Bharati Vidyapeeth

(Deemed to be University)

College of Engineering, Pune

Department of Chemical Engineering

B. Tech. Chemical Curriculum- 2021

Bharati Vidyapeeth

(Deemed to be University)

Faculty of Engineering and Technology

Programme: B. Tech. (Chemical) (2021 Course)

Curriculum Structure (Semester III and IV)

Bharati Vidyapeeth
(Deemed to be University)
Faculty of Engineering and Technology

Program: B. Tech. (Chemical) Semester – III CBCS 2021 Course

Sr. No.	Course Code	Name of Course	Teaching Scheme (Hours/week)			Examination Scheme (Marks)						Credits			
			L	P/D	T	UE	IA	TW	TW & OR	TW & PR	Total	L	P TW/OR/PR	T	Total
1		Chemical Engineering Thermodynamics- I	4	-	1	60	40	-	-	-	100	4	-	1	5
2		Process Heat Transfer	3	4	-	60	40	25	-	25	150	3	2	-	5
3		Fluid Mechanics	3	4	-	60	40	25	-	25	150	3	2	-	5
4		Particulate Technology	4	2	-	60	40	25	-	25	150	4	1	-	5
5		Material Science and Engineering*	4	-	-	60	40	-	-	-	100	4	-	-	4
6		Python Programming	-	4	-	-	-	50	50	-	100	-	2	-	2
7		Vocational Course- I: Analytical Techniques	-	-	-	-	-	25	25	-	50	-	2	-	2
8		MOOC-I	-	-	-	-	-	-	-	-	-	-	-	-	2
9		Environmental Studies#	-	-	-	-	-	-	-	-	-	-	-	-	-
Total			**18**	**14**	**1**	**300**	**200**	**150**	**75**	**75**	**800**	**18**	9	**1**	**30**

*** Industry Taught Course I; # Mandatory Audit Course with end semester examination of 100 marks**

Program: B. Tech. (Chemical) Semester – IV CBCS 2021 Course

Sr. No.	Course Code	Name of Course	Teaching Scheme (Hours/week)			Examination Scheme (Marks)						Credits			
			L	P/D	T	UE	IA	TW	TW & OR	TW & PR	Total	L	P TW/OR/PR	T	Total
1		Numerical Methods for Chemical Engineering	4	-	-	60	40	-	-	-	100	4	-	-	4
2		Chemical Engineering Thermodynamics- II	4	-	1	60	40	-	-	-	100	4	-	1	5
3		Design of Heat Transfer Equipment	3	4	-	60	40	25	-	25	150	3	2	-	5
4		Chemical Technology	3	4	-	60	40	25	-	25	150	3	2	-	5
5		Industrial Pollution and Abatement*	4	2	-	60	40	25	-	25	150	4	1	-	5
6		MATLAB programming	-	4	-	-	-	50	50	-	100	-	2	-	2
7		Vocational Course- II: Industrial Heating Systems	-	-	-	-	-	25	25	-	50	-	2	-	2
8		Social Activities- I	-	-	-	-	-	-	-	-	-	-	-		2
9		Disaster Management#	-	-	-	-	-	-	-	-	-	-	-	-	-
Total			**18**	**14**	**1**	**300**	**200**	**150**	**75**	**75**	**800**	**18**	9	**1**	**30**

*** Industry Taught Course II; # Mandatory Audit Course with end semester examination of 100 marks**

Bharati Vidyapeeth

(Deemed to be University)

Faculty of Engineering and Technology

Programme: B. Tech. (Chemical) (2021 Course)

Syllabi of Semester III and Semester IV Courses

Programme: B. Tech Chemical (2021)

Sem -III (Chemical)

CHEMICAL ENGINEERING THERMODYNAMICS- I					
Designation: Professional Core					
Pre-requisite Courses: Basic knowledge of chemistry, physics and mathematics, Material and energy balance calculations.					
Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 04 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Tutorial	: 01Hours/Week	Internal Assessment	: 40 Marks	Tutorial	: 01
Total	: 05 Hours/Week	Total	: 100 Marks	Total Credits	: 05

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.	**(08 Hours)**
UNIT-II	**First Law of Thermodynamics and its applications** 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.	**(08 Hours)**
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.	**(08 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.	**(08 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; Fugacity and fugacity coefficient: Estimation of fugacity of pure gas; Thermodynamic diagrams: (i) temperature-entropy, (ii) pressure-enthalpy, and (iii) enthalpy-entropy (the Mollier diagram).	**(08 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. **(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.	**(08 Hours)**

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.	Solve question papers of CET I of previous THREE years.
11.	Unsolved numerical from the reference books on various topics studied.
12.	Preparation of a brief report on applicability of equations of states (EOS) in chemical engineering systems.

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.

Syllabus for Unit Tests

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

PROCESS HEAT TRANSFER

Designation: Professional Core

Pre-requisite Courses: Basic knowledge of physics and mathematics; Material and energy balance calculations

Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 03Hours/Week	End Semester Examination	: 60 Marks	Theory	: 03
Practical	: 04 Hours/Week	Internal Assessment	: 40 Marks	TW/OR/PR	: 02
Total	: 07 Hours/Week	Term-work (TW)	: 25 Marks	Total Credits	: 05
		Practical/Oral	: 25 Marks		
		Total	: 150 Marks		

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; 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.	**(06Hours)**
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	**(06Hours)**

	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.	
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)**

Project Based Learning

.

