## M.TECH. CHEMICAL ENGINEERING
### I TO IV SEMESTERS CURRICULA AND SYLLABUS

#### SEMESTER I

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*Audit course is optional

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# LIST OF PROFESSIONAL ELECTIVE COURSES

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AUDIT COURSES

REGISTRATION FOR ANY OF THESE COURSES IS OPTIONAL TO STUDENTS

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COURSE OBJECTIVES:

- To study various numerical techniques to solve linear and non-linear algebraic and transcendental equations.
- To compare ordinary differential equations by finite difference and collocation methods.
- To establish finite difference methods to solve Parabolic and hyperbolic equations.
- To establish finite difference method to solve elliptic partial differential equations.
- To provide basic knowledge in finite elements method in solving partial differential equations.

UNIT I ALGEBRAIC EQUATIONS


UNIT II ORDINARY DIFFERENTIAL EQUATIONS


UNIT III FINITE DIFFERENCE METHOD FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATIONS


UNIT IV FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS

Laplace and Poisson’s equations in a rectangular region: Five point finite difference schemes, Leibmann’s iterative methods, Dirichlet's and Neumann conditions – Laplace equation in polar coordinates: Finite difference schemes – Approximation of derivatives near a curved boundary using a square mesh.

UNIT V FINITE ELEMENT METHOD


TOTAL: 60 PERIODS

COURSE OUTCOMES:

After completing this course, students should demonstrate competency in the following skills:

- Solve an algebraic or transcendental equation, linear system of equations and differential equations using an appropriate numerical method.
- Solving the initial boundary value problems and boundary value problems using finite difference and finite element methods.
- Solving parabolic and hyperbolic partial differential equations by finite difference methods.
- Compute solution of elliptic partial differential equations by finite difference methods.
- Selection of appropriate numerical methods to solve various types of problems in engineering and science in consideration with the minimum number of mathematical operations involved, accuracy requirements and available computational resources.
REFERENCES:

CX4101 ADVANCED SEPARATION PROCESS L T P C 3 0 0 3

COURSE OBJECTIVES:
- To learn about the different separation processes available.
- To make the students understand the fundamental concepts behind the various separation processes.

UNIT I GENERAL
Review of conventional processes, recent advances in separation techniques based on size, surface properties, ionic properties and other special characteristics of substances. Process concept, theory and equipment used in cross flow filtration, cross flow electrofiltration, dual functional filter, surface based solid-liquid separations involving a second liquid, sirofloc filter.

UNIT II MEMBRANE SEPARATIONS
Types and choice of membranes, plate and frame, tubular, spiral wound and hollow fibre. Membrane reactors and their relative merits, commercial, pilot plant and laboratory membrane pemeators involving dialysis, reverse osmosis, nano-filtration, ultrafiltration, microfiltration and Donnan dialysis, economics of membrane operations, ceramic membranes.

UNIT III SEPARATION BY ADSORPTION TECHNIQUES
Mechanism, types and choice of adsorbents, normal adsorption techniques, affinity chromatography and immuno chromatography, types of equipment and commercial processes, recent advances and process economics dielectrophoresis, Ion Exchange chromatography and electrodialysis, Commercial processes.

UNIT IV IONIC SEPARATION
Controlling factors, applications, types of equipment employed for electrophoresis, di-electrophoresis, Ion exchange chromatography and electrodialysis, commercial process

UNIT V OTHER TECHNIQUES
Separations involving lyophilization, pervaporation and permeation techniques for solids, liquids and gases, industrial viability and examples, zone melting, addictive crystallization, other separation processes, supercritical fluid extraction, oils pill management, industrial effluent treatment by modern techniques.

TOTAL: 45 PERIODS

COURSE OUTCOMES:
- The students will understand the importance of separation processes and its applications.
- The students will be in a position to select the best separation process for a given problem.
REFERENCES:

CX4102 FLUID PHASE EQUILIBRIA L T P C
3 0 0 3

COURSE OBJECTIVES:
- To impart knowledge on equilibrium and transport properties of fluids, solids, and interfaces, physical/phase and chemical equilibria; fundamental thermodynamic relations; and stability.

UNIT I BASIC CONCEPTS
Energy and first Law; Reversibility and second Law; Review of Basic Postulates, Equilibrium criteria, Legendre Transformation and Maxwell’s relations

UNIT II STABILITY AND PHASE TRANSITION
Stability of thermodynamic systems, first order phase transitions and critical phenomenon, phase rule, single component phase diagrams, thermodynamic properties from volumetric and thermal data

UNIT III MULTICOMPONENT MIXTURES
Partial molar properties, fugacities in gas and liquid mixtures, activity coefficients, Ideal and Non-ideal solutions, Gibbs-Duhem equation, Wilson, NRTL, and UNIQUAC equations, UNIFAC method

UNIT IV PHASE EQUILIBRIUM
VLE - Equations of state, corresponding states, Henry’s Law, lattice theory, criticality, high pressure VLE. Other phase equilibriums - SLE/LLE/VLLE.

UNIT V CHEMICAL EQUILIBRIUM
Homogeneous gas and liquid phase reactions, heterogeneous reactions – phase and chemical equilibrium

TOTAL: 45 PERIODS

COURSE OUTCOME:
- Students would have gained knowledge on equilibrium and non equilibrium thermo physical properties of fluids, solids and interfaces.

REFERENCES
2. Rao, Y. V. C., Chemical Engineering Thermodynamics, University Press, Hyderabad, 2005
COURSE OBJECTIVE:
- To impart knowledge on different types of chemical reactors, the design of chemical reactors under isothermal and non-isothermal conditions

UNIT I CATALYST AND ITS CHARACTERIZATION 12
General definition of catalysts, Design for catalysts — Primary constituents, secondary constituents; Catalyst supports. Methods of determining catalysts activity — static methods, Study of structure pore radii; Mercury porosimetry, determination of true and apparent densities of catalysts; Structural study of electron microscopy, determination of mechanical strength of catalysts-static methods, dynamic methods; Methods of thermal analysis.

