Mass Transfer II
EC 654

Lecture : 3 **Year: III**
Tutorial : 1 **Part: II**

Course Objectives:

i. Understand the principles of separation of chemical and biological mixtures by equilibrium and rate based processes.
ii. Specific processes include liquid-liquid extraction, washing and leaching, membrane separation and sorption process (adsorption, ion exchange and chromatography)

1. **Leaching and Extraction** **(6 hours)**
   1.1. Leaching, principles and equipment's
   1.2. Liquid extraction and principles
   1.3. Phase equilibrium diagrams

2. **Adsorption** **(9 hours)**
   2.1. Introduction to sorption operations
   2.2. Sorbents for sorption operations
   2.3. Adsorption and principles of adsorption
   2.4. Adsorption isotherms and adsorber design for continuous operation

3. **Ion exchange** **(6 hours)**
   3.1. Ion exchange and principles
   3.2. Sorbent regeneration and design calculations
   3.3. Chromatography and principles

4. **Membrane Separation Processes** **(8 hours)**
   4.1. Introduction and membrane material
   4.2. Membrane modules and transport in membranes
   4.3. Membranes for gas separation
   4.4. Liquid separation (dialysis and reverse osmosis)

5. **Drying of Solids** **(8 hours)**
   5.1. Principles and modes of drying
   5.2. Drying equipment's and psychrometry
   5.3. Equilibrium moisture content of solids
   5.4. Drying rates and dryer models

6. **Crystallization** **(8 hours)**
   6.1 Crystal geometry
   6.2 Thermodynamic and kinetics considerations
   6.3 Crystal nucleation and growth
   6.4 Crystallization Equipment

References:

1. Warren L. McCabe, Julian C. Smith and Peter Harriott, "Unit Operations of Chemical Engineering", McGraw Hill Education Private Limited.
2. Robert E. Treybal, "Mass Transfer Operations", McGraw Hill Education Private Limited.
3. Seader, Henley and Roper, "Separation Process Principles", John Wiley & Sons, Inc.
4. Incorpera, DeWitt, Bergmann and Lavine, "Fundamentals of Heat and Mass Transfer", John Wiley & Sons.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as follows:

Unit	Chapter	Topics	Marks
1	1 & 3	all	**16**
2	2	all	**16**
3	4	all	**16**

4	5	all	**16**
5	6	all	**16**
Total			**80**

Instrumentation and Process Control
EC 652

Lecture: 3 **Year: III**
Tutorial: 1 **Part: II**
Practical: 1.5

Course Objectives:

i. To understand different process instruments
ii. To impart knowledge on various control schemes in order to design control systems for chemical process industry.

1. Instrumentation: Introduction of Materials (3 hours)

1.1 Classification of measuring instruments
1.2 Elements of measuring instruments

2. Process Instrumentation (6 hours)

2.1 Working principles, merits and demerits of transducers/instruments employed for the measurement of temperature, pressure, flow, liquid level, and moisture content.

3. Process Control: Introduction (4 hours)

3.1 The concept of process dynamics and control
3.2 Review of Laplace transform methods
3.3 Laplace transform of disturbances and building functions
3.4 Dynamic model building of simple systems

4. Linear Open-loop Systems (10 hours)

4.1 Laplace domain analysis of first and second orders systems
4.2 Linearization
4.3 Response to step, pulse, impulse and ramp inputs
4.4 Physical examples of first and second order systems such as thermocouple, level tank, U-tube manometer
4.5 Interacting and non-interacting systems
4.6 Distributed and lumped parameter systems
4.7 Dead time

5. Linear Closed-loop Systems (8 hours)

5.1 Controllers and final control elements
5.2 Different types of control valves and their characteristics
5.3 Development of block diagram
5.4 Transient response of simple control systems
5.5 Stability in Laplace domain

6. Frequency Response (6 hours)

6.1 Frequency domain analysis
6.2 Control system design by frequency response
6.3 Bode stability criterion
6.4 Different methods of tuning of controllers

7. Process Applications (8 hours)

7.1 Introduction to advanced control techniques as feed forward, feedback, cascade, ratio
7.2 Application to equipment such as distillation-columns, reactors
7.3 Case study – Development of control scheme of complete plant.

