# DR. A.P.J ABDUL KALAM TECHNICAL UNIVERSITY, LUCKNOW


## EVALUATION SCHEME & SYLLABUS

## FOR

## B. TECH. FOURTH YEAR

## (CHEMICAL ENGINEERING)

## ON

## CHOICE BASED CREDIT SYSTEM (CBCS)

# B Tech. Chemical Engineering

**4th Year VII-SEMESTER** **Session- 2019-20**

| Sl No. | Subject Code | Subject Name | L-T-P | Th/Lab Marks | Sessional | | Total | Credit |
|---|---|---|---|---|---|---|---|---|
| | | | | | Test | Assig/ Att. | | |
| 1 | | OPEN ELECTIVE COURSE-1 | 3---0---0 | 70 | 20 | 10 | 100 | 3 |
| 2 | | DEPTT ELECTIVE COURSE-3 | 3---0---0 | 70 | 20 | 10 | 100 | 3 |
| 3 | | DEPTT ELECTIVE COURSE-4 | 3---1---0 | 70 | 20 | 10 | 100 | 4 |
| 4 | RCH701 | Process Modeling & Simulation | 3---0---0 | 70 | 20 | 10 | 100 | 3 |
| 5 | RCH702 | Process Design & Economics | 3---1---0 | 70 | 20 | 10 | 100 | 4 |
| 6 | RCH751 | CAD Lab | 0---0---2 | 50 | | 50 | 100 | 1 |
| 7 | RCH752 | Energy Lab | 0---0---2 | 50 | | 50 | 100 | 1 |
| 8 | RCH753 | Industrial Training | 0---0---3 | | | 100 | 100 | 2 |
| 9 | RCH754 | PROJECT-1 | 0---0---6 | | | 200 | 100 | 3 |
| | **TOTAL** | | | | | | **1000** | **24** |

**DEPARTMENT ELECTIVE 3:**

RCH071: Corrosion Science & Engg
RCH072: IPA & Waste Management
RCH073: Colloid Surface & Interfacial Phenomena
RCH074: Environmental Impact Assessment

**DEPARTMENT ELECTIVE 4**:

RCH075: Energy Engg. & Management
RCH076: Project Engg & Management
RCH077: Fuel Cell Technology
RCH078: Advance Numerical Analysis

## B Tech. Chemical Engineering

**4th Year VIII- SEMESTER** **Session- 2019-20**

| Sl No. | Subject Code | Subject Name | L-T-P | Th/Lab Marks | Sessional | | Total | Credit |
|---|---|---|---|---|---|---|---|---|
| | | | | | Test | Assig/ Att. | | |
| 1 | | Open Elective Course-2 | 3---0---0 | 70 | 20 | 10 | 100 | 3 |
| 2 | | Deptt. Elective Course-5 | 3---1---0 | 70 | 20 | 10 | 100 | 4 |
| 3 | | Deptt Elective Course-6 | 3---0---0 | 70 | 20 | 10 | 100 | 3 |
| 4 | RCH851 | Seminar | 0---0---3 | | | 100 | 100 | 2 |
| 5 | RCH852 | Project-2 | 0---12---0 | 350 | | 250 | 600 | 12 |
| | **TOTAL** | | | | | | **1000** | **24** |

**DEPARTMENT ELECTIVE 5:**

RCH081: Fertilizer Technology
RCH082: Fluidization Engg
RCH083: Multiphase Reactor Design
RCH084: Biochemical Engineering (MOOCs)

**DEPARTMENT ELECTIVE 6:**

RCH085: Novel Separation Process (MOOCs)
RCH086: Petroleum Refining
RCH087: Petrochemical Technology
RCH088: Polymer Technology

## RCH701:Process Modeling & Simulation (3:0:0)

**UNIT I**

Introduction to mathematical modeling; Advantages and limitations of models and applications of process models of stand-alone unit operations and unit processes; Classification of models: Linear vs. Nonlinear, Lumped parameter vs. Distributed parameter; Static vs. Dynamic, Continuous vs. Discrete; Numerical Methods: Iterative convergence methods, Numerical integration of ODE- IVP and ODE-BVP.

**UNIT II**

Concept of degree of freedom analysis: System and its subsystem, System interaction, Degree of freedom in a system e.g. Heat exchanger, Equilibrium still, Reversal of information flow, Design variable selection algorithm, Information flow through subsystems, Structural effects of design variable selection, Persistent Recycle.

**UNIT III**

Simple examples of process models; Models giving rise to nonlinear algebraic equation (NAE) systems, - steady state models of flash vessels, equilibrium staged processes distillation columns, absorbers, strippers, CSTR, heat exchangers, etc.; Review of solution procedures and available numerical software libraries.

**UNIT IV**

Steady state models giving rise to differential algebraic equation (DAE) systems; Rate based approaches for staged processes; Modeling of differential contactors – distributed parameter models of packed beds; Packed bed reactors; Modeling of reactive separation processes; Review of solution strategies for Differential Algebraic Equations (DAEs), Partial Differential Equations (PDEs), and available numerical software libraries. Introduction to unsteady state models and their applications.

**UNIT V**

Simulation and their approaches, Modular, Sequential, Simultaneous and Equation solving approach, Simulation softwares and their applications, Review of solution techniques and available numerical software libraries. Review of thermodynamic procedures and physical property data banks.

**BOOKS:**

1. Luyben W.L., “Process Modeling, Simulation, and Control for Chemical Engineering”, Mc Graw Hill.
2. D. F. Rudd and C. C. Watson, “ Strategy of Process Engineering”, Wiley international.
3. M.M. Denn, “Process Modelling”, Wiley, New York, (1990).
4. A. K. Jana, “Chemical Process Modelling and Computer Simulation”, PHI,(2011)
5. C.D. Holland, “Fundamentals of Modelling Separation Processes”, Prentice Hall, (1975)
6. Hussain Asghar, “Chemical Process Simulation”, Wiley Eastern Ltd., New Delhi, (1986)

## RCH702: Process Design & Economics (3:1:0)

**UNIT-I**

Introduction , Basic design procedure and theory , Heat exchanger analysis: the effectiveness NTU method , Overallheat-transfer coefficient , Fouling factors (dirt factors) ,Shell and tube exchangers: construction details , Heat exchangerstandards and codes ,Tubes , Shells , Tube-sheet layout (tube count) ,Shell types (passes) , Shell and tubedesignation ,Baffles , Support plates and tie rods , Tube sheets (plates) ,Shell and header nozzles (branches) ,Flow inducedtube vibrations ,Mean temperature difference (temperature driving force) , Shell and tube exchangers:general design considerations , Fluid allocation: shell or tubes ,Shell and tube fluid velocities ,Stream temperatures , Pressure drop ,Fluid physical properties ,Tube-side heat-transfer coefficient and pressure drop (single phase) ,Heat transfer , Tube-side pressure drop ,Shell-side heat-transfer and pressure drop (single phase) ,Flow

pattern , Design methods ,Kern's method ,Bell's method , Shell and bundle geometry ,Effect of fouling on pressure drop , Pressure droplimitations.

