Group No.	Course Code	Course Title	UNIQUE CODE
1	20HCE21	Applied Mathematics in Chemical Engineering	201CH001
1	20HCE243	Multiphase Flow	201CH002
1	20HCE331	Chemical Process Optimization	201CH003
1	20HCE254	Process Integration Techniques	201CH004
2	20HCE14	Transport Phenomena	202CH001
2	20HCE15	Process Equipment Design	202CH002
2	20HCE23	Catalytic Reaction Engineering	202CH003
2	20HCE13	Advanced Chemical Thermodynamics	202CH004
3	20HCE241	Waste Management Techniques	203CH001
3	20HCE251	Fuel Cell Technology	203CH002
3	20HCE252	Air Pollution Control & Equipment	203CH003
3	20HCE323	Process Modelling & Simulation	203CH004
4	20HCE321	Fermentation Engineering	204CH001
4	20HCE334	Food Processing & Engineering	204CH002
4	20CEE13	Applied Environmental Chemistry & Microbiology	204CH003
4	20HCE22	Bioinstrumentation and Biosensors	204CH004
5	20HCE322	Total Quality Management	205CH001
5	20HCE324	Pharmaceutical Technology	205CH002
5	20HCE333	Computational Fluid Dynamics	205CH003
5	20CEE243	Environmental Planning & Management	205CH004
6	20HCE31	Modern Separation Processes	206CH001
6	20HCE332	Gasification Technology	206CH002
6	20CEE253	Renewable Energy and Alternatives Fuels	206CH003
6	20HCE253	Advanced Nanotechnology	206CH004
6	20MST244	Advanced Materials and Processing	206CH005

(Group-1):20HCE21Applied Mathematics in Chemical Engineering

Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Probability and sampling theory: Definitions, Conditional probability, Probability Distributions-Bernoulli, Binomial, Poisson, uniform, exponential, normal and gamma. Random samples, central limit theorem, X2, t and F distributions. Estimation-point estimation, unbiasedness and consistency. Hypothesis testing-types of errors, significance level, Test concerning single mean, single variance and two means and two variance. Goodness of fit test.

Module-2

Design and analysis of experiments: Treatment and interpretation on engineering data: Curve fitting, Non-linear least square regression. Interpolation: Newton's Forward/Backward interpolation formula, Lagrange's interpolation formula and experiments their application.

Module-3

Numerical solution of linear & nonlinear algebraic equations: Linear systems of equations, solutions by Creamer's Rule, Matrix methods, Gaussian, Gauss-Jordan, Jacobean, Gauss-Seidel and Relation methods. Formulation of linear and non-linear first and second order ordinary differential equations, higher order linear, differential equations for systems involving momentum, heat and mass transfer with and without chemical reactions and their analytical solutions.

Module-4

Numerical solution of ordinary differential equations: Ordinary differential equations: Runge-Kutta, Euler's and Milne's predictor corrector methods. Solution of boundary value problems.

Module-5

Partial differential equations: Solutions of elliptic, parabolic, and hyperbolic types of equations by Finite differences method.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module.

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Introduction to Probability and Statistics for Engineers and Scientists	Sheldon M. Ross	John Wiley& Sons, New York	1989
2	Numerical Solution of differential equations	Jain M.K.	Wiley Eastern Publishers, New Delhi	1987
3	Applied Mathematics in Chemical Engineering	H.S. Mickley, T. K. Sherwood and C.E. Reid	Tata McGraw Hill, New Delhi	1978
4	Numerical Solution of partial differential equations	Smith G.D	Oxford University Press, London	1978

(Group-1): 20HCE243Multiphase Flow

Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Multiphase Flow Scope and Significance of multiphase flows – Dimensionless numbers in multiphase flow – Flow pattern and Flow regimes: Fluid-Solid System, Fluid-Fluid Systems, Solid-Fluid-Fluid systems.

Module-2

Flow Classification Two phase Co-current flow of Gas-Liquid, Gas-Solid and Liquid-Liquid, Upward and Downward flow in vertical pipes -- Suspensions of Solid and their transport in Horizontal pipes -- Drag Reduction Phenomena, Laminar, Turbulent and Creeping Flow regimes.

Module-3

Mixing Power Correlations Theories of intensity and scale of turbulence – Calculation of circulation velocities and power consumption in agitated vessels for Newtonian and Non-Newtonian Fluids – Blending and Mixing of phases – Power requirement for aeration to suspend to an immiscible liquid or solids in slurry reactors, prediction of optimum speed of impeller Rotor and design criteria for scale up.

Module-4

Quantification of Flow system Prediction of holdup, pressure drop and bubble size in pipe flow - Lockhart - Martinelli Parameters, Bubble column and its design aspects; Flow through packed bed and fluidized bed, Minimum carryover velocity – Holdup Ratios, Pressure drop and transport velocities and their prediction – Solid Fluid Conveying and Settling.

Module-5

Flow in Three Phase Systems Gas Solid and Liquid composites in slurries in Horizontal pipes, Flow through porous media of composite mixtures, Prediction of holdup, pressure drop and throughput velocities in three phase system – Design of multiphase contactors involving Solids, Liquids and Gases.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	The Flow of Complex Mixtures in Pipes	George Wheeler Govier, Khalid Aziz	Society of Petroleum Engineers	2008
2	One-dimensional Two Phase Flow	Graham B. Wallis	McGraw-Hill	1969
3	Convective Boiling and Condensation	John G. Collier, John R. Thome	Oxford University Press	2002
4	The Phenomena of Fluid motions	Brodkey, R. S	Addision-Weselely	1967
5	Hand Book of Multiphase Sysems	Hestroni, G.	Hemisphere Publishing, Washington	1982

(Group-1): 20HCE331Chemical Process Optimization	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Introduction: Introduction to optimization, Functions of single and multiple variables - optimality criteria, direct and indirect search methods. Formulation of problems and basic concepts.