Practical:

1. Calibration of a pressure gauge using a dead weight calibrator.
2. Level control by pump speed and solenoid valve.
3. Flow control by manual and pump speed
4. Direct and indirect control of heater temperature by varying heater power.
5. Pressure controlled by pump speed and solenoid valve.
6. Case Study – Study of safety controls in the Nepal Oil Corporation Depot.

References:

1. D. R. Coughanowr, S. E. Le Blanc, "Process Systems Analysis and Control", McGraw Hill 2009.

2. D. P. Eckman, "Industrial Instrumentation", John Wiley & Sons 2004.
3. G. Stephanopoulous, "Chemical Process Control: An Introduction to Theory and Practice", Prentice Hall of India 1984.
4. P. Harriott, "Process Control", Tata McGraw Hill 1972.
5. W. L. Luyben, "Essentials of Process Control", McGraw-Hill 1997.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as follows:

Unit	Chapter	Topics	Marks
1	1 & 2	all	16
2	3 & 6	all	16
3	4	all	16
4	5	all	16
5	7	all	16
Total			**80**

Electro-Chemical & Renewable Energy
EC 653

Lecture: 4 | **Year: III**
Practical: 1.5 | **Part: II**

Course Objectives:

i. To introduce the fundamentals of electrochemical system and their production mechanism with application of energy
ii. To introduce different types renewable energy resources, their exploitation and energy audit and supports to entrepreneurship.

1. Introduction to Energy Resources (4 hours)

1.1 Fossil fuels
1.2 Different forms of energy: renewable vs non-renewable, conventional vs non-conventional, perpetual sources

2. Electrochemical System: Production and Storage (16 hours)

2.1 Electrochemical cell
2.2 Hydrogen fuel
2.3 Fuel cell thermodynamics, kinetics and ion transport
2.4 Batteries
2.5 Super capacitor materials and manufacturing
2.6 Water splitting

3. Introduction to Renewable Energy (4 hours)

3.1 Energy resources spectrum
3.2 Renewable and Nonrenewable energy resources,
3.3 Energy Consumption Pattern in different sectors,
3.4 Energy Ladders
3.5 Design aspects of Small Scale Hydropower plants

4. Solar Energy (4 hours)

4.1 Electromagnetic spectrum
4.2 Types of radiation and measuring devices
4.3 Design of a solar photovoltaic system to cover the electricity of a small family members
4.4 Solar thermal, solar dryer, solar water heater, solar water pumping

5. Wind Energy (4 hours)

5.1 Affecting factors of wind speed, anemometer
5.2 Wind energy conversion
5.3 Estimation of wind power
5.4 Types and characteristics of wind turbines and their working principles
5.5 Wind farming

6. Bio- Energy (4 hours)

6.1 Biomass characterization
6.2 Biomass pyrolysis, and gasification
6.3 Biomass to ethanol production
6.4 Household/community biogas plant
6.5 Waste to briquette
6.6 Biodiesel

7. Geothermal Energy (3 hours)

7.1 Structure of earth's interior
7.2 Energy of earth heat flux
7.3 Geothermal system
7.4 Earth air tunnel

8. Nuclear Energy (4 hours)

8.1 Fundamentals of nuclear energy
8.2 Nuclear fission and fusion
8.3 Nuclear reactors, nuclear plants, working mechanism and safety measures
8.4 Health hazards, radiation protection and shielding

9. Nonconventional Energy Resources (4 hours)

9.1 Floating Hydropower production

9.2 Floating solar panels
9.3 Tidal energy
9.4 Cellulosic ethanol, and artificial photosynthesis

10. Energy Audit (3 hours)

10.1 Introduction of basic concept of Energy Audit
10.2 Case study of energy potential
10.3 Distribution of energy demand and supply
10.4 Preparation of Energy audit reports

Practical:

1. Case study of the solar water heater system and its efficiency.
2. Case study of biogas plant and its principle operation.
3. Case study of hydropower plant in the context of Nepal.
4. Measurement/ Data Analysis of Solar Radiation potential and solar energy using solarimeter devices
5. Measurement/ Data Analysis of wind energy potential using wind speed data of anemometer
6. Demonstrate and explanations of performance of Super capacitors

