MINOR REQUIREMENTS IN CHEMICAL ENGINEERING

Total Credit requirement: 20

16 Credits shall be earned by selecting any four courses from the following and 4 credits through MOOCs with two courses of minimum 8 weeks duration.

Course Code	Course	L-T-P	Credit
Minors			
CHE 511 M	Chemical Process Calculation	3-1-0	4
CHE 512 M	Particle Technology	3-1-0	4
CHE 513 M	Momentum Transfer	3-1-0	4
CHE 514 M	Heat Transfer	3-1-0	4
CHE 515 M	Separation Technology	3-1-0	4
CHE 516 M	Chemical Reaction Engineering	3-1-0	4
	MOOCS - I		2
	MOOCS - II		2

CHEMICAL PROCESS CALCULATIONS

Course Code – Category: CHE 511 M - MINOR

L	T	P	E	O	Credits: 4
3	1	0	1	6	Sessional Marks: 40
End Exam: 3 Hours					End Exam Marks: 60

Prerequisites: NIL

Course Objectives:

- To master fundamentals of stoichiometry and gas laws.
- To familiarize and to apply material and energy balance for various chemical operations and processes
- Utilize the knowledge of subject for better understanding of core subjects

Course Outcomes:

By the end of the course, student will be able to

1. Solve basic stoichiometry calculations.
2. Evaluate composition of gases at various temperatures and pressures.
3. Apply material balance on various unit operation and processes.
4. Apply energy balance on various unit operation and processes.
5. Evaluate the theoretical flame temperatures.

CO – PO – PSO Matrix:

		PO												PSO	
		1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO	1														
	2														
	3														
	4														
	5														

UNIT I **9L + 3T**

Stoichiometry and composition relationships: The gram-mole and pound-mole, limiting reactant, excess reactant, degree of completion, basis of calculation, weight percent, volume percent and mole percent, density and specific gravity- Baume and API gravity scales.

Learning Outcomes:

At the end of this unit, student will be able to

- Compute the conversion, yield of a chemical reaction
- Estimate density, specific gravity of substances with various scales.

UNIT II **9L + 3T**

Behavior of ideal gases: Application of the ideal-gas law, Dalton and Amagat's laws to gaseous mixtures, composition of gases on dry basis and on wet basis, humidity fundamentals and calculations using Psychometric chart.

Learning Outcomes:

At the end of this unit, student will be able to

- Calculate the properties of ideal gases at different process conditions
- Estimate the compositions in various unit operations
- Estimate Psychometric properties of gases using humidity charts

UNIT III **9L + 3T**

Material Balances: Tie substance, yield, conversion, and processes involving combustion reactions, material balance- calculations involving drying, dissolution, and crystallization.

Learning Outcomes:

At the end of this unit, student will be able to

- Formulate material balances on various unit operations.
- Solve mass balance of chemical species over various unit operations involving with and without reactions.

UNIT IV **9L + 3T**

Thermophysics: Effect of temperature on vapor pressure, Antoine equation, vapor pressure plots, vapor pressure of immiscible liquids, ideal solutions and Raoult's law, non-volatile solutes. Heat capacities of gases and gaseous mixtures- effect of temperature on heat capacity of gas, Kopp's rule, latent heats of fusion and vaporization, Trouton's rule, Kistyakowsky equation for non-polar liquids.

Learning Outcomes:

At the end of this unit, student will be able to

- Formulate energy balances on various unit operations.
- Estimate heat capacities of substances and mixtures

UNIT V **9L + 3T**

Thermochemistry: Standard heat of reaction - Laws of thermochemistry, Standard heat of formation, standard heat of combustion, standard heat of reaction and their calculations, effect of temperature on heat of reaction, adiabatic and non-adiabatic reactions, theoretical and actual flame temperatures.

Learning Outcomes:

At the end of this unit, student will be able to

- Estimate heat of reactions at various temperatures of chemical reactions.
- Calculate adiabatic flame temperature

Text Books:

1. K.V. Narayanan and B. Lakshmikutty, "Stoichiometry and Process Calculations", 5th ed., Prentice Hall of India Pvt Ltd , 2006.

