CURRICULUM

OF

CHEMICAL ENGINEERING

ME, MSc

(Revised 2016)

HIGHER EDUCATION COMMISSION ISLAMABAD

CURRICULUM DIVISION, HEC

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PREFACE

The curriculum, with varying definitions, is said to be a plan of the teaching-learning process that students of an academic programme are required to undergo. It includes objectives & learning outcomes, course contents, scheme of studies, teaching methodologies and methods of assessment of learning. Since knowledge in all disciplines and fields is expanding at a fast pace and new disciplines are also emerging; it is imperative that curricula be developed and revised accordingly.

University Grants Commission (UGC) was designated as the competent authority to develop, review and revise curricula beyond Class-XII vide Section 3, Sub-Section 2 (ii), Act of Parliament No. X of 1976 titled "Supervision of Curricula and Textbooks and Maintenance of Standard of Education". With the repeal of UGC Act, the same function was assigned to the Higher Education Commission (HEC) under its Ordinance of 2002, Section 10, Sub-Section 1 (v).

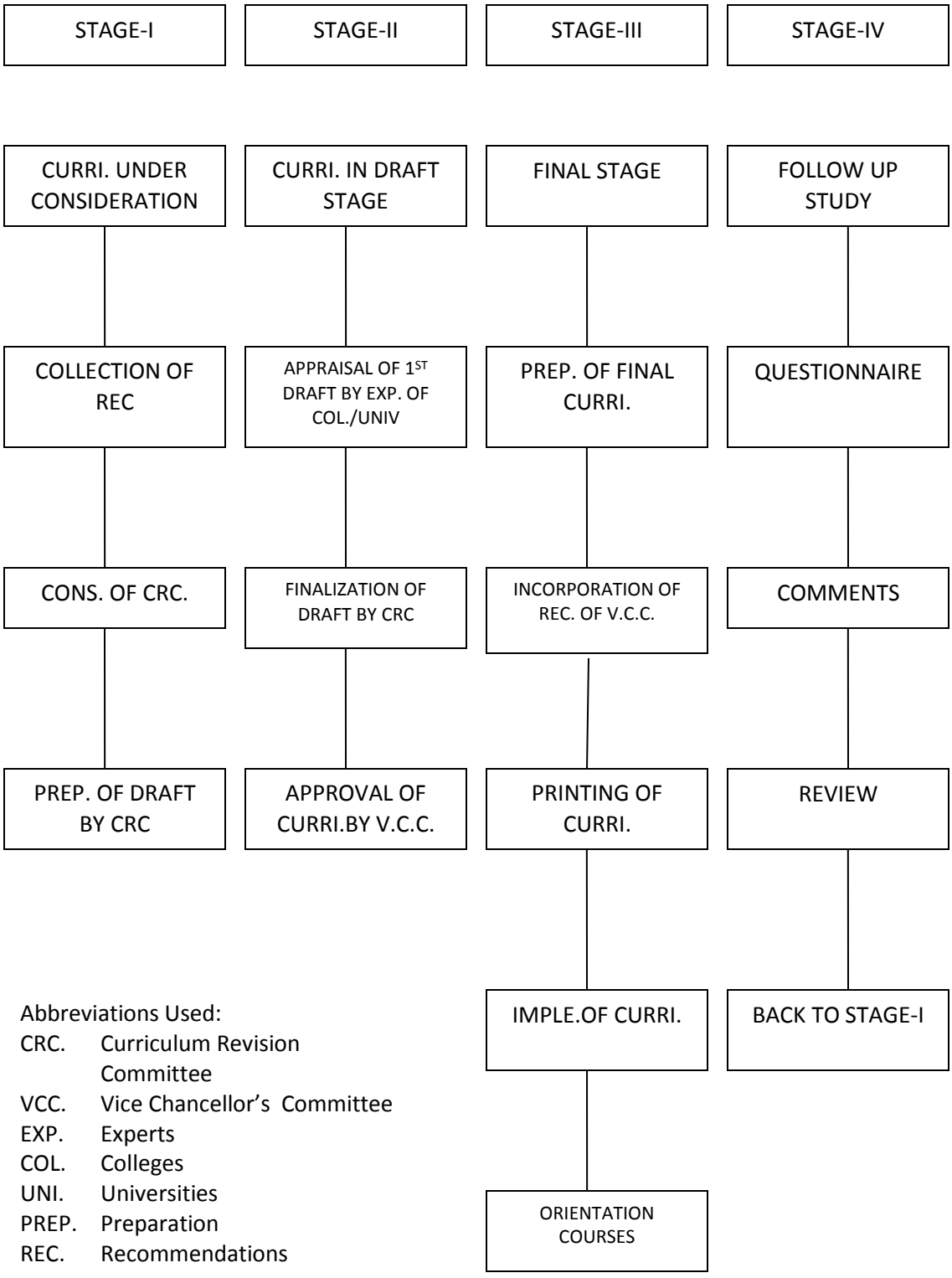
In compliance with the above provisions, the Curriculum Division of HEC undertakes the revision of curricula after every three years through respective National Curriculum Revision Committees (NCRCs) which consist of eminent professors and researchers of relevant fields from public and private sector universities, R&D organizations, councils, industry and civil society by seeking nominations from their organizations.