Module-2

Linearization: Fundamental theorem of linear programming, Degenerate solutions, Simplex methods, Cycling, Duality, Complementary slackness conditions. Transformation methods based on linearization. Quadratic and Geometric Programming: problems.

Module-3

Optimal Control Problems: Euler-Lagrange optimality criteria, Pontryagin's maximum principle, optimal control problems. Numerical methods.

Module-4

Introduction to Artificial Intelligence in optimization. Introduction to Genetic algorithm (qualitative treatment only).

Module-5

Optimization in Chemical Engineering: Importance of Engineering economics, various optimization softwares (qualitative treatment only), use of optimization techniques for process design and integration (take some typical examples).

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Optimization Techniques for Chemical Engineers	T.F. Edgar and D.M. Himmelblau	McGraw-Hill	1985
2	Optimization Techniques	K. Deo	Wiley Eastern	1995
3	Chemical Process Design & Integration	Robin Smith	Wiley	2005

(Group-1): 20HCE254Process Integration Techniques

Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

The nature of Chemical Process Design and Integration: Formulation, Hierarchy, approaches. Thermodynamic properties and phase equilibria: Equations of state, Fugacity, VLE, LLE, Calculation of enthalpy, entropy, simple problems.

Module-2

Energy targets: Composite curves, Temperature interval diagram, process constraints, Grand composite curve, simple Problems.

Module-3

Network design: Pinch design method. Minimum no of heat exchangers, breaking of heat loop, Stream splitting, No of heat exchanger units, heat exchange area targets Simple problems.

Module-4

Mass exchangers, types, cost optimization of mass exchangers, Mass integration strategies, Mass exchange Pinch diagram, Composition interval diagram, simple problems.

Module-5

Application of process integration concepts in minimum water usage, pinch technology for wastewater treatment applications, simple problems.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Chemical Process Design & Integration	Robin Smith	Wiley	2005
2	Process Integration	Mahmoud. M., El – Hawalgi	Academic Press	2006
3	A User Guide on Process Integration for Efficient Use of Energy	Bodo Linnhoff	Institution of Chemical Engineers	1982
4	Pinch Analysis and Process Integration - A user guide on process integration for efficient use of energy	Ian C. Kemp	Elsevier Science	2011

(Group-2): 20HCE14Transport Phenomena

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Newtonian fluids, Non Newtonian Fluids, Analogies between Momentum, Heat and Mass Transport, Rheological behavior of fluids, Differential balance equations for heat , mass and momentum

Module-2

Steady state Shell momentum balances, Boundary conditions applicable to momentum transport problems (flow over flat plate, flow through circular tube and annulus).

Module-3

Friction factor(qualitative treatment only) Introduction to velocity distributions in Turbulent flow (Fluctuations and Time smooth Quantities) and Equation of Change for Isothermal system(Equation of Continuity and Motion), Formation of bubbles and drops and their size distribution, Solid-fluid systems - forces acting on stagnant and moving solids.

Module-4

Heat Transfer coefficient, Free and Forced convection, film type and drop wise condensation and equations for heat transfer coefficients for both, Heat transfer in boiling liquids.
The spectrum of electromagnetic radiation, absorption and emission at solid surfaces, Planck's distribution law, Wein's displacement law and Stefan- Boltzmann law, Lambart's cosine law, heat exchange by radiation between two black surface elements.

Module-5

Introduction to Mass Transport: Fick's law of diffusion, mass transfer co-efficient, Shell mass balance techniques (Diffusion with homogeneous and heterogeneous chemical reaction).

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Transport Phenomena	Bird R.B., W.E. Stewart and E.N. Lightfoot	John Wiley and Sons, Academic Press	2007
2	Fundamental of Momentum, Heat and Mass Transfer	Welty, J.R., C.E. Wicks and R.E. Wilson	John Wiley & Sons, New York	2014
3	Elements of Transport Phenomena	Sissom L.E. and	McGraw Hill	1972
4	Transport Phenomena - A Unifed Approach	Brodkey R.S. and H.C.Hershey	McGraw Hill Book Company	1988

(Group-2): 20HCE15Process Equipment Design	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Detailed Engineering & Process and Mechanical aspects and sketches with sectional front view full top and side view of Double pipe heat exchanger

Module-2

Detailed Engineering & Process and Mechanical aspects and sketches with sectional front view full top and side view of shell and tube heat exchanger

Module-3

Detailed Engineering & Process and Mechanical aspects and sketches with sectional front view full top and side view of horizontal and vertical condensor

Module-4

Detailed Engineering & Process and Mechanical aspects and sketches with sectional front view full top and side view of evaporator

Module-5

Detailed Engineering & Process and Mechanical aspects and sketches with sectional front view full top and side view of bubble cap distillation column and Absorption column

Question paper pattern:

- The question paper will have TWO questions.
- Each full question is for 100 marks.
- Use of Chemical Engineers handbook-Perry & Green and IS codebooks IS 2g25 and 4503 are permitted
- Students will have to answer 1 full question.