**UNIT –II**

Condensers ,Heat-transfer fundamentals , Condensation outside horizontal tubes ,Condensation inside and outside vertical tubes , Condensation inside horizontal tubes , Condensation of steam , Mean temperature difference , Desuperheating and sub-cooling Condensation of mixtures Pressure drop in condensers , Design of forced circulation reboilers , Design of thermosyphon reboilers ,Design of kettle reboilers , Heat transfer to vessels Jacketed vessels , Internal coils , Agitated vessels .

**UNIT –III**

Design methods for binary distillation systems , Basic equations , McCabe-Thiele method ,Low product concentrations , The Smoker equations ,Batch distillation , Steam distillation, Plate efficiency, Prediction of plate efficiency :O'Connell's correlation , Van Winkle's correlation , AIChE method , Entrainment , Approximate column sizing , Plate contactors , Selection of plate type , Plate construction , Plate hydraulic design,Plate-design procedure, Plate areas ,Diameter , Liquid-flow arrangement ,Entrainment ,Weep point , Weir liquid crest , Weir dimensions , Perforated area , Hole size , Hole pitch ,Hydraulic gradient ,Liquid throw , Plate pressure drop , Downcomer design

**UNIT–IV**

Design of packed columns for absorption/stripping, Types of packing, Packed-bed height- Prediction of the height of a transfer unit (HTU), Prediction of the number of transfer units (NTU), Column diameter (capacity) , Column internals , Wetting rates , Column auxiliaries

**UNIT –V**

Analysis of Cost Estimates: Factors affecting investment and production costs, Capital investment, Types of capital cost estimates, Methods for estimating capital investment, Estimation of Revenue, Estimation of total product cost, Gross Profit, Net Profit and Cash flow Simple and Compound interest, Loan Payments, Cash flow pattern –Discrete cash flow & Continuous cash flow, Profitability, Alternative investments by different profitability methods, Effect of inflation on profitability analysis, Methods of profitability evaluation for replacements. Depreciation: Straight line, Declining balance, Double declining balance, sum-of-the-digit, Sinking-fund, Accelerated cost recovery system, Modified accelerated cost recovery system.

**BOOKS:**

1. Towler G. and Sinnott R. K., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", Butterworth-Heinemann.2008

2. Seader J. D. and Henley E. J., "Separation Process Principles", 2nd Ed., Wiley-India.2006

3. I.S.: 4503-1967, "Indian Standard Specification for Shell and Tube Type Heat Exchangers", Bureau of Indian Standards.2007

4. Hewitt G. F., Shires G. L. and Bott T. R., "Process Heat Transfer", CRC Press.1994

5. Serth R.W., "Process Heat Transfer: Principles and Applications", Academic Press.2007

6. Coker A. K., "Ludwig's Applied Process Design for Chemical and Petrochemical Plants", Vol. 1, 4th Ed., Gulf Publishers.2007

7. Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants", Vol. 2, 3rd Ed., Gulf Publishers.1997

8. Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants", Vol. 3, 3rd Ed., Gulf Publishers.

9. Peters M. S. and Timmerhaus K. D., "Plant Design And Economics For Chemical Engineers", 5th Ed., McGraw Hill, International Ed.2004

**RCH751: CAD Lab (0:0:2)**

1. Solve a non-linear algebraic equation using Newton-Raphson's method.
2. Calculate pressure drop in pipe.
3. Calculate minimum fluidization velocity.
4. Calculate terminal velocity.
5. Solve a system of non-linear equations,
6. Calculate the molar volume of saturated liquid water and saturated water vapour using van der

1. Waals, Redlich-Kwong and Peng-Robinson cubic equation of state.
2. Solve system of simultaneous ordinary differential equations.
3. Solve for outlet temperatures of series of stirred tanks with coil heater.
4. Solve for non-isothermal PFR.
5. Solve for concentration profiles of A, B and C in the series reaction A→B→C.

**RCH752: Energy Lab (0:0:2)**

1. Determination of composting of the supplied sample of Coal by Proximate Analysis.
2. To find the effect to temperature on viscosity of the supplied samples of liquid fuel using Red wood viscometer/ lubricating oil using Engler's Viscometer.
3. To find the Flash and Fire point of the supplied samples of liquid fuel using (i) Penslery Martein closed cup apparatus (ii) Abel open cup apparatus.
4. To find the Aniline point of the supplied samples of liquid fuels using Aniline point apparatus and hence find out the Diesel Index Number of the Diesel oil.
5. To find the moisture content of the supplied samples of liquid fuel/ Crude oil using Dean and Stark apparatus.
6. To find the Pour point and Solidification point of the supplied samples of liquid fuels.
7. To determine the Gross calorific value of the supplied sample of coal using Bomb Calorimeter (on ash free basis).
8. To determine the Smoke Point of Kerosene oil using Smoke Point apparatus.

**RCH753: Industrial Training (0:0:3)**

The students must submit the report to their institute complete 4 week Industrial Training after the completion of their $6^{th}$ semester. Students may opt this course at any Industry/ Research Lab for 4 weeks.

**RCH754: PROJECT – 1 (0:0:6)**

The students would be allotted an industrial project or any Research Project in the beginning of the VII semester itself. He/ She may continue this project in details, later in the ($8^{th}$) semester. The assessment of ESE will be done the faculty member of the other department within the same institute.