UNIT II KINETICS OF HETEROGENEOUS CATALYTIC REACTIONS 10

UNIT III TRANSPORT PROCESSES WITH REACTIONS CATALYZED BY SOLIDS 12

UNIT IV CATALYST DEACTIVATION 10

UNIT V THE MODELING OF CHEMICAL REACTORS. 16

TOTAL : 60 PERIODS

COURSE OUTCOME:
- Students would have gained knowledge on the selection of the reactor for the reaction and its design

REFERENCES:
UNIT I  RESEARCH DESIGN  
Overview of research process and design, Use of Secondary and exploratory data to answer the research question, Qualitative research, Observation studies, Experiments and Surveys.

UNIT II  DATA COLLECTION AND SOURCES  
Measurements, Measurement Scales, Questionnaires and Instruments, Sampling and methods. Data - Preparing, Exploring, examining and displaying.

UNIT III  DATA ANALYSIS AND REPORTING  
Overview of Multivariate analysis, Hypotheses testing and Measures of Association. Presenting Insights and findings using written reports and oral presentation.

UNIT IV  INTELLECTUAL PROPERTY RIGHTS  

UNIT V  PATENTS  

REFERENCES

TOTAL : 30 PERIODS

CX4111  COMPUTATIONAL PROGRAMMING LABORATORY FOR CHEMICAL ENGINEERS  
COURSE OBJECTIVE: To give the students an understanding the fundamentals concepts in mathematics, problems solving and computer programming.

SUGGESTED EXERCISES
1. Equations of state using Newton’s method
2. Regression for parameter estimation using a set of data points
3. Equilibrium flash distillation(Multicomponent Ideal)
4. Batch Reactor
5. CSTR in Series Stagewise contacting equipment
6. Solving a simple flow sheet by simultaneous approach
7. Simulation of batch Distillation (binary ideal).
8. Gravity Flow Tank
9. Heat Exchanger
10. Plug Flow Reactor
11. Absorber

Specific examples in ASPEN/HYSYS/MATLAB/EXCEL
1. Solving equation of state, regression of parameters using EXCEL/MATLAB
2. Calculation of Reynolds number, friction factor and pressure drop using EXCEL/MATLAB
3. Calculation of heat transfer coefficient in a Heat Exchanger using EXCEL/MATLAB
4. Calculation of minimum reflux ratio for binary/tertiary system in a fractionators using EXCEL/MATLAB

EXCEL/ MATLAB
5. Calculation of HTU and NTU in a Absorber using EXCEL/MATLAB
6. Calculation of Antoine’s coefficient using EXCEL/MATLAB
7. Estimation of settling velocity of solids in liquid using Stoke’s law using EXCEL/MATLAB
8. Calculation of minimum number of stages in a distillation column using EXCEL/MATLAB
9. Solving mass and energy balance problems using EXCEL/MATLAB
10. Calculation of Power in Reciprocating compressor using EXCEL/MATLAB
11. Steady state simulation of Heat Exchanger using ASPENPLUS/ HYSYS
12. Steady state simulation of a CSTR using ASPENPLUS/HYSYS
13. Steady state simulation of Flash vessel using ASPEN PLUS/HYSYS
14. Steady state simulation of Distillation Column using ASPENPLUS/HYSYS
15. Steady state simulation of an Absorption column using ASPENPLUS/HYSYS
17. Dynamic simulation of a CSTR using ASPENPLUS/HYSYS
18. Dynamic simulation of Flash vessel using ASPENPLUS/HYSYS
19. Dynamic simulation of Distillation Column using ASPENPLUS/HYSYS
20. Dynamic simulation of an Absorption column using ASPENPLUS/HYSYS
21. Developing Heat and Mass balance diagram using ASPEN PLUS/ HYSYS

LIST OF EQUIPMENTS FOR A BATCH OF 18 STUDENTS:
- Standalone desktops/server with respective simulation softwares 18 Nos.
- Softwares
- MATLAB Single user license
- Open source office
- Open source chemical engineering simulation software.

COURSE OUTCOME:
- Students will be equipped with the software applications and the numerical solutions of chemical engineering problems. Minimum 10 experiments to be offered

REFERENCES:
UNITI  INTRODUCTION  12
The Hierarchy of Chemical process Design- Overall process Design, approaches to design.

UNITII  CHOICE OF REACTORS AND SEPARATOR  12
Reaction path, reactor performance, practical reactors, Separation of Heterogeneous mixtures, homogeneous fluid mixtures.

UNITIII  SYNTHESIS OF REACTION – SEPARATION SYSTEMS  12
Process recycle, Batch processes, process yield

UNITIV  DISTILLATION SEQUENCING  12
Using simple columns, using columns with more than two products, Distillation Sequencing Using thermal coupling.

UNITV  HEAT EXCHANGER NETWORK & UTILITIES – ENERGY TARGETS  12
Heat recovery pinch, The Problem table Algorithm, Utilities Selection, Energy targets capital& total Cost targets - Number of Heat Exchanger Units, Area Targets, Number of Shells Targets, Capital Cost Targets, Total Cost Targets.

REFERENCES

UNITI  BASIC CONCEPTS  12
Phenomenological Equations and Transport properties, Rheological behavior of fluids, Balance Equations – Differential and Integral equations.

UNITII  APPLICATIONS OF DIFFERENTIAL EQUATIONS OF CHANGE  12
Applications in laminar and turbulent transport in compressible and incompressible fluids. Boundary layer theory.

UNITIII  APPLICATIONS OF INTEGRAL EQUATIONS OF CHANGE  12
Macroscopic balance for isothermal and non isothermal systems and their applications in Momentum, Heat and Mass transport problems.

UNITIV  INTERPHASE AND MULTIPHASE MOMENTUM TRANSFER  12

UNITV  INTERPHASE TRANSPORT IN NON-ISOTHERMAL SYSTEMS  12
Heat Transfer coefficient, Forced convection in tubes, around submerged objects, Heat Transfer by
free convection, film type and drop wise condensation and equations for heat transfer, Heat transfer in boiling liquids. Mass Transfer co-efficient in single and multiple phases at low and high mass transfer rates, Film theory, Penetration theory, Boundary layer theory, Macroscopic balance to solve steady and Unsteady state problems.