References:

1. J. Bookris, "Modern Electrochemistry", Vol I, II, III, Plenum Press, New York, 1998.
2. A. J. Bard, L. R. Faulkner, H. S. White, "Electrochemical Methods: Fundamentals and Applications, Wiley, 2022.
3. J. Twidel, W. Tony, "Renewable Energy Resources, Taylor and Francies, 2006.
4. J. A. Duffie, W. A. Beckman, "Solar Engineering of Thermal Processes", John Wiley and Sons, Inc.
5. M. Iqbal, "An Introduction to solar radiation", Academic Press, Toronto, CA, 1983.
6. S. Sukhatme, J. Nayak, "Solar Energy principles of Thermal Collection and Storage", Tata Mc Graw-Hill Publishing Company Ltd, 2008.
7. B. H. Khan, "Non-Conventional Energy Resources", Tata McGraw-Hill, 2009.
8. D. Y. Goswami, F. Kreith, "Handbook of Energy Efficiency and Renewable Energy", Taylor & Francis Group, 2016.
9. H. P. Garg, J. Prakash, "Solar Energy Fundamentals and Applications", Tata McGraw Hill Education Private Limited, New Delhi, India.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as follows:

Unit	Chapter	Topics	Marks
1	1, 3 & 4	all	18
2	2	all	30
3	5, 6 & 7	all	16
4	8, 9 & 10	all	16
Total			**80**

Food and Beverage
EC 656

Lecture: 4 **Year: III**
Tutorial: 0 **Part: II**

Course Objectives:

i. This course is structured to introduce and acquire knowledge in food Science, its related constituents and technologies in order to elaborate their significance in global or national context for Chemical Engineers.
ii. The contents of this course helps in developing a concept of sustainable food system.

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1. Food chemistry and Nutrition **(9 hours)**

1.1 Brief revision on chemical constituents of food and food classifications.
1.2 Nutritional aspects of food chemistry, function, sources, deficiency, and glycaemic index (GI), Recommended Dietary Allowances (RDA).
1.3 Gross chemical compositions of staple, non-staple and perishable foods of Nepal/ Worldwide context.
1.4 Vitamins, Minerals and Trace elements: introduction and nutritional aspects.
1.5 Food additives: colors, flavors, aromatic compounds, preservatives.
1.6 Browning in food: enzymatic non enzymatic.
1.7 Concept of balanced diet.

2. Principles of Food process engineering **(10 hours)**

2.1 Concept of food rheology and its measurements.
2.2 Food preservation historical approach.
2.3 Thermal processing of food, pasteurization, sterilization, aseptic sterilization, canning.
2.4 Unit operation in food processing: evaporation, concentration, drying, moisture content, heat exchangers and their application in food industries.
2.5 Microwave processing of food.
2.6 Freezing and freeze drying, freezing system in food, slow and quick-freezing, cryogenic freezing system.
2.7 Introduction to applications of leaching and extraction in food industries.
2.8 Food process mixing and separation techniques: membrane separation/ reverse osmosis.
2.9 Non thermal techniques in food processing: importance and advantages.

3. Food bio-tech **(8 hours)**

3.1 Introduction and history.
3.2 Traditional food fermentation.
3.3 Types of fermentation: batch, feed batch, continuous fermentation.
3.4 Isolation and preservation of industrially important microorganisms.
3.5 Biotechnological processes for manufacture of functional foods: nutraceuticals and probiotics.
3.6 Production of organic acids (citric/acetic), enzymes
3.7 Production of single cell protein.
3.8 RDT in food science: GM crops and their legal, social aspect.
3.9 Commercial enzymes and proteins derived from GMOs in the food industry.

4. Food sanitation and safety **(8 hours)**

4.1 History and overview of food safety.
4.2 Definition and scope of food safety.
4.3 Basic food toxicology: contaminants microbial food borne agents, agricultural, other toxic, physical agents.
4.4 Toxicants introduced during food processing
4.5 Food adulteration.
4.6 Nepal food regulation and standards.

