Bharati Vidyapeeth

(Deemed to be University)

Pune, India

College of Engineering, Pune

B. Tech. Chemical Curriculum

(2023 Course)

VISION OF UNIVERSITY

Social transformation through dynamic education

MISSION OF UNIVERSITY

(i) To make available quality education in different areas of knowledge to the students as per their choice and inclination

(ii) To offer education to the students in a conducive ambience created by enriched infrastructure and academic facilities in its campuses.

(iii) To bring education within the reach of rural, tribal and girl students by providing them substantive fee concessions and subsidized hostel and mess facilities

(iv) To make available quality education to the students of rural, tribal and other deprived sections of the population

VISION OF THE INSTITUTE

To be world class institute for social transformation through dynamic education.

MISSION OF THE INSTITUTE

(i) To provide quality technical education with advanced equipment, qualified faculty members, infrastructure to meet needs of profession and society.

(ii) To provide an environment conducive to innovation, creativity, research and entrepreneurial leadership.

(iii) To practice and promote professional ethics, transparency and accountability for social community, economic and environmental conditions.

VISION OF THE DEPARTMENT

To be globally recognized Chemical Engineering department for academic excellence and research.

MISSION OF THE DEPARTMENT

(i) To impart quality Chemical Engineering education to provide professionally competent engineers.

(ii) To develop conducive research environment to meet ever-changing aspirations of chemical and allied fields.

(iii) To promote entrepreneurship and leadership qualities with a strong foundation of social and professional ethics.

PROGRAM EDUCATIONAL OBJECTIVES

(i) Practice Chemical Engineering in conventional, multidisciplinary and emerging fields

(ii) Pursue advanced studies or other forms of continuing education

(iii) Demonstrate professionalism, ethical and social responsibility and desire for lifelong learning

PROGRAM OUTCOMES

(i) Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

(ii) Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

(iii) Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

(iv) Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

(v) Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

(vi) The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

(vii) Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

(viii) Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

(ix) Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

(x) Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

(xi) Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

(xii) Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES

(i) Utilize the fundamentals of unit operations and unit processes for the design and development of chemical products

(ii) Implement the pollution abatement methodologies in chemical and allied industries

(iii) Adopt sustainable energy strategies in professional practice

Bharati Vidyapeeth (Deemed to be University)

College of Engineering, Pune

Faculty of Engineering and Technology

Department of Chemical Engineering

B. Tech. (Chemical) Curriculum Structure (2023 Course): Semester III and IV

BHARATI VIDYAPEETH (DEEMED TO BE UNIVERSITY)

COLLEGE OF ENGINEERING, PUNE

B. Tech. (Chemical): Semester –III (2023 COURSE)

Sr. No	Category	Course Code	Course	Teaching Scheme			Examination Scheme (Marks)						Credits			
				L	P	T	ESE	IA	TW	PR	OR	Total	L	P	T	Total
1	MJ	MJ1101301	Chemical Engineering Thermodynamics- I	3	-	1	60	40	-	-	-	100	3	-	1	4
2	MJ	MJ1101302	Fluid Mechanics	3	2	-	60	40	25	25	-	150	3	1	-	4
3	MJ	MJ1101303	Material Science and Engineering	3	-	-	60	40	-	-	-	100	3	-	-	3
4	MJ	MJ1101304	Chemical Technology	3	2	-	60	40	25	-	25	150	3	1	-	4
5	MJ	MJ1101305	Process Heat Transfer	3	2	-	60	40	25	25	-	150	3	1	-	4
6	MJ	MJ1101306	Skill Based Course –III- Fluid Moving Machineries	-	2	-	-	-	25	-	25	50	-	1	-	1
Total				**15**	**8**	**1**	**300**	**200**	**100**	**50**	**50**	**700**	**15**	**4**	**1**	**20**
7	AE	AE1101307	MOOC-I	-	-	-	-	-	-	-	-	-	-	-	-	2
8	VA	VA1101308	VAC-I	2		-	-	100	-	-	-	100	2	-	-	2

BHARATI VIDYAPEETH (DEEMED TO BE UNIVERSITY)

COLLEGE OF ENGINEERING, PUNE

B. Tech. (Chemical): Semester –IV (2023 COURSE)

Sr. No	**Category**	**Course Code**	**Course**	**Teaching Scheme**			**Examination Scheme (Marks)**						**Credits**			
				L	P	T	ESE	IA	TW	PR	OR	Total	L	P	T	Total
1	MJ	MJ1101401	Chemical Engineering Thermodynamics- II	3	-	1	60	40	-	-	-	100	3	-	1	4
2	MJ	MJ1101402	Design of Heat Transfer Equipment	3	2	-	60	40	25	25	-	150	3	1	-	4
3	MJ	MJ1101403	Mass Transfer	3	2	-	60	40	25	25	-	150	3	1	-	4
4	MJ	MJ1101404	Chemical Reaction Engineering	3	2	-	60	40	25	25	-	150	3	1	-	4
5	MJ	MJ1101405	Chemical Process Instrumentation	3	-	-	60	40	-	-	-	100	3	-	-	3
6	MJ	MJ1101406	Skill Based Course – IV: Industrial Heating Systems	-	2	-	-	-	25	-	25	50	-	1	-	1
Total				**15**	**8**	**1**	**300**	**200**	**100**	**75**	**25**	**700**	**15**	**4**	**1**	**20**
7	AC	AC1113407	Indian Knowledge System	2	-	-	-	100	-	-	-	100	-	-	-	2
8	EC	EC1101408	Social Activity	-	-	-	-	-	-	-	-	-	-	-	-	2

B. TECH. (CHEMICAL): SEMESTER –III (2023 COURSE)

CHEMICAL ENGINEERING THERMODYNAMICS I

Designation: Professional Core

Pre-requisite Courses: Chemistry, Physics, Mathematics, Material and energy balance calculations.

Teaching Scheme		Examination Scheme		Credits Allotted	
Lectures	: 03 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 03
Tutorial	: 01 Hours/Week	Continuous Assessment	: 40 Marks	Tutorial	: 01
Total	: 04 Hours/Week	Total	: 100 Marks	Total Credits	: 04

Course Outcomes

1	Differentiate between energy, work, and heat
2	Estimate energy requirement for a system using first law of thermodynamics
3	Estimate efficiency of heat engines and entropy of system using second law of thermodynamics
4	Estimate pressure, volume and temperature of fluid.
5	Estimate thermodynamic properties of pure fluids using pressure, volume and temperature conditions.
6	Apply laws of thermodynamics to refrigeration and steam power plants

Topics Covered

UNIT-I	**Basic concepts of Thermodynamics** Scope of Thermodynamics; Macroscopic and microscopic Thermodynamics; Dimensions and units; Thermodynamic properties: pressure, temperature, volume; Work, energy and heat; Thermodynamic systems: Closed, open, and isolated systems; Concept of continuum; Intensive and extensive properties; State function and path function; Thermodynamic equilibrium: Mechanical, thermal and chemical; Phase rule; Reversible and irreversible processes.	**(06 Hours)**
UNIT-II	**First Law of Thermodynamics and its applications**	**(06 Hours)**

	Joule's experiment and internal energy; First law of Thermodynamics and its generalized mathematical form;Enthalpy; Heat Capacity; Constant volume and constant pressure processes; Applications of first law of Thermodynamics: Mass and energy balance equations for flow process; Limitations of first law of Thermodynamics.	
UNIT-III	**Second Law of Thermodynamics** Necessity of second law of Thermodynamics; Kelvin-Plank and Clausius statements of second law of thermodynamics; Heat engine: Carnot cycle and efficiency; Entropy; Clausius entropy inequality; Entropy change of ideal gas; Mathematical statement of second law of thermodynamics; Third law of thermodynamics and its mathematical statement.	**(06 Hours)**
UNIT-IV	**Volumetric Properties of Pure Fluids** PVT behaviour of pure substance: PT and PV diagrams; Basic equation of state; Ideal gas and real gas; PVT behaviour of ideal gas; Thermodynamic relations for ideal gas for isochoric, isobaric, isothermal, adiabatic, and polytropic processes; PVT behaviour of real gas: (i) the Viral equations, (ii) two parameter equations such as van der Waal equation, Redlich-Kwong equation, etc. (iii) compressibility factor: two and three parameter theorems of corresponding state.	**(06 Hours)**
UNIT-V	**Thermodynamic Properties of Fluids** Fundamental property relations for homogeneous phases: (i) Internal energy, Enthalpy, Helmholtz energy, and Gibbs energy, (ii) Maxwell relationships; Two-phase systems: Clausius - Clapeyron equation and Antoine equation; Thermodynamic diagrams: (i) temperature-entropy, (ii) pressure-enthalpy, and (iii) enthalpy-entropy (Mollier diagram).	**(06 Hours)**
UNIT-VI	**Major Applications of Laws of Thermodynamics** **(i) Refrigeration** Carnot theory and ideal efficiency for refrigeration; Industrial refrigeration cycles and efficiency calculations: Vapor compression cycle and gas absorption cycle.	**(06 Hours)**

	(ii) Steam power plant Carnot theory and ideal efficiency for steam power plant; Industrial steam power plants and efficiency calculations: Rankine cycle, reheat cycle, and regenerative cycle.	