In order to impart quality education which is at par with international standards, HEC NCRCs have developed unified templates as guidelines for the development and revision of curricula in the disciplines of Basic Sciences, Applied Sciences, Social Sciences, Agriculture and Engineering in 2007 and 2009.

It is hoped that this curriculum document, prepared by the respective NCRC's, would serve the purpose of meeting our national, social and economic needs, and it would also provide the level of competency specified in Pakistan Qualification Framework to make it compatible with international educational standards. The curriculum is also placed on the website of HEC http://hec.gov.pk/english/services/universities/RevisedCurricula/Pages/default.aspx

(Fida Hussain)
Director General (Academics)

CURRICULUM DEVELOPMENT PROCESS



Abbreviations Used:

CRC. Curriculum Revision Committee
VCC. Vice Chancellor's Committee
EXP. Experts
COL. Colleges
UNI. Universities
PREP. Preparation
REC. Recommendations

MINUTES OF THE FINAL MEETING

The final meeting of National Curriculum Revision Committee (NCRC) in the discipline of Chemical Engineering was held from March 14-16, 2016 at HEC Regional Centre, Lahore to revise and prepare final draft curriculum for BE, BSc & ME, MSc levels of Chemical Engineering. The following members attended the meeting:-

Sr. No.	Name & Address	Status
1.	Prof. Dr. Javaid Rabbani Khan, Professor, Department of Chemical Engineering, GIK University of Engineering Science & Technology, Topi, KP.	Convener
2.	Prof. Dr. Muhammad Tayyeb Javed, Head of Department, Department of Chemical Engineering, Pakistan Institute of Engineering and Applied Sciences, C-209, P.O. Nilore, Islamabad.	Member
3.	Dr. Arshad Chugtai, Visiting Faculty, School of Chemical & Materials Engineering (SCME), National University of Sciences & Technology, Sector H-12, Islamabad.	Member
4.	Dr. Muhammad Mazhar Iqbal, Director, Project Management Organization NESCOM, Opposite EME College, Peshawar Road, Golra More, Rawalpindi.	Member
5.	Prof. Dr. Amir Ijaz, Director. Institute of Chemical Engineering & Technology, New Campus, University of Punjab, Lahore.	Member
6.	Dr. Muhammad Jamil, HoD, Department of Chemical Engineering, University of Faisalabad, Amin Campus, West Canal Road, Faisalabad.	Member
7.	Dr. Ghulam Mustafa Mamoor,	Member

	Professor, Department of Chemical Engineering, Wah Engineering College, University of Wah, Wah Cantt.	
8.	Dr. Fahad Rehman, Assistant Professor, Department of Chemical Engineering, COMSATS Institute of Information Technology, Defence Road, Off Raiwind Road, Lahore.	Member
9.	Prof. Dr. M. Suleman Tahir, Professor, Department of Chemical Engineering, University of Gujrat, Engineering Block, Hafiz Hayat Campus, Gujrat.	Member
10.	Dr. Inayatullah Memon, Professor & Chairman, Department of Chemical Engineering, NED University of Engineering &Technology, Main University Road, Karachi.	Member
11.	Mr. Abdul Waheed Bhutto Assistant Professor, Department of Chemical Engineering, Dawood University of Engineering & Technology, M.A Jinnah Road, Karachi.	Member
12.	Dr. Shaheen Aziz Shaikh, Professor, Department of Chemical Engineering, Mehran University of Engineering & Technology, Jamshoro.	Member
13.	Dr. Shagufta Ishtiaque, Assistant Professor/In-Charge, Department of Chemical Engineering, University of Karachi, Karachi.	Member
14.	Dr. Muhammad Najam Khan, Associate Professor / Chairperson, Department of Chemical Engineering, Balochistan University of Information Technology, Engineering & Management Science, Takatu Campus, Airport Road, Balili, Quetta.	Member
15.	Prof. Dr. Muhammad Zafar Noon, Campus Coordinator, Department of Chemical, Polymer Engineering,	Member

	University of Engineering & Technology, KSK Campus, Lahore.	
16.	Prof. Dr. Shahid Raza Malik, Director / CEO, Department of Chemical Engineering, NFC Institute of Engineering & Fertilizer Research, Jaranwala Road, Faisalabad.	Member
17.	Dr. Muhammad Asim Ibrahim, Assistant Professor, Pakistan Institute of Engineering & Applied Sciences, C-209, P.O. Nilore, Islamabad.	Member
18.	Dr. Saeed Gul, (Secretary) Associate Professor, Department of Chemical Engineering, University of Engineering & Technology, University Campus, Peshawar.	Secretary

The meeting started with recitation of Verses from the Holy Quran by Mr. Rizwan Shoukat, Deputy Director HEC, and he welcomed the participants of the meeting on behalf of the Chairman HEC. He thanked the members of the committee and their institutions for their efforts and their quality contribution in the preparation of the curriculum. He also thanked the Convener, Prof. Dr. Javaid Rabbani Khan, for taking personal interest in the development of the curriculum and for excellent coordination of the efforts of the committee.