1	By determining optimum thickness of insulation give solution to an industrial problem to minimize the heat loss.
2	Design laboratory manuals better than existing ones with clearly shown specimen calculations.
3	With the help of this subject knowledge, write a guideline report on how you would apply your concepts in Industry.
4	Write a technical report on your visit to a process industry.
5	Solve old (last ten years) GATE question papers with reference to heat transfer subject.
6	Group discussion on the recent advances in heat transfer processes.
7	Write a report on your visit to research and development laboratory of national/international repute.
8	Technical interview based on the knowledge of heat transfer.
9	Write a report on the recent advances in heat transfer processes with reference to the current year.
10	Solve old (last five years) question papers with reference to particular topic.
11	Prepare a model for any of the heat transfer equipment.
12	Prepare a report on heat transfer equipments which are newly introduced in the current year.
13	Give fifteen minutes presentation (seminar) on particular topic and prepare a report.
14	Evaluate capacity and economy for any industrial evaporator.
15	Estimate how much heat transfer rate is decreased due to the scale formation on surface of industrial heattransfer equipment?

Term Work	
Term work will consist of the experiments listed below, which are to be performed in laboratory by the students	
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.
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
5	Chapman, A.J. "Heat Transfer", 4th edn. Maxwell Macmillan International Edition, 1984.
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: Material and Wave Physics.

Teaching Scheme		Examination Scheme		Credits Allotted	
Lectures	: 03 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 03
Practical	: 04 Hours/Week	Internal Assessment	: 40 Marks	TW/OR/PR	: 02
Total	: 07 Hours/Week	Term-work (TW)	: 25 Marks	Total Credits	: 05
		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 equipments 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, Reynolds 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.	**(06Hours)**
UNIT-II	**A. Equations of Fluid Flow** 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.	**(06 Hours)**
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.	**(06Hours)**
UNIT-IV	**Major and Minor Losses in Pipe Flow** Major losses: Head loss due to friction, Darcy–Weisbach equation; Friction	**(06 Hours)**

	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.	
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 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.	**(06 Hours)**

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.

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.	
Text Books/References	
1	W. L. McCabe, J. C. Smith, and P. Harriott, Unit Operations of Chemical Engineering, 5th edition, McGraw Hill Publications, 2008.
2	J.M.Coulson, J. F.Richardson, J. R. Backhurst, J. H. Harker, Chemical Engineering Volume 1, 6thedition, Pergamon Press, 2003.
3	S.K.Gupta, Momentum transfer operations, Tata McGraw Hill Publishers.
4	R. K. Bansal, A text book of fluid mechanics and hydraulic machines, 9th Ed., Laxmi Publications (P) Ltd, New Delhi, 2010.
5	R.B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena, John Wiley & Sons, New York, 2007.
6	M.M. Denn, Process fluid mechanics, Prentice Hall Publications, 1979.
Syllabus for Unit Tests	
Unit Test I	Units I, II, and III
Unit Test II	Units IV, V, and VI

PARTICULATE TECHNOLOGY

Designation: Professional Core

Pre-requisite Courses: None.

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

Course Outcomes: After completion of the course students will be able to

1	To select suitable type of screening and size reduction equipment for different particle sizes
2	To select suitable type of thickeners and clarifiers for separation of suspended solid particles from liquid for example applications in Wastewater treatment plants.
3	To apply beneficiation techniques in Chemical Industries.
4	To select a suitable type of conveyor for transportation of different types of solids
5	To select a suitable type of agitator for mixing and agitation and to estimate power consumption in mixing and agitation.
6	To select a suitable type of filter for filtration of a slurry or a suspension.

Topics Covered

UNIT-I	**Screening and Size Reduction of Solids** Properties of solids; Performance of screening equipment; Testing sieves; Tyler standard sieve series; Sieve shaker; Types of screen analysis; Necessity of size reduction; Crushing efficiency; Energy requirement calculations by using crushing laws; Classification of size reduction equipment: Crushers, Grinders, Ultrafine grinders, Cutters, Dry versus wet grinding; Open and closed circuit grinding.	**(08 Hours)**
UNIT-II	**Settling and Sedimentation** Motion of particle in fluid; Drag force; Drag coefficient; Gravity settling methods; Terminal falling velocity; Stoke's law and Newton's law of settling; Gravity sedimentation operations; Sedimentation test; Kynch theory; Determination of thickener area and depth of thickener; Thickeners, Clarifiers, Sedimentation centrifuges.	**(08 Hours)**
UNIT-III	**Beneficiation Equipment** Froth flotation; Magnetic separator; Scrubbers; Electrostatic precipitators: Mineral jig: Cyclone separator: Hydro cyclone types and centrifuges.	**(08 Hours)**
UNIT-IV	**Handling and Conveying of Solids** Storage of solids; Characteristics of bulk solids; Conveyors: Principle, Construction and Working, Advantages, Disadvantages and Design calculations of Belt Conveyors, Screw conveyors, Chain & Flight conveyors, Bucket elevators and Pneumatic conveyors.	**(08 Hours)**
UNIT-V	**Mixing and Agitation** Types of Impellers; Flow patterns in un-baffled and baffled tanks; Draft tube; Mechanically agitated vessel; Power requirement in mixing;	**(08 Hours)**

