5:

- Kinetics parameter estimation (15%)
- Reactor design calculations (15%)
- Selectivity optimization (15%)
- RTD analysis project (10%)

Reading Materials:

- "Elements of Chemical Reaction Engineering" (Fogler, MIT OCW)
- "Chemical Reactor Analysis and Design" (Froment & Bischoff, Open Access)
- "Catalysis: An Integrated Approach" (Moulijn et al., OER chapters)
- "Reaction Engineering Principles" (Rawlings & Ekerdt, MIT OCW)

Week 6: Research Methods and Laboratory Safety

Monday: Research Methodology in Chemical Engineering

- Morning (4 hours):
 - Scientific method and hypothesis formation
 - Literature review techniques
 - Database searching and reference management
 - Research ethics and integrity
- Afternoon (4 hours):
 - Research proposal development
 - Experimental design principles
 - Statistical analysis of data
 - Research planning workshop

Tuesday: Laboratory Safety and Chemical Handling

- Morning (4 hours):
 - Chemical safety fundamentals
 - Personal protective equipment
 - Emergency procedures
 - Chemical storage and compatibility

- Afternoon (4 hours):
 - Safety data sheet interpretation
 - Risk assessment techniques
 - Laboratory tour and safety inspection
 - Emergency response training

Wednesday: Process Safety Management

- Morning (4 hours):
 - Process hazard analysis
 - HAZOP methodology
 - Safety instrumented systems
 - Loss prevention principles
- Afternoon (4 hours):
 - Case studies in process safety
 - Incident investigation methods
 - Safety management systems
 - Regulatory compliance

Thursday: Environmental Health and Safety

- Morning (4 hours):
 - Environmental regulations
 - Waste management
 - Air quality monitoring
 - Water treatment considerations
- Afternoon (4 hours):
 - Pollution prevention strategies
 - Life cycle assessment introduction
 - Sustainable engineering principles
 - Environmental impact analysis

Friday: Technical Communication and Documentation

- Morning (4 hours):
 - Technical writing principles
 - Report structure and formatting
 - Data presentation techniques
 - Graphical communication
- Afternoon (4 hours):
 - Oral presentation skills
 - Poster design and presentation
 - Peer review process
 - Week 6 comprehensive review

Assessment for Week 6:

- Research proposal draft (15%)
- Safety protocol development (10%)

- Process safety analysis (15%)
- Technical presentation (10%)

Reading Materials:

- "Guidelines for Laboratory Safety" (AIChE, Open Access)
- "Process Safety Management" (CCPS, OER chapters)
- "Scientific Writing and Communication" (Angelika Hofmann, Open Access)
- "Research Methods in Chemical Engineering" (MIT OpenCourseWare)

Week 7: Advanced Mathematical Applications

Monday: Numerical Methods for Chemical Engineering

- Morning (4 hours):
 - Root finding algorithms
 - Numerical integration techniques
 - Solution of ODEs
 - Boundary value problems
- Afternoon (4 hours):
 - MATLAB/Python implementation
 - Chemical engineering applications
 - Error analysis and convergence
 - Computational workshop

Tuesday: Optimization Methods

- Morning (4 hours):
 - Linear programming
 - Nonlinear optimization
 - Constrained optimization
 - Multi-objective optimization
- Afternoon (4 hours):
 - Process optimization applications
 - Software tools and algorithms
 - Case studies
 - Problem-solving workshop

Wednesday: Process Modeling and Simulation

- Morning (4 hours):
 - Model development principles
 - Parameter estimation
 - Model validation
 - Sensitivity analysis
- Afternoon (4 hours):
 - Process simulation software
 - Model-based design
 - Virtual experimentation

- Computational laboratory

Thursday: Statistical Process Control

- Morning (4 hours):
 - Control charts and process monitoring
 - Statistical quality control
 - Process capability analysis
 - Six Sigma methodology
- Afternoon (4 hours):
 - Industrial applications
 - Quality improvement projects
 - Data analysis workshop
 - Case studies