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Process Heat Transfer	Kern. D. Q.	McGraw Hill Book Company	2008
2	Introduction to Process Design Equipment	B.I. Bhatt & Thakore	Tata McGraw Hill Book Company, New Delhi	2007
3	Joshi's Process Equipment design	V. V. Mahajani and S. B. Umaeji	MacMillan Publications India Ltd, New Delhi	2009
4	Chemical Engineering Design (Vol. 6)	Coulson and Richardson	Butter-Worth Heinemann Ltd., New York	2005
5	Perry's Chemical Engineering Hand Book	Don W. Green & Robert H. Perry	McGraw Hill Book Company	2008

(Group-2): 20HCE23Catalytic Reaction Engineering

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Industrial Catalysis: Classification on catalyst- homogeneous ,heterogeneous, Biocatalysts, Typical industrial catalytic processes, preparation of catalysts- laboratory techniques, Industrial methods, Transition models, dual functional catalysts, zeolites, Enzymes, Solid Supportive materials, Catalyst activation.
Catalyst Characterization: Surface area measurements, BET Theory, pore size distribution, Porosity-Chemisorption techniques, Static and dynamic methods, Crystallography and surface analysis techniques, XRD, XPS,ESCA, ESR, NMR, Raman and Molecular spectroscopies, Surface acidity and toxicity, activity, life time, Bulk density, Thermal stability Kinetics of Heterogeneous Reactions(catalytic): Catalytic Reactions, Rate controlling steps, Langmuir - Hinshelwood model, Riedel – Eiley Mechanism.

Module-2

Catalyst Deactivation: Poisons, Sintering of catalysts, pore mouth plugging and uniform poisoning models, Kinetics of deactivation, Catalyst regeneration.

Module-3

Heterogeneous Reactions (non-catalytic): Introduction, non-catalytic fluid-fluid reactions. Non-catalytic fluid solid reactions & models for such reactions to determine time of conversion.

Module-4

Non ideal reactor analysis: Mixing concepts, Residence Time Distribution, Response measurements, Segregated flow model, Dispersion model, Series of stirred tanks model, Recycle reactor model, Analysis of non-ideal reactors, Two parameter model for CSTR.

Module-5

External Diffusion Effects in Heterogeneous Reactions: surface kinetics& pore diffusion effects, Evaluation of effectiveness factor, Design of reactors for heterogeneous Catalytic & Non catalytic Reactions: Design of reactors for non-catalytic fluid-fluid and fluid- solid reactions.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Chemical Reaction Engineering	Octave Levenspiel	John Wiley and sons, New York	1999
2	Catalysis (Vols. I & II)	Emmett, P.H.	Reinhold Publishing Corporation, New York	1954
3	Elements of Chemical Reaction	Fogler H.S	Prentice Hall,	1986
4	Chemical Engineering Kinetics	Smith J.M	McGraw- Hill Book Company, New York	2014
5	Chemical Reactor Design and Analysis	Bischoff and Froment	Addision Wesley, New York	2011

(Group-2): 20HCE13Advanced Chemical Thermodynamics

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Review of First & Second Law of Thermodynamics: First Law of Thermodynamics: General statement of First law of thermodynamics, First law of cyclic process and non – flow processes, Heat capacity. Derivation for closed system & steady state flow process-flow calorimeter & heat capacity

Second Law of Thermodynamics: General statements of the Second law, concept of Entropy, The Carnot Principle, Calculation of entropy changes, Clausius Inequality, Entropy and irreversibility, Third law of thermodynamics.

Module-2

Applications Solution Thermodynamics: Partial Molar Properties: Ideal & non ideal solutions, fugacity and it's coefficient, Determination of fugacity coefficient, Gibbs Duhem equation, azeotropic separation techniques–VLE

Module-3

Vapor Liquid Equilibrium Correlations: Correlation Techniques: Van Laar, Margules, Wilson,, NRTL and other types of correlation Equation , applications of -High pressure VLE and Partially miscible systems.

Module-4

Chemical Reaction Equilibria:-Industrial chemical reaction equilibria-homogeneous and heterogeneous systems, Effect of pressure and temperature – Complex reactions – liquid phase and vapour phase reactions.

Module-5

Third Law of Thermodynamics: Verification of third law, Applications and evaluation of Statistical Thermodynamics, Energy levels, Boltzmann Distribution Law and Partition functions.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Thermodynamics and Its Applications	Jefferson W. Tester, Michael Modell	Prentice Hall, India	1997
2	Textbook of Chemical Engineering Thermodynamics	Narayanan, K.V	Prentice Hall, India	2001
3	Introduction to Chemical Engineering Thermodynamics	J.M. Smith and Van Ness H.C	McGraw Hills, New York	1996

(Group-3): 20HCE241Waste Management Techniques

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction to Waste water: Ecosystem, characteristics, standards, effects of waste water on health, ecosystem, and materials.
Physical Treatment Methods: Introduction to Screening, flow equalization, flocculation, Grit removal, sedimentation, flotation.
Chemical Treatment Methods: Introduction to coagulation, precipitation, oxidation, Neutralization, chlorination. Detailed study on phosphorous and heavy metals removal.

Module-2

Biological Treatment: Introduction to Bacterial life cycle, cell culturing, types of biological processes. Anaerobic Process: Construction and working of UASBR, Rotating biological contactors. Algal ponds, Hyacinth and Duckweed, fish ponds.

Module-3

Aerobic process. Theory of aeration, factor affecting oxygen transfer, Mixing requirements, types of aerators. Nitrification & Denitrification. Detailed study on Activated sludge process & Trickling filter.

Module-4

Solid waste Management: sources, characteristics, present techniques of solid waste management, integrated solid waste management, Measures and methods to assess solid waste quantities. Functional elements, Generation of solid waste, Onsite handling. Collection SCS, HCS, and separation processes, source reduction, 3R's.

Module-5

Solid Waste Transformation: Thermal conversion techniques Pyrolysis, Gasification, waste to energy, composting.
Disposal: Site selection, landfill and engineering landfill, Leachate and gas collection. Industrial Regulations pertaining to waste water and solid waste.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Wastewater Treatment for Pollution Control and Reuse	Arecivala S.J. and S.R.Asolekar	Tata McGraw Hill Pvt. Ltd., New Delhi	2009
2	Integrated Solid Waste Management	George Tchobanoglous, Victor M. Alaniz	McGraw-Hill	1993
3	Wastewater Engineering -Treatment	Metcalf and Eddy	McGraw-Hill	1991
4	Environmental Pollution Control and Engineering	C S Rao	New age international Pvt. Ltd New Delhi	2009

(Group-3):20HCE251 Fuel Cell Technology	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Overview of fuel cells: Introduction to fuel cells and their characteristics – Classification Low and high temperature fuel cells.