5. **Beverage technology** **(7 hours)**
   - 5.1 Biochemistry of brewing, malt and malting, exo-enzymes in brewing.
   - 5.2 Beverage classification, ingredients, additives, preservatives.
   - 5.3 Carbonated beverages.
   - 5.4 Fruit based beverages.
   - 5.5 Fermented beverages.
   - 5.6 Drinking water standards: bottled water.

6. **Food packaging technology and process waste** **(3 hours)**
   - 6.1 Food packaging techniques: introduction, principle, packaging materials and methods.
   - 6.2 Food industry by-products and waste utilization, Identification of useful products from food processing waste.
   - 6.3 Types of wastes in food processing industries.

References:

1. F. A. Lee, "Basic Food Chemistry", Springer, 2012.
2. J. M. DeMan, "Principles of Food Chemistry", Aspen Publishers, Inc., 2018.
3. D. R. Heldman, R. P. Singh, "Introduction to Food Engineering" Academic press & Elsevier, 2008.
4. J. F. Hanlon, "Handbook of Package Engineering", CRC press, 1998.
5. P. Stanbury, A. Whitaker, "Principles of Fermentation Technology", Elsevier, 2016.
6. S. M. Hershdorfer, "Quality Control in the Food Industry", Academic Press 2012.
7. P. L. Knechtges, "Food safety: Theory and practice", Jones & Bartlett Learning, 2011.
8. T. Foster, P. C. Vasavada, "Beverage quality and safety", CRC Press, 2003.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as follows:

Unit	**Chapter**	**Topics**	**Marks**
1	1	all	16
2	2	all	16
3	3	all	16
4	4	all	16
5	5 & 6	all	16
Total			**80**

Chemical Engineering Design I
EC 651

Lecture: 3 | **Year: III**
Tutorial: 1 | **Part: II**

Course Objectives:
- i. To acquire basic understanding of design parameters
- ii. Use of simulation software in designing process equipment.

1. Mechanics of Materials **(8 hours)**
- 1.1 Stress, strain, biaxial stress, stress-strain relationship for elastic bodies, theories of failure
- 1.2 Thermal stresses, membrane stresses in shells of revolution
- 1.3 Thin and thick cylinder
- 1.4 Materials of construction
- 1.5 Corrosion resistance

2. Design and Flow-sheeting **(6 hours)**
- 2.1 Nature of design
- 2.2 The anatomy of a chemical manufacturing process
- 2.3 The organization of a chemical engineering project
- 2.4 Codes and standards
- 2.5 Flow-sheet presentation, block diagrams, process flow diagram (PFD), engineering line diagram (ELD, P & ID), utility line diagram (ULD), plant layout
- 2.6 Manual flow-sheet calculations
- 2.7 Computer – aided flow – sheeting
- 2.8 Full steady – state simulation programs
- 2.9 Manual calculations with recycle stream

3. Flanges and Support **(2 hours)**
- 3.1 Selection of gaskets and standard flanges
- 3.2 Lug and leg supports, saddles support

4. Piping **(4 hours)**
- 4.1 Valve selection
- 4.2 Pumps and compressors
- 4.3 Mechanical design of piping systems
- 4.4 Pipe size selection

5. Storage Tanks Design **(6 hours)**
- 5.1 Filling and breathing losses
- 5.2 Classification of storage tanks
- 5.3 Optimum length to diameter ratio
- 5.4 Design of liquid and gas storage tanks with and without floating roof.

6. Pressure Vessel: Classification **(4 hours)**
- 6.1 Selection of type of vessels
- 6.2 Material of construction selection and design considerations
- 6.3 Introduction of codes for pressure vessel design, classification of pressure vessels as per codes

7. Pressure Vessel: Design **(9 hours)**
- 7.1 Design of cylindrical and spherical shells under internal and external pressure
- 7.2 Pipe thickness calculation under internal and external pressure
- 7.3 Selection and design of closures and heads, design of jacketed portion of vessels.
- 7.4 Compensation of openings
- 7.5 Design of high pressure monoblock and multilayer vessels
- 7.6 Inspection and testing of pressure vessels

8. Tall Tower Design and Support **(6 hours)**
- 8.1 Design of shell, skirt, bearing-plate and anchor bolts for tall tower used at high wind and seismic conditions.