At the beginning of the regular agenda, the Convener and Secretary discussed the curriculum prepared by the members in the first meeting and thanked the members for providing additional information for the curriculum after the first meeting.

The committee also visited the Chemical Engineering Department of the University of the Punjab. All members of the committee appreciated the efforts and hospitality of Prof. Dr. Amir Ijaz Director Institute of Chemical Engineering & Technology (ICET) for arranging the visit of ICET postgraduate and undergraduate labs and interactive meeting with the faculty members.

The Convener, Prof. Dr. Javaid Rabbani Khan, closed the meeting with thanks on behalf of all committee members to HEC for its efforts on the advancement of higher education and for providing a platform at the national level to bring together the experts from various institutions to develop the electronic engineering curriculum. He thanked all members of the committee for their dedication, hard work, and excellent teamwork in the preparation of

the revised curriculum. He requested the members of the committee to convey his thanks to their respective institutions for support of this task of national importance. Finally, he thanked Mr. Nazeer Hussain and the staff of the HEC Regional Centre, Lahore, for their dedicated support of the committee and generous hospitality.

RATIONALE:

The chemical engineering curriculum is designed so that its graduates are familiar with the techniques used in analyzing and solving engineering problems associated with the chemical and related industries (petroleum, pharmaceutical, metallurgical, plastics, pollution control etc.).

Chemical engineering is the application of mathematical and Natural Sciences by processing the raw material to finished product, economically without polluting environment for the benefit of mankind. Chemical engineering also applies the principles and application of other fields to improve and solve the problems of chemical engineering processes encountered in industries.

The chemical engineering curriculum is so designed that it not only includes the core chemical engineering courses but also courses from basic sciences (mathematics, chemistry, physics), communication skills, Islamiat and Pakistan studies, so that the graduate will not only have professional skills but also have a knowledge and understanding of basic principles, ethical considerations and leadership qualities.

Courses in chemical engineering fundamentals (material and energy balances) are introduced, followed by intensive work in engineering science and analysis (heat, mass, and momentum transfer; chemical thermodynamics; chemical reaction engineering; continuous and stage-wise separation processes; process dynamics and control). Computer solutions and simulation topics are stressed. An understanding of the ethical, and social issues, economic, and safety considerations in engineering practice is stressed throughout the curriculum. The appreciation of these professional concepts is incorporated as a part of all engineering course work.

MISSION STATEMENT:

Mission of chemical engineering undergraduate program is to provide qualified manpower with inter-disciplinary academic foundations needed to develop chemical products for the society. The program is aligned to integrate critical thinking, scholarly training, leadership qualities and

sustainable vision in graduates to enable them to cope with the complex problems of the chemical and allied industries.

OBJECTIVES:

This curriculum is designed to impart knowledge, skills and training in order to prepare graduates to have:

- Understanding of the needs of the society and demands of the 21st century and be able to improve quality of life
- Understanding of the principles of chemical engineering design and their application for sustainable development
- Ability to understand, analyze, interpret and solve problems of chemical and allied industries by using modern techniques, engineering tools, research and innovation
- Understanding of safety principles and practices in process industries
- Understanding of professional and ethical responsibilities
- Knowledge of contemporary issues and ability to work in multidisciplinary teams
- Leadership skills to serve on managerial positions within chemical and associated industries
- Understanding of life cycle environmental impacts of chemical and allied industries and their mitigation measures
- Effective communication of technical knowledge, skills and training
- Motivation to maintain and raise their level of engineering competence and achievement by engaging in lifelong learning

ME/MSc. (Engg) CHEMICAL ENGINEERING

This program aims to provide in-depth knowledge of Chemical Engineering to enhance analytical skills and research capabilities of the candidates.

The program will prepare chemical engineers for careers in teaching, research and development, and management in academia, government, and industry. This program shall also provide a basis for continued study leading to PhD degree.

Eligibility Criteria:

The committee determined the eligibility of the candidates seeking admission to the degree of ME/MSc. (Engg.) in Chemical Engineering and recommended that:

Bachelor's Degree in Chemical Engineering or equivalent from a recognized University should be the minimum requirement for eligibility of a candidate seeking admission to the degree of MS/ME/MSc. (Engg.) in Chemical Engineering.