Module-2

Fuel cell thermodynamics: Heat, work potentials, prediction of reversible voltage, fuel cell efficiency.

Module-3

Fuel cell reaction kinetics: Electrode kinetics, over voltages, Tafel equation, charge transfer reaction, exchange currents, electro-catalyses - design, activation kinetics, Fuel cell charge a n d mass transport - flow field, transport in electrode and electrolyte.

Module-4

Fuel cell characterization: In-situ and ex-situ characterization, techniques, i-V curve, frequency response analyses; Fuel cell.

Module-5

Balance of plant: Hydrogen production from renewable sources and storage; safety issues, cost expectation and life cycle analysis of fuel cells.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Fuel Cell Fundamentals	Ryan O'Hayre, Suk-Won Cha, Whitney Colella, Fritz B. Prinz	Wiley & Sons	2006
2	Electrochemical Methods	Allen J. Bard, Larry R. Faulkner	John Wiley & Sons	2000
3	Recent Trends in Fuel Cell Science and	S. Basu	Springer	2007
4	Principles of fuel cells	Liu, H	Taylor & Francis	2006

(Group-3): 20HCE252Air Pollution Control & Equipment

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Definition and concentrations, classification and properties of air pollutants, emission sources-natural and anthropogenic sources, effects of air pollution on flora and fauna, human health and materials. Photochemical smog. Air Pollution Laws and Standards.

Module-2

Meteorological aspects of air pollution: Dispersion- Temperature lapse rates and stability, wind velocity and turbulence, plume behavior, dispersion of air pollutants, solutions to atmospheric dispersion equation, the Gaussian plume model, effective stack height.

Module-3

Air Pollution Sampling and Measurements: Types of pollution sampling and measurements, ambient air sampling, Collection of gaseous air pollutants, collection of particulate pollutants, stack sampling, analysis of air pollutants like sulphur dioxide, nitrogen oxide, carbon monoxide, oxidants and ozone, hydrocarbon, particulate matter.

Module-4

Air Pollution Control Methods and Design of Equipments: Control methods, source correction methods, cleaning of gaseous effluents, Particulate Emission Control: Gravitational settling chambers, cyclone separators, bag house filters, electrostatic precipitators, wet scrubbers, Selection of particulate collector.

Module-5

Control of Gaseous Emissions: Absorption by liquids, adsorption by solids, combustion. Air pollution control in specific industries: control of sulphur dioxide, nitrogen dioxides, carbon monoxides and hydrocarbon emissions. Acid rain, green house effects, important air pollution episodes.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Environmental Pollution Control Engineering	C S Rao	New Age International	2010
2	Principles and Practices of Air Pollution Control and Analysis	J. R. Mudakavi	I.K. International Publishing House Pvt. Limited	2010
3	Air Pollution control theory	Martin Crawford	Tata McGraw-Hill	1980
4	Air Pollution Part A&B	Joe Ledbetter	Marcel Dekker	1972
5	Air Pollution Control Design Hand Book Part I and II	Paul N. Cheremisinoff, Richard Alan Young	M. Dekker	1977

(Group-3): 20HCE323 Process Modelling & Simulation	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Introduction to process modelling: a systematic approach to model building, classification of models, types of mathematical equations, Conservation principles, thermodynamic principles of process systems.

Module-2

Numerical methods: Iterative convergence methods, numerical integration of ordinary differential equations, numerical solutions of partial differential equations.

Module-3

Steady state and unsteady state lumped parameter models: Boiling of multi component mixture, condensation of vapor mixture, flash drum, boiler with hold up, tank models.

Module-4

Steady state distributed parameter models: Co-current and counter-current DPHE, PFR with axial dispersion, tubular permeation process, pipe line flasher, packed bed tubular reactor.

Module-5

Un steady state distributed parameter models: Thermal conduction through a rod, unsteady state steam heated heat exchanger, unsteady state counter current DPHE, reactor with axial dispersion, binary distillation column, chlorination of benzene, Parameter estimation. Introduction to finite element and finite volume methods.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Process Modeling, Simulation and Control for Chemical Engineers	Luyben	International Student Edition	1981
2	Modeling and Simulation in Chemical Engineering	Franks R.E.	John Wiley	1972
3	Process Modelling and Simulation	Gaikwad R.W, and Dr. Dhirendra	Denetted & Co.	2006
4	Computational Methods In Process	Ramirez W.F.	Butterworth	1997

(Group-4):20HCE321 Fermentation Technology

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction to fermentation Process: Interaction between chemical engineering, Microbiology and Biochemistry. Introduction and scope of microbial processes. Microbial biomass, Microbial enzymes, Microbial metabolites, Recombinant products, Batch culture, continuous culture. Sources of industrial cultures and maintenance. Production of Industrial Alcohol, proteases, celluloses, amylase, lipase.

Module-2

Microbial growth kinetics: Batch culture, continuous culture, multistage systems, fed batch culture, comparison between batch and continuous culture in industrial processes. Media formulation and process optimization.

Module-3

Improvement of industrially important micro-organisms: Isolation, preservation and improvement of industrial micro-organism, development of media for industrial fermentation. Development of inoculate for yeast and bacterial processes.

Module-4

Sterilization: Introduction, medium sterilization, sterilization of feed, fermenter, design of batch and continuous sterilization processes.