Text Books/References

1	J. M. Smith and H. C. Van Ness, "Introduction to Chemical Engineering Thermodynamics", McGraw- Hill Publication
2	T. E. Daubert, " Chemical Engineering Thermodynamics", McGraw- Hill Publication
3	K.V. Narayanan," Chemical Engineering Thermodynamics", PHI Learning Pvt. Ltd.
4	B. F. Dodge, "Chemical Engineering Thermodynamics", McGraw- Hill Publication
5	M. D. Koretsky, "Engineering and Chemical Thermodynamics", 2nd Edition, John Wiley & Sons
6	S. I. Sandler, "Chemical Engineering Thermodynamics", McGraw- Hill Publication
7	S. Glasstone, "Thermodynamics for Chemists", Affileated East West Press Pvt.Ltd.

Project Based Learning

1.	Draw P-T and P-V diagrams for pure substances.
2.	Numerical involving Pure Fluid Properties Coupled to 1st and 2nd Laws.
3.	Solving numerical based on application of thermodynamics to transient open and closed systems
4.	Students have to study any five NPTEL videos related to Chemical Engineering Thermodynamics I and prepare/present power point presentation.
5.	Group discussions on any of the following topics: a) Importance of Chemical Engineering Thermodynamics in chemical industries. b) Practical applications involving various thermodynamic processes. c) Ideal Gas, Real Gas, Ideal gas mixture, Ideal solution.
6.	Questions involving first law applied to pure component systems.
7.	Solving numerical in connection with entropy changes of ideal gas for various thermodynamic processes.
8.	Solving numerical based on Refrigeration and Liquefaction.

9.	Enhancement in collaborative learning is done through, group assignments that will be given to encourage students to work with classmates to discuss and complete homework assignments.
10.	Preparation of a brief report on applicability of equations of states (EOS) in chemical engineering systems.

Syllabus for Unit Tests	
Unit Test I	Units I, II, and III
Unit Test II	Units IV, V, and VI

FLUID MECHANICS					
Designation: Professional Core					
Course Pre-requisite: Physics, Mathematics, Mechanical Operation.					
Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 03 Hours/Week	End Semester Examination	: 60 Marks	Lecture	: 03
Practical	: 02 Hours/Week	Internal Assessment	: 40 Marks	Practical	: 01
Total	: 05 Hours/Week	Term Work	: 25 Marks	Total	: 04
		Practical/Oral	: 25 Marks		
		Total	: 150 Marks		

Course Outcomes	
1	Evaluate properties of fluids using basic concept of fluid flow.
2	Apply the basic equations of fluid flow to study various flow systems
3	Select an appropriate type of flow measuring device.
4	Determine the major and minor energy losses for fluid flowing through a pipe.
5	Identify and select various types of fluid moving equipment for fluid flow.
6	Determine the friction factors and pressure drop for flow through packed and fluidized bed.

Topics Covered		
UNIT-I	**Basic Concepts of Fluid Flow** Fluid statics and dynamics: Scope and applications; Rheological classification of fluids; Incompressible and compressible fluids; Types of flow: laminar, transition and turbulent flow and their characteristics, Reynold's experiment; Properties of fluids: concept of viscosity, Newton's law of viscosity, viscosity of gases and liquids, eddy viscosity; Concept of fluid pressure and hydrostatic equilibrium.	**(06 Hours)**
UNIT-II	**A. Equations of Fluid Flow**	**(06 Hours)**

	Equation of continuity and motion: Cartesian coordinates, Navier Stokes equation; Bernoulli's equation: assumptions, equation with and without friction, limitations of Bernoulli's equation, correction factors; Applications of equations of fluid flow. **B. Flow of Incompressible Fluids** Characteristics of pipe flow: laminar flow in pipes, shear stress distribution and velocity profiles, relationship between skin friction and wall shear, Hagen Poiseuille equation, relation between average and maximum velocity.	
UNIT-III	**A. Turbulent flow** Basics of turbulent flow, equations of continuity and motion for turbulent flow, Boussinesq hypothesis, Prandtl mixing length theory, turbulent pipe flow, basis of Universal velocity profile and its use. **B. Flow metering devices** Pitot tube, orifice meter, venturi meter, rotameter, notches and weirs.	**(06 Hours)**
UNIT-IV	**Major and Minor Losses in Pipe Flow** Major losses: Head loss due to friction, Darcy–Weisbach equation; Friction factor: concept, correlations of friction factor for laminar, transition and turbulent flow, friction factor chart (Moody's diagram), frictional loss in highly turbulent flow, effect of wall roughness; Minor losses: pipe entrance and exit, sudden expansion and contraction, fittings, valves, bends etc.	**(06 Hours)**
UNIT-V	**Flow Moving Machinery** Pumps: types, selection and specifications, characteristic curves, cavitation phenomena, net positive suction head (NPSH) calculations, operating parameters affecting the performance of a pump, calculation of power requirement; Blowers and compressors: selection and specifications, factors affecting performance, power calculations for given duty.	**(06 Hours)**
UNIT-VI	**Flow Past Immersed Bodies** Hydrodynamic boundary layer: concept, boundary layer thickness, growth over a flat plate, boundary layer separation, drag on a flat plate for laminar and turbulent flow, drag on immersed bodies; Flow through packed and fluidized	**(06 Hours)**

	beds: flow through beds of solids, motion of particles through the fluid, particle settling, mechanism of fluidization, minimum fluidization velocity, friction factors for flow through beds of solids, pressure drop calculations, particulate and aggregative fluidization, applications of fluidization.	

Text Books/References	
1	McCabe W.L, Smith J.C, and Harriott P.: "Unit Operations of Chemical Engineering", 5th edition, McGraw Hill Publications.
2	Coulson J.M., Richardson J.F., Backhurst J.R., J.H. Harker J.H.: "Chemical Engineering Volume 1", 6th edition, Pergamon Press.
3	Gupta S.K.:"Momentum transfer operations", Tata McGraw Hill Publishers.
4	Bansal R.K.:"A text book of fluid mechanics and hydraulic machines", Laxmi Publications (P) Ltd, NewDelhi.
5	Bird R.B., Stewart W.E., Lightfoot E.N.:"Transport Phenomena", John Wiley & Sons, New York.
6	Denn M.M.: "Process fluid mechanics", Prentice Hall Publications.

Project Based Learning:	
1	Investigate and prepare a report on any one of the following topics.
	a) Importance of fluid flow operations in chemical industries.
	b) Pumps, blowers and compressors.
	c) Flow measuring devices.
2	Students have to study any five NPTEL videos related to fluid flow operations and prepare/present power point presentation.
3	Visit to suppliers and prepare a report on detailed specifications of following fluid moving equipments.
	a) Pumps.
	b) Blowers.
	c) Compressors.
4.	Visit to suppliers and prepare a report on detailed specifications of following flow measuring devices.
	a) Venturimeter.
	b) Orificemeter.

	c) Pitot tube.
	d) Roatameters.
5.	Students have to visit chemical industry and make a detailed report on overall fluid flow operations.
6.	Prepare models for various types of valves and write industrial applications.
7.	Prepare models for various types of bends and write industrial applications.
8.	Prepare models for various types of fittings and write industrial applications.
9.	Prepare a report on fluid flow operations which are newly introduced in the current year.
10	Write a report on your visit to research and development laboratory of national/international repute.
11	Technical interview based on knowledge of fluid flow operations.
12	With the help of this subject knowledge, write a report on how you would apply your concepts in industry.

Students in a group of 3 to 4 shall complete any one project from the above list. In addition to these above stated topics concern faculty member may design his/her won topics.

Term Work

Term work will consist of the experiments listed below, out of which at least eight experiments should be performed in laboratory by the students.

1	To determine kinematic viscosity and to study the effect of temperature on kinematic viscosity of given oil.
2	To study flow characteristics using Reynolds apparatus and determine Reynolds number.
3	To determine the coefficient of discharge for venturimeter.
4	To determine the coefficient of discharge for orificemeter.
5	To determine Darcy Weisbach coefficient of friction for laminar and turbulent flow.
6	To determine friction and pressure drop for flow through helical/spiral coils.
7	To find losses due to sudden expansion and contraction in pipe.
8	To calculate minimum fluidization velocity using fluidized bed reactor.
9	To verify Bernoulli’s theorem.
10	To study characteristics of centrifugal pump.
11	To Study Darcy’s law.
12	To study pressure drop in packed bed for different fluid velocities.

13	To determine the coefficient of discharge for different notches like rectangular notch, V notch, and trapezoidal notch.
14	To determine terminal velocity of particles in fluids of different viscosity and plot a graph of drag coefficient (C_D) as a function of NRe.