	Performance of mixers; Paste and viscous material mixing; Solid-solid mixing; Batch and continuous mixers; Agitator selection.	
UNIT-VI	**Filtration** Classification of filtration and filters; Theory of filtration-equations; Filter media and filter aids; Batch and continuous filters; Plate and frame filter press; Filling and washing in a filter press; Horizontal pressure leaf filters; Rotary drum vacuum filters; Fabric filter: Centrifugal filters-basket type.	**(08 Hours)**

List of Experiments:

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

1	To determine effectiveness of given set of standard screen.
2	To determine energy consumption and crushing law constants for jaw crusher.
3	To determine Critical speed of Ball mill & Average particle size of the product obtained in ball mill.
4	To determine mixing Index of a mixture in Ribbon Blender. **OR** To determine mixing Index of mixture in Sigma Mixer.
5	To determine filter medium resistance and cake resistance by using Vacuum Leaf filter.
6	To determine filter medium resistance and cake resistance by using Plate & frame Filter Press **OR** by using centrifuge machine.
7	To determine area of batch thickener by conducting batch sedimentation test.
8	To determine separation efficiency by using froth flotation cell.
9	To determine separation efficiency by using magnetic separator.
10	To determine efficiency of Cyclone separator.

Project Base Learning :

1	What is surface loading rate explain in brief. The flow into clarifier is 3.2 MGD in tank 80 feet long and 40 feet wide. What is surface loading rate?
2	Research on Recent trends in particle size technology.
3	Watch the NPTEL video on this subject of any TWO modules and summarize it
4	Solve numerical problems asked in previous THREE year question papers.
5	Solve questions asked on filtration in previous THREE year question papers.
6	If your particles are not spherical which equivalent particle size would be suitable to calculate for the purpose of filtration
7	What media are used in filters? What factors affect filter efficiency?
8	How does sedimentation fit in to the waste water treatment process?
9	What zones are present in sedimentation basin?
10	How is sedimentation sludge disposed of?
11	Pilot scale solid-liquid fluidization: Expansion characteristics of solids
12	Estimate power consumption for homogeneous system
13	Industry related unit operation (ANY ONE INDUSTRY) detailing of it.
14	How does filtration fit into the water treatment process?
15	How Does Filtration clean water?
16	What types of filters are used for water treatment? Explain in brief

Text Books/References

1	McCabe, W. L.; Smith, J. C. and Harriott, P.; Unit Operations of Chemical Engineering, 6th edition, McGraw Hill Publications.
2	Coulson, J.M.; Richardson, J. F.;Backhurst, J. R.; Harker, J. H.; Chemical Engineering Volume 2,

	6th edition, Pergamon Press.
3	Badger W. L &Banchero J.T. “Introduction to Chemical Engineering”, McGraw Hill
4	Foust A. S “Principles of Unit Operation”.
5	George G. Brown, “Unit operations”, CBS publishers and distributors.

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

MATERIAL SCIENCE AND ENGINEERING		
Designation: Professional Core		
Pre-requisite Courses: Chemistry, Physics and Biology		
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Lectures : 4 Hours/Week	End Semester Examination : 60 Marks	Theory : 04
	Internal Assessment : 40 Marks	Total credits : 04
	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.	**(08 Hours)**
UNIT-II	**Metal and Their Alloys** ***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**.**	**(08 Hours)**
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	**(08 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	**(08 Hours)**

	non-crystalline ceramics: Silicates, refractory, clays, glass, vitreous silica and borosilicate. Cement and its properties: Special cements, cement concrete, RCC- Pre stressed concrete.	
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.	**(08 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.	**(08 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

PYTHON PROGRAMMING					
Designation: Computational					
Course Pre-requisite: Basic knowledge of computer fundamentals.					
Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Practical	: 04 Hours/Week	Term-work (TW)	: 50 Marks	TW/OR/PR	: 02
Total	: 04 Hours/Week	Practical/Oral	: 50 Marks	Total Credits	: 02
		Total	: 100 Marks		
Course Outcomes					
1	Develop algorithm and explain building blocks of algorithms.				
2	Elaborate data type and operators.				
3	Elucidate concept of control flow statements and functions				
4	Elaborate concept of advanced data types				
5	Elucidate concept of data structure				
6	Elucidate concept of files, modules, packages.				
Topics Covered					
UNIT-I	**ALGORITHMIC PROBLEM SOLVING** Algorithms, building blocks of algorithms (statements, state, control flow, functions), notation (pseudo code, flow chart, programming language), algorithmic problem solving, simple strategies for developing algorithms (iteration, recursion). 1. Programs based on arithmetic operations. 2. Programs based on operators. 3. Programs based on areas of different geometrical figures.				
UNIT-II	**DATA, EXPRESSIONS, STATEMENTS** Python interpreter and interactive mode; Values and types: int, float, boolean, string, and list; variables, expressions, statements, tuple assignment, precedence of operators, comments, modules and functions, function definition and use, flow of execution, parameters and arguments. 4. Write a program to exchange the values of two variables. 5. Programs based on data types.				
UNIT-III	**CONTROL FLOW, FUNCTIONS** Conditionals: Boolean values and operators, conditional (if), alternative (if-else), chained conditional (if-elif-else); Iteration: state, while, for, break, continue, pass; Fruitful functions: return values, parameters, local and global scope, function composition, recursion; Strings: string slices, immutability, string functions and methods, string module. 6. Programs based on conditional statements. 7. Programs based on loop statements. 8. Programs based on functions. 9. Programs based on recursion. 10. Programs based on local and global scope.				
UNIT-IV	**LISTS, TUPLES, DICTIONARIES** Lists: list operations, list slices, list methods, list loop, mutability, aliasing, cloning lists, list parameters; Tuples: tuple assignment, tuple as return value; Dictionaries: operations and				