**DEPARTMENT ELECTIVE 3:**

## RCH071:Corrosion Science & Engg (3:0:0)

**UNIT I**

Basic aspects introduction, classification, economics and cost of corrosion. Emf series, Galvanicseries,corrosion theories derivation of potential- current relationship of activation controlled and diffusioncorrosion processes. Potential- pH diagrams Fe-H2O system, application and limitations. Passivationdefinition, anodic Passivation, theory of Passivation, oxidation laws, effects of oxygen and alloying onoxidation rates.

**UNIT II**

Forms of corrosion-definition, factors and control methods of various forms of corrosion such as pitting,inter granular, crevice, stress corrosion, corrosion fatigue, hydrogen embrittlement, corrosion processesand control methods in fertilizers, petrochemical and petroleum refineries

**UNIT III**

Environmental aspects: Atmospheric corrosion- classification, factors influencing atmospheric corrosion,temporary corrosion preventive methods, corrosion in immersed condition, effect of dissolved gases,salts, pH, temperature and flow rates on corrosion, Underground corrosion- corrosion process in the soil,factors influencing soil corrosion.

**UNIT IV**

Corrosion control aspects: Electrochemical methods of protection-theory of cathodic protection, design ofcathodic protection, sacrificial anodes, anodic protection. Corrosion inhibitors for acidic, neutral andalkaline media, cooling water system-boiler water system. Organic coating-surface preparation, naturalsynthetic resin, paint formulation and applications. Design aspects in corrosion prevention, corrosionresistant materials.

**UNIT V**

Corrosion Testing, monitoring and inspection, laboratory corrosion tests, accelerated chemical tests forstudying different forms of corrosion. Electrochemical methods of corrosion rate measurements by DCand AC methods, corrosions monitoring methods, chemical and electrochemical removal of corrosionproducts.

**BOOKS:**

1. S.N. Banerjee, An Introduction to Corrosion and Corrosion Inhibition,
Oxonian Press Ltd., New Delhi.
2. LL Shrier Corrosion Vol. I & II George NownonsLtd., Southhampton Street London Endn. II
3. M.G. Fontana & N.D. Greene,Corrosion Engineering, McGraw Hill, New York (3/e)
4. H.H. Uhlig, Corrosion and Corrosion Control. A Wiley- Inter Science. Publication John Wiley & Sons, New York.
5. C.T.Munger- Organic Coatings
6. Jain & Jain, Engineering Chemistry, Dhanpat Rai & Sons, New Delhi

## RCH072:IPA & Waste Management (3:0:0)

**UNIT I**

**Introduction:** Industrial Pollution and types of pollution from chemical process industries, Characterization of emission and effluents, Global consideration of environmental pollution,

Environmental legislation - Water Act 1974, Air Act 1981, Environmental Protection Act 1986;Standards for liquid effluents from chemical process industries, air quality, nuclear radiationemission, noise emission.

**UNIT II**

**Pollution Prevention:** Process modification, Alternative raw material, Recovery of by productfrom industrial emission/effluents, Recycle and reuse of waste, Energy recovery and wasteutilization, Material and energy balance for pollution minimization, Water minimization,Fugitive emission/effluents and leakages and their control-housekeeping and maintenance.

**UNIT III**

**Air Pollution Control:** Air pollutants classification, Equipments for controlling particulate andgaseous pollutants, lapse rate, atmospheric stability, Dispersion models, Plume behavior, Stackdesign, Design of gravity settling chamber, cyclones, electrostatic precipitator, fabric filters andabsorbers, Air pollution control for petroleum refineries and cement plants.

**UNIT IV**

**Water Pollution Control:** Waste water characteristics, Primary, secondary and tertiary treatments for wastewater, Anaerobic and aerobic treatment biochemical kinetics, Design of trickling filter, activated sludge systems, ponds and lagoons and aeration systems, Water pollution control for petroleum refineries, fertilizer industry, pulp and paper industry.

**UNIT V**

**Solid Waste Management**: Characterization of solid wastes-hazardous and non-hazardous wastes, Waste disposal and management laws and guidelines, Non-hazardous industrial wastestreatment,disposal, utilization and management, Value-extraction from the wastes, Handling,storage and disposal of hazardous wastes, Waste disposal for nuclear power plants.

**BOOKS:**

1. Metcalf & Eddy, "Wastewater Engineering - Treatment and Reuse", Revised by G. Tchobanoglous, F. L. Burton, and H. D. Stensel, 4th edition. Tata McGraw-Hill, 2003.
2. Mahajan S. P., Pollution control in process industries, Tata McGraw-Hill, 1985
3. Peavy H.S., Rowe D.R. and Tchobanoglous G., Environmental Engineering, McGraw-Hill edition, 1985
4. Kreith F. and Tchobanoglous G., "Handbook of Solid Waste Management", 2nd Ed., Mc Graw Hill, 2002
5. Pichtel J., "Waste Management Practices: Municipal, Hazardous and Industrial", CRC, 2005

## RCH073:Colloid Surface & Interfacial Phenomena (3:0:0)

**UNIT I**

**Surface tension, adhesion and capillarity**

Effects of confinement and finite size, concepts of surface and interfacial energies and tensions,

Apolar (aan der Waals) and polar (acid-base) components of interfacial tensions. Young-Laplace

equation of capillarity, examples of equilibrium surfaces, multiplicity, etc., Stability of equilibrium solutions, contact angle and Young's equation, Determination of aploar (van der Waals) and acid-base components of surface/interfacial tensions. Free energies of adhesion, kinetics of capillary and confined flow.

**UNIT II**

**Intermolecular, nanoscale and interfacial forces in organic, polymeric, biological and aqueous systems**

Van der waals, electrostatic double layer, acid-base interactios including hydrophobic attraction
and hydration pressure

**UNIT III**

**Mesoscale thermodynamics and Mesoscale phenomena in soft matter & applications**

Gibb's treatment of interfaces, concept of excess concentration, variation of interfacial tension
with surface concentration, Adhesion, wetting, nucleation, flotation, patterning of soft material
by self organization and other techniques.

**UNIT IV**

**Stability of nanoparticle dispersions**

DLVO and DLVO like theories and kinetics of coagulation plus general principles of diffusion in
a potential field/Brownian movement.