Degree Requirements:

The committee determined the requirements for the award of degree of ME/MSc. (Engg.) in Chemical Engineering and recommended that the ME/MSc. (Engg.) in Chemical Engineering course shall comprise of:

1. A minimum of thirty (30) credit hours of course work or a minimum of twenty four (24) credit hours of course work along with a minimum of six (6) credit hours of research work/thesis.
2. A minimum of one academic year for full-time students or two academic years for part-time students.
3. The minimum number of teaching weeks per semester shall be sixteen.
4. Candidates should be evaluated during the session through tests, quizzes and assignments followed by a comprehensive examination at the end of each semester.

Framework ME/MSc Chemical Engineering

This program is built around:

- a minimum of 12 credit hours of course work from the core chemical engineering courses, and
- a minimum of 12 credit hours of course work from elective courses
- a minimum of 6 credit hours of research work, preferably resulting in a publication in peer reviewed journal/conference.

LIST OF ME/MSc. (Engg.) COURSES

LIST OF CORE COURSES:

(Select any 04 courses; "*Advanced Engineering Mathematics"* is compulsory)

1. Advanced Chemical Engineering Thermodynamics Advanced Chemical Reaction Engineering
2. Advanced Transport Phenomena
3. Advanced Engineering Mathematics
4. Process Dynamics and Control
5. Advanced Separation Processes

LIST OF ELECTIVE COURSES:

Group 1: Design Engineering:

1. Advanced Chemical Reactor Design
2. Advanced Fluid Mechanics
3. Advanced Heat Transfer
4. Numerical Methods in Chemical Engineering
5. Design of Heat Recovery Systems
6. Particle Dynamics
7. Experimental Design and Analysis
8. Project Management

Group 2: Process Engineering

1. Biochemical Engineering
2. Computational Fluid Dynamics
3. Computer Aided Process Design
4. Occupational Health and Safety in Process Industries
5. Process Design and Optimization
6. Transport Processes
7. Process Modeling and Control
8. Process Safety and Loss Prevention

Group 3: Energy Engineering

1. Sustainable Energy Engineering
2. Environmental Engineering
3. Energy Management & Auditing
4. Power Plant Engineering
5. Coal Technology

Group 4: Energetic Materials

1. Polymer Engineering
2. Explosives and Propellants
3. Rocket Propulsion Technology
4. Combustion of Energetic Materials.

Group 5: Advanced Materials

1. Advanced Composite Materials
2. Nano Technology
3. Materials Engineering
4. Mechanical & Thermal Behaviour of Materials

Other elective subjects may also be included according to the specialization/availability of the faculty and the facilities.

Students may undertake up to two relevant elective courses from other Academic Departments of the same Institution or from any other Academic Institution of Pakistan.

DETAIL OF COURSES
FOR ME/MSc IN CHEMICAL ENGINEERING

The proposed course contents are recommended to be offered as part of three credit hour courses.

Group 0; Core Engineering Courses

ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS:
Advanced topics in thermodynamics with emphasis on chemical and physical equilibria, and the estimation of thermodynamic properties. Methods of treating chemical and phase equilibria in multi-component systems through the application of thermodynamics and molecular theory.

ADVANCED CHEMICAL REACTION ENGINEERING:
Review of fundamental principles; Order of reaction and rate equation; Theory of rate processes; Diffusion and types of reactors; Estimation of reaction rate parameters using empirical and quantum chemical methods, detailed chemical kinetic modeling. Design of chemical reactors for homogeneous and heterogeneous reactions; Analysis and comparison of the differences between batch and continuous reactor by using kinetics and mass, energy and momentum balances. Design of fixed-bed, fluidized-bed and industrial catalytic reactors.

ADVANCED TRANSPORT PHENOMENA:
Advanced treatment of conductive heat transfer and convective heat and mass transfer. Use of boundary conditions to obtain solutions in particular situations. Interfacial phenomena. Simultaneous heat and mass transfer. Turbulence and its measurements. Statistical approach to turbulent flow. Mathematical model of turbulence. Applications of continuity and Navier-Stokes equations of particular situations. Solutions of boundary layer equations. Application to equipment design. Transfer through membranes and transpiration cooling.

ADVANCED ENGINEERING MATHEMATICS:
Application of advanced mathematical techniques to chemical engineering analysis. Mathematical modeling, scaling, regular and singular perturbation, multiple scales and asymptotic analysis. An introduction to modeling of Chemical Engineering problems. Formulation and classification of partial differential equations. Finite difference approximation. Method of characteristics. Formulation of boundary conditions and treatment of non linearities. Coupled equations. Application of the above principles in chemical engineering problems including linear and nonlinear ordinary differential equations and partial differential equations.

PROCESS DYNAMICS & CONTROL:
Fundamentals of mathematical modeling; Modeling and simulation of chemical processes. Transient response of control systems. Frequency response analysis. Root locus method of analysis. Frequency response of controllers. Frequency response of closed loop systems. Complex control scheme. Optimum controller settings. Dynamics and control of heat exchangers, distillation columns and chemical reactors. An introduction to modern control theory and computer control.