	methods; advanced list processing - list comprehension. 11. Programs based on list. 12. Programs based on tuple. 13. Programs based on dictionaries.
UNIT-V	**DATA STRUCTURE** Lists as arrays. OOPs concepts; linear search, binary search, selection sort, insertion sort, mergesort, histogram. 14. Programs based on searching. 15. Programs based on sorting. 16. Programs based on OOPs concept.
UNIT-VI	**FILES, MODULES, PACKAGES** Files and exception: text files, reading and writing files, format operator; command lineargumentS, errors and exceptions, handling exceptions, modules, packages. Application to Data Science. 17. Programs based on files. 18. Programs based on modules. 19. Programs based on exception handling.
In addition to these above stated programs/practical's concern faculty member may design his/her own programs / practical's.	
Term Work	
Term work will consist of the programs/practical listed above, out of which any eight programs/practical's are to be performed in laboratory by the students.	
Text Books/References	
1	A. B. Downey, Think Python: How to Think Like a Computer Scientist, 2nd edition, Updated for Python 3, Shroff/O' Reilly Publishers, 2016 (http://greenteapress.com/wp/thinkpython/).
2	G. Van Rossum, F. L. Drake, An Introduction to Python – Revised and updated for Python 3.2, Network Theory Ltd., 2011.
3	C. Dierbach, Introduction to Computer Science using Python: A Computational Problem-Solving Focus, Wiley India Edition, 2013.
4	J. V Guttag, Introduction to Computation and Programming Using Python, Revised and expanded Edition, MIT Press , 2013.
5	K. A. Lambert, Fundamentals of Python: First Programs, CENGAGE Learning, 2012.
6	P. Gries, J. Campbell, J. Montojo, Practical Programming: An Introduction to Computer Science using Python 3, 2nd edition, Pragmatic Programmers,LLC,2013.
7	R. Sedgewick, K. Wayne, R. Dondero, Introduction to Programming in Python: An Inter-disciplinary Approach, Pearson India Education Services Pvt. Ltd., 2016.

VOCATIONAL COURSE – I: ANALYTICAL TECHNIQUES					
Designation: Basic Science					
Course Pre-requisites: Basic Chemistry					
Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Practical	: 04 Hours/Week	Term-work (TW)	: 25 Marks	TW/OR/PR	: 02
Total	: 04 Hours/Week	Practical/Oral	: 25 Marks	Total Credits	: 02
		Total	: 50 Marks		
Course Outcomes					
After completion of the course students will be able to					
1.	Analyse the samples using HPLC and define its content and concentration				
2.	Analyse the samples using GC and define its content and concentration				
3.	Analyse the samples using UV and FTIR, and define its content and concentration				
4.	Analyse the samples for carbon, fluoride ion content and define its flow properties				
5.	Analyse water and fuel samples for properties and composition				
6.	Analyse the samples for surface properties and particle size				
Topics Covered					
Analytical Method - I	**High Precision Liquid Chromatography** Analysis principle; Criteria of selection; Preparation of samples; Selection of eluent and detector; Selection of elution conditions; Standardization and calibration; Sample analysis: Qualitative and quantitative results				**(08 Hours)**
Analytical Method - II	**Gas Chromatography** Analysis principle; Criteria of selection; Preparation of samples; Selection of eluent and detector; Temperature programming; Elution conditions; Standardization and calibration; Sample analysis: Qualitative and quantitative results				**(08 Hours)**
Analytical Method - III	**Spectrographic analysis** Analysis principle and limitations of spectroscopic analysis ***UV-visspectrophotometry:*** Beart- Lamberts law; Preparation of samples; Dilutions; Standardization and calibration; Sample analysis: Qualitative and quantitative assessment ***Fourier Transfer Infrared Spectroscopy:*** Preparation of samples; KBr palate formation; Film analysis; Powder analysis; Interpretation of data: Sample analysis				**(08 Hours)**
Analytical Method - IV	**Carbon and Fluoride Ion analysis** Selection of methods for analysis; Preparation of samples; Standardization; Analysis and interpretation **Viscometry analysis** Redwood and plate and cone type viscometers: Measurement principle; Sample Analysis;				**(08 Hours)**
Analytical Method–	**Fuel Analysis:** Bomb calorimetry; Flash point analysis; Fire point analysis; Coal analysis: Ultimate and proximate analysis; Moisture content measurement				**(08 Hours)**

V	by Karl Fisher titration: Standardization and data analysis. **Water Analysis:** Concept of Biological oxygen demand (BOD), Chemical oxygen demand (COD), Total Organic Carbon (TOC) and heavy metal content analysis; Sample analysis	
Analytical Method - VI	**Surface and particle analysis:** ***Particle size analysis:*** Principle; Preparation of solution or dispersion; Sample analysis ***Atomic forced microscopic analysis:*** Principle; AFM analysis.	**(08 Hours)**
The analytical methods and their applications would be defined along with background information, principal and application determination, limitation and applications		
Text Books/ References:		
1	I. M. Kolthoff, J. D. Winefordner, M. M. Bursey: Treatise on Analytical Chemistry, Part 1 Vol. 11: Theory and Practice, 2nd Ed., Wiley and Sons, New York, 1989	
2	J. A. C. Broekaert: Analytical Atomic Spectrometry withFlames and Plasmas, Wiley-VCH Verlag GmbH & Co. KGaA, New York, 2002	
3	G. D. Christian, P. K. Dasgupta, K. A. Schug: Analytical Chemistry, John Wiley & Sons, Inc., Danvers, 2014	
4	D. Harvey: Modern Analytical Chemistry, McGraw-Hill Higher Education, Kingsport, 2000	
5	J. Mendham, A. Vogel: Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Addison Wesley Publishing Co., Boston, 2000	