**UNIT V**

**Nanofluidics and Advanced & Functional Interfaces**

Stability of thin (< 100 nm) film, self-organization in confined systems, mesoscale patterning. Superhydrophobicity, functionsl coatings, structural colours, nano-adhesives, nano-composites.

**BOOKS:**

1. Principles of Colloid and Surface Chemistry, Paul C. Hiemenz, Marcel DEker, 2nd edition and ionwards, 1986.
2. Physical Chemistry of Surfaces, Arthur W. Adamson, 5th edition, Wiley, 1990.
3. Foundations of Colloid Science, Robert J. Hunter, Clarendons, Oxford, Volume 1, 1989.
4. Colloidal Dispersions, W. B. Russel, D. A. Saville, and W, R. Schowalter, Cambridge University Press, 1989.
5. Intermolucular and Surface forces, Jacon N. Israelachvili, Academic Press, 1992 or later editions.
6. Interfacial Forces in Aqueous Media, Carel J. van Oss, Marcel Dekker or Taylor Francis, 1994.

## RCH074:Environmental Impact Assessment(3:0:0)

| S. No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Introduction**: Historical perspective and evolution of guidelines for environmental impact assessment (EIA); Developmental and economic activities and their impact on environmental quality; Carrying capacity and sustainable development. | 4 |
| 2. | **Environmental Impact Policy**: Guidelines for EIA for various developmental activities, environmental indices and indicators; Operational framework, rapid and comprehensive EIA. Environmental review and screening of projects, public hearing, scoping and baseline studies; Projects requiring EIA. | 6 |
| 3. | **Monitoring and Analysis of Environmental Quality**: Monitoring and analysis of wastewater, surface water, ground water, ambient air and emissions; Micro-meteorology, atmospheric dispersion; Noise level monitoring and modeling; | 8 |
| 4. | **Environmental Impacts**: Impact of developmental activities on environmental components and their analysis, quality of air, water and land and their impact on biodiversity, socioeconomic and cultural/ethical aspects and their interconnectivity. | 8 |
| 5. | **Environmental Impact Assessment Methodologies**: Modeling and prediction, impact valuation and composite impact analysis and assessment. | 6 |
| 6. | **Environmental Management Plan**: Protective and preventive planning, cost-benefit analysis, environmental management plan (EMP) and disaster management plan (DMP), on-site and off-site management plan, forest management plan and green-belt design. Post project monitoring. | 5 |

| S. No. | Authors / Name of Book / Publisher | Year of Publication |
|---|---|---|
| 1. | Canter L.W., "Environmental Impact Assessment", McGraw Hill. | 1996 |
| 2. | Rau J.G. and David C., "Environmental Impact Analysis Handbook", McGraw Hill. | 1980 |
| 3. | "Guidelines for EIA of Industrial and other Projects" Ministry of Environment and Forests, Government of India. | 2009 |
| 4. | Cheremisinoff P.N. and Morresi A.C., "Environmental Assessment and Impact Statement Handbook", Ann Arbor. | 1977 |
| 5. | Pollution Control Law Series: Pollution Control Acts, Rules and Notification Issued There under, Central Pollution Control Board, Ministry of Environment and Forest, Government of India. | 2006 |

**DEPARTMENT ELECTIVE 4**:

## RCH075:Energy Engg. & Management (3:1:0)

**UNIT I**

**Energy Scenario:**Indian and global, energy crisis, Classification of various energy sources, Renewable and non-renewable energy sources, Remedial measures to some energy crisis. EnergyConservation.

**UNIT II**

**Alternative Sources of Energy :** Fuel cell ,Solar Energy : Photo thermal and photovoltaic conversion and utilization methods , solar water heating , cooking , drying and its use for otherindustrial processes ,solar cells their material and mode of operation . direct and indirect methodssolar energystorage , sensible heat and latent heat storage materials Solar ponds .Bio energy,Biogas plants and their operation , Biomass and its conversion roots to gaseous and liquid fuels, Wind energy , its potential and generation by wind mills.

**UNIT III**

Hydroelectric potential, its utilization & production, Geothermal energy its potential status andproduction, Nuclear energy : Status, nuclear raw materials, nuclear reactors and otherclassification, Generation of Nuclear power, Nuclear installations in India and their capacity ofgeneration, Limitations of nuclear energy, Reprocessing of spent nuclear fuel, Cogeneration offuel and power, Energy from tidal and ocean thermal sources, MHD systems.

**UNIT IV**

**Fossil and Processed Fuel:** Coal its origin and formation, Coal analysis, Coal classification, Coal preparation, Coal washing and coal blending, Coal carbonization, Treatment of coal gas andrecovery of chemical from coal tar, Coal gasification, liquid fuel synthesis from coal, CBM.

**UNIT V**

Petroleum crude , Types of crude ,emergence of petroleum products as energy, GaseousFuels:

Natural gas, Water gas, producer gas, L.P.G., bio- gas, coke oven gas, blast furnace gas, LNG,CNG,Gas hydrates ,GTL Technology (gas to liquid), Bio-diesel.

**BOOKS:**

1. Brame J.S.S. and King J.G., Edward Arnold “Fuel Solid, Liquid and Gases” Edward Arnold (1967).
2. Sukhatme S.P, "Solar Energy - Principles of Thermal Collection and Storage",2nd Ed., Tata McGraw- Hill.,(1996).

## RCH076:Project Engg & Management (3:1:0)

**Unit 1**

Project identification, preliminary techno-economic feasibility, laboratory development and research, pilot plant level studies, scale-up methods. Process selection, alternative process. Flow sheet preparation, different components of PFD, equipment numbering, stream designation, battery limit and off sites.

**Unit 2**

Selection of process equipments. standard versus special equipments, selection Criteria, specification sheet of equipment, Process auxiliaries-Piping design, layout, process control and instrumentation, Process utilities process water, boiler-feed water, waste treatment & disposal, oil heating system, chilling plant, compressed air, instrument air.

**Unit 3**

Interest – types & calculations, Cost estimation – factors involved in project cost estimation, total capital investment, fixed capital and working capital, process equipment cost estimation. Cost index and scaling for equipment cost. Estimation of total product cost-factors involved.

**Unit 4**

Depreciation – type & methods of determination, Profitability-criteria of profitability, Payout period, return on investment, present value, cash flow analysis, alternative investment and replacement methods, factors in alternative & replacement investment, project profitability analysis.