Reference Books:

1. David M. Himmelblau," Basic principles and Calculations in Chemical Engineering", 6th ed., Prentice Hall of India Pvt Ltd, 1995.
2. Olaf A Hougen, K.M. Watson and R. A. Ragatz, "Chemical Process Principles Part-I - Material and Energy balances" 2nd ed., CBS Publishers and Distributors, 1995.
3. B.I. Bhatt and S.M. Vora, "Stoichiometry", 3rded., Tata McGraw Hill Publishing Company Limited, New Delhi, 1996.

PARTICLE TECHNOLOGY

Course Code – Category: CHE 512 M - Minor

L	T	P	E	O	Credits: 4
3	1	0	1	6	Sessional Marks: 40
End Exam: 3 Hours					End Exam Marks: 60

Prerequisites: NIL

Course Objectives:

1. To familiarize with the characteristics of solids, size reduction aspects, working of various size reduction equipment and their operations.
2. To know about the different screening techniques and screening equipment and other separation methods.
3. To understand the principles of filtration and the working of different filtration equipment.
4. To understand the principles of settling of solids in fluids and sedimentation.
5. To understand the concepts of agitation of liquids and mixing of solids.

Course Outcomes:

By the end of the course, student will be able to

1. Identify the size reduction equipment for various size reduction operations.
2. Apply the screening techniques for different size separations.
3. Analyze the filtration techniques for various filtration operations.
4. Apply the principles of settling in classification of solids.
5. Calculate the power consumption for various mixing operations and identify mixers for cohesive and non cohesive solids.

CO – PO – PSO Matrix:

		PO												PSO	
		1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO	1														
	2														
	3														

	4														
	5														

UNIT I **9L + 3T**

Characteristics of solid particles: shape, size, differential and cumulative screen analyses, specific surface area, particle population, different mean diameters for a mixture of particles. Principles of comminution: Laws of crushing, description and working of size reduction equipment - jaw, gyratory and roll crushers, hammer mills, revolving mills, attrition mills, fluid energy mill, cutting machines, equipment operations, open and closed circuit grinding, wet and dry grinding.

Learning Outcomes:

At the end of this unit, student will be able to

- Identify the characteristics of particulate solids.
- Calculate different mean diameters for a mixture of particles.
- Suggest different types of size reduction methods such as crushing, grinding milling depending on the type and size of the material**.**

UNIT II **9L + 3T**

Mechanical separations: screening, industrial screens - grizzly, gyratory and vibratory screens, revolving screens - trommels, capacity and effectiveness of screens, magnetic separation, electrostatic separation, froth flotation.

Learning Outcomes:

At the end of this unit, student will be able to

- Calculate the effectiveness of screens.
- Apply the principles on magnetic separation, electrostatic separation, froth flotation techniques

UNIT III **9L + 3T**

Filtration: description and working of filtration equipment, plate and frame filter press, shell and leaf filter, rotary drum filter, filter aid, centrifugal filtration, top suspended batch centrifuge, theory of filtration, washing of cakes. (Qualitative treatment only).

Learning Outcomes:

At the end of this unit, student will be able to

- Enumerate the theory of filtration.
- Classify the filtration techniques.

UNIT IV **9L + 3T**

Motion of particles through fluids: drag, free and hindered settling, settling velocities, classification, sink and float methods, differential setting methods - jigging, cyclone separators, batch sedimentation, thickeners, flocculation, centrifugal sedimentation, gravity and centrifugal decanters.

Learning Outcomes:

At the end of this unit, student will be able to

- Identify the settling regime and calculate the settling velocities.
- Elucidate the various equipment used for classification of solids.

UNIT V **9L + 3T**

Agitation of liquids: Power consumption in agitated vessels, equipment for mixing of solids and pastes, mixers for dry powders.

Storage and conveying of solids: Storage of solids, types of conveyors –belt, chain and screw conveyors, elevators, pneumatic conveyors, size enlargement.

Learning Outcomes:

At the end of this unit, student will be able to

- Select appropriate conveyor from different conveying operations.
- Calculate the power requirements for different mixing operations.
- Classify different mixers for cohesive and non cohesive solids.