Programme: B. Tech Chemical (2021)

Sem: IV (Chemical)

NUMERICAL METHODS FOR CHEMICAL ENGINEERING					
Designation: Professional Core					
Pre-requisites courses: Basic knowledge of mathematics including derivative, integration etc.					
Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 04 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 04 Hours/Week	Internal Assessment	: 40 Marks	Total Credits	: 04
		Total	: 100 Marks		
Course Outcomes					
After completion of the course students will be able to					
1	Estimate the true percent relative error for given problem				
2	Compute the roots of the equation using bracketing methods and open methods				
3	Solve Chemical Engineering problems using regression analysis				
4	Solve Chemical Engineering problems using numerical differentiation methods				
5	Evaluate the integral value using Trapezoidal rule, Simpson's $1/3^{rd}$ rule, Simpson's $3/8^{th}$ rule, and Romberg integration				
6	Apply finite difference methods to solve boundary value problems				
Topics covered					
UNIT-I	**Approximations and Error Analysis** Approximations; Significant figures; Accuracy and precision; Error definitions; Round off error; Truncation error; True percent relative error; Prespecified percent tolerance; Total numerical error; Error propagation; Error analysis of numerical differentiation; Root mean square error; Mean square error; Analysis of variance.			**(08Hours)**	
UNIT-II	**Engineering Applications: Roots of equations** Bracketing methods: Bisection method, False position method; Open methods: Secant method, Newton-Rapson method, Modified Newton-Rapson method; Roots of Polynomials: Mueller's method, Bairstow's method, Picard's method; Solve Chemical Engineering problems using above methods.			**(08 Hours)**	
UNIT-III	**Regression analysis and Interpolation** Regression analysis: Linear regression, Least square regression, Logistic regression, Polynomial regression, Nonlinear Regression, Curve fitting, Regression Vs Classification. Interpolation: Direct Method, Lagrange interpolating polynomials, Newton's Divided-Difference interpolating polynomials, Sterling's interpolation, Inverse			**(08 Hours)**	

	interpolation, Approximation of functions. Solve Chemical Engineering problems using above methods.	
UNIT-IV	**Engineering Applications: Differential Equations** Problems based on Process Calculation, Fluid Flow operation and Heat Transfer to be solved using following methods: Euler's method, Modified Euler's method, 2^{nd} order Runge-Kutta Method, 4^{th} order Runge-Kutta method; Picard's method of successive approximations; Taylor series method; Milne's predictor-corrector method; Richardson Extrapolation; Ordinary Differential Equation: Boundary Value Problems.	**(08 Hours)**
UNIT-V	**Numerical Integration** Solve Chemical Engineering problems using Newton- Cotes integration, Trapezoidal rule, Simpson's $1/3^{rd}$ rule, Simpson's $3/8^{th}$ rule, Romberg integration; Cauchy integral formula; Multiple application of Simpson's $1/3^{rd}$, $3/8^{th}$ rule, Trapezoidal rule.	**(08 Hours)**
UNIT-VI	**Finite Difference Methods** Introduction to finite difference method; Boundary value problems of exact differential equations up to second order; Hyperbolic equations; Finite difference approximations to derivatives; Elliptical Equation; Control Volume Approach; Heat Conduction Equation. Problems based on Process Calculation, Fluid Flow operation and Heat Transfer to be solved using these methods.	**(08 Hours)**

Assignments

There will be six (6) assignments from various units mentioned in the syllabus. Each assignment will carry 10 marks.

1.	Estimate the error and do the error analysis for any chemical Engineering based problem
2.	Find the roots of equations for the problems based on Fluid Mechanics, Heat Transfer
3.	Solve the equations from Heat Transfer, Fluid Mechanics, and Particulate Technology using numerical differentiation methods
4.	Estimate the integral value for the problems based on Heat Transfer, Fluid Mechanics, Chemical Engineering Thermodynamics, and Particulate Technology etc.
5.	Solve Chemical Engineering problems using regression analysis
6.	Solve the boundary value problems using finite difference methods
7.	Solve old (last five years) question papers with reference to particular topic
8.	Solve old (last five years) GATE paper questions of Numerical Methods for Chemical Engineering subject
9.	With suitable case study explain in detail how this subject is prerequisite for Process Modeling of chemical processes
10.	With the help of this subject knowledge, write a guideline report on how you would apply your concepts for industrial practice