Syllabus for Unit Test	
Unit Test : I	Units : I, II, and III
Unit Test : II	UNIT : IV, V, and VI

MATERIAL SCIENCE AND ENGINEERING					
Designation: Professional Core					
Pre-requisite Courses: Chemistry, Physics and Biology					
Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 3 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 03
Total	: 3 Hours/Week	Internal Assessment	: 40 Marks	Total credits	: 03
		Total	: 100Marks		

Course Outcomes:

After completion of the course students would be able to:

1	Appraise material properties to choose appropriate material for desired application
2	Compare properties of metals and alloys to select appropriate metal for desired application
3	Analyze properties of hydrocarbon materials and recommend proper material for desired application
4	Define appropriate ceramic material for required applications
5	Assess possibility of material failure by mechanical and chemical failure based upon application and environmental conditions
6	Design appropriate preventive measure to avoid material failure

Topics covered

UNIT-I	**Introduction** Introduction to materials; Bonding between atoms: metallic, ionic, covalent; Van der Waals forces; Role of materials selection in design; Structure-property-processing-performance relationships; Materials and criteria for selection of material in process industries; Material properties: Mechanical, thermal, chemical, electrical, magnetic and technological properties; Modification and control of material properties.	**(06 Hours)**
UNIT-II	**Metal and Their Alloys**	**(06 Hours)**

	Ferrous materials: Pure iron, cast iron, mild steel, stainless steels, special alloy steels, iron and iron carbide; Phase diagram: Heat treatment of carbon steels. ***Nonferrous materials:*** Lead, tin, aluminium, zinc, nickel, copper, magnesium and their alloys; Properties and applications in process industries**.**	
UNIT-III	**Hydrocarbon Materials** ***Polymers:*** Natural and synthetic polymeric materials; Polymer material structure and properties: Deformation, flow and melt characteristics, morphology and order in crystalline polymers, mechanical properties of polymers; Polymer structure and physical properties correlation; Selection of polymeric materials for equipment linings; Fibre reinforced plastic; Application of special polymers like Polyester, Teflon in engineering; Sustainable and biodegradable polymers; Depolymerization; Polymer composites and blends ***Paints, Coatings and Adhesives:*** Compositions, properties and applications	**(06 Hours)**
UNIT-IV	**Ceramic, Glasses and Cement** Definition of ceramics and glasses; Interaction between structure, processing, and properties; Applications of ceramic and glass materials; Crystalline and non-crystalline ceramics: Silicates, refractory, clays, glass, vitreous silica and borosilicate. Cement and its properties: Special cements, cement concrete, RCC- Pre stressed concrete.	**(06 Hours)**
UNIT-V	**Material Failure Analysis** ***Thermal and mechanical failures:*** Creep; Stress; Crystal structure and defects: Vacancies, equilibrium concentration of vacancies, interstitial and substitution impurities in solids, dislocations, types and characteristics of dislocations, interfacial defects, stacking faults ***Chemical failure:*** Acid base environment, water; Corrosion: Theories of corrosion, corrosion attack methods; Types of corrosion: Chemical, biochemical, and electrochemical; Internal and external factors affecting corrosion of chemical equipments; Corrosion charts for process equipment.	**(06 Hours)**

UNIT-VI	**Material failure prevention** Property enhancement by electroplating; Glass and ceramic linings; Polymer lining; Paints; Coatings; Heat treatment techniques; Alloy preparation; Composite and blend formation; Control and prevention of corrosion.	**(06 Hours)**

Text Books/References:

1	Kodgire V. D.: Material Science and Metallurgy for Engineers, 44th Ed. Everest publication India, 2018
2	Gowarikar V. R., Vishwanath N. V., Shreedhar J.: Polymer science, New age International publication, India, 1986
3	Budinsky K. G., Budinsky K. M.: Engineering materials- Properties and Selection, 9th Ed. Prentice Hall of India, 2009.
4	Clauster H. R.: Industrial and Engineering materials, McGraw Hill Book Co. India, 1995
5	Lee J. L. and Evans: Selecting Engineering Materials for Chemical and Process Plants, Business Works, New York, 1974
6	Raghavan V.: Material Science and Engineering, 4th Ed. PHI Learning Private Limited, India, 2015

Project based learning: Below is the list of possible topics, which is for guidance faculty can design and provide relevant topics in addition to these

1	Study and prepare a presentation of different materials, their bonds, bond energy and their effect on material properties
2	Study and prepare a presentation on factors affecting selection of material for any particular engineering application
3	Investigate and prepare the report on cast iron, composition of cast iron and variation in property and application of cast iron based on its composition
4	Investigate and prepare the report on stainless steel and its types, composition of stainless steel based upon its types and variation in property and application of stainless steel based on its composition
5	Investigate and prepare the report on lead and its alloys, composition of alloys and variation in property and application of alloys based on its composition

6	Investigate and prepare the report on Tin and its alloys, composition of alloys and variation in property and application of alloys based on its composition
7	Investigate and prepare the report on Aluminium and its alloys, composition of alloys and variation in property and application of alloys based on its composition
8	Investigate and prepare the report on Nickel and its alloys, composition of alloys and variation in property and application of alloys based on its composition
9	Investigate and prepare the report on Copper and its alloys, composition of alloys and variation in property and application of alloys based on its composition
10	Investigate and prepare the report on Magnesium and its alloys, composition of alloys and variation in property and application of alloys based on its composition
11	Investigate and prepare the report on properties and benefits of polymer, property tuning based upon monomer and composition variation
12	Investigate and prepare the report on properties and benefits of polymer, property tuning based upon monomer and composition variation
13	Investigate and prepare the report on biodegradable polymers and depolymerization, its importance and environmental impact
14	Investigate and prepare the report on surface coating, its importance, and preparation of surface for the same
15	Investigate and prepare the report on effect of composition variation and processing on the properties and applicability of ceramics
16	Investigate and prepare a report on the causes of material failure (chemical or mechanical) bay taking a suitable industrial or real life example

Syllabus for Unit Test:

Unit Test : I	UNIT: I, II, and III
Unit Test : II	UNIT : IV, V, and VI

CHEMICAL TECHNOLOGY					
Designation: Professional Core					
Pre-requisite Courses: Chemistry, Material and energy balance calculations					
Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 03 Hours/Week	End Semester Examination	: 60 Marks	Lecture	: 03
Practical	: 02 Hours/ Week	Internal Assessment	: 40 Marks	Practical	: 01
Total	: 05 Hours / Week	Term Work	: 25 Marks	Total	: 04
		Practical/Oral	: 25 Marks		
		Total	: 150 Marks		

Course Outcomes	
1	Learn the concept of unit operations and unit processes.
2	Analyze recent methods used in chloro alkali and electrolytic industries.
3	Learn the manufacturing processes used in sulfur and nitrogen industry
4	Learn the recent techniques used in oil industry.
5	Analyze the various processes used in Sugar-Starch industry and fermentation industry.
6	Learn the production methods used in petrochemical industry .

Topics covered		
UNIT-I	**Unit operations and unit processes** Unit operations and unit processes; Concept of block diagram; Process flow diagram (ASME guidelines);Major engineering problems; Advantages and disadvantages of the process and product applications; Schematic representation and applications for unit operations and unit processes.	**(06 Hours)**
UNIT-II	**Chlor-alkali and electrolytic industry, sea chemicals** i) Chlor-alkali industry: Recent processes for the production of soda ash, NaOH and Chlorine	**(06 Hours)**

	ii) Sea chemicals: Sodium-Magnesium compounds, different methods for different salt recovery iii) Electrolytic industry: Production of Aluminium, Magnesium	
UNIT-III	**Nitro- Phosphorous Industry and Sulphur Industry** i) Nitrogen Industry: Recent processes for the production of Ammonia, Nitric acid, Urea, Ammonium Nitrate ii) Phosphorous Industry: Production of Phosphoric acid, single and triple Super Phosphate, Ammonium Phosphate iii) Sulphur Industry: Production of Sulphur, Sulphuric acid, Ammonium sulphate.	**(06 Hours)**
UNIT-IV	**Oils, Fats, Soaps and Detergents** Different fatty acids, Extraction of oil from seeds, Oil purification, Hydrogenation of oil. Solvent extraction process, hydrogenation of oil, production of soap, natural glycerine, production of detergents.	**(06 Hours)**
UNIT-V	**Sugar-Starch Industry and Fermentation industry** **Sugar-Starch Industry**: Production of Sugar, Starch Derivatives Raw and refined sugar, By-products of sugar industries, Starch and starch derivatives. **Fermentation Industry**: Production of ethyl alcohol, absolute alcohol. Bio Pharmaceutical Industry: Production of penicillin, antibiotics	**(06 Hours)**
UNIT-VI	**Petrochemical Industry** i) C1 Compounds: Production of methanol, formaldehyde, and halogenated hydrocarbons. ii) C2 Compounds: Production of ethylene and acetylene- steam cracking of hydrocarbons, ethylene dichloride, vinyl chloride. iii) C3 Compounds: Production of propylene by indirect hydration, acetone, cumene. iv) Aromatic Compounds: Production of phenol, phthalic anhydride, and styrene.	**(06 Hours)**
Text Books/References		

1	C.E.Dryden, Outlines of Chemical Technology" (Edited and Revised by M.Gopal Rao and Sittig .M) 3 rd Ed., East West Press. , New Delhi, 1997.
2	G.T.Austin, Shreve's Chemical Process Industries, 5th Ed., McGraw Hill Education publisher, 2017.
3	P.H.Groggins, Unit process in organic synthesis, 5th Ed.Tata McGraw-Hill Edition, 2004.
4	W.L.Faith, D.B. Keyes, R.L. Clark, Industrial Chemicals, John Wiley, 1975.
5	Kirk and Othmer, Encyclopedia of Chemical Technology, Wiley, 2005
6	G.N.Pandey and S.D.Shukla, Chemical Technology Vol – I,Vikas publication, 2004

Project Based Learning

1	Model making of any one Unit operation used in chemical process industry.
2	Students should compile the list of vendors (manufacturers of pumps, contact, and address) along with the details like type, specifications, and costs and should prepare the comparative for the same.
3	Based on one process industry (preferably visited during the term), students will prepare the report which includes the consumption pattern of the products produced, process flow diagram and process description, major engineering problems in the industry.
4	Students should compile the list of Boiler manufacturers, contacts, and address along with their product range specifications.
5	AutoCAD drawing of process flow diagram for any one process from the syllabus

Term Work

Term work will consist of the experiments listed below, which are to be performed in laboratory by the students.