Module-5

Design of Fermenter: Basic functions of fermenter for microbial or animal cell culture, Aseptic operation and containment, construction materials, Aeration and agitation, stirrer glands and bearings, baffles, fermentation vessels – Waldhof type fermenter, tower fermenter, cylindro – conical vessels, air-lift fermenters, packed tower, rotating disc fermenters.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Biochemical Engineering Fundamentals	Bailly, J.E. and Ollis D.F.	McGraw-Hill	1986
2	Introduction to Biochemical Engineering	Dubasi Govardhana Rao	Tata McGraw-Hill	2010
3	Principles of Fermentation Technology	Peter F. Stanbury, Allan Whitaker, Stephen J Hall	Elsevier Science	1995

(Group-4): 20HCE334Food Processing & Engineering	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Introduction: General aspects of food industry, world food demand and Indian scenario, constituents of food, quality and nutritive aspects, need for food additives and preservatives and their applications. Stabilizers and thickeners, other additives. Food safety, food contamination and adulteration. Food laws and standards.

Module-2

Food processing methods: general processing methods for various food products - soft and alcoholic beverages, dairy products, meat, poultry and fish products. Treatment and disposal of food processing wastes.

Module-3

Separation processes in food processing: Electro-dialysis Systems, Membrane Systems, Reverse-Osmosis and Ultra filtration Systems, Drying Processes, Dehydration System, Sedimentation, Centrifugation and Mixing.

Module-4

Food preservation methods: Preservation by heat and cold, dehydration, concentration, drying irradiation, microwave heating, sterilization and pasteurization, fermentation and pickling.

Module-5

Packaging: Introduction, Food Protection, Product Containment, Product Communication, Product Convenience, Mass Transfer in Packaging Materials. Innovations in Food Packaging, Product Shelf-life. Food canning technology-fundamentals. Heat sterilization of canned food, containers - metal, glass and flexible packaging. Canning procedures for fruits, vegetables, meats, poultry and marine products.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Food Science	B Srilakshmi	New Age	2003
2	Introduction to Food Science	Rick Parker	Delmar/Thomsn Learning	2003
3	Food Processing and Preservation	G.Subbulakshmi and Shobha A. Udupi	New Age	2001
4	Introduction to Food Biotechnology	Sinosh Skariyachan, Abhilash M	CBS	

(Group-4): 20CEE13Applied Environmental Chemistry & Microbiology

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Importance of Environmental Chemistry as applied to the Environmental Engineering, types of reactions, reversible and irreversible reaction redox-reactions, reaction kinetics. Modes of expression for molarity, normality, molality, etc., Electrochemistry and its applications. Physical and equilibrium Chemistry – fundamentals and applications. pH–Principle, Measurement, Numerical Examples, Buffers and Buffer index.

Module-2

Colloidal Chemistry: Colloids – Types, properties and environmental significance. Colloidal dispersions in water, air and emulsions. Theory of colloids – double layer theory, zeta potential, destabilization of colloids (Schulze – Hardy rule) as applied to coagulation process. Absorption and adsorption process, adsorption isotherms.

Module-3

Instrumental methods of analysis: Lambert's and Beer's law. Colorimetry – estimation of iron and manganese in water samples. Methods of determining the trace organic and inorganic contaminants using emission and absorption technique

Module-4

Water & wastewater analysis: Fluoridation, deflouridation, chlorination, BOD, DO, types and measurement of BOD, rate of BOD & theoretical oxygen removal, COD- determination & its application in wastewater treatment.

Module-5

Microbiology - Microorganisms of importance in air, water and soil environment Principles and applications of microscopy, microscopic flora and fauna of importance. Metabolism and metabolic pathways, Bioconcentration, Biomagnification and Bioaccumulation. Bacteria – Morphology, typical growth curve and generation time, Measurement Techniques – APC, MPN (Probability and Thomas methods), MFT. Monod's equation and its applications. Algae - orphology, classification and their importance. Fungi - Protozoa - morphology, classification and their importance. Enzymes - classification, kinetics – Michaelis - Menten equation, factors influencing enzyme reaction.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Textbook of Microbiology	Pelczar M.J ,Chan ECS, Krieg, NR	Tata McGraw Hill	
2	Chemistry for Environmental Engineering and Science	Sawyer C.N. and McCarty, P.L	Tata McGraw Hill	
3	Microbiology for Environmental Scientists	Gaudy and Gaudy	McGraw Hill	
4	Standard Methods for Examination of	APHA		
5	Aquatic Chemistry	Stumn and Morgan	John Willey & Sons	

(Group-4): 20HCE22Bioinstrumentation and Biosensors

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Basic concept of biomedical instrumentation: Generalized medical Instrumentation System, Medical Measurement constraints, Classification of Biomedical Instruments, Generalized static and dynamic characteristics, Design criteria.

Module-2

Analytical instruments in Biomedical Engineering: Chromatography, Electrophoresis oximeter, spectrophotometer, colorimeter, blood gas analyzer, blood cell counter. , Applications to biomedical systems.

Module-3

Introduction: Overview of Biosensors, Fundamental elements of biosensor devices, advantages and limitations, components of biological elements and their immobilization techniques. Desired characteristics of biosensors: reliability, simplicity, cost, and related parameters.

Module-4

Transducers in biosensor: Choice of Transduction Parameter, types of transducer- resistive, conductive, inductive, Photoelectric, piezoelectric and mechano-electronics. Biochip – introduction -Gene chip, Cantilever based chemical sensors - AFM, FAB.