Enhancement of single loop control, digital control systems. Multi loop and multivariable control. Design of control systems.

ADVANCED SEPARATION PROCESSES:
Solvent extraction; Industrial processes and reagents; Equilibrium; Extraction kinetics. Extraction processes for metals including copper and uranium. Laboratory data collection; Column equipment and design principles; Mixer-settler performance; Coalescence; Adsorption. Ion exchange, principles, application and equipment. Fundamentals of membrane separation processes. Operating principles and equipment for dialysis. Reverse osmosis. Gas separation. Leaching and sorption.

Group 1; Design Engineering

ADVANCED CHEMICAL REACTOR DESIGN:
Design, scale-up and optimization of chemical reactors with allowance for heat and mass transfer and non-ideal flow patterns. Analysis of rate data for gas-solid, gas- liquid, and three-phase reaction systems. Transport processes in heterogeneous catalytic systems. Nonlinear boundary value problems arising in chemical reactors. Chemical reactor stability and sensitivity.

ADVANCED FLUID MECHANICS:
Solutions of the Navier-strokes equation; Percolation in porous media. Low Reynolds number flow. Creeping flow around a sphere. Laminar boundary layer. Free surface flows. Bubble dynamics at low, intermediate and large Reynold's number. Boundary conditions in the presence of surface active agents. Inter phase transport in isothermal systems. Fluid dynamics of two phase flow; Purely viscous non-newtonian constitutive equations. Fluidization.

ADVANCED HEAT TRANSFER:
Optimal design of shell and tube heat exchangers; Pinch technology. Flow arrangements of increased heat recovery. Condensation of single vapours; Condensation of single and mixed vapours; Vaporizers, evaporators and reboilers. Extended surfaces heat transfer. Cooling

towers. Furnace design and operation. Process design of equipment for heat transfer operation based on performance and economic optima.

ADVANCED MASS TRANSFER:
Uses and characteristics of separation processes; Simple equilibrium processes. Additional factors influencing product purities. Multi-stage separation processes. Patterns of change and computational approaches. Limiting flows and stage requirements. Empirical correlation, stage to stage methods. Successive approximation methods. Capacity and efficiency of contacting devices; Energy requirements of separation processes. Selection of separation processes. Optimal design and operation of separation processes.

NUMERICAL METHODS IN CHEMICAL ENGINEERING:
Numerical treatment of ordinary differential equations and partial differential equations; Sampling theory, Inference and estimation; Tests of Hypotheses,; THEORY-test, chi-square test, F-Test and analysis of variance. Regression analysis and correction. Random walk and poison processes, Application of simulation to the solution of engineering problems. Linear programming.

DESIGN OF HEAT RECOVERY SYSTEMS:
Introduction to heat integration, energy targeting and pinch analysis, heat exchanger network design for maximum heat recovery, heat exchanger design, utilities provision, capital and energy trade-offs, automated design of heat exchanger networks, retrofit of heat exchanger networks, heat engines, heat pumps, and refrigeration. Heat integration of reactors, separation processes. Data extraction.

PARTICLE DYNAMICS:
Flow around particles. Drag force, Motion of particles and bubbles; Sedimentation. Settling. Fluidization. Centrifugation. Filtration. Gas cleaning. Theory of cyclones. Atomization. Power storage. Solid conveying. Aerodynamics; Instability of liquids and mechanics of drop formation. Agglomeration mechanics.

EXPERIMENTAL DESIGN AND ANALYSIS:
Fundamentals of design of experiments; Interactions in processes; A systematic methodology for design of experiments; Single factor experiments; Analytical comparisons among treatments and trend analysis; Two factor experiments; higher- order factorial experiments; Decreasing error variance; Other designs; Fitting regression models.

PROJECT MANAGEMENT:
Project identification and formulation. Project selection models. Feasibility

preparation including market evaluation, Demand forecasting. Site selection and survey. Plant capacity decisions. Project engineering including selection of technology. Industrial proprietary rights. Procurement operations; Contracts and contractors. Project implementation, PERT/CPM. Resource allocation; Cost estimates. Progress reporting. Industrial hazards and safety consideration; Quality Management in Projects. Project Audit; Use of computer software packages in project management.

Group 2; Process Engineering

BIOCHEMICAL ENGINEERING:
Characteristics of industrial micro-organism. Growth of micro-organism. Basic metabolic processes. Bio-degradation. Bio-mass productivity and activity. Aerobic and anaerobic processes; Nitrification and De-nitrification processes. Stirred tank bioreactor. Jet bioreactor. Reciprocating jet bioreactor. Hollow fibre bioreactor. Fuidized bed bioreactor. Application of various bio processes for the treatment of industrial wastes and production of chemicals. Theory of Bio-chemical processes involved in the production of food products, beverages, organic acids, industrial solvents, various pharmaceutical products and commercial enzymes.