**Unit 5**

Project management, scheduling a project using CPM/ PERT, Inventory control methods, Optimum conditions- productions schedule, optimum production rates in plant operations, optimum conditions in batch and cyclic operations, Design reports, Plant location and layout principles – factors involved, case studies for specific plants.

Text Books:


1. Peters, M.S. and Timmerhaus, K.D., " Plant Design & Economics for Chemical Engineers", McGraw Hill
2. Vilbrabdt and Dryden, "Chemical Engineering Plant Design", McGraw Hill.
3. Ulrich, G.D., :A guide to Chemical Engineering Process Design & Economics", John Wiley and Sons.


## RCH077: Fuel Cell Technology (3:1:0)

**Unit I**

**Introduction**

Basic principles - classifications - heat of reactions - enthalpy of formation of substances - Gibbs free energy of substances - Efficiency - power - heat due to entropy change and internal ohmic heating.

**Unit II**

**Fuel cell charge and mass transport**

Nernst equation and open circuit potential - pressure and temperature effect - Stoichiometric coefficients and reactants utilization - Mass flow rate calculation - voltage and current in parallel and serial connection.

**Unit III**

**Polarization**

Over potentials and polarizations - Activation polarization - Tafel equation and exchange current density. Ionic conductivity - catalysts - Temperature and humidification effect - electro-osmotic Drag effect.

**Unit IV**

**Fuel Cell stacks**

PEM Fuel cell stacks - Rate of mass transfer of reactants and products - water management - current collections and gas removal - Bipolar plates - flow distribution - Heat and water removal from the stack.

**Unit V**

**Designing**

Fuel cell systems analyze: Energy systems - power - Train or Drive - Train Analysis - PEMFC powered Bus - Flow Sheet and conceptual Design-Detailed Engineering Designs.

**TEXT BOOKS**


1. James Larminie, J., Dicks, A. (2003), Fuel Cell Systems Explained, 2nd Edition, John Wiley & Sons Inc., New Jersey, ISBN: 9780470848579.
2. Ryan O'Hayre, Suk-Won Cha, Colella, W., Prinz, F. B. (2009), Fuel Cell Fundamentals, Wiley, New Jersey,ISBN: 9780470258439.


**REFERENCE BOOKS**


1. Gregor Hoogers, (2003), Fuel Cell Technology Handbook, CRC Press, New Jersey, ISBN: 9780849308772.
2. Revankar, S., Majumdar, P. (2014), Fuel Cells Principles Design and Analysis, CRC Press, New Delhi, ISBN: 9781420089684.


## RCH078: Advanced Numerical Analysis (3:1:0)

| Lecture (1 hr) | Contents (Sections from a module, which are relevant for each lecture, are indicated in the last column) | |
|---|---|---|
| | **Module 1: Equation Forms in Process Modeling** | **Sections** |
| 1 | Introduction and Motivation, Linear and Nonlinear Algebraic Equation | 1,2.12.2 |
| 2 | Optimization based Formulations, ODE-IVPs and Differential Algebraic Equations | 2.3,2.4, 3 |
| 3 | ODE-BVPs and PDEs | 4 |
| 4 | ODE-BVPs and PDEs, Abstract model forms | 4,5 |
| | **Module 2: Fundamentals of Vector Spaces** | **Sections** |

| | | |
|---|---|---|
| 5 | Generalized concepts of vector space, sub-space, linear dependence | 1,2 |
| 6 | Concept of basis, dimension, norms defined on general vector spaces | 2 |
| 7 | Examples of norms defined on different vector spaces, Cauchy sequence and convergence, introduction to concept of completeness and Banach spaces | 3 |
| 8 | Inner product in a general vector space, Inner-product spaces and their examples, | 4 |
| 9 | Cauchy-Schwartz inequality and orthogonal sets | 4 |
| 10 | Gram-Schmidt process and generation of orthogonal basis, well known orthogonal basis | 5 |
| 11 | Matrix norms | 6 |

| | **Module 3: Problem Discretization Using Approximation Theory** | **Sections** |
|---|---|---|
| 12 | Transformations and unified view of problems through the concept of transformations, classification of problems in numerical analysis, Problem discretization using approximation theory | 1,2 |
| 13 | Weierstrass theorem and polynomial approximations, Taylor series approximation | 2, 3.1 |
| 14 | Finite difference method for solving ODE-BVPs with examples | 3.2 |
| 15 | Finite difference method for solving PDEs with examples | 3.3 |
| 16 | Newton's Method for solving nonlinear algebraic equation as an application of multivariable Taylor series, Introduction to polynomial interpolation | 3.4 |
| 17 | Polynomial and function interpolations, Orthogonal Collocations method for solving ODE-BVPs | 4.1,4.2,4.3 |
| 18 | Orthogonal Collocations method for solving ODE-BVPs with examples | 4.4 |
| 19 | Orthogonal Collocations method for solving PDEs with examples | 4.5 |
| 20 | Necessary and sufficient conditions for unconstrained multivariate optimization, Least square approximations | 8 |
| 21 | Formulation and derivation of weighted linear least square estimation, Geormtraic interpretation of least squares | 5.1,5.2 |
| 22 | Projections and least square solution, Function approximations and normal equation in any inner product space | 5.3 |
| 23 | Model Parameter Estimation using linear least squares method, Gauss Newton Method | 5.4 |
| 24 | Method of least squares for solving ODE-BVP | 5.5 |
| 25 | Gelarkin's method and generic equation forms arising in problem discretization | 5.5 |
| 26 | Errors in Discretization, Generaic equation forms in transformed problems | 6,7 |

| | **Module 4: Solving Linear Algebraic Equations** | **Sections** |
|---|---|---|
| 27 | System of linear algebraic equations, conditions for existence of solution - geometric interpretations (row picture and column picture), review of concepts of rank and fundamental theorem of linear algebra | 1,2 |
| 28 | Classification of solution approaches as direct and iterative, review of Gaussian elimination | 3 |
| 29 | Introduction to methods for solving sparse linear systems: Thomas algorithm for tridiagonal and block tridiagonal matrices | 4 |
| 30 | Block-diagonal, triangular and block-triangular systems, solution by matrix decomposition | 4 |
| 31 | Iterative methods: Derivation of Jacobi, Gauss-Siedel and successive over-relaxation methods | 5.1 |