Project Based Learning	
Students in a group of 3 to 4 shall complete any one project from the below list	
1.	Estimate the roots of polymeric equations for fluid flow operations, equations such as buoyancy of any ball, liquid level in manometer etc.
2.	Apply numerical differentiation techniques to solve the case studies of process heat transfer.
3.	Evaluate the integral value/area under the curve for given equations related to any unit operation/process.
4.	Apply finite difference method for boundary value problems of exact differential equations up to second order for specific chemical engineering system.
5.	Collect experimental data from open source literature and do the regression analysis.
6.	Apply Sterling's interpolation formula for the given experimental data and calculate the desired results.
7.	Analyze the given experimental data and apply the curve fitting techniques.
8.	Collect experimental data from open source literature, apply regression analysis for prediction and calculate root mean square error (RMSE).
9.	Using Euler's method solve the case study related to transient heat conduction.
10.	Apply the bracketing methods to find the root of equations of fluid flow systems.
Text Books/References	
1	S. C. Chapra and R.P. Canale, Numerical Methods for Engineers, 6th Ed., Tata-McGraw Hill Publications, 2015.
2	T. F. Edgar and D. M. Himmblblau, Optimization of Chemical Processes, 2nd Ed., Tata-McGraw Hill Publications, 2001.
3	M. K. Jain, S. R .K. Iyengar and R. K. Jain, Numerical methods for Scientific and Engineering Computational, 5th Ed., New Age International (P) Publishers, 2005.
4	S. S. Sastri , Introductory methods of Numerical analysis, 4th Ed., Prentice-Hall India, 2009.
5	S. Pushpavanam, Mathematical Methods for Chemical Engineering, 1st Ed., Prentice-Hall of India, 2012.
6	E. Balagurusamy, Numerical Methods, McGraw Hill Education (India) Private Limited, 2008.
Syllabus for Unit Tests	
Unit Test I	Units I, II, and III
Unit Test II	Units IV, V, and VI

CHEMICAL ENGINEERING THERMODYNAMICS II

Designation: Professional Core

Pre-requisite Courses: Basic knowledge of chemistry, physics and mathematics, Chemical engineering thermodynamics, Material and energy balance calculations

Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 04Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Tutorial	: 01Hours/Week	Internal Assessment	: 40 Marks	Tutorial	: 01
Total	: 05 Hours/Week	Total	: 100 Marks	Total Credits	: 05

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.	**(08 Hours)**
UNIT-II	**Thermodynamics of Non-ideal Gas Mixtures** 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.	**(08 Hours)**
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.	**(08 Hours)**
UNIT-IV	**Vapor-liquid equilibrium (VLE):** Criteria of vapour liquid equilibria and stability; Basic equation for vapor-liquid equilibrium(Raoult'slaw); 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;	**(08 Hours)**

	Thermodynamic consistency test for VLE data.	
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, Solid liquid equilibrium models and estimation of design parameters.	**(08 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.	**(08 Hours)**

Project Based Learning	
1.	Group discussions on any of the following topics:
2.	Importance of Phase equilibria in chemical industries.
3.	Solving numerical in connection with phase equilibria
4.	Solving numerical based on application of Roult's law for the calculation of dew point and bubble point
5.	Unsolved numerical from the reference books on various topics studied.
6.	Draw P-xy and T-xy diagrams.
7.	Solving numerical based on chemical reaction equilibrium.
8.	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.
9.	Students have to study any five NPTEL videos related to Chemical Engineering Thermodynamics I and prepare/present power point presentation.
10.	Solving numerical in connection with the solution thermodynamics
a)	Questions involving fugacity and activity for the species in solution.
b)	Thermodynamic properties for pure species and species in solution
11.	Preparation of a brief report on applicability of liquid-liquid equilibrium (LLE) in chemical engineering systems.
12.	Solve question papers of CET II of previous THREE years.

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.

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: Basic knowledge of 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	: 04 Hours/Week	Internal Assessment	: 40 Marks	TW/OR/PR	: 02
Total	: 07 Hours/Week	Term-work (TW)	: 25 Marks	Total Credits	: 05
		Practical/Oral	: 25 Marks		
		Total	: 150 Marks		

Course Outcomes

1	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 coefficient; Heat transfer area; Concept of hydraulic diameter; Pressure drop calculations: Design and working pressure.	**(08Hours)**
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.	**(08 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	**(08 Hours)**

	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.	
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.	**(08 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;	**(08 Hours)**
UNIT-VI	**Furnaces** 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.	**(08 Hours)**

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

CHEMICAL TECHNOLOGY

Designation: Professional Core

Pre-requisite Courses: Basic knowledge of chemistry

Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 03 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 03
Practical	: 04 Hours/Week	Internal Assessment	: 40 Marks	TW/OR/PR	: 02
Total	: 07 Hours/Week	Term-work (TW)	: 25 Marks	Total Credits	: 05
		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; Schematic representation and applications for unit operations and unit processes. **Chlor-alkali industry, sea chemicals** i) Chlor-alkali industry: Recent processes for the production of soda ash, NaOH and Chlorine ii) Sea chemicals: Sodium-Magnesium compounds, methods for salt recovery	**(06 Hours)**
UNIT-II	**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-III	**Oils, Fats, Soaps and Detergents** Extraction of oil from seeds, Oil purification, Hydrogenation of oil. Solvent extraction process; Biodiesel production Production of soap, natural glycerine, production of detergents.	**(06 Hours)**
UNIT-IV	**Sugar-Starch Industry and Fermentation industry** i) Sugar-Starch Industry: Production of Sugar, Starch Derivatives ii) Fermentation Industry: production of ethyl alcohol, citric acid and antibiotics.	**(06 Hours)**
UNIT-V	**Natural products** Terpenes, alkaloids, plant pigments, their applications, Methods for extraction, isolation, molecular separation and purification of biomolecules from natural sources.	**(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)**