Text Books:

1. W.L. McCabe, J.C. Smith and P.Harriot, "Unit Operations of Chemical Engineering", 7th ed., McGraw- Hill Book Co., 2005.

2. J.H.Coulson and J.F.Richardson, “Chemical Engineering -Vol.2” 5th ed., Elsevier Science, 2002 (for topics of trommels, magnetic separators, electrostatic separators and froth flotation).

Reference Books:

1. R.H.Perry,“Chemical Engineer’s Hand Book”,8th ed., McGraw-Hill Book Co., 2007.
2. Brown et al., “Unit Operations”, 1st ed., CBS Publisher,2005.
3. Badger and Banchero, “Introduction to Chemical Engineering”, 1st ed.,McGraw-Hill, 2002 (for conveying topic).

MOMENTUM TRANSFER

Course Code – Category: CHE 513 M - Minor

L	T	P	E	O	Credits: 4
3	1	0	1	6	Sessional Marks: 40
End Exam: 3 Hours					End Exam Marks: 60

Prerequisites: NIL

Course Objectives:

1. To provide an understanding of fluid mechanics and its scope in the chemical industry.
2. To impart fundamental concepts in fluid mechanics with the knowledge of applying basic quantitative laws and the equations of fluid flow.
3. To provide the basic knowledge on compressible fluids, pressure drop, friction factor, Reynolds number and their relations in flow systems.
4. To provide an understanding about flow past immersed bodies and fluidization.
5. To acquaint knowledge on fluid moving machinery and flow measuring devices.

Course Outcomes:

By the end of the course, student will be able to

1. Apply the basic principles of static to fluid systems.
2. Apply quantitative laws to hydrostatic and fluid flow problems.
3. Analyze the velocity distributions, frictional flow patterns in pipes and piping networks.
4. Determine the pressure drop, velocities in packed and fluidized bed columns.
5. Analyze the performance aspects of fluid machinery specifically for pumps and flow metering devices.

CO – PO – PSO Matrix:

		PO												PSO	
		1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO	1														
	2														

	3														
	4														
	5														

UNIT I **9L + 3T**

Basic concepts: Unit systems, units and dimensions, dimensional analysis – Rayleigh's method, Buckingham π theorem, equations of state, similarity.

Fluid statics: Nature of fluids, hydrostatic pressure, pressure distribution in a static fluid, pressure measuring devices.

Learning Outcomes:

At the end of this unit, student will be able to

- Apply dimensional analysis
- Calculate hydrostatic pressure

UNIT II **9L + 3T**

Fluid flow phenomenon: Types of fluids, concept of stream lines, stream tubes, viscosity, rheological properties of fluids, turbulence, flow in boundary layers, its formation and growth in tubes and on plates, boundary layer separation.

Basic equations of fluid flow: Mass balance, steady state energy balance, equation of motion, momentum balance and Bernoulli's equation with the correction factors

Learning Outcomes:

At the end of this unit, student will be able to

- Identify the formation and growth of boundary layer
- Apply mass, momentum and Bernoulli's equation

UNIT III **9L + 3T**

Flow of incompressible fluids: Relation between skin friction - wall shear, laminar flow in pipes, Hagen-Poiseuille equation, turbulent flow in pipes, velocity distribution equation, friction factor, friction from changes in velocity or direction.

Learning Outcomes:

At the end of this unit, student will be able to

- Calculate pressure drop in laminar and turbulent flow
- Evaluate friction factors in a flowing fluid

UNIT IV **9L + 3T**

Flow past immersed bodies: Flow through beds of solids, motion of particles through fluids, terminal velocity, fluidization, mechanism of fluidization, pressure drop in fluidization, applications of fluidization.

Learning Outcomes:

At the end of this unit, student will be able to

- Calculate terminal velocity
- Estimate pressure drop in packed and fluidized beds
- Classify various kinds of fluidization

UNIT V **9L + 3T**

Transportation and metering of fluids: Pipes, fittings, valves, positive displacement and centrifugal pumps, fans, blowers and compressors, jet ejectors.

Flow measuring devices: venturi meter, orifice meter, pitot tube, rotameter, notches and weirs.