1	Prepare a report on "Indian scenario of Chemical Process industries" which will include the name of industries (from different chemical zones), products manufactured, and production capacity.
2	Prepare a report on Importance of Chlor-alkali industries in India
3	Prepare a report on "Fertilizer industries in Maharashtra and Gujarat" which will include the name of industries (from different chemical zones), products manufactured, and production capacity.
4	Manufacture of liquid soap on Laboratory scale.
5	Study of fermentation process in wine manufacturing.

6	Give a presentation on “commercial aspects of petrochemical products”.
7	Students should compile the list of vendors providing “water treatment plants” in chemical process industries along with their product specifications.
8	Study of various valves used in Chemical process industries.
9	Study of Material Safety Data Sheet (MSDS) for the chemicals used in laboratory

Syllabus for Unit Test	
Unit Test : I	Units : I, II, and III
Unit Test : II	UNIT : IV, V, and VI

PROCESS HEAT TRANSFER

Designation: Professional Core

Pre-requisite Courses: Basic science courses, Thermodynamics, Fluid mechanics, Material and energy balance calculations.

Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 03 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 03
Practical	: 02 Hours/Week	Internal Assessment	: 40 Marks	Tutorial	: -
Total	: 05 Hours/Week	Term-work (TW)	: 25 Marks	Practical	: 01
		Practical/Oral	: 25 Marks	Total Credits	: 04
		Total	: 150Marks		

Course Outcomes

1	Estimate rate of heat transfer by conduction mode
2	Estimation of overall heat transfer coefficient.
3	Estimation of heat transfer coefficient for natural and forced convection using appropriate empirical correlation.
4	Estimate rate of heat transfer in boiling and condensation phenomena.
5	Estimation of radiative heat transfer rate.
6	Estimation of time required to raise/reduce the temperature of given process/operation by a desired degree.

Topics Covered

UNIT-I	**Conduction** Concept of heat conduction; Fourier's law of heat conduction; Thermal conductivity: solids, liquids and gases; Effect of temperature and pressure on thermal conductivity; Steady state heat conduction through composite wall;	**(06 Hours)**

	Steady state heat conduction through a variable area: Cylinder and sphere; Steady state heat conduction with heat sources: plane wall, cylinder and sphere; Average temperature calculations.	
UNIT-II	**Heat Transfer Coefficient** Concept of convective heat transfer and heat transfer coefficient; Newton's law of convective heat transfer; Overall heat transfer coefficient: Heat transfer between fluids separated by plane wall and cylindrical wall; Heat transfer from extended surfaces; Thermal contact resistance; Critical insulation thickness; Optimum insulation thickness.	**(06 Hours)**
UNIT-III	**Natural and Forced Convection** Concept of natural and forced convection; Estimation of heat transfer coefficients: Dimensional analysis and dimensionless groups; Factors affecting individual heat transfer coefficient; Empirical correlations for natural convection: flat plate, cylinder and sphere; Empirical correlations for forced convection: Internal flows (laminar and turbulent flow through circular and non-circular pipes) and external flow (flat plate, cylinder and sphere); Heat transfer with variable driving force: Counter current and co-current operations; Momentum and heat transfer analogies.	**(06 Hours)**
UNIT-IV	**Boiling and Condensation** Concept of boiling; Boiling regimes and heat transfer rate: Natural convection, nucleate boiling, transition boiling and film boiling; Concept of condensation; Film-wise and drop-wise condensation; Film condensation on vertical and horizontal surfaces; Estimation of condensation heat transfer coefficient: Nusselt's theory; Factors affecting the rate of condensation.	**(06 Hours)**
UNIT-V	**Radiation** Concept of radiation; Blackbody radiation; Radiative heat transfer laws: Planck's law, Wien's law, Stefan-Boltzmann law, Kirchhoff's law; Radiativeheat exchange between surfaces: View factor; Rate of radiation exchange between black and grey bodies; Radiation intercepted by shield; Radiation combined with conduction and convection.	**(06 Hours)**

UNIT-VI	**Unsteady State Heat Transfer** Unsteady state heat conduction; Concept of thermal diffusivity; Unsteady state heat transfer in mechanically agitated contactors (MAC): MAC configurations, Overall heat transfer calculations, Estimation of time needed to attain desired temperature for a given operation/process using isothermal and non-isothermal heating medium; Unsteady state heat transfer in multiphase reactors: Estimation of overall heat transfer coefficient and time needed to calculate process temperature attainment.	**(06 Hours)**

Text Books/References

1	Holman, J.P., "Heat Tansfer", 9th edn. The McGraw-Hill Companies, India, 2008
2	Dutta B. K., "Heat Transfer: Principles and Applications", Prantice Hill Inc. India, 2001
3	Kern D. Q., "Process Heat Transfer", Tata McGraw-Hill Edition, Singapore, 1997
4	McCabe, W. L., Smith, J. C., and Harriott, P., "Unit Operations of Chemical Engineering", 6th Ed., McGraw-Hill, Singapore, 2001
5	Chapman, A.J. "Heat Transfer", 4th Ed. Maxwell Macmillan International Edition, 1984.

Project Based Learning

1.	Suggest best suitable heat transfer mechanism for given heat load requirement.
2.	Derive the correlation for the heat transfer for given conditions of fluids and heat supply mechanisms and designs.
3.	Prepare a model for any of the heat exchanger.
4.	Elaborate in detail use of heat transfer systems for process requirements.
5.	With the help of this subject knowledge, write a guideline report on how you would apply your concepts in industry.
6.	Group discussion on the recent advances in heat transfer systems and heat economy.
7.	Write a report on your visit to research and development laboratory of national/international repute.
8.	Give fifteen minutes presentation (seminar) on particular topic and prepare a report.
9.	Visit chemical industry and prepare a detailed report on heat exchangers used in industry.
10.	Students have to study any five NPTEL videos related to heat transfer and prepare/present power point

	presentation.
11.	Explain in detail use of heat analysis and material conditions on heat transfer economy.
12.	Prepare a report on heat exchangers design updates which are newly introduced in the current year,
13	Design suitable heat exchange using HTRI or other software in heat exchanger design
*Students in a group of 3 to 4 shall complete any one project from the above list.	

Term Work

Term work will consist of the experiments listed below, which are to be performed in laboratory by the students. The list is not inclusive of all more experiments can be designed as per course curriculum and conducted

1	To determine rate of heat flow and thermal conductivity of an insulating material.
2	To determine thermal conductivity of a metal bar.
3	To study Newton's law of cooling to find rate of heat flow.
4	To determine the local heat transfer coefficients using the various correlations in natural convection.
5	To determine heat transfer coefficient in forced convection.
6	To study film wise condensation.
7	To study drop wise condensation.
8	To determine the critical heat flux
9	To study Stefan-Boltzman law and find the value of its constant.
10	To study heat transfer through a composite wall.
11	To determine emissivity of an aluminum plate.
12	To study unsteady state processes.

Syllabus for Unit Tests

Unit Test I	Units I, II, and III
Unit Test II	Units IV, V, and VI

SKILL BASED COURSE-III: FLUID MOVING MACHINERIES

Designation: Skill Development

Pre-requisite Courses: Fluid Mechanics

Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Practical	: 02 Hours/Week	Term Work	: 25 Marks	Practical	: 01
Total	: 02 Hours/Week	Practical/Oral	: 25 Marks	Total	: 01
		Total	: 50 Marks		

Course Outcomes

After completion of the course students will be able to

1	Select the type of pump according to the requirement and calculate net positive suction head.
2	Obtain the operating parameters affecting the performance of a pump and calculate power requirement.
3	Analyse various types of blowers and obtain the factors affecting the performance of blowers.
4	Calculate the power requirement of blowers.
5	Select the various types of compressors and obtain the factors affecting the performance of compressors
6	Calculate the power requirement of compressors.