COMPUTATIONAL FLUID DYNAMICS:
General Differential Equations; Numerical solution of energy and Navier-Stokes Equations; Numerical schemes and algorithms; Methods of obtaining convergence; Transient analysis; finite difference and finite element methods applied to fluid mechanics; Matrix solving Techniques; Recent developments in CFD; Control Volume Formulation; Finite Volume Method. Development of computer programs for CFD problems.

COMPUTER AIDED PROCESS DESIGN:
Selection and design of chemical, biochemical or petrochemical processes, equipment and control systems, case studies. Comparison and optimization; Equipment evaluation and estimating procedures using computer methods. Process oriented Languages, data banks, decompositional methods related to process systems arrangement. Heuristic synthesis of equipment sequences. Application in chemical and petro-chemical processes.

OCCUPATIONAL HEALTH AND SAFETY IN PROCESS INDUSTRIES:
Introduction to occupational health and safety, basic concepts of health and safety in process industries. Hazards and types of hazards in chemical and process industries. Causes of accidents in industries, concept and principles of accident prevention in industries, risk analysis, safety performance measurement in industries, strategies for control of

occupational safety and health hazards in process industries.

PROCESS DESIGN AND OPTIMIZATION:

A coordinating course consisting of Chemical Engineering problems of considerable complexity which require for their solutions the application of thermodynamics, transport processes, reaction engineering. The selection of materials of construction. The organization for optimization. Optimization techniques. Function of a single variable. Analytical and numerical methods. Multivariable functions, analytical and numerical methods. Function of continuous variable, analytical and numerical methods. Optimization in practice.

TRANSPORT PROCESSES:

Development of differential and integral forms of Momentum and Energy conservation equations; The analogy between heat and momentum transfer; Solution of laminar flow and inviscid flow problem; Boundary layer theory; Turbulent flow, conductive and convective heat transfer problems; Heat transfer during laminar and turbulent flow. Solution of steady and transient heat and mass diffusion problems; Convective heat and mass transfer in laminar and turbulent flow; Interphase heat and mass transport.

PROCESS MODELING & CONTROL:

Mathematical Modeling; Dynamic Behaviour of Linear Low Order Systems; Dynamic Behaviour of Linear Higher Order Systems; Inverse Response Systems; Time-Delay Systems; Frequency-Response Analysis; Stability. Process Identification: Empirical Process Modeling; Feedback Control Systems; Conventional Feedback; Controller Design; Controller Design for Processes with Difficult Dynamics; Model-Based Control; Review of Partial Differential Equations, Physical behaviours of Partial Differential Equations; Mathematical Tools, e.g. Tensors, combination of variables; Mathematical Modeling in MATLAB, SIMULINK.

PROCESS SAFETY AND LOSS PREVENTION:

Introduction to hazard, accident and loss. Legislation and law. Major hazard control and management systems. Hazard identification and safety audit. Hazard assessment. Plant layout. Process and pressure system design. Safety in plant operation. Maintenance and modification. Control system design. Human factors in control system design. Emission and dispersion. Fire, explosion and toxic release and storage. Transport. Emergency planning, Personal safety and safety systems.

Group 3: Energy Engineering

SUSTAINABLE ENERGY ENGINEERING:

Chemical fuels; Characteristics of chemical fuels; Chemical fuels reserves and production in Pakistan; Combustion chamber design. Clean coal technology. Fluidized bed combustion. Atmospheric pressure FBC boiler. Atmospheric pressure FBC furnaces. Fast fluidized bed systems. Pressurized fluidized bed combustion. Pollutant emissions in combustion processes. Primary and secondary fuels; Energy conversion with combustion. Wind power. Water power; Solar power. Geo thermal power. Nuclear power. Calculations in fuel and energy, energy economics. Energy conservation methodologies of selected systems, Renewable energy technologies.

ENVIRONMENTAL ENGINEERING:

Introduction to environmental engineering and basic terminology. Environmental issues at global, regional and national levels. Types of environmental pollution and their control. Land pollution. Water pollution. Air pollution and noise pollution. Plastic materials. Recycling. Effects of pollutants on living systems. Effluent Guidelines and standards; Monitoring of pollution; Conservation of Material Resources and Energy through recycling. Water pollution, Waste water and its treatment. Industrial waste treatment and disposal. Air pollution and its abatement. Solid waste management; Noise pollution and its abatement; Radioactivity and its monitoring. Pollution control of selected industry. Mathematical modeling of environmental pollution control. Environmental Management and Auditing system (EMAS). Sustainable development. Environment friendly technologies and cleaner production. Pollution prevention. Life cycle analysis.

ENERGY MANAGEMENT & AUDITING:

Definition, Energy audit- need, Types of energy audit, Energy management (audit) approach-understanding energy costs, Bench marking, Energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments.