REFERENCES

TOTAL: 60 PERIODS

CX4203 ADVANCED PROCESS CONTROL L T P C 3 1 0 4

UNIT I ADVANCED CONTROL STRATEGIES 12
Feed forward, cascade, dead time compensation, split range, selective and override control; automatic tuning and gain scheduling

UNIT II INTERNAL MODEL CONTROL 12
Model based control – IMC structure – development and design; IMC based PID control, MPC

UNIT III MULTIVARIABLE CONTROL 12
Control loop interaction – general pairing problem, relative gain array and application, sensitivity. Multivariable control – zeros and performance limitations, directional sensitivity and operability, decoupling

UNIT IV DISCRETE SYSTEMS 12

UNIT V DIGITAL FEEDBACK CONTROLLERS 12
Design of digital feedback controllers, digital approximation of classical, effect of sampling, Case study of Industrial Instrumentation and Control system, DCS, PLC, shutdown system.

TOTAL: 60 PERIODS

REFERENCES
UNIT I THERMODYNAMIC PRINCIPLES 12

UNITII THERMODYNAMIC PROPERTY EVALUATION 12
Fundamental principles involved in the separation of multi component mixtures – Determination of bubble-point and Dew Point Temperatures for multi component mixtures – equilibrium flash distillation calculations for multi component mixtures – separation of multi component mixtures at total reflux.

UNITIII MINIMUM REFLUX RATIO FOR MCD SYSTEM 12

UNITIV VARIOUS METHODS OF MCD COLUMN DESIGN 12
Theta method of convergence – Kb method and the constant composition method -Application of the Theta method to complex columns and to system of columns – Lewis Matheson method – Stage and reflux requirements – Short cut methods and Simplified graphical procedures.

UNITV VARIOUS TYPES OF MCD COLUMNS 12
Design of sieve, bubble cap, valve trays and structured packing columns for multi component distillation – computation of plate efficiencies.

TOTAL : 60 PERIODS

REFERENCES

CX4211 SEPARATION TECHNIQUES LABORATORY L T P C 0 0 4 2

List of Experiments:
1. Determination of VLE for a binary mixture at different temperatures
2. Determination of VLE & VLLE for a ternary mixture (azeotropic binary mixture and entrainer)
3. LLE of Extraction system of Type I, II and Type III systems
4. Study of extraction efficiency for the extraction of essential oils
5. Aqueous Two Phase Extraction and Design of ATPE using Hofmeister Series
6. Cross flow filtration using Microfiltration to characterize Specific cake resistance and filter medium resistance of membranes
7. Tangential flow filtration using Ultrafiltration for finding flux in membranes and to characterize
concentration polarization and fouling
8. Verification of Van't Hoff Equation and design of reverse osmosis systems
9. Adsorption Equilibria and fixed bed adsorption studies for generation of breakthrough curves
10. Gas Hold up studies in sparged column, bubble column, wetted wall column
11. Determination of mass transfer coefficient in a wetted wall column
12. Preparative HPLC
13. Thin Layer and paper chromatography
14. Calculation of yield in crystallization process
15. Simulation of refinery operations (catalytic cracking, hydrocracking) using ASPENHYSYS

TOTAL: 60 PERIODS

REFERENCES

CX4212 SEMINAR

COURSE OBJECTIVES:
- To provide exposure to the recent developments.
- To improve the students presentation skills.
- To make the students to come out of stage fear

Students are expected to present a seminar along with report on any technical topic

COURSE OUTCOMES:
The students will have the
CO1: Ability to communicate well
CO2: Ability to review, prepare and present technological developments
CO3: Ability to face the placement interviews

CX4301 PROCESS MODELING AND SIMULATION

UNIT I INTRODUCTION
Introduction to modeling and simulation, classification of mathematical models, conservation equations and auxiliary relations.

UNIT II STEADY STATE LUMPED SYSTEMS
Degree of freedom analysis, single and network of process units, systems yielding linear and non-linear algebraic equations, flowsheeting – sequential modular and equation oriented approach, tearing, partitioning and precedence ordering, solution of linear and non-linear algebraic equations.

UNIT III UNSTEADY STATE LUMPED SYSTEMS
Analysis of liquid level tank, gravity flow tank, jacketed stirred tank heater, reactors, flash and distillation column, solution of ODE initial value problems, matrix differential equations, simulation of closed loop systems.
UNIT IV  STEADY STATE DISTRIBUTED SYSTEM  12
Analysis of compressible flow, heat exchanger, packed columns, plug flow reactor, solution of ODE boundary value problems.

UNIT V  UNSTEADY STATE DISTRIBUTED SYSTEM  12

TOTAL : 60 PERIODS

REFERENCES

CX4311  PROJECT WORK I  L T P C  0 0 12 6

OBJECTIVES:
The course aims to enable the students to
- identify the problem/process relevant to their field of interest that can be carried out
- search databases and journals to collect and analyze relevant data
- plan, learn and perform experiments to find the solution
- prepare project report

TOTAL : 180 PERIODS

Individual students will identify a problem relevant to his/her field of study, collect and analyze literature, design, and carryout experiment, collect data, interpret the result and prepare the project report.

OUTCOMES:
At the end of the course the students will be able to
CO1  Identify the research/industrial problems
CO2  Collect and analyze the relevant literature
CO3  Design, conduct experiment and analyse the data
CO4  Prepare project report

CX4312  INTERNSHIP  L T P C  0 0 0 1

Students shall undergo training in R&D institutions / Academics / Industries for a minimum period of 15 days. At the end of internship students must submit a report for internal evaluation.
The course aims to

- train students to analyze the problem/think innovatively to develop new methods/product/process
- make them understand how to find solutions/create products economically and in an environmentally sustainable way
- enable them to acquire technical and experimental skills to conduct experiment, analyze the results and prepare project report
- enable them to effectively think about strategies to commercialize the product.

TOTAL : 360 PERIODS

Individual students will identify a problem relevant to his/her field of study, collect and analyze literature, design, and carryout experiment, collect data, interpret the result and prepare the project report.