| | | |
|---|---|---|
| 32 | Convergence of iterative solution schemes: analysis of asymptotic behavior of linear difference equations using eigen values | 9 |
| 33 | Convergence of iterative solution schemes with examples | 5.2 |
| 34 | Convergence of iterative solution schemes, Optimization based solution of linear algebraic equations | |
| 35 | Matrix conditioning, examples of well conditioned and ill-conditioned linear systems | 7 |

| | **Module 5: Solving Nonlinear Algebraic Equations** | **Sections** |
|---|---|---|
| 36 | Method of successive substitutions derivative free iterative solution approaches | 1,2 |
| 37 | Secant method, regula falsi method and Wegsteine iterations | 3.1,3.2 |
| 38 | Modified Newton's method and qausi-Newton method with Broyden's update | 3.3, 3.4, 3.5 |
| 39 | Optimization based formulations and Leverberg-Marquardt method | 4 |
| 40 | Contraction mapping principle and introduction to convergence analysis (Optional lecture) | 6 |

| | **Module 6: Solving Ordinary Differential Equations – Initial Value Problems (ODE-IVPs)** | **Sections** |
|---|---|---|
| 39 | Introduction, Existence of Solutions (optional topic), | |
| 40 | Analytical Solutions of Linear ODE-IVPs | 3 |
| 41 | Analytical Solutions of Linear ODE-IVPs (contd.), Basic concepts in numerical solutions of ODE-IVP: step size and marching, concept of implicit and explicit methods | 4 |
| 42 | Taylor series based and Runge-Kutta methods: derivation and examples | 5 |
| 43 | Runge-Kutta methods | 5 |
| 44 | Multi-step (predictor-corrector) approaches: derivations and examples | 6.1 |
| 45 | Multi-step (predictor-corrector) approaches: derivations and examples | 6.1 |
| 46 | Stability of ODE-IVP solvers, choice of step size and stability envelopes | 7.1,7.2 |
| 47 | Stability of ODE-IVP solvers (contd.), stiffness and variable step size implementation | 7.3,7.4 |
| 48 | Introduction to solution methods for differential algebraic equations (DAEs) | 8 |
| 49 | Single shooting method for solving ODE-BVPs | 9 |
| 50 | Review | |

## REFERENCES


1. Gilbert Strang, Linear Algebra and Its Applications (4th Ed.), Wellesley Cambridge Press (2009).
2. Philips, G. M.,Taylor, P. J. ; Theory and Applications of Numerical Analysis (2nd Ed.), Academic Press, 1996.
3. Gourdin, A. and M Boumhrat; Applied Numerical Methods. Prentice Hall India, New Delhi, (2000).
4. Gupta, S. K.; Numerical Methods for Engineers. Wiley Eastern, New Delhi, 1995.

## RCH851: Seminar (0:0:3)

Students have to present a detailed power point presentation on their own project topics. Tjis seminar will help them to enhance their personality.

## RCH852: Project-2 (0:12:0)

This project course may be in continuation of Project-I (RCH-754) allotted in the beginning of the VII semester. Here, the students are supposed to do the detailed work as scheduled in the last semester. Finally, he/she will be required to submit the detailed project report on which viva-voice examination will be conducted by a committee having at least one external examiner.

## DEPARTMENT ELECTIVE 5:

## RCH081: Fertilizer Technology (3:1:0)

**Unit 1**
Introduction of Indian fertilizer industries, types of fertilizers process details.

**Unit 2**
Manufacture of Nitrogeneous, Phosphatic, potassic, complex, NPK, mixed, Dio and other fertilizers.

**Unit 3**
Discussion of existing Indian plants pollution and its control, abetment and disposal of waste of fertilizer units.

**Unit 4**
Retrofits and modernization, computer control and Instrumentation, Energy conservation and diversification.

**Unit 5**
Design of Ammonia converters and other reactors, cooling water, expansion, capacity utilization and other problem of fertilizers industry.

**Books:**

1. Mortvedt J. J., Murphy L. S. & Follett R. H., Fertilizer Technology & Application, Meister Publishing Company
2. Shreves Chemical Process Industries, McGraw Hill
3. Drydens Outlines of Chemical Technology, East West Press

## RCH082: Fluidization Engg (3:1:0)

### UNIT I

Importance of fluidization in process industry, comparison of fluidized beds with other modes of contacting, advantages and disadvantages, industrial applications.

**Fluidization and Mapping of Regimes :** Fixed bed of particles of one and mixed sizes, fluidization with and without carryover of particles, minimum fluidization, terminal velocity of particles, pneumatic transport of solids, mapping of regimes, Distributors for dense beds, types and design, power consumption for fluidized beds

## UNIT II

**Bubble Behavior and Bed Properties :** Single rising bubble models, wake region and solids within bubbles, interaction and coalescence of bubbles, bubble formation, slug flow.

**Bubbling Fluidized Beds :** Emulsion phase, gas flow, bubble properties, physical and flow models.

## UNIT III

**Entrainment and Elutriation From Eluidized Beds :** Free boards behavior, gas outlet location, entertainment from tall and short vessels.

**Hight Velocity Fluidization :** Turbulent fluidized beds, fast fluidization, pressure drop in turbulent and fast fluidization

### UNIT IV

**Spouted Beds :** Hydrodynamics and processing in spouted beds.

**Circulation Systems :** Circuits for the circulation of solids, pressure balance, flow of gas-solid mixtures in downcomers, flow in pneumatic transport lines.

## UNIT V

**Design for Physical Operations:** Design of single stage and multistage systems, heat and mass transfer, fluid bed drier

### LIST OF RECOMMENDED BOOKS


1. Kunii, D. and Levenspiel, O., “Fluidization Engineering”, II ed. Butterworth – Heinemann, (1991)
2. Davidson, D. and Harrison, J.F., “Fluidization Engineering”, II ed. Academic Press (1992)

## RCH083: Multiphase Reactor Design (3:1:0)

### Unit I

Introduction to advanced reactor analysis tools, Role of Multiphase Reactors, Catalysis, Catalysis, Heterogeneous Catalysis, Homogeneous Catalysis, Parameters Concerning Catalyst Effectiveness in Industrial Operations, Importance of Advanced Instrumental Techniques in Understanding Catalytic Phenomena, Role of Nanotechnology in Catalysis, Role of Multiphase Reactors.