Topics Covered

UNIT-I	**Pumps** Types, selection and specifications, characteristic curves, net positive suction head (NPSH) calculations.
UNIT-II	**Power requirement of pumps** Operating parameters affecting the performance of a pump, Calculation of power requirement of various types of pumps, Operation and maintenance of pumps.
UNIT-III	**Blowers** Selection and specifications, Factors affecting performance the performance of blowers

UNIT-IV	**Power requirement of Blowers** Operation and maintenance of blowers, Power calculations for given duty.
UNIT-V	**Compressors** Design principle, Classification and types of compressors, Selection and specifications, Factors affecting performance.
UNIT-VI	**Power requirement of Compressors** Operation and maintenance of compressors, Power calculations for given duty.
Text Books/References	
1	McCabe W.L, Smith J.C, and Harriott P.:"Unit Operations of Chemical Engineering", 5thedition, McGraw Hill Publications.
2	Coulson J.M., Richardson J.F., Backhurst J.R., J. H. Harker J.H.:"Chemical Engineering Volume 1", 6thedition, Pergamon Press.
3	Gupta S.K.:"Momentum transfer operations", Tata McGraw Hill Publishers.
4	Bansal R.K.:"A text book of fluid mechanics and hydraulic machines", Laxmi Publications (P) Ltd, NewDelhi.
5	Denn M.M.: "Process fluid mechanics", Prentice Hall Publications.
Term Work	
Term work will consist of the practical based on the above topics. Any eight practical are to be performed in laboratory/industry by the students.	

B. TECH. (CHEMICAL): SEMESTER –IV (2023 COURSE)

CHEMICAL ENGINEERING THERMODYNAMICS II

Designation: Professional Core

Pre-requisite Courses: Chemistry, physics and mathematics, Chemical engineering thermodynamics, Material and energy balance calculations

Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 03 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 03
Tutorial	: 01 Hours/Week	Continuous Assessment	: 40 Marks	Tutorial	: 01
Total	: 04 Hours/Week	Total	: 100 Marks	Total Credits	: 04

Course Outcomes

1	Characterize ideality of gaseous mixtures and liquid solutions.
2	Estimate fugacity coefficient to measure the deviation from ideality.
3	Estimate activity coefficient to measure the deviation from ideality.
4	Analyze vapor liquid equilibrium using thermodynamic stability and consistency tests.
5	Estimate partition coefficient for liquid liquid equilibrium and solid liquid equilibrium.
6	Estimate chemical reaction constant and composition of system at thermodynamic equilibrium.

Topics Covered

UNIT-I	**Thermodynamics of Ideal Solution** Fundamental property relationships for solutions; Concept of chemical potential and partial molar properties; Estimation of partial molar properties; Gibbs-Duhem equation; Ideal gas mixtures: Gibbs theorem; Ideal solution: Characteristics of ideal solution, Lewis Randall law.	**(06 Hours)**
UNIT-II	**Thermodynamics of Non-ideal Gas Mixtures**	**(06 Hours)**

	Concept of non ideality in gaseous mixtures; Fugacity and fugacity coefficient for non-ideal gas mixtures; Effect of temperature and pressure on fugacity coefficient; Estimation of fugacity coefficient; Concept of residual property; Relation between residual property and fugacity coefficient.	
UNIT-III	**Thermodynamics of Non-ideal Liquid Solution** Concept of non-ideality in liquid solution; Activity and activity coefficient for non-ideal solution; Effect of temperature and pressure on activity coefficient; Estimation of activity coefficient; Excess properties: Gibbs excess energy; Relation between excess property and activity coefficient; Excess properties of mixing and heat effects.	**(06 Hours)**
UNIT-IV	**Vapor-liquid equilibrium (VLE):** Criteria of vapour liquid equilibria and stability; Basic equation for vapor-liquid equilibrium (Raoult's law); Qualitative behavior of VLE; Non-ideality in vapour and liquid phases (Modified Raoult's law); Estimation of liquid phase properties from VLE data; Excess Gibbs free energy models; Azeotropic data; Multicomponent VLE; Bubble point and dew point calculations; Thermodynamic consistency test for VLE data.	**(06 Hours)**
UNIT-V	**Liquid-liquid Equilibria (LLE) and Siquid-liquid Equilibria (SLE):** Equilibrium and stability; LLE: Basic equation governing LLE, Distribution coefficient (Partition Coefficient), solubility diagram, Intermolecular interactions; SLE: Basic equation governing SLE.	**(06 Hours)**
UNIT-VI	**Chemical reaction equilibria** The reaction coordinate; Application of equilibrium criteria to chemical reactions; The standard Gibbs energy change and the equilibrium constant; Effect of temperature on the equilibrium constant; Evaluation of equilibrium constant; Relation of equilibrium constants to composition; Phase rule for reacting systems; Multi-reaction equilibria.	**(06 Hours)**
Text Books/References		

1	J. M. Smith and H. C. Van Ness, "Introduction to Chemical Engineering Thermodynamics", McGraw- Hill Publication
2	T. E. Daubert, " Chemical Engineering Thermodynamics", McGraw- Hill Publication
3	K.V. Narayanan," Chemical Engineering Thermodynamics", PHI Learning Pvt. Ltd.
4	B. F. Dodge, "Chemical Engineering Thermodynamics", McGraw- Hill Publication
5	M. D. Koretsky, "Engineering and Chemical Thermodynamics", 2nd Edition, John Wiley & Sons
6	S. I. Sandler, "Chemical Engineering Thermodynamics", McGraw- Hill Publication
7	S. Glasstone, "Thermodynamics for Chemists", Affileated East West Press Pvt.Ltd.

Project Based Learning	
1.	Solving numerical in connection with phase equilibria
2.	Solving numerical based on application of Roult's law for the calculation of dew point and bubble point
3.	Unsolved numerical from the reference books on various topics studied.
4.	Draw P-xy and T-xy diagrams.
5.	Solving numerical based on chemical reaction equilibrium.
6.	Enhancement in collaborative learning is done through, group assignments that will be given to encourage students to work with classmates to discuss and complete homework assignments.
7.	Students have to study any five NPTEL videos related to Chemical Engineering Thermodynamics I and prepare/present power point presentation.
8.	Solving numerical in connection with the solution thermodynamicswrt industrial case studies
9.	Evaluation of thermodynamic properties for pure species and species in solution
10.	Preparation of a brief report on applicability of liquid-liquid equilibrium (LLE) in chemical engineering systems.

Syllabus for Unit Tests	
Unit Test I	Units I, II, and III
Unit Test II	Units IV, V, and VI

DESIGN OF HEAT TRANSFER EQUIPMENT		
Designation: Professional Core		
Pre-requisite Courses: Process heat transfer, Particulate technology, Chemical engineering thermodynamics, Material and energy balance calculations		
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Lectures : 03 Hours/Week	End Semester Examination : 60 Marks	Theory : 03
Practical : 02 Hours/Week	Internal Assessment : 40 Marks	Practical : 01
Total : 05 Hours/Week	Term-work (TW) : 25 Marks	Total Credits : 04
	Practical/Oral : 25 Marks	
	Total : 150 Marks	

Course Outcomes	
1	Perform process design of double pipe heat exchanger
2	Perform process design of shell and tube heat
3	Perform the evaporation calculations and estimate heat transfer area of evaporator.
4	Analyse heat transfer characteristics of mechanically agitated contactors
5	Analyse heat transfer characteristics of fluidised beds
6	Analyse the heat transfer characteristics of furnaces

Topics Covered		
UNIT-I	**Double pipe heat exchanger (DPHE)** Selection criteria of DPHE, Heat load calculations; Estimation of physical properties of fluid if any; Material of construction (MOC); Selection of flow arrangements; LMTD calculations; Estimation of film heat transfer coefficient using appropriate empirical correlation; Estimation of overall heat transfer	**(06 Hours)**

	coefficient; Heat transfer area; Concept of hydraulic diameter; Pressure drop calculations: Design and working pressure.	
UNIT-II	**Shell and tube heat exchangers** Shell and tube configurations; Heat load calculations; Material of construction (MOC); Estimation of film heat transfer coefficient; Estimation of overall heat transfer coefficient; Heat transfer area and number of tubes; Sizing of shell and tube heat exchanger: Design of baffle, tie rods, tube sheet and nozzles; Pressure drop calculations: Design and working pressure; TEMA standards.	**(06 Hours)**
UNIT-III	**Evaporators** Concept of evaporation; Types of evaporators; Performance parameters of evaporators: capacity, economy and steam consumption; Methods of feeding for evaporators; Material and energy balances; Sizing of evaporators; Design of steam chest: Estimation of heat transfer coefficient and area, boiling point elevation; Factors affecting performance of evaporators; Pressure drop calculations: Design and working pressure.	**(06 Hours)**
UNIT-IV	**Mechanically agitated contactors (MAC)** Heat transfer configurations of MAC; Heat load calculations; Heat transfer calculations for homogeneous and heterogeneous systems: Estimation of film heat transfer coefficient, overall heat transfer coefficient and heat transfer area; Sizing of MAC; Material of construction (MOC); Factors affecting heat transfer characteristics: system and operating parameters; Indian MAC standards.	**(06 Hours)**
UNIT-V	**Fluidised beds** Concept of fluidization; Fluidization regimes; Pressure drop calculations: Effect of superficial velocity and physical properties of solid and fluidising medium; Velocity voidage relationship; Determination of heat transfer rates: Overall heat transfer coefficient calculations; Sizing of fluidised beds based on heat transfer characteristics;	**(06 Hours)**
UNIT-VI	**Furnaces**	**(06 Hours)**

	Components of a furnace; Classification, Performance measures in furnaces: Excess air, heat distribution, temperature control, draft control, waste heat recovery; Heat transfer in furnace. Furnace efficiency calculations. Lobo and Evans method. Wohlenberg simplified method.	