**COURSE OUTCOMES**

At the end of the project the student will be able to

CO1 Formulate and analyze problems for developing new methods/solutions/processes

CO2 Plan and conduct experiments to find solutions in a logical manner

CO3 Analyze the results, interpret and prepare project report/know the strategies for commercialization

**CX4001 MULTIPHASE FLOW**

**UNIT I CHARACTERISTICS OF MULTIPHASE FLOWS**

Significance of multiphase flows, important non-dimensional numbers, parameters of characterization, particle size measurement, size distribution and moments, size distribution models

**UNIT II PARTICLE FLUID INTERACTION**


**UNIT III MODELING OF MULTI-PHASE FLOWS**

Flow patterns - identification and classification - flow pattern maps and transition – momentum and energy balance - homogeneous and separated flow models - correlations for use with homogeneous and separated flow models - void fraction and slip ratio correlations - influence of pressure gradient - empirical treatment of two phase flow - drift flux model - correlations for bubble, slug and annular flows

**UNIT IV CONSERVATION EQUATIONS**

Averaging procedures - time, volume, and ensemble averaging, quasi-one-dimensional flow, two-fluid volume-averaged equations of motion, turbulence and two-way coupling

**UNIT V MULTI-PHASE SYSTEMS**

Flow regime and hydrodynamic characteristics of packed bed, fluidized bed, pneumatic conveying, bubble column, trickle beds; Conventional and novel measurement techniques for multi phase systems including CARPT, Laser Doppler anemometry, Particle Image Velocimetry.

TOTAL : 45 PERIODS
REFERENCES

CX4002 ENVIRONMENTAL RISK ASSESSMENT

UNIT I RISK ANALYSIS
Risk analysis introduction, quantitative risk assessment, rapid risk analysis – comprehensive risk analysis—identification, evaluation and control of risk

UNIT II RISK ASSESSMENT
Risk assessment – introduction and available methodologies, Risk assessment steps, Hazard identification, Hazard assessment (consequence analysis), probabilistic hazard assessment (Fault tree analysis)

UNIT III EMERGENCY PLANNING
Overall risk contours for different failure scenarios – disaster management plan – emergency planning – onsite and offsite emergency planning, risk management ISO 14000, EMS models – case studies–marketing terminal gas processing complex.

UNIT IV HAZARD MODELS
Safety measures design in process operations. Accidents modeling– release modeling, toxic release and dispersion modeling, fire and explosion modeling.

UNIT V POLICIES FOR MITIGATION
Past accident analysis: Flux borough – Mexico – Bhopal analysis. Government policies to manage environmental risk

TOTAL : 45 PERIODS

REFERENCES
UNIT I  CONCEPTS AND TERMINOLOGY  5
Review of hypothesis testing – P Value, –tIVs paired—tII test, simple comparative experiment, planning of experiment – steps, Terminology - factors, levels, variables, Design principles – replication, randomization, blocking, confounding, Analysis of variance, sum of squares, degrees of freedom.

UNIT II  SINGLE FACTOR EXPERIMENTS  10
Completely randomized design, Randomized block design, effect of coding the observations, Latin Square design, orthogonal contrasts, comparison of treatment means – Duncan’s multiple range test, Newman-Keuel’s test, Fisher’s LSD test, Tukey’s test.

UNIT III  FACTORIAL EXPERIMENTS  10
Main and interaction effects, Rules for sum of squares and expected mean square, two and three factor full factorial design, 2k designs with two and three factors, Yate’s algorithm, practical applications

UNIT IV  SPECIAL EXPERIMENTAL DESIGNS  10
Blocking and confounding in 2k design, nested design, split – plot design, two level fractional factorial design, fitting regression models, introduction to response surface methods- Central composite design.

UNIT V  TAGUCHI TECHNIQUES  10
Introduction, Orthogonal designs, data analysis using ANOVA and response graph, parameter design – noise factors, objective functions (S/N ratios), multi-level factor OA designs, applications

TOTAL : 45 PERIODS

REFERENCES
2. Douguls C. Montgomery, Design and Analysis of Experiments, John Wiley & Sons, 2005
4. George W Cobb., - Introduction to Design and Analysis of Experiments, Wiley India Exclusive (CBS), 2015
5. Panneerselvam R., - Design and Analysis of Experiments, PHI Learning, 2012

CX4004  ELECTRO CHEMICAL PROCESS  L T P C  3 0 0 3

UNIT I  INTRODUCTION OF ELECTROCHEMICAL PROCESS  9
Industrial importance of electrolytic processes, Basic concepts and definitions, Criteria for reactor performance, Electrochemical and catalytic reactions and reactors - Fundamentals of reaction kinetics, rate of electrochemical reaction, electrochemical thermodynamics, practical cell voltage requirements and polarization, single electrochemical reactions, potentiostatic operations of first order reaction and galvanostatic operation of first order reactions.

UNIT II  ASPECTS OF MASS AND HEAT TRANSFER IN ELECTROLYTIC CELL SYSTEMS  9
Basic aspects of fluid dynamics, mass transfer-mass flux in a fully developed turbulent regime,entranceandexiteffects,obtainingnumericalvaluesofmasstransfercoefficientbycalculationand experiment, mass transfer in two phase flow, energetic and energy balances, CSTR with general order reactions, effect of mass transport and side reaction.
UNIT III RATE PROCESSES AND REACTION MODELS 9
Rate processes, kinetics of elementary reactions, reaction mechanism and rate laws, transition state theory, derivation of kinetic relationships, reaction models.

UNIT IV REACTOR MODELS 9
General considerations, batch reactor and continuous reactor - Fed batch, continuous, cell recycle, plug flow reactor, two stage reactors, Reactor dynamics and stability - Reactors with non-ideal mixing. Other types of reactors-fluidized bed reactors; packed bed reactors, bubble column reactors, trickle bed reactors.

UNIT V ELECTROLYTIC REACTOR DESIGN, SELECTION AND SCALE-UP 9
Electrolytic reactor designs, Electrolytic reactor selection, scale up of electrolytic reactors, effect of scale up on mass transfer, effect of scale up on current distribution, multiple electrode models and time factors.