Friday: Advanced Data Analysis

- Morning (4 hours):
 - Multivariate statistics
 - Principal component analysis
 - Machine learning fundamentals
 - Pattern recognition
- Afternoon (4 hours):
 - Process data analysis
 - Fault detection and diagnosis
 - Predictive modeling
 - Week 7 assessment

Assessment for Week 7:

- Numerical methods programming (15%)
- Optimization project (15%)
- Process modeling assignment (15%)
- Statistical analysis report (10%)

Reading Materials:

- "Numerical Methods for Chemical Engineers" (Finlayson, MIT OCW)
- "Process Optimization" (Edgar et al., Open Access)
- "Applied Statistics for Chemical Engineers" (Montgomery, OER version)
- "Process Systems Engineering" (Pantelides & Renfro, MIT OCW)

Week 8: Reaction Engineering Applications

Monday: Reactor Design for Complex Systems

- Morning (4 hours):
 - Recycle reactors
 - Reactor networks

- Temperature and pressure effects
- Heat effects in reactors
- Afternoon (4 hours):
 - Adiabatic and non-adiabatic operation
 - Optimal temperature profiles
 - Case studies in reactor design
 - Problem-solving workshop

Tuesday: Catalytic Reactor Design

- Morning (4 hours):
 - Packed bed reactors
 - Fluidized bed reactors
 - Catalyst effectiveness factor
 - Pressure drop in reactors
- Afternoon (4 hours):
 - Laboratory: Packed bed characterization
 - Mass transfer effects
 - Heat transfer in reactors
 - Industrial applications

Wednesday: Biochemical Reaction Engineering

- Morning (4 hours):
 - Enzyme kinetics
 - Microbial growth kinetics
 - Bioreactor design
 - Sterilization and contamination
- Afternoon (4 hours):
 - Laboratory: Enzyme kinetics study
 - Scale-up considerations
 - Bioprocess optimization
 - Case studies

Thursday: Polymerization Reactors

- Morning (4 hours):
 - Polymerization mechanisms
 - Molecular weight distributions
 - Heat and mass transfer effects
 - Reactor selection and design
- Afternoon (4 hours):
 - Industrial polymerization processes
 - Quality control in polymers
 - Laboratory: Polymerization kinetics
 - Problem-solving workshop

Friday: Advanced Reactor Concepts

- Morning (4 hours):
 - Membrane reactors
 - Reactive distillation
 - Microreactors
 - Plasma reactors
- Afternoon (4 hours):
 - Process intensification
 - Novel reactor technologies
 - Research frontiers
 - Week 8 comprehensive assessment

Assessment for Week 8:

- Complex reactor design (15%)
- Catalytic reactor analysis (15%)
- Bioreactor design project (15%)
- Advanced reactor concepts report (10%)

Reading Materials:

- "Chemical Reactor Design and Control" (Luyben, MIT OCW)
- "Biochemical Engineering Fundamentals" (Bailey & Ollis, Open Access)
- "Polymer Reaction Engineering" (Hamielec & MacGregor, OER chapters)
- "Microreactor Technology and Process Intensification" (Hessel et al., Open Access)

Week 9: Transport Phenomena Applications

Monday: Advanced Momentum Transfer

- Morning (4 hours):
 - Boundary layer theory
 - Flow around immersed objects
 - Fluidization phenomena
 - Two-phase flow basics
- Afternoon (4 hours):
 - Laboratory: Boundary layer visualization
 - Drag coefficient measurements
 - Fluidization experiments
 - Engineering applications

Tuesday: Heat Transfer in Chemical Processes

- Morning (4 hours):
 - Conduction in chemical reactors
 - Convective heat transfer
 - Heat transfer coefficients
 - Heat exchanger fundamentals
- Afternoon (4 hours):
 - Laboratory: Heat transfer measurements

- Heat exchanger design
- Thermal analysis
- Problem-solving workshop

Wednesday: Mass Transfer Operations

- Morning (4 hours):
 - Molecular diffusion
 - Convective mass transfer
 - Mass transfer coefficients
 - Interphase mass transfer
- Afternoon (4 hours):
 - Laboratory: Mass transfer experiments
 - Film theory applications
 - Mass transfer equipment
 - Design calculations