Project Based Learning:

1	Visit to any heat transfer equipment fabrication industry and prepare report on internals of heat exchanger.
2	Perform process design for heat exchanger for given application
3	Visit to sugar industry to observe operation of evaporators and prepare report.
4	Enlist TEMA Standards.
5	Make Power point presentation on recent advances in heat transfer characteristics of any one chemical process equipment
6	Write report on heat transfer aspect and any one multiphase reactor based on recent advances.
7	Design experimental methodology to estimate time needed to heat a given fluid to design temperature with a given heat resource.
8	Designed any one heat transfer equipment on laboratory scale and demonstrate its working.
9	Propose suitable heat exchanger for given operation/ process based rational reasoning.
10	Enlist empirical correlations to estimate HTC in heat exchanger and report applicability.
11	Enlist empirical correlations to estimate HTC in mechanically agitator vessel.
12	Demonstrate effect and specific heat of fluid time needed to raise desired temperature by experimental methodology
13	Enlist possible ways to enhance HTC in a given heat exchange system.

Term Work

Term work will consist of the experiments listed below, which are to be performed in laboratory by the students

1	To study temperature distribution and overall heat transfer coefficient, in parallel flow finned tube heat exchanger.

2	To study effectiveness and heat transfer rates in counter flow finned tube heat exchanger.
3	To study temperature distribution, effectiveness, overall heat transfer coefficient, heat transfer rates in double pipe heat exchanger.
4	To study Wilson plot in double pipe heat exchanger.
5	To determine overall heat transfer coefficient, effectiveness for shell and tube heat exchanger.
6	To determine number of tubes, pressure drop for shell and tube heat exchanger.
7	Calculation of heat transfer coefficient, rate of heat flow and effectiveness in Double pipe heat exchanger.
8	Detailed flow arrangements, design and drawing of double pipe heat exchanger
9	Detailed design and drawing of shell and tube heat exchanger
10	Detailed design and drawing of evaporator.
11	Calculation of heat transfer coefficient, No of tubes and rate of heat flow in shell and tube heat exchanger
12	Detailed design and drawing of agitated vessel.

Text Books/References

1	Holman, J.P., "Heat Tansfer", 9th edn. The McGraw-Hill Companies, 2008
2	Dutta B. K., "Heat Transfer: Principles and Applications", PHI, 2001
3	Kern D. Q., "Process Heat Transfer", Tata McGraw-Hill Edition, 1997
4	McCabe, W. L., Smith, J. C., and Harriott, P., "Unit Operations of Chemical Engineering", McGraw-Hill, 6th. Ed., 2001
	Richardson, J. F., and J. M. Coulson: “Chemical Engineering,” Butterworth Heinemann, Volume 6.
5	Chapman, A.J. "Heat Transfer", 4th edn. Maxwell Macmillan International Edition, 1984.
6	George E.Totten and M.A.H.Howes: Steel heat treatment handbook
7	P.Mullinger and B. Jenkins: Industrial and process furnaces

Syllabus for Unit Tests

Unit Test I	Units I, II, and III
Unit Test II	Units IV, V, and VI

MASS TRANSFER		
Designation: Professional Core		
Pre-requisite Courses: Heat transfer, Fluid mechanics, Thermodynamics, Material and energy balance calculations		
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Lectures : 03 Hours/Week	End Semester Examination : 60 Marks	Theory : 03
Practical : 02 Hours/Week	Internal Assessment : 40 Marks	Term-work : --
Total : 05 Hours/Week	Term-work (TW) : 25 Marks	Practical/Oral : 01
	Practical/Oral : 25 Marks	Total Credits : 04
	Total : 150 Marks	

Course Outcomes:	
After completion of the course students would be able to	
1	Evaluate diffusivity and rate of diffusion.
2	Evaluate mass transfer coefficients and understand interphase mass transfer.
3	Determine the height of transfer unit, number of transfer unit, in absorption column.
4	Determine the humidity and rate of mass transfer in humidification.
5	Estimate rate and time of drying.
6	Analyze type of crystallization and estimate the yield of crystallization.

Topics Covered		
UNIT-I	**Diffusion** Molecular diffusion in fluids: Steady state diffusion in fluids at rest and in laminar flow, Steady state diffusion of A through non-diffusing B, equimolar counter diffusion, steady state diffusion in multicomponent mixture , molecular diffusion in fluids, diffusivity of liquids and gases, effect of temperature and	**(06 Hours)**

	pressure on diffusivity, diffusion in solids. Laws of diffusion and empirical equations – Maxwell’s law, Stefan’s law, Winkle man’s method.	
UNIT-II	**Mass transfer Coefficient and Interphase Mass Transfer:** a) Mass transfer coefficients: Mass transfer coefficient in laminar flow and in turbulent flow. Relation of individual and overall mass transfer coefficient. Theories of mass transfer. Mass, heat and momentum transfer analogies. b) Interphase mass transfer. Equilibrium in mass transfer, two resistance concept. diffusion between phases. Steady state co-current and counter current processes. continuous crosscurrent, counter-current, crosscurrent cascade operations and mass balances.	**(06 Hours)**
UNIT-III	**Absorption:** Introduction to absorption, types of tower packing’s, contact between liquid and gas, pressure drop and limiting flow rates, material balances for each flow , limiting gas-liquid ratio, rate of absorption, calculation of HTU, NTU and HETP. Alternate forms of transfer coefficients and their relations. Tray Efficiencies, absorption in plate columns, absorption with chemical reaction. Equipment for absorption column.	**(06 Hours)**
UNIT-IV	**Humidification** Vapor-liquid equilibrium, enthalpy for pure substances, definitions of humidity terms, adiabatic saturation temperature, wet bulb and dry bulb temperatures, study of humidity charts, Lewis relation, method of adiabatic humidification and dehumidification. Equipment for humidification, cooling tower design.	**(06 Hours)**
UNIT-V	**Drying** Basic principles of drying. equilibrium in drying. definitions of terms in drying, types of moisture binding, rate of drying curve, mechanism of batch drying and continuous drying, time requirement for drying, mechanism of moisture movement in solids. Equipment used for drying: Classification of dryers, solids handling in dryers, equipment for batch and continuous drying processes: working principle of tray driers, tower driers, rotary driers, spray driers. Concept of freeze drying	**(06 Hours)**

UNIT-VI	**Crystallization** Introduction to the process, principal rate of crystallization, Mier's super-saturation theory, growth and properties of crystals, crystallization rate, calculations of yield, mass and enthalpy balances. Equipment used in crystallization.	**(06 Hours)**

Project Based Learning

1.	Prepare a model for any of the Mass transfer equipment.
2.	Power point presentation (seminar) on any topic of mass transfer and prepare a report.
3.	Evaluate efficiencies of different Gas-liquid contact equipment. .
4.	With the help of this subject knowledge, write a guideline report on how you would apply your concepts in industry.
5.	Compare working and principles for different mass transfer operations.
6.	Solve numerical based on crystallization and humidification.
7.	Write a technical report on your visit to a process industry.
8.	Solve old (last three years) GATE question papers with reference to Mass transfer-I subject.
9.	Group discussion on the recent advances in mass Transfer equipment.
10.	Technical interview based on the knowledge of Mass transfer.

Term Work:

Term work will consist of the experiments listed below, out of which any eight experiments are to be performed in laboratory by the students.

1.	To calculate diffusion coefficient in Liquid-Liquid diffusion.
2.	To calculate diffusion coefficient in still air..
3.	To study characteristics of Wetted Wall Column.
4.	To calculate individual and overall interface mass transfer coefficient.
5.	To estimate efficiency of cooling Tower.
6.	To estimate rate of drying in tray drier/rotary drier
7.	To study the crystallization process by air, water cooling and seeding.