### Unit II

The Scale-Up Conundrum, Intrinsic Kinetics: Invariance with Respect to Type/Size of Multiphase Reactor, Transport Processes: Dependence on Type/Size of Multiphase Reactor, Prediction of the Rate-Controlling Step in the Industrial Reactor, Laboratory Methods for Discerning Intrinsic Kinetics of Multiphase Reactions, Two-Phase (Gas–Liquid) Reaction, Three-Phase (Gas–Liquid–Solid) Reactions with Solid Phase Acting as Catalyst

### Unit III

Classification of Multiphase Reactors, Criteria for Reactor Selection, Material of Construction, Some Examples of Large-Scale Applications of Multiphase Reactors: Fischer–Tropsch Synthesis and Oxidation of p-Xylene to Purified Terephthalic Acid for Poly(Ethylene Terephthalate), Fluid Turbulence, Eddy Size Distribution and Effect of Eddy Size on Transport Rates, States of Similarity of Relevance to Chemical Process Equipments.

### Unit IV

Mass Transfer in Multiphase Reactors: Empirical Correlations Using Operating Parameters and Physical Properties, Correlations Based on Mechanical Similarity, Correlations Based on Dynamic Similarity; Correlations Based on Hydrodynamic/Turbulence Regime Similarity, The Slip Velocity Approach, Approach Based on Analogy between Momentum and Mass Transfer; The Standard Stirred Tank, Power Requirements of Different Impellers; Hydrodynamic Regimes in Two-Phase (Gas–Liquid) Stirred Tank Reactors.

### Unit V

Hydrodynamic Regimes in Three-Phase (Gas–Liquid–Solid) Stirred Tank Reactors: Gas Holdup in Stirred Tank Reactors, Relative Gas Dispersion (N/NCD) as a Correlating Parameter for Gas Holdup, Gas–Liquid Mass Transfer Coefficient in Stirred Tank Reactor,
Solid–Liquid Mass Transfer Coefficient in Stirred Tank Reactor: Solid Suspension in Stirred Tank Reactor, Design of Stirred Tank Reactors with Internal Cooling Coils, Gas–Liquid Mass Transfer Coefficient, Solid–Liquid Mass Transfer Coefficient , Stirred Tank Reactor with Internal Draft Tube, Worked Example: Design of Stirred Reactor for Hydrogenation of Aniline to Cyclohexylamine (Capacity: 25000 Metric Tonnes per Year), Elucidation of the Output

## TEXT BOOKS

1. Vishwas Govind Pangarkar (2014), Design of Multiphase Reactors, 1st Edition, John Wiley & Sons, Inc., ISBN:978-1-118-80776-7.

2. Octave Levenspiel(2008), Chemical Reaction Engineering, Edition 3, John Wiley & Sons, ISBN:978-81-265-1000-9.

## RCH084: Biochemical Engg (3:1:0) (MOOCs)

COURSE DETAIL

| S.No | Topics | No. of Lectures |
|---|---|---|
| 1 | Basics of Biology; Overview of Biotechnology; Diversity in Microbial Cells, Cell Constituents, Chemicals for Life **(Dr. Rintu Banerjee).** | 7 |
| 2 | Kinetics of Enzyme Catalysis **(Dr. Saikat Chakraborty)**. | 5 |
| 3 | Immobilized Enzymes: effects of intra and inter-phase mass transfer on enzyme kinetics **(Dr. Saikat Chakraborty)**. | 5 |
| 4 | Major Metabolic Pathways: Bioenergetics, Glucose Metabolism, Biosynthesis **(Dr. Rintu Banerjee)**. | 5 |
| 5 | Microbial Growth: Continuum and Stochastic Models **(Dr. Saikat Chakraborty)**. | 3 |
| 6 | Design, Analysis and Stability of Bioreactors **(Dr. Saikat Chakraborty)**. | 4 |
| 7 | Kinetics of Receptor-Ligand Binding **(Dr. Saikat Chakraborty)**. | 3 |
| 8 | Receptor-mediated Endocytosis **(Dr. Saikat Chakraborty)**. | 3 |
| 9 | Multiple Interacting Microbial Population: Prey-Predator Models **(Dr. Saikat Chakraborty)**. | 1 |
| 10 | Bio-product Recovery & Bio-separations; Manufacture of Biochemical Products **(Dr. Rintu Banerjee)**. | 4 |

## REFERENCES


1. Biochemical Engineering Fundamentals by J. E. Bailey & D. F. Ollis, McGraw Hill Book Company, 1986.
2. Biochemical Engineering by H. W. Blanch & D. S. Clark, Marcel Dekker, Inc., 1997.
3. Bioprocess Engineering (Basic Concepts) by M. L. Shuler & F. Kargi, Prentice Hall of India, 2003.


## DEPARTMENT ELECTIVE 6:

## RCH085: Novel Separation Process (3:0:0) (MOOCs)

COURSE DETAIL

| S.No | Topics | No. of Hours |
|---|---|---|
| 1 | Fundamentals of Separation Processes. | 1 |
| 2 | Basic definitions of relevant terms. | 1 |
| 3 | Membrane based separation processes:<br>Fundamentals and various terms.<br>Classifications.<br>Design aspects: various models and their applicabilities. | 20 |
| 4 | External field induced membrane separation processes for colloidal particles:<br>Fundamentals of various colloid separation.<br>Derivation of profile of electric field strength.<br>Coupling with membrane separation and electrophoresis. | 6 |
| 5 | Gas separation. | 2 |
| 6 | Surfactant based separation processes:<br>Liquid membranes: fundamentals and modeling.<br>Micellar enhanced separation processes.<br>Cloud point extraction. | 4 |
| 7 | Centrifugal Separation processes and their calculations. | 2 |
| 8 | Ion exchange and chromatographic separation processes. | 2 |
| 9 | Supercritical fluid extraction. | 2 |
| | **Total** | 40 |

## REFERENCES


1. Handbook of Separation Process Technology by R W Rousseau (John Wiley & Sons).
2. Supercritical Fluid Extraction by M A Mchugh & V J Krukonis (Butterworth Heinmann).