Module-5

Potentiometric sensors & amperometric sensors: Define Electric Potential, Measuring electrode potential -glass electrode, Ion-selective electrodes - Measurement Considerations - Potentiometric solid-state sensors .The working of Potentiostat - Amperometric Oxygen Sensor Semiconductor Gas Sensors.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Fundamentals of Bioanalytical Techniques And Instrumentation	Sabari Goshal, Srivastava A K	PHI Learning	2018
2	Instrumental Methods of Analysis in Biotechnology	Dinesh Kumar Chatanta, Prahlad Singh Mehra	IK International	2012
3	Principles and Techniques of Biochemistry And Molecular Biology	Keith Wilson and John Walker	Cambridge University Press	2010
4	Bioanalytical Techniques	Abhilasha Shourie and Shilpa S Chapadgaonkar	The Energy and Resources Institute	2015

(Group-5): 20HCE322Total Quality Management	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Introduction – Need for quality – Evolution of quality – Definition of quality – Dimensions of manufacturing and service quality – Basic concepts of TQM – Definition of TQM – TQM Framework – Contributions of Deming, Juran and Crosby – Barriers to TQM.

Module-2

TQM PRINCIPLES Leadership – Strategic quality planning, Quality statements – Customer focus – Customer orientation, Customer satisfaction, Customer complaints, Customer retention -Employee involvement – Motivation, Empowerment, Team and Teamwork, Recognition and Reward, Performance appraisal – Continuous process improvement – PDSA cycle,5s, Kaizen – Supplier partnership – Partnering, Supplier selection, Supplier Rating.

Module-3

TQM TOOLS & TECHNIQUES I The seven traditional tools of quality – New management tools – Six-sigma: Concepts,methodology, applications to manufacturing, service sector including IT – Bench marking – Reason to bench mark, Bench marking process – FMEA – Stages, Types.

Module-4

TQM TOOLS & TECHNIQUES II Quality circles – Quality Function Deployment (QFD) Taguchi quality loss function –TPM – Concepts, improvement needs – Cost of Quality – Performance measures.

Module-5

QUALITY SYSTEM Need for ISO 9000- ISO 9000-2000 Quality System – Elements, Documentation, Quality auditing- QS 9000 – ISO 14000 – Concepts, Requirements and Benefits – Case studies of TQM implementation in manufacturing and service sectors.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Total Quality Management	Dale H. Besterfield et al.	Pearson Education	2004
2	Total Quality Management – Text and Cases	Shridhara Bhat K	Himalaya Publishing	2002

(Group-5): 20HCE324Pharmaceutical Technology	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Electrophilic Substitution Reaction: Preparation of Cyclo Alkane, Bayer's strain theory and orbital picture of angle stream. Electrophilic Substitution Reaction Mechanism & Application: Dehydrogenation of alkylhalides. 1-2 elimination kinetics: E2 and E1 mechanisms. Isotope effect. Dehydration of alcohols. Ease of dehydration.

Module-2

Nucleophilic Addition Reaction: Mechanism. Important chemicals. Oxidation-Reduction reactions.

Module-3

Rheology of Fluids in Mixing and Blending.

Module-4

Preparation: Test for purity and medical uses of Chlorobutal, Dimercopral, Glycerol trinitrate. Urea, ethylene diamine dihydrate, vanillin paraldehyde.

Module-5

Preparation: Test for purity and medical uses of lactic acid, citric acid, salicylic acid, saccharin Sodium, Ethyl borate, dimethyl phthalate, aspirin.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Organic Chemistry	T.R. Morisson and R. Boyd	Prentice Hall	1992
2	Organic Chemistry Fundamentals	I. L. Finar	Pearson Education	1973
3	Fundamental of Organic Chemistry	John McMurry	Brooks	1990
4	A text book of Organic Chemistry	R. K. Gupta	Arihant Prakashan	2010

(Group-5): 20HCE333Computational Fluid Dynamics

Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Introduction to Governing equations – Impact and applications of CFD in diverse fields – Governing equations of fluid dynamics – Continuity – Momentum and Energy – Generic integral form of governing equations – Initial and boundary conditions – Governing equations for boundary layers – Classification of partial differential equations – Hyperbolic – Parabolic – Elliptic and Mixed types – Applications and relevance.

Module-2

Basic aspects of discretization – Finite difference – Finite volume and Finite Element method - Comparison of discretization by the three methods. Introduction to Finite Differences – Transient One dimensional and two dimensional conduction – Explicit – Implicit – Crank Nicolson, ADI Scheme- Stability Criterion Difference equations – Numerical errors – Grid independence test – optimum step size.

Module-3

Grid generation – General transformation of the equations – Form of the governing equations suitable for CFD – Boundary fitted co-ordinate systems – Elliptic grid generation – Adaptive grids- Modern developments in grid generation.

Module-4

Convection Diffusion Steady one dimensional convection and diffusion – Central difference, upwind, quick, exponential, false diffusion, hybrid and power law scheme. Transient one dimensional het conduction equation.

Module-5

Calculation of Flow Field Representation of the pressure – Gradient term and continuity equation – Staggered grid – Momentum equations – Pressure and velocity corrections – Pressure correction equation - Numerical procedure for SIMPLE algorithm – Boundary conditions for the pressure correction method – Stream function – Vorticity method – Discussion of case studies.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Computational Fluid Dynamics – The basic with applications	J. D. Andersor Jr	Mc Graw Hill	2000
2	Computational Fluid Dynamics for Engineering (vol. III)	K A Hoffman	Engineering Education System	2001
3	Computational Fluid Flow and Heat transfer	K. Muralidhar, T. Sundarajan	Narosa	2011

(Group-5): 20CEE243Environmental Planning & Management

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Environment and Sustainable Development: Carrying capacity, relationship with quality of life, carrying capacity and resource utilization.
Engineering Methodology in Planning and its Limitations: Carrying capacity based short and long term regional planning.

Module-2

Environmental Protection: Economic development and social welfare consideration in socio economic developmental policies and planning.
Total cost of development and environmental Protection cost. Case studies on Regional carrying capacity

Module-3

Engineering Economics: Value Engineering, Time Value of Money, Cash Flows, Budgeting and Accounting

Module-4

Environmental Economics: Introduction, economic tools for evaluation, Green GDP, Cleaner development mechanisms and their applications.