TOTAL : 45 PERIODS

REFERENCES:
5. Hartmut Wendt, Gerhard Kreysa, Electrochemical engineering, Science and technology in chemical and other industries, Springer, 1999

CX4005 FLUIDIZATION ENGINEERING L T P C 3 0 0 3

UNIT I INTRODUCTION 5
The Fluidized state, Nature of hydrodynamic suspension, particle forces, species of Fluidization, Regimization of the fluidized state, operating models for fluidization systems, Applications of fluidization systems

UNIT II HYDRODYNAMICS OF FLUIDIZATION SYSTEMS 12

UNIT III SOLID MIXING AND SEGREGATION 8
Phase juxta positions operation shifts, Reversal points, Degree of segregation, Mixing Segregation equilibrium, Generalised fluidization of poly disperse systems, liquid phase mixing and gas phase mixing.

UNIT IV HEAT AND MASS TRANSFER IN FLUIDIZATION SYSTEMS 12
Mass transfer – Gas Liquid mass transfer, Liquid Solid mass transfer and wall to bed mass transfer, Heat transfer – column wall – to – bed heat transfer, Immersed vertical cylinder to bed heat transfer, Immersed horizontal cylinder to bed heat transfer.

UNIT V MISCELLANEOUS SYSTEMS 8
Conical Fluidized bed, Moving bed, Slurry bubble columns, Turbulent bed contactor, Two phase
and Three phase inverse fluidized bed, Draft tube systems, Semi fluidized bed systems, Annular systems, Typical applications, Geldart’s classification for powder assessment, Powder characterization and modeling by bed collapsing.

REFERENCES


CX4006 ENERGY MANAGEMENT L T P C
3 0 0 3

UNIT I INTRODUCTION
Energy sources; coal, oil, natural gas; nuclear energy; hydroelectricity, other fossil fuels; geothermal; supply and demand; depletion of resources; need for conservation; uncertainties; national and international issues

UNIT II ENERGY DEMAND FORECAST
Forecasting techniques, energy demand, magnitude and pattern, input and output analysis, energy modeling and optimal mix of energy sources - Energy - various forms, energy storage, structural properties of environment.

UNIT III ENERGY CONSUMPTION
Bio-geo-chemical cycles; society and environment population and technology, Energy and evolution, growth and change, patterns of consumption in developing and advances countries, commercial generation of power requirements and benefit.

UNIT IV ENERGY CONSERVATION IN PROCESS INDUSTRIES
Chemical industries, classification, conservation in unit operation such as separation, cooling tower, drying, conservation applied to refineries, petrochemical, fertilizers, cement, pulp and paper, food industries, chloroalkali industries, conservation using optimization techniques.

UNIT V ALTERNATE ENERGY SOURCES
Sources of continuous power, wind and water, geothermal, tidal and solar power, MHD, fuel cells, hydrogen as fuel, Cost analysis, capacity; production rate, system rate, system cost analysis, corporate models, production analysis and production using fuel inventories, input-output analysis, economics, tariffs. Energy audit

TOTAL : 45 PERIODS

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**UNIT I**  
**PRINCIPLES OF SIMILARITY, PILOT PLANTS & MODELS**  
Introduction to scale-up methods, pilot plants, models and principles of similarity

**UNIT II**  
**DIMENSIONAL ANALYSIS AND SCALE-UP CRITERION**  
Dimensional analysis, regime concept, similarity criterion and scale up methods used in chemical engineering

**UNIT III**  
**SCALE-UP OF HEAT TRANSFER EQUIPMENT**  
Typical problems in scale-up of mixing equipment and heat transfer equipment

**UNIT IV**  
**SCALE-UP OF MASS TRANSFER EQUIPMENT**  
Scale-up of distillation columns and packed towers for continuous and batch processes

**UNIT V**  
**SCALE-UP OF CHEMICAL REACTORS**  
Kinetics, reactor development & scale – up techniques for chemical reactors

**TOTAL : 45 PERIODS**

**REFERENCES:**
3. Marko Zlokarnik, Dimensional Analysis and Scale up in Chemical Engg., Springer Verlag, Berlin, Germany, 1986

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**UNIT I**  
**INTRODUCTION**  
Overview of fuel cells: materials for fuel cells; Low and high temperature fuel cells; Fuel cell thermo dynamics- heat, work potentials ,prediction of reversible voltage, fuel cell efficiency.

**UNIT II**  
**FUEL CELL KINETICS**  
Fuel cell reaction kinetics - electrode kinetics, overvoltage, Tafel equation, charge transfer reaction, exchange currents, electro catalysis - design, activation kinetics, Fuel cell charge and mass transport – flow field, transport in electrode and electrolyte

**UNIT III**  
**CHARACTERIZATION**  
Fuel cell characterization - in-situ and ex-situ characterization techniques, i-v curve, frequency response analysis; Fuel cell modeling and system integration: 1D model–analytical solution and CFD models

**UNIT IV**  
**HYDROGEN FUEL CELL**  
Balance of plant; Hydrogen production from renewable sources and storage; safety issues, cost
expectation and life cycle analysis of fuel cells

UNIT V   FUEL CELL POWER PLANT
Fuel cell power plants: fuel processor, fuel cell power section (fuel cell stack), power conditioner; automotive applications, portable applications

TOTAL : 45 PERIODS

REFERENCES

CX4009   COMPUTATIONAL FLUID DYNAMICS

UNIT I   CONSERVATION LAWS AND TURBULENCE MODELS
Governing equations of fluid flow and heat transfer – mass conservation, momentum and energy equation, differential and integral forms, conservation and non-conservation form. Characteristics of turbulent flows, time averaged Navier Strokes equations, turbulence models– one and two equation, Reynolds stress, LES and DNS

UNIT II   FINITE DIFFERENCE APPROXIMATION
Mathematical behaviour of PDE, finite difference operators, basic aspects of discretization by FDM, explicit and implicit methods, error and stability analysis

UNIT III   FINITE VOLUME METHOD
Diffusion problems – explicit and implicit time integration; Convection - diffusion problems – properties of discretization schemes, central, upwind, hybrid, QUICK schemes; Solution of discretized equations.