8.	Humidification and Dehumidification experiment.
9.	To study agitated batch crystallizer
10.	Study of Spray drier
Text Books/References	
1	Treybal R.E., Mass Transfer Operations, 3rd Ed., McGrawHill, 1981.
2	McCabe, W. L., J. Smith, and Harriot: "Unit operations of chemical engineering," Tata McGraw Hill.
3	King C. J. "Separation Techniques," McGraw Hill Publications
4	Richardson, J. F., and J. M. Coulson: "Chemical Engineering," Butterworth Heinemann, Volume 1.
5	E. L. Cussler, "Diffusion Mass Transfer in fluid systems " 3rd Ed. Cambridge Series in Chemical Engineering.
Syllabus for Unit Tests	
Unit Test I	Units I, II, and III
Unit Test II	Units IV, V, and VI

CHEMICAL REACTION ENGINEERING		
Designation: Professional Core		
Pre-requisite Courses: Chemistry, Process heat transfer, Mass transfer, Fluid mechanics, Material and energy balance calculations.		
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Lectures : 03Hours/Week	End Semester Examination : 60 Marks	Theory : 03
Practical : 02Hours/Week	Internal Assessment : 40 Marks	Tutorial : -
Total : 05 Hours/Week	Term-work (TW) : 25 Marks	Practical : 01
	Practical/Oral : 25 Marks	Total Credits : 04
	Total : 150Marks	

Course Outcomes

1	Define rates of homogeneous chemical reactions and express temperature dependent term of rate equation with Arrhenius' law and other theories.
2	Design experiments to analyze and interpret the reaction progression analysis for chemical processes.
3	Apply the rate expression and other analysis to design ideal reactors: batch, CSTR and plug flow.
4	Optimize thermal effects to optimize reaction output for multiple reactions, autocatalytic and recycle processes.
5	Define operating conditions to produce desired products from parallel and series chemical reactions.
6	Evaluate effect of temperature on reaction.

Topics Covered

UNIT-I	**Chemical Kinetics** Classification of reactions; rate laws and stoichiometry; relative rates of reaction; reaction order; rate limiting step; half life; concentration-dependent term of a rate equation; temperature-dependent term of a rate equation; Temperature dependency from Arrhenius law; Transition state theory; collision	**(06 Hours)**

	theory; rate equation using partial pressure and concentration; their interrelation; searching for a reaction mechanism.	
UNIT-II	**Interpretation of Batch reactor data** Interpretation of batch experimental kinetics data using integral and differential analysis; constant volume batch reactor system; design equation for zero, first, second and third order irreversible and reversible reactions; graphical interpretation of these equations and their limitations; variable volume batch reactors; design equation for zero, first and second order irreversible and reversible reactions; graphical interpretation of their limitations.	**(06 Hours)**
UNIT-III	**Introduction to Reactor Design** Single ideal reactors under steady state conditions; design equations for batch; mixed flow & plug flow reactor; development of rate expression for mean holding time for a plug flow reactor; space time and space velocity; Introduction to Semi-batch reactor.	**(06 Hours)**
UNIT-IV	**Isothermal flow reactors** Size comparison of reactor performance; sequences of reactors; reactors with recycle; optimum size determination; reactors in series and parallel; performance of infinite number of back mix reactors in series; back mix and plug flow reactors of different sizes in series and their optimum way of staging; optimum recycle ratio for auto –catalytic (recycle) reactors.	**(06 Hours)**
UNIT-V	**Design of reactors for Single and Multiple reactions** Parallel and consecutive reactions in batch; CSTR and PFR; qualitative discussion about product distribution; quantitative treatment of product distribution and reactor size; factors affecting such as choice; optimum yield, conversion, selectivity, reactivity on consecutive and parallel reactions in reactors.	**(06 Hours)**
UNIT-VI	**Non-Isothermal reactor for homogeneous reactor systems** Energy balances in reactors; adiabatic operations; non-adiabatic operations; stability of reactors; non-isothermal homogeneous reactor systems; rates of heat exchanges for different reactors; adiabatic operations for batch and	**(06 Hours)**

	continuous reactors; optimum temperature progression; rate, temperature and conversion profiles for exothermic and endothermic reactions.	

Text Books/References	
1	Levenspiel O.: "Chemical Reaction Engineering", 3rd Edition, John Wiley and sons, New Delhi, India 2007.
2	Fogler H.S.: "Elements of Chemical Reaction Engineering", 4th Edition, Prentice Hall of India, New Delhi;, India, 2006.
3	Laidler K.J.: "Chemical Kinetics", 3rd Edition, Pearson Education Inc. UK 2013
4	Smith J.M. "Chemical Engineering Kinetics", 3rd Edition, McGraw Hill, 1981

Project Based Learning	
1.	Suggest best suitable reactor arrangement for zero, first and second order reaction.
2.	Derive the rate equations for various combinations of reactors.
3.	Prepare a model for any of the reactor.
4.	Elaborate in detail use of kinetics in equipment/reactor design.
5.	With the help of this subject knowledge, write a guideline report on how you would apply your concepts in industry.
6.	Group discussion on the recent advances in reaction engineering.
7.	Write a report on your visit to research and development laboratory of national/international repute.
8.	Give fifteen minutes presentation (seminar) on particular topic and prepare a report.
9.	Visit chemical industry and prepare a detailed report on reactors used in industry.
10.	Students have to study any five NPTEL videos related to chemical reaction engineering and prepare/present power point presentation.
11.	Explain in detail use of kinetics in equipment/reactor design.
12.	Prepare a report on reactors which are newly introduced in the current year.
*Students in a group of 3 to 4 shall complete any one project from the above list.	

Term Work

Term work will consist of the experiments listed below, which are to be performed in laboratory by the students.	
1	Study of first order reaction.
2	Study of PFR & CSTR combination in second order reaction.
3	Rate constant of hydrolysis of methyl acetate by dilute HCl.
4	Hydrolysis of ester (e.g. ethyl acetate) by alkali (NaOH).
5	Study of CSTR combination in first order reactions.
6	Determination of Arrhenius parameters.
7	Rate constant for saponification of ethyl acetate with NaOH using CSTR
8	Rate constant for saponification of ethyl acetate with NaOH at ambient cond itions using PFR
9	Rate constant for saponification of ethyl acetate with NaOH at ambient conditions using (i) Isothermal batch reactor (ii) Isothermal CSTR.
10	Study and operation of an adiabatic batch reactor.
11	Use MATLAB software to simulate Batch / CSTR / Plug flow reactor data

Syllabus for Unit Tests	
Unit Test I	Units I, II, and III
Unit Test II	Units IV, V, and VI

CHEMICAL PROCESS INSTRUMENTATION		
Designation: Professional Core		
Course Pre-requisites: Mathematics, Material science and engineering		
Teaching scheme:	**Examination scheme:**	**Credits allotted:**
Lectures : 3 Hour/Week	End Semester Examination: 60 Marks	Theory : 03
Total : 3 Hour /Week	Internal Assessment : 40 Marks	Total Credits : 03
	Total : 100 Marks	

Course Outcomes:

After completion of the course students will be able to

1.	To explicate the need of process instrumentation and process control in chemical industries.
2.	To illustrate various pressure and strain measuring instruments.
3.	To elucidate spectrophotometry, colorimetry and conductometry
4.	To describe nephelometry, turbidimetry, refractometry and chromatography methods.
5.	To develop an ability to use theorems to compute the Laplace transform, inverse Laplace transforms. To calculate the transfer functions for first order and second order systems.
6.	To give details various control action for first order and second order system.

Topics covered

UNIT-I	**Introduction**: Basic Concepts and characteristics of measurement system; various elements of instrument; performance characteristics. **Temperature measurement**: Introduction, methods of temperature measurement by expansion thermometers, filled system thermometers; electrical temperature instruments; pyrometers; Calibration of Thermometers. **Level measurement**: Displacers; ultrasonic; microwaves; laser light.	**(06 Hours)**
UNIT-II	**Pressure and strain measuring instruments**: Introduction; classification; low, medium, and high pressure measuring instruments, pressure scales (units), manometers, elastic element pressure gauges with pressure equations (using bourdon tube, diaphragms, capsule, and bellows), transduction/ electrical sensors	**(06 Hours)**

	with pressure equations (based on variable capacitance, resistance, and inductance/reluctance-LVDT), force- balance transducers along with mathematical equations, solid-state devices, thin-film transducers, digital transducers, piezoelectric transducers, vibrating element sensors, pressure multiplexer, calibration of pressure sensors using dead- weight tester, Mechanical, optical, and electrical strain gauges.	
UNIT-III	**Introduction to instrumental methods of analysis**: General Introduction; classification of instrumental methods; spectroscopy, properties of electromagnetic radiation, pH metry, Karl Fischer Titration. **Visible Spectrophotometry & Colorimetry**: Deviation from Beer's law; instrumentation applications; Molar compositions of complexes; examples. **Conductometry**: Introduction, laws; conductance; measurements; types of conductometric titrations; applications; advantages and disadvantages.	**(06 Hours)**
UNIT-IV	**Nephelometry and Turbidimetry**: Introduction; theory; comparison with spectrophotometry; applications. **Refractometry:** Introduction; Abbe refractometer; applications. **Chromatography**: Introduction; types; theoretical principles; theories of chromatography; development of chromatography; qualitative and quantitative analysis; applications. Gas Chromatography; Introduction, principles of gas chromatography, gas liquid chromatography, instrumentation, evaluation, retention volume, resolution. Branches of gas chromatography, applications and numerical. High Performance (Pressure) Liquid Chromatography; Introduction, principles, instrumentation, apparatus & materials, column efficiency and selectivity, applications.	**(06 Hours)**
UNIT-V	**Process dynamics:** Introduction; tools of dynamics analysis; ideal forcing function; input output model; transfer function models; proportion of transfer function; poles & zeros of transfer function with qualitative response; dynamic behavior of pure integrator;	**(06 Hours)**

	pure gain; first order & second order systems (with or without dead time); physical example of these systems.	
UNIT-VI	**Introduction to feedback control:** Final Control Elements - Valve characteristics; Instrumentation symbols. Introduction to Process Flow Diagram (PFD) and Piping & Instrumentation Diagram (P&ID). **Control theory basics:** The control loops; process control terms; components of control loops; basic control action i.e. on-off, P, I, D, PI, PD, PID for 1st order process control loops and 2^{nd}order response.	**(06 Hours)**

Project based learning:

1.	Students have to visit chemical industry and prepare a detailed report on various instruments used for process variable measurement.
2.	Students have to visit chemical industry and prepare a detailed report on various instruments used for chemical analysis.
3.	Watch NPTEL video and make report on various instruments used for process variable measurement.
4.	Presentation on instruments used for process variable measurement.
5.	Group discussions on instruments used for process variable measurement.
6.	To find Transfer Function for 1^{st} order and 2^{nd} order Instrument or process.
7.	Draw the Control Loop for HEfor different process variable control.
8.	Draw the Control Loop for Batch Reactor for different process variable control.
9.	Draw the Control Loop for CSTR for different process variable control.