Module-5

Total Quality Management in environmental management and protection – ISO 9000, 14000 and 18000 series of standards. Environmental Audit – methods, procedure, reporting and case studies.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Environmental Quality Management	Lohani B.N	South Asian	
2	Environmental Protection	Chanlett	McGraw Hill	
3	Planning and Design of Engineering Systems	Danoy G.E., and Warner R.F.	Unwin Hyman	
4	Carrying Capacity Based Developmental Planning Studies for the National Capital Region	MOEF, Government of India		1995-96
5	Annual Reports	NEERI, Nagpur		1995 & 1996

(Group-6): 20HCE31Modern Separation Processes

Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Introduction: 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 electro filtration, dual functional filter, Surface based solid - liquid separations involving a second liquid, Sirofloc filter.

Module-2

Membrane Separations: Introduction to membranes, types and choice of membranes, Plate and frame, tubular, spiral wound and hollow fiber membrane and their relative merits, Commercial, pilot plant and laboratory membrane permeators involving dialysis, reverse osmosis, Nano filtration, ultra-filtration, Micro filtration and Donnan dialysis, Economics of membrane operations, Ceramic membranes.

Module-3

Supercritical Fluid Extraction: Concept, modeling, design aspects and applications Separation by Adsorption Techniques: Mechanism, Types and choice of adsorbents, Normal adsorption techniques, PSA TSA operation. Types of equipments and commercial processes. Recent advances and process economics.

Module-4

Ionic Separations: Controlling factors, Applications, Types of equipment employed for electrophoresis, Dielectrophoresis, Ion exchange, and electro dialysis. Chromatography: Affinity chromatography and immuno chromatography Commercial Processes.

Module-5

Miscellaneous separation Techniques: Separations involving Lyophilization, Pervaporation and permeation techniques for solids, liquids and gases. Industrial viability and examples, Zone melting, Adductive crystallization, Oil spill Management, Industrial effluent treatment by modern techniques.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Separation Processes	King, C.J	Tata McGraw Hill	2013
2	Separation Process Principles	Seader, J. D and Ernest J. Henley	John Wiley and Sons	2011
3	New Chemical Engineering Separation Techniques	Herbert M. Schoen	Interscience Publishers	1962
4	Perry's Chemical Engineering Hand book	Robert H. Perry, Don W. Green	Mc Graw Hills	1999

(Group-5): 20HCE332Gasification Technology

Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Biomass and its properties: Types and Sources of Biomass, Physical and Thermal Properties of Biomass, Proximate and Ultimate analysis, stoichiometric considerations, Equivalence Ratio, Thermochemical conversion processes, Types of gasifiers, gas yield and its composition.

Module-2

Theory of gasification Gasification reactions, Gasification processes - Drying, Devolatilization/Pyrolysis, combustion and gasification/reduction, Pyrolysis types and product yield, torrefaction, catalytic gasification.

Module-3

Gasification Kinetics Kinetic models for gasification - Drying, Devolatilization/Pyrolysis, combustion and gasification/reduction, Chemical equilibrium, char reactivity, Effect of feed properties on gasification, Estimating Equilibrium Gas Composition.

Module-4

Design of Gasifiers Energy and Mass Balance, Heat transfer in gasifiers, Gasifier Efficiency, sizing of downdraft biomass gasifier, design optimization.

Module-5

Gas Cleaning Technologies Tar formation, composition, reduction of tar by operating conditions, reduction by design, Particulate removal technologies, Environmental emissions.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Gasification Technologies - A Primer for Engineers and Scientists	John Rezaiyan and Nicholas P. Cheremisinoff	Taylor & Francis	2005
2	Biomass Gasification and Pyrolysis	Prabir Basu	Elsevier Science	2010
3	Gasification	Christopher Higman, Maarten van der Burgt	Elsevier Science	2003

(Group-6): 20CEE253Renewable Energy & Alternative Fuels

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction to energy and resources – Renewable energy sources - Availability of solar energy – Sun-earth relationships - - Solar radiation measurement – Flat plate collectors – Solar water heating systems – Evacuated Tubular Concentrators - Solar air heating systems and applications – Concepts on solar drying, cooking, desalination, solar ponds and solar cooling - Passive heating and cooling of buildings – Basics of solar concentrators and types Solar thermal power generation

Module-2

Biomass to energy conversion processes – Anaerobic digestion, process parameters, biogas composition, digester types, high rate anaerobic conversion systems – Alcohol from biomass – Biodiesel: preparation, characteristics and application - Biomass combustion and power generation – Briquetting – Gasification: Process, types of gasifiers, applications – Waste to energy technologies

Module-3

Power in the wind - Types of wind mills – WEG components, Power curves and energy estimation– Indian wind potential. Small Hydro Power: Types, site identification, head and flow measurement, discharge curve, estimation of power potential and system components. Technologies for harnessing renewable energy sources like geothermal, wave, tidal and ocean thermal energy.