UNIT IV   FLOW FIELD COMPUTATION
Pressure velocity coupling, staggered grid, SIMPLE algorithm, PISO algorithm for steady and unsteady flows

UNIT V   GRID GENERATION
Physical aspects, simple and multiple connected regions, grid generation by PDE solution, grid generation by algebraic mapping

TOTAL : 45 PERIODS

REFERENCES
UNIT I OVERVIEW OF REMOTE SENSING

UNIT II REMOTE SENSING TECHNOLOGY
Classification of Remote Sensing Systems, Energy recording technology, Aerial photographs, Photographic systems – Across track and along track scanning, Multispectral remote sensing, Thermal remote sensing, Microwave remote sensing – Active and passive sensors, RADAR, LIDAR, Satellites and their sensors, Indian space programme - Research and development

UNIT III DATA PROCESSING
Characteristics of Remote Sensing data, Photogrammetry – Satellite data analysis–Visual image interpretation, Digital image processing – Image rectification, enhancement, transformation, Classification, Data merging, RS–GIS Integration, Image processing software

UNIT IV GEOGRAPHICAL INFORMATION SYSTEM
GIS Concepts – Spatial and non spatial data, Vector and raster data structures, Data analysis, Data base management–GIS software

UNIT V REMOTE SENSING AND GIS APPLICATIONS
Monitoring and management of environment, Conservation of resources, Sustainable land use, Coastal zone management–Limitations: case studies

TOTAL : 45 PERIODS

REFERENCES
UNIT II  PROJECT PLANNING  9

UNIT III  SITE SELECTION AND COMMISSIONING  9
Plant Engineering Management, Objectives, Programme, Control, Plant Location and Site Selection, Layout diagrams, storage of raw materials: Selection and procurement to equipment and machineries, Installation, Re-commission, Commissioning and performance appraisal, Strategies choice and Influence, Product planning and development, Provision and maintenance of service facilities.

UNIT IV  POLLUTION ABATEMENT AND SAFETY IN DESIGN  9
Process safety, Materials safety and Handling regulations, Safety in equipment and machinery operations, Design considerations of safety organization and control, Pollution, Pollution control and Abatement, Industrial Safety Standard Analysis

UNIT V  TAX AND GOVERNMENT POLICIES  9

TOTAL : 45 PERIODS

REFERENCES

CX4012  PROCESS INTENSIFICATION  L T P C
3 0 0 3

UNIT I  INTRODUCTION  9

UNIT II  MINIATURIZATION AND MICROFABRICATION  9
Process Intensification through micro reaction technology: Effect of miniaturization on unit operations and reactions, Implementation of Micro-reaction Technology, From basic Properties To Technical Design Rules, Inherent Process Restrictions in Miniaturized Devices and Their Potential Solutions, Micro-fabrication of Reaction and unit operation Devices - Wet and Dry Etching Processes.
UNIT III  MIXING AND PROCESS INTENSIFICATION  

UNIT IV  HEAT EXCHANGER INTENSIFICATION  

UNIT V:  ENERGY INTENSIFICATION  

TOTAL : 45 PERIODS

REFERENCES:
5. Reay, Ramshaw, Harvey, Process Intensification, Engineering for Efficiency, Sustainability and Flexibility, Butterworth-Heinemann, 2013
Alternative MBR Configurations, Commercial Technologies, Case Studies

UNIT IV  PRETREATMENT SYSTEMS  9
Membrane Fouling – Pretreatment methods and strategies – monitoring of Pretreatment – Langlier Index, Silt Density Index, Chemical cleaning, Biofoulant control

UNIT V  CASE STUDIES  9
Case studies on the design of membrane based water and wastewater treatment systems – zero Liquid effluent discharge Plants

TOTAL : 45 PERIODS

REFERENCES

0014  GAS TRANSPORTATION  L T P C
3 0 0 3

UNIT I  INTRODUCTION  9
Introduction, widespread use, the various types, the advantages and the special features of pipelines

UNIT II  MULTI PHASE FLOW IN PIPELINES  9
The fluid mechanics of various types of pipe flow including incompressible and compressible flows of Newtonian fluids, non-Newtonian fluids, flow of solid / liquid mixture (slurry), flow of solid / air mixture (pneumatic transport), and flow of capsules (capsule pipelines)

UNIT III  TYPES OF PIPES AND ACCESSORIES  9
Various types of pipes (steel, concrete, PE, PVC, etc.), valves (gate, globe, ball, butterfly, etc.) and pressure regulators in pipelines, Blowers and compressors (for gases), Various kinds of flow meters, sensors, pigs (scrapers) and automatic control systems used in pipelines

UNIT IV  PIPELINE PROTECTION  9
Various means to protect pipelines against freezing, abrasion and corrosion, such as cathodic protection, Planning, construction and operation of pipelines, including modern use of advanced technologies such as global positioning systems (GPS), directional drillings, automatic control using computers, and pipe line integrity monitoring such as leak detection.

UNIT V  PIPELINE DESIGN  9
Structural design of pipe line load considerations and pipe deformation and failure. Economics of pipelines including life-cycle, Cost analysis and comparison of the cost effectiveness of pipelines with alternative modes of transport such as truck or railroad. Legal, safety and environmental issues about pipelines

TOTAL : 45 PERIODS

REFERENCES

CX4015 GREEN CHEMISTRY AND ENGINEERING L T P C 3 0 0 3

UNIT I INTRODUCTION 9

UNIT II ENVIRONMENTAL CHEMICAL EXPOSURE 9
Pollution Prevention - Pollution Prevention Concepts and Terminology, Chemical Process Safety, Responsibilities for Environmental Protection, Environmental Persistence, Classifying Environmental Risks Based on Chemical Structure, Exposure Assessment for Chemicals in the Ambient Environment

UNIT III GREEN SYNTHESIS PROCESSES 9
Green Chemistry: Green Chemistry Methodologies, Quantitative / Optimization – Based Frameworks for the Design of Green Chemical Synthesis Pathways, Green Chemistry Pollution Prevention in Material Selection for Unit Operations, Pollution Prevention for Chemical Reactors, Pollution Prevention for Separation Devices, Pollution Prevention Applications for Separative Reactors, Pollution Prevention in Storage Tanks and Fugitive Sources

UNIT IV PROCESS INTEGRATION 9

UNIT V ESTIMATION OF REALISTIC ENVIRONMENTAL COST 9

TOTAL : 45 PERIODS

REFERENCES
UNIT I INTRODUCTION
Valuing the Environment: Concepts, Valuing the Environment: Methods, Property Rights, Externalities, and Environmental Problems

UNIT II CONCEPT OF SUSTAINABILITY
Sustainable Development: Defining the Concept, the Population Problem, Natural Resource Economics: An Overview, Energy, Water, Agriculture

UNIT III SIGNIFICANCE OF BIODIVERSITY
Biodiversity, Forest Habitat, Commercially Valuable Species, Stationary - Source Local Air Pollution, Acid Rain and Atmospheric Modification, Transportation

UNIT IV POLLUTION IMPACTS
Water Pollution, Solid Waste and Recycling, Toxic Substances and Hazardous Wastes, Global Warming.