Thursday: Simultaneous Heat and Mass Transfer

- Morning (4 hours):
 - Combined transport phenomena
 - Drying operations
 - Humidification and dehumidification
 - Cooling tower design
- Afternoon (4 hours):
 - Laboratory: Drying kinetics
 - Psychrometric analysis
 - Equipment design
 - Case studies

Friday: Transport in Porous Media

- Morning (4 hours):
 - Diffusion in porous solids
 - Flow through packed beds
 - Adsorption and chromatography
 - Membrane transport
- Afternoon (4 hours):
 - Laboratory: Permeability measurements
 - Chromatographic analysis
 - Membrane characterization
 - Week 9 assessment

Assessment for Week 9:

- Heat transfer design project (15%)
- Mass transfer analysis (15%)
- Combined transport problems (15%)
- Porous media transport (10%)

Reading Materials:

- "Fundamentals of Heat and Mass Transfer" (Incropera & DeWitt, MIT OCW)
- "Mass Transfer Operations" (Treybal, Open Access)
- "Transport Processes and Separation Process Principles" (Geankoplis, OER chapters)
- "Membrane Technology in Chemical Engineering" (Baker, Open Access)

Week 10: Process Analysis and Integration

Monday: Process Flow Diagrams and P&ID

- Morning (4 hours):
 - Process flow diagram development
 - Piping and instrumentation diagrams
 - Equipment symbols and conventions
 - Process documentation standards
- Afternoon (4 hours):
 - CAD software for process design
 - Industrial case studies
 - Documentation workshop
 - Team project work

Tuesday: Material and Energy Balances

- Morning (4 hours):
 - Steady-state material balances
 - Energy balance applications
 - Recycle and bypass streams
 - Complex process analysis
- Afternoon (4 hours):
 - Process simulation software
 - Balance calculations workshop
 - Industrial examples
 - Problem-solving session

Wednesday: Heat Integration and Pinch Analysis

- Morning (4 hours):
 - Pinch technology principles
 - Heat exchanger networks
 - Utility requirements
 - Energy efficiency optimization
- Afternoon (4 hours):
 - Pinch analysis software
 - Heat integration case studies
 - Economic evaluation
 - Design workshop

Thursday: Process Synthesis and Design

- Morning (4 hours):
 - Process synthesis methodology
 - Heuristic design methods
 - Equipment selection criteria
 - Process alternatives evaluation
- Afternoon (4 hours):
 - Synthesis case studies
 - Design decision making
 - Team design project
 - Progress presentations

Friday: Economic Evaluation and Optimization

- Morning (4 hours):
 - Capital cost estimation
 - Operating cost analysis
 - Economic optimization
 - Profitability analysis
- Afternoon (4 hours):
 - Cost estimation software
 - Optimization case studies
 - Project economics
 - Week 10 comprehensive review

Assessment for Week 10:

- Process design project (20%)
- Heat integration analysis (15%)
- Economic evaluation report (15%)
- Process synthesis assignment (10%)

Reading Materials:

- "Chemical Process Design and Integration" (Robin Smith, OER chapters)
- "Analysis, Synthesis, and Design of Chemical Processes" (Turton et al., MIT OCW)
- "Process Design Principles" (Seider et al., Open Access)
- "Plant Design and Economics for Chemical Engineers" (Peters & Timmerhaus, OER version)

Week 11: Thermodynamic Applications and Advanced Topics

Monday: Advanced Phase Equilibria

- Morning (4 hours):
 - Multi-component VLE
 - Complex phase behavior
 - Supercritical extraction

- Crystallization thermodynamics
- Afternoon (4 hours):
 - Laboratory: Multi-component VLE
 - Supercritical fluid experiments
 - Process simulation applications
 - Case studies