Learning Outcomes:

At the end of this unit, student will be able to

- Classify types of pumps and fans
- Calculate capacity, head and power requirement of pumps
- Estimate volumetric flowrate using different flow meters

Textbooks:

1. Warren L.McCabe and Julian C.Smith, "Unit Operations of Chemical Engineering", 7th ed., McGraw Hill, 2005.
2. R. K. Bansal, " A Text Book of Fluid Mechanics and Hydraulic Machines", 8th ed., Laxmi publisher, 2008. (for topics Unit systems, units and dimensions, dimensional analysis,notches and weirs)

Reference Books:

1. De Nevers N., "Fluid mechanics for chemical engineers", 3rd ed., McGraw Hill.

2. J.M.Coulson, J.F.Richardson, “Chemical engineering”, 5th ed., Vol –I & II,,Elseveir,1999.
3. Cengel and Cimbala, “Fundamentals of fluid mechanics”, 3rded.,McGraw Hill Education,2014.
4. R. K. Rajput, “ A Text Book of Fluid Mechanics and Hydraulic Machines”, 3rd ed., S. Chand, 2002.

HEAT TRANSFER

Course Code – Category: CHE 514 M - Minor

L	T	P	E	O	Credits: 4
3	1	0	1	6	Sessional Marks: 40
End Exam: 3 Hours					End Exam Marks: 60

Prerequisites: Engineering Mathematics, Chemical Process Calculations.

Course Objectives:

1. To familiarize with three modes of heat transfer and to know about steady state and unsteady state heat conduction.
2. To know about heat transfer involving phase change and without phase change.
3. To familiarize the operation of different heat transfer equipments.
4. To understand the fundamental principles of radiation.
5. To impart knowledge on the principles of evaporation and evaporator design.

Course Outcomes:

By the end of the course, the student will be able to:

1. Implement the basic laws of conduction to steady state and unsteady state problems.
2. Predict convective heat transfer coefficients at various conditions.
3. Compute heat loss / gain due to radiation.
4. Classify various heat transfer equipments.
5. Determine the performance of different Evaporators.

CO – PO – PSO Matrix:

		PO												PSO	
		1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO	1														
	2														
	3														
	4														
	5														

UNIT I **9L + 3T**

Modes of heat flow: Conduction, convection and radiation.

C**onduction:** Basic laws of conduction, thermal conductivity; steady-state conduction – compound resistances in series, heat flow through a cylinder; critical insulation thickness.

Learning Outcomes:
At the end of this unit, student will be able to

- Classify the various modes of heat transfer
- Calculate heat transfer rate for steady state conduction
- Construct heat transfer rate for steady state conduction

UNIT II **9L + 3T**

Convection:

Principles of heat flow in fluids – typical heat exchange equipment, counter current and parallel flows, energy balances, heat flux and heat transfer coefficients, LMTD.

Heat transfer to fluids without Phase change : Boundary layers, laminar flow heat transfer, heat transfer in turbulent flow, estimation of wall temperature, cross-sections other than circular, natural convection.

Heat transfer to fluids with Phase change: heat transfer from condensing vapors, heat transfer to boiling liquids

Learning Outcomes:
At the end of this unit, student will be able to

- Calculate heat transfer by forced convection in laminar flow and turbulent flow
- Calculate heat transfer by natural convection
- Classify types of condensation process of heat transfer

UNIT III **9L + 3T**

Radiation:

Fundamental facts concerning radiation, emission of radiation, absorption of radiation by opaque solids, radiation between surfaces, radiation to semitransparent materials, combined heat transfer by conduction-convection-radiation

Learning Outcomes:
At the end of this unit, student will be able to

- Categorize the laws of radiation
- Calculate radiation between the surfacess
- Compute combined heat transfer by conduction-convection and radiation

UNIT IV **9L + 3T**

Heat-exchange equipment:

General design of heat exchange equipment, shell and tube heat exchangers, plate-type exchangers, extended surface equipment, scraped-surface exchangers, condensers and vaporizers.

Learning Outcomes:

At the end of this unit, student will be able to

- Understands the design of heat exchanger
- Estimates heat transfer coefficients in shell and tube heat exchanger
- Categorize types of heat exchangers

UNIT V **9L + 3T**

Evaporation:

Evaporation, types of evaporators, capacity and economy of evaporators, boiling point elevation and Duhring's rule, material and energy balances in single effect evaporator, multiple effect evaporators, methods of feeding and economy of multiple effect evaporators.