Module-4

Fossil fuels and their availability - Potential alternative liquid and gaseous fuels - Merits and demerits of various alternative fuels - Engine requirements
Methods of production - Properties - Blends of gasoline and alcohol - Performance in SI engines – Adaptability - Combustion and emission characteristics - Performance in CI engines - Emission characteristics - Properties of alcohol esters. Production and properties of CNG, LPG, hydrogen gas, biogas and producer gas - Performance and Storage, distribution and safety aspects

Module-5

Various vegetables oils - Properties - Esterification - Performance and emission characteristics - Bio-diesel: Feed stock, characteristics, preparation (lab and commercial), storage, applications, environmental impacts, economics, policy.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Handbook of Energy Efficiency and Renewable Energy	Frank Kreith and D.Yogi Goswami	CRC Press	2007
2	Renewable Energy Resources	John Twidell and Tony Weir	Taylor & Francis	2006
3	Solar Engineering of Thermal Process	John A. Duffie and William A. Beckman	John Wiley & Sons	2006
4	Renewable and Efficient Electric Power Systems	Gilbert M. Masters	Wiley Interscience	2004
5	Present and Future Automotive Fuels	Osamu Hirao and Richard Pefley	Wiley Interscience	1988

(Group-6): 20HCE253 Advanced Nanotechnology	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

The science of miniaturization Moore's Laws (1,2,&3) and technology' Roadmap–clean rooms Processing Methods: Cleaning – Oxidation – Lithography – Etching- – CVD - Diffusion – Ion implantation – metallization – state of the art CMOS architectures Photolithography Overview – Critical Dimension – Overall Resolution – Line-Width – Lithographic Sensitivity and Intrinsic Resist Sensitivity (Photochemical Quantum Efficiency) – Resist Profiles – Contrast and Experimental Determination of Lithographic Sensitivity – Resolution in Photolithography – Photolithography Resolution Enhancement Technology.

Module-2

Physico-chemical methods of nanostructured material synthesis Chemical Methods: Metal Nanocrystals by Reduction - Solvothermal Synthesis- Photochemical Synthesis - Sonochemical Routes- Chemical Vapor Deposition (CVD) – Metal Oxide - Chemical Vapor Deposition (MOCVD).Physical Methods:Ball Milling – Electrodeposition - Spray Pyrolysis - Flame Pyrolysis - DC/RF Magnetron Sputtering - Molecular Beam Epitaxy (MBE).

Module-3

Characterization of nanophase materials: Fundamentals of the techniques – experimental approaches and data interpretation – applications/limitations of Xray characterization: – X-ray sources – wide angle, extended x-ray absorption technique – Electron microscopy: SEM/TEM – high resolution imaging – defects in nanomaterials – Spectroscopy: – electron energy-loss mechanisms – electron filtered imaging – prospects of scanning probe microscopes – optical spectroscopy of metal/semiconductor nanoparticles.

Module-4

Carbon nanotubes: Carbon materials – Allotropes of carbon – Structure of carbon nanotubes – Types of CNTs – Electronic properties of CNTs – Band structure of Graphene – Band structure of SWNT from graphene – Electron transport properties of SWNTs – Scattering in SWNTs – Carrier mobility in SWNTs.

Module-5

Application of Nanotechnology: Nanotechnology in electrical and electronics industry : Advantages of nano electrical and electronic devices –Sensors, Actuators, Optical switches, Bio-MEMS ,Nanotechnology in biomedical and pharmaceutical industry Nanosensors in Diagnosis– Neuro-electronic Interfaces – Protein Engineering – Drug delivery – Therapeutic applications - Nanotechnology in chemical industry Nanocatalyts Molecular Encapsulation and its applications Nanoporous zeolites – Self-assembled Nanoreactors - Organic electroluminescent displays Nanotechnology in Food industry - Packaging, Food processing - Food safety and biosecurity – Contaminant detection – Smart packaging.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Introduction to Nanotechnology	Charles P. Poole Jr and Frank J. Owens	Wiley	2003
2	Nano: The essentials: Understanding nanoscience and nanotechnology	T. Pradeep	Tata McGraw-Hill	2008
3	Nanomaterials Chemistry	Rao C. N., A. Muller, A. K. Cheetham	Wiley	2007
4	Handbook of Nanoscopy	Dirk van Dyck, Gustaaf van Tendeloo, Stephen J.	Wiley	2012

(Group-6): 20MST244Advanced Materials and Processing	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Classification and Characteristics: Metals, Nonferrous Metals and Ferrous Metals, classification of Ferrous Metals and Non-Ferrous Metals, Types of Ceramics, Polymers and composites and classification of composites. General Properties and Structure: Atoms, molecules bonds in solids, Crystalline – Defects in Metallic structure, Dislocations and plastic deformation - Strengthening mechanism – grain size, dislocation - Cold work, precipitation hardening, dispersion hardening - phase reactions, fatigue and Creep behaviour.

Module-2

Ferrous Alloys: iron carbon equilibrium diagrams - Steels and cast irons - properties, structure, composition and applications transformation hardening in steels - TIT diagrams - Heat treatment processes - Effect of alloying elements - High alloy steels, Stainless steel types, tool Steels, Manganese steels, heat resistant steels, HSLA, Managing steels. Non-Ferrous Alloys: Alloys of copper, Aluminium, nickel, magnesium, titanium, lead, tin, Zinc - composition, heat treatment, structure, properties and application.

Module-3

Polymers and Polymerizations: Structure and properties of thermoplastics and thermosets – Engineering Applications - property modifications - Mechanical and thermal behaviour – processing methods Ceramics: Nature and structure of Ceramics - Refractory Abrasives glasses - glass ceramics - Advanced ceramics processing methods.

Module-4

Composites: Definition - classification and characteristics of composite materials - Volume fraction - laminated composites particulate composites, fibrous composites – Types of reinforcements, their shape and size - production and properties of fiber reinforced plastics, Metal Matrix composites and ceramic matrix composites - Applications.

Module-5

Processing of Polymers: composites, ceramics - thermal spraying - Ion beam machining diamond coating techniques-tribological applications.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

	Title of the book	Author Name	Publisher's Name	Publication year
1	Advanced Materials and Processes	James W. Evans Lutgard C. De Jonghe	Springer	2016
2	Introduction to Material Science for Engineers	James F. Shackelford	Prentice Hall	2000
3	Metals Handbook: Powder metallurgy	ASM Handbook Committee	American Society for Metals	2007
4	Composite Materials - Science and Engineering	Chawla K.K	Springer	1998
5	Elements of Material Science and Engineering	Lawrence H. Van Vlack	Addison-Wesley	1980