Tuesday: Chemical Reaction Thermodynamics

- Morning (4 hours):
 - Reaction equilibrium in complex systems
 - Temperature and pressure optimization
 - Equilibrium reactor design
 - Thermodynamic databases
- Afternoon (4 hours):
 - Equilibrium calculations workshop
 - Process optimization
 - Industrial applications
 - Problem-solving session

Wednesday: Electrochemical Thermodynamics

- Morning (4 hours):
 - Electrochemical cells
 - Nernst equation
 - Corrosion thermodynamics
 - Battery and fuel cell systems
- Afternoon (4 hours):
 - Laboratory: Electrochemical measurements
 - Corrosion analysis
 - Energy storage applications
 - Case studies

Thursday: Polymer and Biological Thermodynamics

- Morning (4 hours):
 - Polymer solution thermodynamics
 - Protein folding and stability
 - Biomolecular interactions
 - Phase behavior in biological systems
- Afternoon (4 hours):
 - Laboratory: Polymer characterization
 - Biological system modeling
 - Bioprocess applications
 - Research applications

Friday: Computational Thermodynamics

- Morning (4 hours):

- Molecular simulation methods
- Monte Carlo techniques
- Molecular dynamics
- Property prediction methods
- Afternoon (4 hours):
 - Computational workshop
 - Simulation software
 - Research applications
 - Week 11 assessment

Assessment for Week 11:

- Advanced phase equilibria (15%)
- Reaction thermodynamics project (15%)
- Electrochemical analysis (10%)
- Computational thermodynamics (15%)

Reading Materials:

- "Molecular Thermodynamics of Complex Systems" (Lu & Guo, MIT OCW)
- "Electrochemical Engineering" (Fuller & Harb, Open Access)
- "Biomolecular Thermodynamics" (Cooper, OER chapters)
- "Molecular Simulation of Fluids" (Allen & Tildesley, Open Access)

Week 12: Advanced Reaction Engineering

Monday: Multiphase Reactors

- Morning (4 hours):
 - Gas-liquid reactors
 - Gas-liquid-solid reactors
 - Slurry reactors
 - Trickle bed reactors
- Afternoon (4 hours):
 - Laboratory: Multiphase reactor study
 - Mass transfer effects
 - Hydrodynamics characterization
 - Scale-up considerations

Tuesday: Reactive Separations

- Morning (4 hours):
 - Reactive distillation
 - Membrane reactors
 - Adsorptive reactors
 - Chromatographic reactors
- Afternoon (4 hours):
 - Process intensification benefits
 - Design methodologies

- Case studies
- Economic evaluation

Wednesday: Advanced Catalysis

- Morning (4 hours):
 - Catalyst deactivation
 - Catalyst regeneration
 - Catalyst selection
 - Novel catalytic materials
- Afternoon (4 hours):
 - Laboratory: Catalyst characterization
 - Deactivation studies
 - Industrial catalyst management
 - Research frontiers

Thursday: Reaction Engineering in Biotechnology

- Morning (4 hours):
 - Immobilized enzyme reactors
 - Cell culture bioreactors
 - Fermentation engineering
 - Biofilm reactors
- Afternoon (4 hours):
 - Laboratory: Bioreactor operation
 - Scale-up challenges
 - Bioprocess optimization
 - Industrial applications

Friday: Safety in Reaction Engineering

- Morning (4 hours):
 - Thermal stability analysis
 - Runaway reaction prevention
 - Emergency relief systems
 - Safe reactor design
- Afternoon (4 hours):
 - Safety analysis tools
 - Case studies of incidents
 - Risk assessment
 - Week 12 comprehensive assessment

Assessment for Week 12:

- Multiphase reactor design (15%)
- Reactive separation analysis (15%)
- Catalyst study project (15%)
- Safety analysis report (10%)

Reading Materials:

- "Multiphase Reactors in Chemical Processing" (Gianetto & Silveston, Open Access)
- "Reactive Distillation Design and Control" (Luyben & Yu, MIT OCW)
- "Heterogeneous Catalysis in Industrial Practice" (Satterfield, OER chapters)
- "Biochemical Engineering" (Blanch & Clark, Open Access)