Learning Outcomes:

At the end of this unit, student will be able to

- Compute capacity and economy of evaporators
- Classify the methods of feeding multiple effect evaporators

Text Book:

1. W. L. McCabe, J. C. Smith and P. Harriot, *Unit Operations of Chemical Engineering*, 7th Edition McGraw Hill International Edition, Singapore (2005).

Reference book:

1. D. Q. Kern, *Process Heat Transfer*, Tata McGraw Hill, New Delhi.
2. Holman. J.P., *Heat Transfer*, 9th Edition Tata McGraw Hill Book Co., New Delhi, 2008.
3. ssNecatiOzisik, *Heat Transfer: A Basic Approach*, Vol. 1, McGraw Hill, 1985.
4. Robert W. Serth, *Process Heat Transfer: Principles and Applications*, Academic Press, 2007.
5. J.P. Holman, *Heat Transfer*, 8th Edition, McGraw Hill, NewYork, 1997.

SEPARATION TECHNOLOGY

Course Code – Category: CHE 515 M - Minor

L	T	P	E	O	Credits: 4
3	1	0	1	5	Sessional Marks: 40
End Exam: 3 Hours					End Exam Marks: 60

Prerequisites: Chemical Process Calculations.

Course Objectives:

1. To understand the concepts of diffusion , stages, through mathematical equations
2. To understand the concepts of absorption and distillation
3. To expose the student to different types of equipment for Gas-Liquid Operations

Course Outcomes:

By the end of the course, student will be able to

1. Estimate the flux of molecules and diffusivity of gases, liquids and solids
2. Predict the mass transfer coefficients and know its importance
3. Identify the equipment for different gas-liquid operations
4. Design absorption column and distillation column
5. Plot Ternary liquid equilibrium and Estimate total time for drying operation

CO – PO – PSO Matrix:

		PO												PSO	
		1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO	1														
	2														
	3														
	4														
	5														

UNIT I **9L + 3T**

Introduction:

Classification of the mass transfer operations, molecular diffusion in fluids, binary solutions, Fick's law, equation of continuity, steady state molecular diffusion in fluids at rest and in laminar flow, Stefan's diffusion, estimation of diffusivity of gases and liquids,

diffusion in solids.

Learning Outcomes:

At the end of this unit, student will be able to

- Describe the importance of various mass transfer operations and their classification
- Derive diffusion equation in steady state
- Compute the diffusivity of gases, liquids and solids.

UNIT II **9L + 3T**

Mass Transfer Coefficients and Inter Phase Mass Transfer:

Concept of equilibrium, diffusion between phases, Theories of mass transfer, Mass, heat-, and momentum transfer analogies, Mass transfer coefficients in laminar flow, Mass transfer coefficients in turbulent flow, Material balances in steady state co-current and counter current stage processes

Learning Outcomes:

At the end of this unit, student will be able to

- Describe diffusion between phases
- Estimate the mass transfer coefficients in laminar and turbulent flows
- Explain material balances in steady state co-current and counter current stage processes

UNIT III **9L + 3T**

Equipment for Gas - Liquid Operations:

Sparged vessels (Bubble columns), mechanically agitated vessels for single phase liquids and gas-liquid mixtures, Tray towers for absorption (Qualitative treatment), venturi scrubbers, wetted wall towers, packed towers, Comparison between Tray towers and packed towers and cooling towers, spray chambers.

Learning Outcomes:

At the end of this unit, student will be able to

- Classify various equipments for gas liquid operations.
- Differentiate tray tower and packed tower.

UNIT IV **9L + 3T**

Separation techniques for Gas Liquid

Absorption and Stripping:
Solubility of gases in liquids, two component systems, ideal and non-ideal solutions, choice of solvent for absorption, single component absorption material balances.