***Project Based Learning**	
1	Development of working model of belt conveyor
2	Development of working model of bucket elevator
3	Prepare prototype of effluent treatment plant with different units like clarifier, bioreactor , pressure sand filter etc. (Activated sludge process: prototype working model)
4	Prepare prototype of any chemical process industry representing the all the unit operations
5	Prepare prototype of any chemical process industry representing the all the unit processes
6	Analyze Safety aspects in Chemical Process industry
7	Prepare working model of cooling tower
8	Prepare prototype of distillation column using packed column/rasching rings
9	Prepare prototype of dryer tray dryer or rotary dryer
10	Analyze Personal protective equipment used in chemical industry

*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	Determination of saponification value of oil sample.
2	Application of pH meter to find acidity and alkalinity of a solution.
3	To study the hydrolysis of cane sugar solution in the presence of an acid by Fehling‘s solution method and find out the reaction constant.
4	Determination of the strength of unknown hydrochloric acid by titrating it against caustic soda by conductometric method.
5	Preparation of laundry soap and to determine its yield.
6	Analysis of acid oils and soap stocks.
7	Analysis of Glycerine (sweet water).
8	Analysis of detergent powders.
9	Preparation of report on industrial visit.

Text Books/References

1	C.E.Dryden, Outlines of Chemical Technology” (Edited and Revised by M.GopalRao 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, 5thEd.Tata McGraw-Hill Edition, 2004.
4	W.L.Faith, D.B. Keyes, R.L. Clark, Industrial Chemicals, John Wiley, 1975.
5	Kirk and Othmer, Encyclopaedia of Chemical Technology, Wiley, 2005
6	G.N.Pandey and S.D.Shukla, Chemical Technology Vol – I,Vikas publication, 2004

Syllabus for Unit Tests

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

INDUSTRIAL POLLUTION AND ABATEMENT

Designation: Professional Core

Course Pre-requisites:

Before studying this subject the student should have knowledge of

1.	Basic fundamentals included in environmental sciences.
2.	Fundamentals of unit operation.

Teaching Scheme	**Examination Scheme**	**Credits allotted**
Lectures: 04Hours/Week	End Semester Examination : 60 Marks	Theory: 04
Practical: 02Hours/Week	Internal Assessment : 40 Marks	TW/PR/OR: 01
Total : 06 Hours/Week	Term-work (TW) : 25 Marks	Total Credits 05
	Practical/Oral : 25 Marks	
	Total : 150 Marks	

Course Outcomes:

1.	Identify and demonstrate the characterization of wastewater with statutory limits for disposal.
2.	To analyze the important parameters of the wastewater such as BOD, COD, DO, etc.
3.	Demonstrate the various physical unit operations used in the treatment.
4.	Define the various treatment methods available for wastewater and solid waste.
5.	Demonstrate the effect of various air pollutants on man and environment.
6.	Demonstrate the operations of various air pollution control equipments.

Topics covered

UNIT - I	**Introduction** Overview of pollution aspects in Chemical Process Industries (CPI); Types of pollution; Introduction to all prevailing international standards of Health, Safety, and Environment; Environmental laws and regulations; ISO 14000+; Environmental legislation; Air pollution control act; Indian standards for disposal of industrial effluents; Environmental impact assessment; Life cycle assessment.	**(08 Hours)**
UNIT -II	**Air pollution** Air pollutants: sources, classification of air pollutants, air quality, air pollution minimisation and control, source and control of fugitive emissions, Effects of air pollutants, Measurement of air pollutants; Air pollution control: Particulate emission control by mechanical separation and electrostatic precipitation, wet gas scrubbing, gaseous emission control by absorption and adsorption, Design of cyclones, ESP, fabric filters and absorbers.	**(08 Hours)**
UNIT - III	**Water pollution and its control** Groundwater and surface water pollution: types, sources and effects of water pollutants; Physical treatment: solids removal by setting and sedimentation, filtration centrifugation, coagulation and flocculation; Biological Treatment: Anaerobic and aerobic treatment, biochemical kinetics, trickling filter, activated sludge and lagoons, aeration systems, sludge separation and drying; Assessment of water quality through the measurement of: Dissolved oxygen, biological oxygen demand and chemical oxygen demand.	**(08 Hours)**
UNIT IV	**Advanced treatment methods** Advanced oxidation processes viz. Ozonation, Fenton's and photo-Fenton process, electrochemical process, photocatalysis, ultrasound and hydrodynamic cavitation etc. for the treatment of recalcitrant organics and inorganics/metals;	**(08 Hours)**

	Hybrid treatment processes; recent advanced in treatment methods.	
UNIT- V	**Solid waste management** Analysis and quantification of hazardous and non-hazardous wastes; Treatment and disposal of solid wastes; Land filling; Leachate treatment; briquetting / gasification and Incineration.	**(08 Hours)**
UNIT - VI	**Industrial case studies** Concept of zero discharge system; Application of advanced treatment methods for water reclamation and reuse; Study of minimum two case studies for treatment of industrial waste: pesticide industry, textile industry, pharmaceutical industry etc.	**(08 Hours)**
Expert Interaction	Lecture(s) by eminent scholar(s) on the topic(s) mentioned in the syllabus.	**(02 Hours)**