*Students in a group of 3 to 4 shall complete any one or two projects from the above list.

Text Books/References:

1	S.K.Singh, “Industrial Instrumentation & Control”, Tata McGraw Hill publishing company ltd, New Delhi, 2000
2	D. Pastranabis, “Principals of industrial instrumentation”, 2nd edition, Tata McGraw 4

	Hill publishing company ltd, New Delhi, 2003
3	Eckman D.P. “Industrial Instrumentation”, Willey Eastern Ltd, New Delhi, 1984.
4	A.C. Shrivastav “Techniques in Instrumentation”, New Delhi, 1984.
5	W.Boltan, “Instrumentation and Process Measurement”, Orient Longman Ltd, Hyderabad, 1st Edition, 1993.
6	Willard H.H, “Instrumental methods of analysis”, 6th Edition, CBS Publication New Delhi 1986
7	Galen W. Ewing, “Instrumental Methods of Chemical Analysis”, 5th Edition, McGraw Hill Book Company, Singapore, 1990
8	D. A. Skoog, “Principal of Instrumental Analysis”, Southern Collage Publication, Japan 1984
9	G. R. Chatwal, S.K. Anand, “Instrumental method of chemical analysis”, 5th Edition, Himalaya Publishing House, Mumbai 2002.
10	Ray Choudhuri and Ray Choudhuri “Process Instrumentation, Dynamics and control for Engineers”, 1st Edition, Asian Books Pvt Ltd, New Delhi, 2003.
11	B.G. Liptak, “Instrument Engineers Handbook”, 4thEdition , CRC Press, 2005.

Syllabus for Unit Test:	
Unit Test -I	UNIT – I , II, III
Unit Test -II	UNIT – IV, V, VI

SKILL BASED COURSE-IV: INDUSTRIAL HEATING SYSTEMS

Designation: Skill Development

Pre-requisite Courses: Chemical Engineering Thermodynamics, Heat Transfer, Particulate technology

Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Practical	: 02 Hours/Week	Term-work (TW)	: 25 Marks	Practical	: 01
Total	: 02 Hours/Week	Practical/Oral	: 25 Marks	Total Credits	: 01
		Total	: 50 Marks		

Term Work

Term work will consist of the practicals based on the following topics. Any ten practicals are to be performed in laboratory by the students.

Topics Covered

1	**Liquid Fired Thermic Fluid Heaters** Design principle, selection and characterization of liquid fuel and thermic fluid, Efficiency of system, Control system for thermic fluid heaters, Operation and maintenance of liquid fired thermic fluid heaters.
2	**Solid Fired Thermic Fluid Heaters** Design principle, selection and characterization of solid fuel and thermic fluid, Efficiency of system, Control system for solid thermic fluid heaters, Operation and maintenance of solid fired thermic fluid heaters.
3	**Boiler (Fire-Tube Boiler)** Design principle, Construction and working principle, Types of fire tube boilers, Selection criteria, Operation and maintenance of fire tube boilers,
4	**Boiler (Water-Tube Boiler)** Design principle, Construction and working principle, Types of water tube boilers, Selection criteria, Operation and maintenance of water tube boilers

5	**Furnaces** Design principle, Classification and types of furnaces, Construction and working principle, Heating distribution within furnace, selection criteria for furnace. Operation and troubleshooting of furnaces.
6	**Selection of Heating System for Industrial Purpose** Selection criteria and factors to be considered, Characteristics of a good heating system, Risk barriers and uncertainty, Case studies.
Text Books/References	
1	Y. V. Deshmukh, "Industrial Heating, Principles, Techniques, Materials, Applications, and Design", 1st edition, CRC Press 2005
2	H. Pfeifer, “Handbook of Heat Processing: Fundamentals - Calculations – Processes” 2nd edition, Vulkan-Verlag(2016)
3	J. G. Wünning, A.Milani,“Handbook of Burner Technology for Industrial Furnaces: Fundamentals - Burner – Applications” 2nd Edition, Vulkan-Verlag(2015)

INDIAN KNOWLEDGE SYSTEM

Teaching scheme	Examination scheme	Credits allotted
Theory : 02	End Semester Examination : -	Credits : 02
Practical : -	Internal Assessment : 100 Marks	Total Credit : 02
Tutorial : -		

Course Objectives:

1.	To sensitize the students about Indian culture and civilization including its Knowledge System and Tradition.
2.	To help student to understand the knowledge, art and creative practices, skills, and values in ancient Indian system
3.	To help to study the enriched scientific Indian heritage.
4.	To introduce the contribution from Ancient Indian system & tradition to modern science & Technology

Course Outcomes: After learning this course students will be able to understand

1	Concepts of Indian Knowledge System
2	India's contribution in Philosophy and Literature
3	India's involvement in Mathematics and Astronomy
4	India's role in Medicine and Yoga
5	India's influence in Sahitya
6	Concepts of Indian Shastra

UNIT – I	**Introduction to Indian Knowledge System**	**(04 Hours)**
	Definition, Concept and Scope of IKS, IKS based approaches on Knowledge Paradigm, IKS in ancient India and in modern India	
UNIT – II	**Philosophy and Literature**	**(04 Hours)**

	Contributions by Maharishi Vyas, Manu, Kanad, Pingala, Parasar, Banabhatta, Nagarjuna and Panini in Philosophy and Literature	
UNIT - III	**Mathematics and Astronomy**	**(04 Hours)**
	Contribution of Aryabhatta, Mahaviracharya, Bodhayan, Bhashkaracharya, Varahamihira and Brahmgupta in Mathematics and Astrononmy	
UNIT -IV	**Medicine and Yoga**	**(04 Hours)**
	Major contributions of Charak, Susruta, Maharishi Patanjali and Dhanwantri in Medicine and Yoga	
UNIT -V	**Sahitya**	**(04 Hours)**
	Introduction to Vedas, Upvedas, Upavedas (Ayurveda, Dhanurveda, Gandharvaveda), Puran and Upnishad) and shad darshan (Vedanta, Nyaya.Vaisheshik, Sankhya, Mimamsa, Yoga, Adhyatma and Meditation)	
UNIT -VI	**Shastra**	**(04 Hours)**
	Introduction to Nyaya, vyakarana, Krishi, Shilp, Vastu, Natya and Sangeet	

Reference Books

1.Textbook on IKS by Prof. B Mahadevan, IIM Bengaluru

2. Kapur K and Singh A.K (Eds) 2005). Indian Knowledge Systems, Vol. 1. Indian Institute of Advanced Study, Shimla. Tatvabodh of sankaracharya, Central chinmay mission trust, Bombay, 1995.

3. The Cultural Heritage of India. Vol.I. Kolkata:Ramakrishna Mission Publication, 1972.

4. Nair, Shantha N. Echoes of Ancient Indian Wisdom. New Delhi: Hindology Books, 2008.

5. Dr. R. C. Majumdar, H. C. Raychaudhuri and Kalikinkar Datta: An Advanced History of India (Second Edition) published by Macmillan & Co., Limited, London, 1953.

6. Rao, N. 1970. The Four Values in Indian Philosophy and Culture. Mysore: University of Mysore.

7. Avari, B. 2016. India: The Ancient Past: A History of the Indian Subcontinent from c. *7000* BCE to CE 1200. London: Routledge.

8. Textbook on The Knowledge System of Bhārata by Bhag Chand Chauhan,

9. Histrory of Science in India Volume-1, Part-I, Part-II, Volume VIII, by Sibaji Raha, et al. National Academy of Sciences, India and The Ramkrishan Mission Institute of Culture, Kolkata (2014).

10. Pride of India- A Glimpse of India's Scientific Heritage edited by Pradeep Kohle et al. Samskrit Bharati (2006).

12. Vedic Physics by Keshav Dev Verma, Motilal Banarsidass Publishers (2012).

13. India's Glorious Scientific Tradition by Suresh Soni, Ocean Books Pvt. Ltd. (2010).

14.Kapoor, Kapil, Avadesh Kr. Singh (eds.) *Indian Knowledge Systems* (Two Vols), IIAS, Shimla, 2005