Week 13: Research Project Development

Monday: Literature Review and Research Planning

- Morning (4 hours):
 - Advanced literature search techniques
 - Critical analysis of research papers
 - Research gap identification
 - Hypothesis formulation
- Afternoon (4 hours):
 - Research proposal development
 - Methodology selection
 - Timeline and milestone planning
 - Resource requirements

Tuesday: Experimental Design and Statistics

- Morning (4 hours):
 - Design of experiments principles
 - Factorial designs
 - Response surface methodology
 - Statistical analysis planning
- Afternoon (4 hours):
 - DOE software applications
 - Experimental planning workshop
 - Statistical power analysis
 - Sample size determination

Wednesday: Advanced Analytical Techniques

- Morning (4 hours):
 - Spectroscopic methods
 - Chromatographic analysis
 - Surface characterization
 - Microscopy techniques
- Afternoon (4 hours):
 - Laboratory: Analytical techniques
 - Method selection criteria
 - Quantitative analysis
 - Error analysis

Thursday: Data Analysis and Interpretation

- Morning (4 hours):
 - Advanced statistical methods
 - Multivariate analysis
 - Model validation techniques
 - Uncertainty quantification
- Afternoon (4 hours):
 - Data analysis software
 - Statistical modeling workshop
 - Results interpretation
 - Scientific conclusions

Friday: Research Presentation and Communication

- Morning (4 hours):
 - Scientific presentation skills
 - Poster design principles
 - Graphical data presentation
 - Scientific writing techniques
- Afternoon (4 hours):
 - Practice presentations
 - Peer review process
 - Research communication workshop
 - Week 13 assessment

Assessment for Week 13:

- Research proposal (20%)
- Experimental design project (15%)
- Analytical method development (10%)
- Research presentation (15%)

Reading Materials:

- "The Craft of Research" (Booth et al., Open Access)
- "Design and Analysis of Experiments" (Montgomery, OER version)
- "Analytical Chemistry Handbook" (Kenkel, Open Access)
- "Scientific Writing and Communication" (Hofmann, MIT OCW)

Week 14: Professional Development and Industry Applications

Monday: Chemical Industry Overview

- Morning (4 hours):
 - Industry sectors and markets
 - Value chains and supply networks
 - Technology trends
 - Competitive analysis
- Afternoon (4 hours):
 - Industry case studies

- Guest speaker sessions
- Market analysis workshop
- Industry visits (virtual/physical)

Tuesday: Process Safety and Risk Management

- Morning (4 hours):
 - Process safety management systems
 - Quantitative risk assessment
 - Safety culture and leadership
 - Regulatory compliance
- Afternoon (4 hours):
 - HAZOP workshop
 - Incident analysis
 - Safety management case studies
 - Risk communication

Wednesday: Environmental and Sustainability Issues

- Morning (4 hours):
 - Green chemistry principles
 - Sustainable process design
 - Carbon footprint analysis
 - Circular economy concepts
- Afternoon (4 hours):
 - LCA methodology
 - Sustainability metrics
 - Green technology case studies
 - Environmental compliance

Thursday: Project Management and Leadership

- Morning (4 hours):
 - Project management fundamentals
 - Team leadership skills
 - Communication and negotiation
 - Conflict resolution
- Afternoon (4 hours):
 - Project planning workshop
 - Leadership assessment
 - Team building exercises
 - Professional development planning

Friday: Career Development and Networking

- Morning (4 hours):
 - Career paths in chemical engineering
 - Resume and portfolio development
 - Interview skills

- Professional networking
- Afternoon (4 hours):
 - Career planning workshop
 - Mock interviews
 - Industry networking session
 - Week 14 assessment

Assessment for Week 14:

- Industry analysis report (15%)
- Safety management plan (10%)
- Sustainability project (15%)
- Professional development portfolio (10%)

Reading Materials:

- "Chemical Industry Structure and Global Markets" (CEFIC, Open Access)
- "Process Safety Management Guidelines" (CCPS, OER chapters)
- "Green Engineering" (Anastas & Zimmerman, MIT OCW)
- "Project Management for Engineers" (Badiru, Open Access)

Week 15: Comprehensive Review and Final Assessment

Monday: Thermodynamics Comprehensive Review

- Morning (4 hours):
 - Fundamental principles review
 - Phase equilibria integration
 - Reaction equilibria summary
 - Advanced applications
- Afternoon (4 hours):
 - Problem-solving marathon
 - Group study sessions
 - Concept mapping
 - Q&A sessions

Tuesday: Transport Phenomena and Reaction Engineering Review

- Morning (4 hours):
 - Momentum, heat, and mass transfer integration
 - Reactor design principles
 - Scale-up methodologies
 - Industrial applications
- Afternoon (4 hours):
 - Comprehensive problem solving
 - Case study analysis
 - Design challenge
 - Peer teaching sessions

Wednesday: Mathematical Methods and Process Design Review

- Morning (4 hours):
 - Mathematical tools summary
 - Process synthesis methodology
 - Optimization techniques
 - Economic evaluation
- Afternoon (4 hours):
 - Integrated design problem
 - Software applications
 - Economic analysis
 - Design presentations

Thursday: Research Methods and Professional Skills Review

- Morning (4 hours):
 - Research methodology summary
 - Safety and environmental considerations
 - Statistical analysis techniques
 - Communication skills
- Afternoon (4 hours):
 - Research proposal refinement
 - Safety assessment exercise
 - Data analysis workshop
 - Professional skill assessment

Friday: Final Examinations and Course Evaluation

- Morning (4 hours):
 - Comprehensive written examination
 - Problem-solving assessment
 - Design project evaluation
 - Oral examination preparation
- Afternoon (4 hours):
 - Oral examinations
 - Course evaluation and feedback
 - Semester reflection
 - Next semester preparation

Assessment for Week 15:

- Comprehensive written exam (30%)
- Oral examination (20%)
- Final design project (25%)
- Research proposal final (15%)
- Course participation and professionalism (10%)

Reading Materials:

- "Chemical Engineering Review" (Compilation of key concepts)
 - "Process Design Case Studies" (Various authors, Open Access)
 - "Chemical Engineering Fundamentals" (Summary resources)
 - "Professional Development in Engineering" (MIT OCW)
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SEMESTER GRADING BREAKDOWN

Continuous Assessment (70%):

- Weekly assignments and quizzes: 30%
- Laboratory reports: 20%
- Design projects: 20%

Final Assessment (30%):

- Comprehensive written examination: 20%
- Oral examination: 10%

Minimum Requirements:

- Attendance: 90% minimum
- Laboratory participation: 100%
- Safety certification: Required
- Research proposal: Satisfactory completion

Grade Scale:

- A: 90-100%
 - B: 80-89%
 - C: 70-79%
 - D: 60-69%
 - F: Below 60%
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SEMESTER LEARNING OUTCOMES

Upon successful completion of the first semester, students will be able to:

1. Apply advanced mathematical methods to solve complex chemical engineering problems
2. Analyze thermodynamic systems and predict phase and reaction equilibria
3. Design and analyze chemical reactors for various reaction systems
4. Apply transport phenomena principles to momentum, heat, and mass transfer problems
5. Integrate process design principles with economic and safety considerations

6. Conduct independent research and communicate results effectively
 7. Demonstrate professional skills including teamwork, leadership, and ethical behavior
 8. Apply computational tools for process modeling and optimization
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NEXT SEMESTER PREVIEW

First Year - Second Semester (Spring) will focus on:

- Transport Phenomena II (Heat and Mass Transfer)
- Separation Processes Design and Analysis
- Process Dynamics and Control Systems
- Advanced Materials for Chemical Engineering
- Statistical Methods and Data Analysis for Process Improvement

Students will build upon the fundamental knowledge gained in the first semester to tackle more complex separation and control problems while developing expertise in advanced materials and statistical methods essential for modern chemical engineering practice.