UNIT V ENVIRONMENTAL ECONOMICS
Development, Poverty, and the Environment, Visions of the Future, Environmental economics and policy by Tom Tietenberg, Environmental Economics

REFERENCES

UNIT I INTRODUCTION
Problem formulation, degrees of freedom analysis, objective functions, constraints and feasible region, Types of optimization problem

UNIT II LINEAR PROGRAMMING
Simplex method, Barrier method, sensitivity analysis, Examples

UNIT III NON-LINEAR UNCONSTRAINED OPTIMIZATION
Convex and concave functions unconstrained NLP, Newton's method Quasi-Newton's method, Examples

UNIT IV CONSTRAINED OPTIMIZATION
Direct substitution, Quadratic programming, Penalty Barrier Augmented Lagrangian Methods

UNIT V MULTI OBJECTIVE OPTIMIZATION
Weighted Sum of Squares method, Epsilon constrains method, Goal attainment, Examples. Introduction to optimal control and dynamic optimization

TOTAL : 45 PERIODS
REFERENCES

CX4018
POLYMER TECHNOLOGY

UNIT I  GENERAL ASPECTS OF POLYMERS  9
Classification, mechanisms and methods of polymerization, properties - molecular weight, glass transition temperature, crystallinity, thermal, electrical and mechanical properties

UNIT II  APPLICATION ORIENTED POLYMERS  9
Resins – PVC - Silicon oil and resin, fibrous polymers - nylon 66, poly acrylo nitrile, adhesives epoxides, phenol formaldehyde, urea formaldehyde

UNIT III  ELASTOMERS  9
Natural rubber, styrene - butadiene, poly isopropane - neoprene, silicon rubber, thermoplastic elastomer

UNIT IV  PROCESSING OF POLYMERS  9
Processing additives, plasticizer, antiaging additives, surface and optical properties, modifiers, fire retardants, additives for rubber and elastomer, various molding techniques

UNIT V  PHYSICAL AND CHEMICAL TESTING OF PLASTICS  9
Mechanical properties, tensile strength and hardness, electrical properties, volume resistivity, dielectric strength, optical properties glass, light transmission and refractive index, chemical analysis - elemental and functional analysis.

TOTAL : 45 PERIODS

REFERENCES

CX4019
ENVIRONMENTAL NANOTECHNOLOGY

UNIT I  GENERAL  9
Background of nanotechnology, particle size and surface area, quantum dot - Converging science and technology, nanotechnology as a tool for sustainability, health, safety and environmental issues
UNIT II SYNTHESIS AND FABRICATION OF NANOMATERIALS
Preparation of nano scale metal oxides, metals, CNT, functionalized nano porous adsorbents, nano composite- Chemical vapour deposition, sol gel, sonochemical, microwave, solvo-thermal, plasma, pulsed laser ablation, magnetron sputtering, electro spinning, Molecular imoring

UNIT III CHARACTERISATION OF NANOMATERIALS
AFM, STM, SEM, TEM, XRD, ESCA, IR & Raman, UV-DRS, of nanomaterials for structural & chemical nature

UNIT IV OTHER FEATURES OF NANO PARTICLES
Nanoparticle transport, aggregation & deposition, Energy applications- HYDROGEN storage

UNIT V ENVIRONMENTAL APPLICATIONS
Gas sensors, microfluidics and lab on chip, catalytic and photocatalyic applications, Nonmaterials for ground water remediation, nanomaterials as adsorbents, membrane process

TOTAL : 45 PERIODS

REFERENCES
1. Environmental applications of nanomaterials-Synthesis, Sorbents and Sensors, edited by Glen E Fryxell and Guozhong Cao, worldscibooks, UK
AUDIT COURSES

AX4091 ENGLISH FOR RESEARCH PAPER WRITING LTPC 2000

COURSE OBJECTIVES:
- Teach how to improve writing skills and level of readability
- Tell about what to write in each section
- Summarize the skills needed when writing a Title
- Infer the skills needed when writing the Conclusion
- Ensure the quality of paper at very first-time submission

UNIT I INTRODUCTION TO RESEARCH PAPER WRITING 6
Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

UNIT II PRESENTATION SKILLS 6

UNIT III TITLE WRITING SKILLS 6
Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check

UNIT IV RESULT WRITING SKILLS 6
Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions

UNIT V VERIFICATION SKILLS 6
Useful phrases, checking Plagiarism, how to ensure paper is as good as it could possibly be the first-time submission

TOTAL: 30 PERIODS

COURSE OUTCOMES:
CO1 – Understand how to improve your writing skills and level of readability
CO2 – Learn about what to write in each section
CO3 – Understand the skills needed when writing a Title
CO4 – Understand the skills needed when writing the Conclusion
CO5 – Ensure the good quality of paper at very first-time submission

REFERENCES:
COURSE OBJECTIVES:
- Summarize basics of disaster
- Explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.
- Illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
- Describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
- Develop the strengths and weaknesses of disaster management approaches

UNIT I INTRODUCTION 6
Disaster: Definition, Factors and Significance; Difference between Hazard And Disaster; Natural and Manmade Disasters: Difference, Nature, Types and Magnitude.

UNIT II REPERCUSSIONS OF DISASTERS AND HAZARDS 6

UNIT III DISASTER PRONE AREAS IN INDIA 6
Study of Seismic Zones; Areas Prone To Floods and Droughts, Landslides And Avalanches; Areas Prone To Cyclonic and Coastal Hazards with Special Reference To Tsunami; Post-Disaster Diseases and Epidemics

UNIT IV DISASTER PREPAREDNESS AND MANAGEMENT 6
Preparedness: Monitoring Of Phenomena Triggering a Disaster or Hazard; Evaluation of Risk: Application of Remote Sensing, Data from Meteorological And Other Agencies, Media Reports: Governmental and Community Preparedness.