References:

1. R. K. Sinnott, "Coulson & Richardson's Chemical Engineering Design", Volume 6, Elsevier Butterworth-Heinemann.

2. L. E. Brownell, H. E. Young, "Process Equipment Design", John Wiley. 2004.
3. B. C. Bhattacharya, "Introduction of Chemical Equipment Design", CBS Publisher, 2003.
4. I. S.:2825-1969, "Code for Unfired Pressure Vessels", Bureau of Indian Standards, New Delhi, 1998.
5. I. S.:803-1976, "Code of Practice for Design, Fabrication and Erection of Vertical Mild Steel Cylindrical Welded Oil Storage Tanks", Bureau of Indian Standards, New Delhi, March 1998.
6. D. R. Moss, "Pressure Vessel Design Manual", Elsevier Gulf Professional Publishing, 2004.
7. E. F. Megyesy, "Pressure Vessel Handbook", Pressure Vessel Publishing, 2001.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as follows:

Unit	Chapter	Topics	Marks
1	1	all	16
2	2 & 3	all	16
3	4 & 5	all	16
4	6 & 8	all	16
5	7	all	16
Total			**80**

Chemical Reaction Engineering II
EC 655

Lecture: 3 **Year: III**
Tutorial: 1 **Part: II**
Practical: 1.5

Course Objectives:

i. Understand fundamentals of reaction mechanism, non-elementary rate laws, energy balance in reactors, reaction with catalysts, bioreactions, diffusion effects on heterogeneous reactions and residence time distribution in chemical reactors.
ii. Design non isothermal reactors, bioreactors and catalytic reactors using Polymath and Aspen.

1. Rate mechanisms **(4 hours)**
   1.1. Non-elementary rate laws
   1.2. Pseudo steady state hypothesis
   1.3. Determining reaction mechanism

2. Steady state non isothermal reactor design **(9 hours)**
   2.1. Steady state energy balance
   2.2. Adiabatic operation
   2.3. Tubular reactors with heat exchange
   2.4. Equilibrium conversion

3. Unsteady state non isothermal reactor design **(4 hours)**
   3.1. Unsteady state energy balance
   3.2. Energy balance on batch reactors
   3.3. Problem solving with Polymath

4. Catalysis and Catalytic reactors **(8 hours)**
   4.1. Steps in a catalytic reaction
   4.2. Rate law for catalytic reaction
   4.3. Heterogeneous data analysis for reactor design
   4.4. Catalyst deactivation

5. Enzymatic reactions and bioreactors **(6 hours)**
   5.1. Enzymatic reaction fundamentals
   5.2. Inhibition of enzymatic reactions
   5.3. Design of Bioreactors

6. Diffusion and reaction **(4 hours)**
   6.1. Diffusion and reaction in catalyst pellets
   6.2. External resistance to mass transfer
   6.3. Overall effectiveness factor

7. Residence time distribution **(6 hours)**
   7.1. Residence time distribution (RTD) function
   7.2. Measurement and characteristics of the RTD
   7.3. RTD in ideal reactors (batch, CSTR, PFR)

8. Conversion on the basis of RTD **(4 hours)**
   8.1. Reactor modelling with RTD
   8.2. Zero parameter models
   8.3. Problems elucidated with the help of Polymath

Practical:

1. To find the reaction rate constant in a stirred batch reactor.
2. To find the effect of reactant concentration on the reaction rate by using batch rector.
3. To find the reaction rate constant in a continuous stirred tank reactor.
4. To determine the effect of inadequate mixing on the reaction rate using stirred tank reactor.
5. To determine the rate constant using tubular reactor.
6. To demonstrate the temperature dependence of the reaction and the rate constant using tubular reactor.
7. Characterization of pressure drops through fixed and fluidized bed

References:

1. H. Scott Fogler, "Elements of Chemical Reaction Engineering", Prentice Hall International.
2. Octave Levenspiel, "Chemical Reaction Engineering", John Wiley & Sons.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as follows:

Unit	Chapter	Topics	Marks
1	1 & 3	all	**16**
2	2	all	**16**
3	4	all	**16**
4	5 & 6	all	**16**
5	7 & 8	all	**16**
Total			**80**

Construction Materials
EC 653

Lecture: 4 — **Year: III**
Practical: 1.5 — **Part: II**

Course Objectives:

i. To provide detailed knowledge about the manufacturing procedure and properties of cement.
ii. To understand the formulation, processing and manufacturing of ceramics.
iii. To understand the principle behind the glass formation and structures of different types of glasses.