POWER PLANT ENGINEERING:

A thermodynamics review, First & Second Law of Thermodynamics, Open and Closed system, Cycle, Property Relationships, Concept of Reversibility, Concept of Entropy, Carnot Cycle, Rankine, Ideal Rankine & Externally & Internally Irreversible Rankine cycle, superheat, Reheat, Regeneration, Open and closed or Direct-Contact Feed water Heaters, Efficiency and Heat Rate, The Placement of Feedwater Heaters, Supercritical-Pressure Cycle,

Cogenerations.

Introduction to Fossil-Fuel Steam Generators, Fire and water-Tube Boiler, Once-through Boiler**,** Steam-Generator Control, Fuels and Combustion, Coal Analysis, Coal Firing**,** Mechanical Stoker, Fluidized-Bed Combustion**,** Liquid Fuels**,** Liquid, Gas, and Solid By-products**,** Synthetic Fuels**,** Biomass**,** Heat of Combustion, Heating Values, Turbines**,** Impulse Principle & turbines, Efficiencies, Turbine Arrangements, Gas Turbines & Combined Cycles, Ideal & non ideal Bryton Cycles, combined Cycle for Nuclear Power plants Principles of Nuclear Energy

Atomic Structure, Chemical and Nuclear Equations, Energy from Nuclear Reactions, Nuclear Fusion and Fission, Energy from Fission and Fuel Burnup, Radioactivity, Decay Rates and Half-Lives, Neutron Energies, Thermal Neutrons, Nuclear Cross Sections, Neutron Flux and Reaction Rates, Fission Reactor Types, Reactor Control, Pressurized-water Reactor (PWR), boiling-water Reactor (BWE), The Gas-Cooled Reactor (GCR), High-Temperature Gas-Cooled Reactor (HTGR), Pebble-bed Reactors

Geothermal Energy, Past, Present, and Future, Origin and Types of Geothermal Energy, Operational and Environmental Problems, Petrothermal Systems, Hybrid Geothermal-Fossil Systems. Solar Energy, Extraterrestrial & Terrestrial Solar Radiation, Solar-Electric Conversion System, Receiver, Thermal-Storage System, World Experience Wind Energy, Principles of Wind Power, Wind Turbine Operation, Site Characteristics, New Developments: Small & large Machines Energy from the Oceans**,** Ocean Temperature Differences, Open or Claude Cycle, Ocean Waves & Wave Motion, Energy and Power from Waves, Wave-Energy Conversion by Floats, Tides, Simple Single-Pool Tidal System.

Energy-Storage Systems, Pumped Hydro, Compressed-Air Storage, Energy Storage by Flywheels, Electrical Battery Storage, Superconducting Magnetic Energy Storage, Thermal Sensible Energy Storage, Latent Heat Energy Storage, Chemical-Reaction Storage

Recommended Book:

1. Power plant Technology by M.M. El-Wakil

COAL TECHNOLOGY:

Introduction to combustion & coal Technology, coal preparation, processing, Utilization & Emission, Clean Coal Technology, Co-combustion, Co-firing concepts, Coal carbonization, Coal Washing, Coal Blending, Coal Gasification, Integrated Gasification Combined Cycles (IGCC) ,Early and Commercial Gasifies, Coal Briquetting, Coal Utilization in power plants and

other industries, CO_2 Capturing Technology, Effects of usage of coal on human health and environment, LCA process.

Group 4: Energetic Materials

POLYMER ENGINEERING:

Structure and properties of polymers. Analysis and testing of polymers. Methods of polymerization and co-polymerisation. Preparation and properties of commercially important polymers. Polymers processing, equipment and machinery. Polymer blends, formulation and performances. Synthesis of high polymers, properties, thermodynamics and molecular weight. Polymer additives, blends and composites. Commodity thermoplastics and specializing polymers. Polymer processing and rheology. Application of polymers. Energetic polymers for composite propellents. Extrusive and Casting of polymer-based composition.

PROPELLANTS AND EXPLOSIVES:

Explosion theory and types of explosions; The chemistry of explosive compounds and mixtures; The concept of fuel and oxidant, oxygen balance; Thermo-chemistry, simple prediction of heat, temperature and pressure of explosion; Introduction to deflagration, detonation and classification of explosives; Commercial and military HE, power, brisance; Aluminized HE; Introduction to wave shaping and shaped charges; Principles of propellant chemistry, solid and liquid propellants for guns, rockets and mortars; Primary explosives, initiation, effect of heat on explosives, explosives trains; Principles and applications of pyrotechnics; Safety, reliability and testing of explosives; Management of explosive including classification and storage.

ROCKET PROPULSION TECHNOLOGY:

Background and History of Rocket Propulsion, Classification, Applications, Thrust, Exhaust Velocity, Energy and Efficiencies, Nozzle Theory and Thermodynamic Relations, Chemical Rocket Propellant Performance Analysis, Solid Propellant Rocket Fundamentals, Propellant Burning Rate, Combustion Models, Basic Performance Relations, Propellant Grain and Grain Configurations, Solid Propellant Classification, Propellant Characteristics, Hazards, Propellant Ingredients, Propellant Processing and Manufacture, Propellant Grain Mechanical Properties, Solid Rocket Components and Motor Design, Introduction to Liquid Propellant Rocket Engines, Liquid Propellants.