UNIT V RISK ASSESSMENT 6
Disaster Risk: Concept and Elements, Disaster Risk Reduction, Global and National Disaster Risk Situation. Techniques of Risk Assessment, Global Co-Operation in Risk Assessment and Warning, People’s Participation in Risk Assessment. Strategies for Survival

TOTAL : 30 PERIODS

COURSE OUTCOMES:
CO1: Ability to summarize basics of disaster
CO2: Ability to explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.
CO3: Ability to illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
CO4: Ability to describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
CO5: Ability to develop the strengths and weaknesses of disaster management approaches

REFERENCES:

AX4093 CONSTITUTION OF INDIA L T P C
2 0 0 0

COURSE OBJECTIVES:
Students will be able to:
- Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
- To address the growth of Indian opinion regarding modern Indian intellectuals’ constitutional
- Role and entitlement to civil and economic rights as well as the emergence nation hood in the early years of Indian nationalism.
- To address the role of socialism in India after the commencement of the Bolshevik Revolution in 1917 and its impact on the initial drafting of the Indian Constitution.

UNIT I HISTORY OF MAKING OF THE INDIAN CONSTITUTION
History, Drafting Committee, (Composition & Working)

UNIT II PHILOSOPHY OF THE INDIAN CONSTITUTION
Preamble, Salient Features

UNIT III CONTOURS OF CONSTITUTIONAL RIGHTS AND DUTIES

UNIT IV ORGANS OF GOVERNANCE
Parliament, Composition, Qualifications and Disqualifications, Powers and Functions, Executive, President, Governor, Council of Ministers, Judiciary, Appointment and Transfer of Judges, Qualifications, Powers and Functions.

UNIT V LOCAL ADMINISTRATION

UNIT VI ELECTION COMMISSION
Election Commission: Role and Functioning. Chief Election Commissioner and Election Commissioners - Institute and Bodies for the welfare of SC/ST/OBC and women.

TOTAL: 30 PERIODS
COURSE OUTCOMES:
Students will be able to:
- Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
- Discuss the intellectual origins of the framework of argument that informed the conceptualization of social reforms leading to revolution in India.
- Discuss the circumstances surrounding the foundation of the Congress Socialist Party [CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
- Discuss the passage of the Hindu Code Bill of 1956.

SUGGESTED READING
1. The Constitution of India, 1950 (Bare Act), Government Publication.

AX4094 தமிழில் இலக்கியம்  L T P C  2000
UNIT I சங்க இலக்கியம் 6
1. கருப்பீட்டுக்கான சிவனைப் போட்டி
   - டம்பூக், டாவர், வீரக்
2. அன்றாணம் (82)
   - சூழ்பால் விளைநிலை அவர்கள்
3. குருதிப்பூர்வர் பார்வையலைக்களின்
4. பாம்பால் (95,195)
   - பாம்பால் வழிசோதி வகைக்கொள்கை

UNIT II வாழ்க்கை கதை 6
1. அற்காலி வாழ்க்கை கற்றைக்கொள்ளமுதல்
   - அர்த்த வாழ்க்கைத், அர்த்தபண்டத்தை, துறைமுறைத்தை, ககக், பது
   - புது அர்த்தாணம் - உன்னைப் பரத்தை
   - கர்க்கிச, கிருப்பாண்டை, குரோமை, அளவநமதுகை (அப்பாலம்பல் வாழ்க்கைத் தோன்)

UNIT III இரட்டடக் காப்பியங்கள் 6
1. கரீசுண்ணிக்கான பந்தை
   - சிவப்புக்கார் வயத்துக்கார் கரைக
2. குருதிப்பூர்வர் சிவனைப் போட்டி காட்சிகள
   - குருதிப்பூர்வர் வழிசோதியலம் காட்சிகள

UNIT IV அருள்நநறித் தமிழ் 6
1. சிவப்புக்கார் புரூசாக
   - பார்வர் புரூசாக சிவனையானை, பயிற்சி வழியைப் பயிற்சியானை, கரைகளை, அளவநமது வழிசோதியல் வழி நமது காட்சிகளை, அர்த்தாணம் பந்தை
UNIT V

தமிழ் இலக்கியம்

1. உத்தானத்திற்குப் புதுக்கை திறந்த
2. அறிக்கையிற்கு கொண்டு விளக்க
3. திருமந்திரம் (617, 618)
4. தர்மபுராணம் விளக்கிறும் வள்ளலொர்
5. புறாணங்க
6. அகந்துவூறு (4) - பண்டை
7. அகந்துவூறு (11) - பண்டை

அறிவியல் பபொரொட்டமும்

TOTAL : 30 PERIODS

தமிழ் இலக்கிய விளக்கங்கள் / புத்தகங்கள்

1. தமிழ் விளக்கங்கள் தமிழியின் முதல் புதிநர் தமிழின் முதல் சிறுககத
2. தமிழ் விளக்கங்கள் தமிழியின் முதல் புதிநர்
3. பயண இலக்கியம் தமிழ் விளக்கமும்
4. வொழ்வியல் கற்றுந்து தமிழ் விளக்கமும்
5. அறிவியல் தமிழ் விளக்கமும்
6. வொழ்வியல் கற்றுந்து தமிழ் விளக்கமும்
7. கற்றுந்து விளக்கிய புத்தகங்கள் / புத்தகங்கள்

TOTAL : 30 PERIODS

தமிழ் விளக்கங்கள்

1. தமிழ் விளக்கங்கள்
2. தமிழ் விளக்கங்கள்
3. தமிழ் விளக்கங்கள்
4. தமிழ் விளக்கங்கள்
5. தமிழ் விளக்கங்கள்
6. தமிழ் விளக்கங்கள்

TOTAL : 30 PERIODS

தமிழ் இலக்கிய விளக்கங்கள் / புத்தகங்கள்

1. தமிழ் விளக்கங்கள்
2. தமிழ் விளக்கங்கள்
3. தமிழ் விளக்கங்கள்
4. தமிழ் விளக்கங்கள்
5. தமிழ் விளக்கங்கள்
6. தமிழ் விளக்கங்கள்