Project based learning	
1	Visit to any waste water treatment plant and specify the advanced in the treatment methods
2	Conduct the survey of air quality in Pune city
3	Write a report on concept of zero discharge and its significance
4	Enlist Indian standards for disposal of industrial effluents.
5	Prepare power point presentation on recent advances in waste water treatment
6	Group discussion on health hazards of air and water pollution.
7	Design a novel method for effective solid waste management.
8	Demonstrate the applications of biological processes in waste water treatment.
9	Design the activated sludge process for any particular industrial effluent.
10	Enlist the characteristics of industrial effluent.
11	Prepare the report on primary, secondary and tertiary treatment methods used in industries
12	Visit a pesticide manufacturing industry and prepare a case study for treatment of pesticide industry effluent
13	Prepare a technical report on the effective treatment of pharmaceutical waste.
14	Visit to nearby municipal water treatment plant.
List of Practical:	
1.	Determination of pH, color, and turbidity of a given waste water sample.
2.	Inorganic characterization of waste water sample.
3.	Measurement of D. O. of waste water sample.
4.	Measurement of C. O. D. of waste water sample.
5.	Estimation of B. O. D. of waste water sample.
6.	Study of flocculation technique for a given waste water sample.
7.	Study of froth flotation technique for a given waste water sample.
8.	Study of sedimentation method for the treatment of waste water.
9.	Characterization of dairy waste- A report.
10	Characterization of domestic sewage - A report.
Text Books/References:	
1.	Theodore L &Bhomlore A.J. "Air Pollution Control Equipments."
2.	Coulson J. M. Richerdson J.F. Vol.6.Tata McGraw-Hill.

3.	Rao M.N. & H.V.N. Rao. "Air Pollution McGraw-Hill.
4.	S.P. Mahajan "Pollution Controls in process industries." Tata McGraw-Hill.
5.	C.S.Rao, "Environmental Pollution control Engg." Willey Estern Ltd.
6.	Noel de Nevers, "Air Pollution control Engg." McGraw-Hill, Inc, Publication.

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

MATLAB PROGRAMMING			
Designation: Professional Core			
Pre-requisite Courses: Computer fundamentals			
Teaching Scheme		**Examination Scheme**	**Credits Allotted**
Practical : 04 Hours/Week		TW : 50 Marks	TW/OR/PR : 02
		Practical/Oral : 50 Marks	Total Credits : 02
		Total : 100 Marks	
Course Outcomes:			
After completion of the course students would be able to:			
1	Develop a basic programme applying MATLAB syntax.		
2	Design programs involving matrix and publish report.		
3	Develop programs involving loops.		
4	Apply MATLAB to solve mathematical problems.		
5	Design a program to evaluate Thermodynamics, Process calculation problems.		
6	Design a program to evaluate Heat transfer and Fluid flow problems.		
Topics Covered			
UNIT-I	**Getting started with MATLAB** Features of MATLAB window: Command window, current directory pane, workspace, command history window, figure window, editor window, data type, file type; Performing operations: Arithmetic operators, create arrays and vectors, working with arrays of number; File creation: creating, saving and executing a script file and function file.Creating and printing simple plots. 1. Programs based on Fundamentals in MATLAB Programming.		
UNIT-II	**Creating files** Programs using Arrays and Matrices; working with anonymous function; symbolic computation; importing and exporting data; publishing reports. 2. Programs based on Matrix calculations. 3. Programs based on function creation and evaluation. 4. Programs based on publishing report.		
UNIT-III	**Programming** Creating a script file; creating function file; programs using while, if and for loop. 5. Programs for script and function file. 6. Programs based on loops. 7. Combined program of script file with function and loops.		
UNIT-IV	**Applications to Numerical Methods** Programs to solve linear and Nonlinear equations; Curve fitting and interpolation; Numerical Integration; Partial and Ordinary differential equation. 8. Program to solve set of linear equations. 9. Program to solve set of non- linear equations. 10. Program based on curve fitting and interpolation. 11. Program based on partial/ ordinary differential equations.		
UNIT-V	**Application to Chemical Engineering** Applications of MATLAB to solve Thermodynamics, physical property estimation and process calculation problems. 12. Vapor pressure estimation of a given component. 13. Estimating bubble point/dew point for a given mixture**.**		

	14**.** Estimating physical properties of components like humidity, density, viscosity etc.
UNIT-VI	**Application to Chemical Engineering** Applications of MATLAB to solve Heat Transfer and Fluid Mechanics problems. 15.Program based on flow in horizontal pipe (average velocity calculation). 16. Program for estimating pipe diameter/ power requirement. 17. Program for estimating LMTD 18. Estimating heat transfer coefficient for shell and tube heat exchanger.
In addition to these above stated programs/practical's concern faculty member may design his/her own programs / practical's.	
Term Work	
Term work will consist of the programs/practical listed above, out of which any eight programs/practical's are to be performed in laboratory by the students.	
Text Books/References:	
1	Yeong K. Y. , Chemical Engineering Computation with MATLAB, Taylor and Francis Group, CRC Press, Newyork, 2017.
2	Rudra P., Getting Started with MATLAB: A quick introduction for scientist and engineers, Oxford University Press. Reprint India 2011.
3	Gilat A., MATLAB –An introduction with Application, Wiley, India 2012.
4	Jain S. and Kaphse S., Modeling and Simulation using MATLAB Wiley, India 2016.

VOCATIONAL COURSE II: INDUSTRIAL HEATING SYSTEMS

Designation: Skill Development

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

Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Practical : 04 Hours/Week	Term-work (TW) : 25 Marks	TW/OR/PR : 02
Total : 04 Hours/Week	Practical/Oral : 25 Marks	Total Credits : 02
	Total : 50 Marks	

Term Work

Term work will consist of the practicalsbased 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)