COMBUSTION OF ENERGETIC MATERIALS:

Thermochemistry of Combustion, Energetics of Propellants and Explosives, Combustion of Crystalline and Polymeric Materials, Combustion of Double

Base Propellants, Combustion of Composite Propellants, Combustion of Explosives, Combustion in a Rocket Motor. Combustion Rate Predictions and Measurement Methods.

CIVILIAN APPLICATIONS OF ENERGETIC MATERIALS:
Rock blasting, Mining, Motor car safety bags, Oil exploration, Outer space exploration, Fireworks, Explosive welding, Controlled demolition industry, Agriculture sector, Medical industry, Civil Engineering and Nuclear devices.

Group 5: Advanced Materials

ADVANCED COMPOSITE MATERIALS:
Introduce to advanced materials for engineers, emphasizing the production /structure /property /function relation and application of a number of advanced materials mainly for Biomedical and Aerospace applications. Background to thermosetting and thermoplastic polymer matrix composites; Overview of established manufacturing processes; Developing processes; Automation; Machining; Future process developments (including tufting, nanoparticle modified resins, hybridised materials, Applications - case studies from aerospace, automotive, marine and energy sectors; Refractory materials and coatings for high temperature applications, thin film shape memory alloys for MEMS.

NANO TECHNOLOGY:
Basic Concepts, History of Nano, Size Effects on Properties, Top Down vs Bottom Up, Nano –Tools, Nanoparticle synthesis & characterization, Other Nanomaterials, Sensors, Biomaterials, Energy, Nanomaterials in the Environment.

MATERIALS ENGINEERING:
Introduction to materials: Atomic structure, crystal structure, imperfections, diffusion, mechanical properties, dislocations and strengthening mechanisms, phase diagrams, phase transformations, solidification, corrosion. Basic and alloy steels, tensile behaviour of metals, work and precipitation hardening, recovery and recrystallization.

Structural steels C-Mn ferrite-pearlite structural steels, specifications and influence of composition, heat treatment and microstructure on mechanical properties. Fracture, weldability and the influence of welding on mechanical properties. Corrosion Resistant Materials - Stainless steels - austenitic, ferritic, martensitic and duplex stainless steels compositions, microstructures, properties. Welding and joining processes, weld metal, heat affected zones and weld cracking. Non-metallic Materials - Polymers and composites manufacturing issues, physical properties and mechanical

behavior Structure and properties and applications of ceramics. Principles underlying electrical and magnetic properties of materials.

MECHANICAL BEHAVIOUR OF MATERIALS:

Overview of failure behaviour of cracked bodies; crack size influence, brittle and ductile behaviour; influence of material properties; cyclic loading and chemical environment. Linear elastic fracture mechanics (LEFM) and crack tip stress fields, stress concentration, stress intensity, plane stress and plane strain; fracture toughness in metallic materials; fracture toughness testing; calculations of critical defect sizes and failure stress. elastic- plastic failure criteria; Fracture of rigid polymers and standard tests for fracture resistance of polymers. Delamination fatigue tests. Emerging CEN/ISO standards, current ESIS test procedures. Crack extension under cyclic loading; regimes of fatigue crack growth; influence of material properties and crack tip plastic zones; calculation of crack growth life and defect assessment in fatigue; crack closure and variable amplitude loading; short cracks and the limits of LEFM; software design tools for fatigue crack growth. Static loading-stress corrosion cracking; corrosion fatigue.

RECOMMENDATIONS

1. All Chemical Engineering institutions should review their educational process and make it more sustainable.
2. The courses should be taught in a way to develop a more application based and research oriented approach.
3. The student assessment should be based on questions related with knowledge and understanding of subject including engineering analysis, investigation, engineering practices and transferable skills.
4. Latest software relating to chemical engineering subjects such as HYSYS, MATLAB, ANSYS, Auto CAD, Math, CAD, Pro-E should be made available at Institutions offering programmes in Chemical Engineering.
5. Faculty training in core disciplines should be arranged at Institutions offering programmes in Chemical Engineering.
6. Laboratory facilities should be strengthened to facilitate the lab work associated with theory courses.
7. All laboratories should be supervised and managed by qualified Lab Engineers.
8. Efforts should be made to strengthen academia-industry interaction.
9. Masters in Chemical Engineering by research is strongly recommended to be incorporated in the postgraduate programme.
10. The Practical/Lab work should comprise at least 20-30% of the total credit hours.
11. All the Universities/Institutions should make arrangements for practical training of their students in industrial organizations during summer.
12. To strengthen research capacity of HEIs, the honorarium for the postgraduate students, in engineering disciplines, is recommended to be equivalent to BPS- 17 salary.