3. Large Scale Adsorption & Chromatography by W C Wankat (CRC Press Inc).
4. Advanced Membrane Technology and Applications by N N Li (Wiley).

## RCH086: Petroleum Refining (3:0:0)

**UNIT I**

Petroleum Exploration Production and Refining of Crude oils, Crude oils:Characteristics and constituents of crude oils, Classification of crude oils.

**UNIT II**

Quality Control of Petroleum Products. Classification of laboratory tests, distillation, vapour pressure, flash and fire points, octane number, performance number, cetane number, aniline point, viscosity index, calorific value, smoke point, char value, viscosity, viscosity index, penetration tests, cloud and pour points, drop point of grease, melting and settling points of wax,softening point of Bitumen, induction period of gasoline, thermal stability of jet fuels, gumcontent, Total Sulphur, Acidity and Alkalinity,, Copper Strip Corrosion Test, Silver – StripCorrosion Test for ATF, Ash, Carbon Residue (Conradson method, Ramsbottom method)Colour, Density and Specific gravity, Refractive index of hydrocarbon liquids, water separationindex (modified) (WSIM), ductility.

**UNIT III**

**Petroleum Products:**Composition, Properties & Specification of LPG, Naphthas, motor spirit,Kerosine, Aviation Turbine Fuels, Diesel Fuels, Fuel Oils, Petroleum Hydrocarbon Solvents,Lubricating oils (automotive engine oils, industrial lubricating oils electrical insulating oils, JuteBatching oils, white oils, steam turbine oils, metal working oils, etc.) Petroleum WaxesBitumens, Petroleum coke. **Crude Oil Distillation**: Desalting of crude oils, Atmosphericdistillation of crude oil, Vacuum distillation ofatmospheric residue.Thermal Conversion Process:Thermal Cracking Reactions, Thermal Cracking, Visbreaking, (Conventional Visbreaking andSoaker Visbreaking) Coking (Delayed Coking, Fluid Coking, Flexicoking), Calcination of GreenCoke.

**UNIT IV**

Catalytic Converson Process: Fluid catalytic cracking; Catalytic reforming; Hydrocracking Catalytic Alkylation, Catalytic Isomerization; Catalytic Polymerization.

Finishing Process: Hydrogen sulphide removal processes; Sulphur conversion processes; Sweetening processes (Caustic treatment, Solutizer process; Doctor treating process; Copper chloride sweetening,; Hypochlorite sweetening ;Air and inhibitor treating process; Merox processes;Sulphuric acid treatment; Clay treatment); Solvent extraction processes (Edeleanu process, Udex process, Sulfolane process), Hydrotreating processes.

**UNIT V**

Lube Oil Manufacturing Process: Evaluation of crude oils for lube oil base stocks, Vacuum distillation, Solvent deasphalting Solvent extraction of lube oil fractions (Furfural, NMP and Phenol), Solvent dewaxing, Hydrofinshing, Manufacture of petroleum waxes (Wax sweating, Solvent deoiling)

Manufacture of Bitumens: Selection of crude oil, Methods of manufacture of bitumens,

(Distillation, Solvent precipitation, Air blowing).

**BOOKS:**

1. Ram Prasad, Petroleum Refining Technology, Khanna Publishers, Delhi (2000)
2. Nelson, W.L., Petroleum Refining Engineering, McGraw Hill

## RCH087: Petrochemical Technology (3:0:0)

**Unit 1**
Production and consumption pattern of petrochemicals in India, Feedstocks for petrochemicals-Natural gas, LPG, Refinery off-gases, Hydroforming of petroleum stocks, Naphtha and fuel oils, Petroleum coke

**Unit 2**
Steam reforming and partial oxidation processes for syngas, Manufacture of Methanol, Formaldehyde, Chloromethanes, Trichloroethylene, Perchloroethylene, Acetic acid, adipic acid

**Unit 3**
Ethylene and acetylene via steam cracking of hydrocarbons, Manufacture of Ethylene dichloride, Vinyl chloride, Ethylene oxide, Ethanolamines, Acetaldehyde, Vinyl acetate, Ethyl acetate, Ethylene glycol

**Unit 4**
Manufacture of Isopropanol, Acetone, Methyl ethyl ketone, Methyl isobutyl ketone, Cumene, Acrylonitrile, Propylene oxide, Butadiene, Oxo process

**Unit 5**
Manufacture of Benzene, Toluene, Xylenes, Phenol, Styrene, Phthalic anhydride, Maleic anhydride, Nitrobenzene, Aniline, Bisphenol-A, Caprolactum

**Books Recommended:**

1. Mall, I D, Petrochemical Process Technology, McMillan India
2. Rao Bhaskar, Modern Petroleum Refining Processes, Oxford & IBH Publishing
3. Speight J., Chemistry & Technology
4. Robert Mayer, Handbook of Petroleum Refining Processing, McGraw Hill

## RCH088: Polymer Technology (3:0:0)

**UNIT I**

Addition polymers, Condensation polymers, Copolymers, Cross-linked polymers, Molecular symmetry and the tendency to form crystals, Distribution of relative molecular mass, Structure ofthe crystal, Crystal shape, Crystallinity, Crystallization and melting, the glass transitiontemperature, Molecular conformation in the amorphous polymer, the freely jointe chain, theGaussian chain, Molecular orientation.

**UNIT II**

Structure of an ideal rubber, Entropy elasticity, elasticity of a network, Stress-strain relationship,Engineering rubbers, The nature of visco elasticty, Creep, Stress relaxation, Dynamic properties,Theory of linear viscoelasticity, Polymer selection: stiffness.

**UNIT III**

Yielding, Crazing, Linear elastic fracture mechanics, Elastic-plastic fracture mechanics, Brittlefracture of polymer, rubber toughening, Reinforced plastics, Forming of reinforced plastics, themechanics of fibre reinforcement, Reinforced rubbers.

**UNIT IV**

The flow properties of polymer melts, Cooling and solidification, Extrusion, Injection moulding,Compression and transfer moulding.

**UNIT V**

Materials selection, Designing for manufacture, Designing for stiffness, Designing for strength, Case Histories.

**BOOKS:**

1. N. G. McCrum, C. P. Buckley and C. B. Bucknall, Principles of Polymer Engineering, 2nd Edition, Oxford University Press, (1997).