Distillation:

Principles of VLE for binary systems, phase diagrams, relative volatility, ideal solutions, flash vaporization, partial condensation, differential distillation, steam distillation, continuous distillation, McCabe-Thiele method (theory)

Learning Outcomes:

At the end of this unit, student will be able to

- Apply the concept of absorption over single component material balances on various stages.
- Make material balances for a binary multistage distillation column

UNIT V **9L + 3T**

Separation techniques for Liquid-Liquid and Solid-fluid

Extraction:

Fields of applications of ternary liquid systems, triangular and solvent free coordinate systems, choice of solvent selectivity, single stage and multistage cross current and counter current extraction without reflux (theory), equipment for liquid-liquid extraction operation.

Drying:

Moisture contents of solids, equilibrium moisture content, bound and unbound moisture, drying conditions –rate of batch drying under constant drying conditions, mechanism of batch drying, drying time, batch and continuous drying equipment.

Learning Outcomes:

At the end of this unit, student will be able to

- Plot ternary equilibrium diagram.
- Calculate batch drying time.

Text Books:

1. Treybal R.E., *Mass transfer operations*, 3rd Edition, McGraw Hill, 1980.

Reference Books:

1. Cussler E. L., *Diffusion: Mass Transfer in fluid system*, Cambridge University Press, 2009.
2. Binay.K. Dutta, *Principles of Mass Transfer and Seperation Processes*, PHI LearningPvt. Ltd, 2007.

Chemical Reaction Engineering

Course Code – Category: CHE 516 M - Minor

L	T	P	E	O	Credits: 4
3	1	0	1	4	Sessional Marks: 40
End Exam: 3 Hours					End Exam Marks: 60

Prerequisites: Engineering Mathematics, Chemical Process Calculations.

Course Objectives:

- To learn principles of reaction engineering
- To understand various mechanisms of chemical reactions
- To gain knowledge on different reactors and their design

Course Outcomes:

By the end of the course, student will be able to

1. Predict various mechanisms for various reactions.
2. Analyze batch reactor data by various methods
3. Design various ideal reactors
4. Design various combinations of reactor systems.
5. Quantify product distribution for multiple reactions

CO – PO – PSO Matrix:

		PO												PSO	
		1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO	1														
	2														
	3														
	4														
	5														

UNIT I **9L + 3T**

Introduction: Introduction and overview of chemical reaction engineering –Variables affecting a chemical reaction –Kinetics of homogeneous reactions –Concentration dependent term of rate

equation –Elementary and non-elementary reactions –Temperature dependent term –Arrhenius law, activation energy, collision theory, transition state theory Searching for a mechanism

Learning Outcomes:

At the end of this unit, student will be able to

- Estimate the rate constant for a reaction
- Estimate the mechanism for a reaction

UNIT II **9L + 3T**

Interpretation of Batch Reactor Data: Methods of analysis, integral, differential and half life methods –Analysis of different types of reactions, irreversible and reversible –Variable volume reactor.

Learning Outcomes:

At the end of this unit, student will be able to

- Analyze the batch reactor data by integral and differential methods.
- Analyze the batch reactor data by half life methods.

UNIT III **9L + 3T**

Ideal Reactors: Ideal reactors for a single reaction –Performance equations for batch, mixed flow and plug flow reactors–Space time, space velocity and mean residence time.

Learning Outcomes:

At the end of this unit, student will be able to

- Derive the performance equations for various reactors
- Calculate the exit concentrations for various reactors

UNIT IV **9L + 3T**

Design of Multiple Reactors: Design for single reactions –Size comparison of reactors – Multiple reactor systems –Recycle reactor.

Learning Outcomes:

At the end of this unit, student will be able to

- Compare the reactors in terms of volume
- Design a multiple reactors

UNIT V **9L + 3T**

Design of Reactors with Multiple Reactions: Design for parallel and series reactions – Qualitative and quantitative discussion about product distribution.

Learning Outcomes:

At the end of this unit, student will be able to

- Estimate the product composition for parallel reactions
- Estimate the product composition for series reactions

Text books:

1. Levenspiel, O., Chemical Reaction Engineering, 3rd Edition, John Wiley and Sons.

Reference Books:

1. J. M. Smith., Chemical Engineering Kinetics, 3rdedition.,Mc-Graw Hill, Inc
2. H. Scott Fogler., Elements of Chemical Reaction Engineering, 5thedition., PHI Learning Private Ltd.