1. Cement Technology (15 hours)

1.1 Raw materials, geology, deposits, exploration, quarrying the raw materials, storage
1.2 Cement Chemistry, raw materials and the raw mix, chemical, physical and mineralogical aspects of the burning process, Portland cement clinker, finish grinding, storage of cement
1.3 Hydration of cement, relation between chemical reactions, phase content and strength of Portland cement
1.4 Types, strength classes, designation and quality, designation and quality control of cements
1.5 Manufacturing of cement, material preparation, raw meal silos, cement burning technology, clinker storage, cement silos
1.6 Packaging and loading, conveyor

2. Ceramics Technology (15 hours)

2.1 Introduction: oxide and non-oxide ceramics, their chemical formulae, crystal and defect structures, non-stoichiometry and typical properties, phase diagram.
2.2 Applications: high-temperature, wear and corrosion resistance, cutting and grinding, electrical, magnetic, optical, composites, medical, energy efficiency and pollution, military.
2.3 Powder Preparation: Physical methods (different techniques of grinding), chemical routes – co-precipitation, sol-gel, hydrothermal, combustion synthesis, high temperature reaction (solid state reaction).
2.4 Basic principles and techniques of consolidation and shaping of ceramics: powder pressing- uniaxial, biaxial and cold isostatic and hot isostatic, injection moulding, slip casting, tape-casting, calendaring, multi-layering.
2.5 Sintering: different mechanisms and development of microstructure (including microwave sintering)
2.6 Mechanical behavior, design consideration, failure analysis.

3. Glass Technology (15 hours)

3.1 Definition, kinetic approaches to glass formation, structure of glasses, phase diagrams
3.2 Raw materials, glass compositions, glass batch calculations
3.3 Glass melting process, physicochemical reaction during glass melting, refining, gas bubbles, refining agents, homogenization
3.4 Thermodynamics, thermal, mechanical, electrical and transport properties of glass
3.5 Defects and remedies of glass
3.6 Pot furnace, electric tank furnace, design and operation, thermal insulation and cooling
3.7 Fabrication processes- hand operations, flatware-sheet glass, float glass, plate glass, and patterned glass. Hollow ware-press and blow, blow and blow, IS machine, bulbs and tubes
3.8 Temporary and permanent strain, annealing equation, problems in annealing, annealing glass plate, optical glass, ideal annealing cycle
3.9 Physical/chemical vapor deposition process, laminated glass, tempered glass, decorated glass, glass ceramic, glass fibre.

Practical:

1. Consistency test and comprehensive strength of cement.
2. Initial and final setting time test of cement.
3. Fineness and soundness test of cement.
4. Preparation of raw materials for ceramic production.
5. Determination of moisture content of raw material for ceramics.
6. Plaster mould making.
7. Determination of bulk density, apparent porosity and water absorption of ceramic.
8. Determination of density, thermal expansion, refractive index and chemical durability of glass.
9. Determination of hardness of toughened glass.

References:

1. O. Labahn, B. Kohlhaas, "Cement Engineers' Handbook", Bauverlag, Germany.
2. M. W. Barsoum, "Fundamental of Ceramics", McGraw Hill International edition, 1997.
3. D. W. Richerson, W. E. Lee, "Modern Ceramic Engineering, Properties, Processing, and use in design", CRC Press, Taylor & Francis Group.
4. M. N. Rahman, "Ceramic Processing and Sintering", Marcel Dekker, New York.
5. J. E. Shelby, "Introduction to Glass Science and Technology", The Royal Society of Chemistry, 1997.
6. A. Paul, "Chemistry of Glasses", Chapman and Hall, 1990.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as follows:

Unit	**Chapter**	**Topics**	**Marks**
1	1	all	30
2	2	all	25
3	3	all	25
Total			**80**