CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY
KANPUR

SYLLABUS

(B.Tech.)

Applicable from 2024-25

CHEMICAL ENGINEERING

UNIVERSITY INSTITUTE OF ENGINEERING & TECHNOLOGY

SCHOOL OF ENGINEERING & TECHNOLOGY

UNIVERSITY INSTITUTE OF ENGINEERING & TECHNOLOGY

SCHOOL OF ENGINEERING & TECHNOLOGY

Vision

To achieve excellence in engineering education, empower students to be technically competent professionals and entrepreneurs with strong ethical values so as to significantly contribute as agents for universal development and societal transformation

Mission

To provide affordable quality education at par with global standards of academia and serve society with harmonious social diversity

To encourage new ideas and inculcate an entrepreneurial attitude amongst the students, and provide a robust research ecosystem

To practice and encourage high standards of professional ethics and accountability among students

Bachelor of Technology in Chemical Engineering

Program Outcomes (POs)

PO1	**Engineering knowledge:** Apply the knowledge of basic science, mathematics and fundamentals of engineering with specialization to solve the complex problems of chemical engineering.
PO2	**Problem analysis:** Attain the capability to identify, formulate and analyze chemical engineering problems considering the knowledge of engineering mathematics, natural, and engineering sciences and review of the research articles
PO3	**Design/Development of solutions:** Demonstrate and develop the appropriate solutions to chemical engineering design based problems to meet the specified needs of the nation and overall sustainability of the processes, considering the necessary approaches of safety, health hazards, societal and environmental factors.
PO4	**Conduct investigations of complex problems:** Investigate, demonstrate and conduct the design based complex problems using research based knowledge and methodologies, experimental studies, subsequent analysis and interpretation of data to prepare the valid technical reports as per national and global standards
PO5	**Modern tool usage:** Select and apply appropriate available resources, and modern chemical engineering tools such as optimization techniques, simulations, including predictions and modelling to complex process engineering problems with an understanding of their limitations
PO6	**Engineer and society:** Able to carry out their professional practice in chemical engineering by appropriately considering and weighing the issues related to society, health and culture and the consequent responsibilities
PO7	**Environment and sustainability:** Understand and demonstrate the impact of chemical engineering solutions in societal and environmental contexts, and understand the need for global sustainable development
PO8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the chemical engineering practice.
PO9	**Individual and team work:** Work effectively as an individual or in diverse and multidisciplinary global environments showing team solidarity.
PO10	**Communication:** Ability to communicate efficiently with the engineering community, society and able to represent and explain the design documentation effectively with clear instructions, following standard national and international codes

PO11	**Project management and Finance:** Demonstrate the knowledge and principles of chemical engineering, management, cost and feasibility studies for the desired projects as an individual, or a member or leader in a team of multidisciplinary settings.
PO12	**Life-long learning:** Possess the attitude of lifelong independent learning as per the need of wider context of technological changes and can pursue higher education for careers in academics, research and development

Program Specific Outcomes (PSOs)

PSO-1	Impart education and training of Chemical Engineering to the students and to make them competent and well qualified Chemical Engineers who can meet global challenges
PSO-2	Provide best knowledge of the Chemical Engineering to the students and nurture their creative talent by motivating them to work on various challenging problems facing the nation
PSO-3	Acquire high end industry centric skills in the field of Chemical Engineering to solve local, regional and national problems
PSO-4	Knowledge of the software used in the field of Chemical Engineering
PSO-5	To prepare Professional Engineer with ethical, social and moral values

Program Educational Outcomes (PEOs)

1. To make the students ready for successful career leading to global higher education and /or in national industry related domains of design, regional research and development, testing, and local manufacturing.
2. To solve diverse real-life national and global engineering problems equipped with a solid foundation in global mathematical, scientific, and chemical engineering principles.
3. To motivate and encourage the students to adopt global professionalism, teamwork, leadership, communication skills, ethical approach.
4. To provide global learning opportunity in a broad spectrum of multidisciplinary field.

Curricular Components

Category of courses	Credits offered
Basic Science Core	**29**
Engineering Science Core	**32**
Humanities and Social Science Core	**16**
Departmental Core	**67**
Departmental Electives	**09**
Open Electives	**09**
Projects and Seminars	**18**
Total	**180**

Semester-wise Course Structure for B. Tech Chemical Engineering Major

1st Year - Semester 1

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	MTHS101	Mathematics-I	3	1	0	4
2.	PHYS101	Physics-I	3	1	3	5
3.	TCAS101	Engineering Drawing	3	0	3	5
4.	ESCS101	Basic Electrical & Electronics Engineering	3	1	3	5
5.	CHMS101	Chemistry-I	3	1	3	5
6.	UHVS101	Universal Human Values – I (SIP)				0
		Total	**15**	**4**	**12**	**24**

1st Year - Semester 1I

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	MTHS102	Mathematics-II	3	1	0	4
2.	PHYS102	Physics-II	3	1	3	5
3.	TCAS102	Workshop Practice & IDEA Lab	3	0	6	5
4.	ISCS101	Programming & Computing (C & UNIX)	3	1	3	5
5.	HSSS101	Professional Communication	3	1	0	4
		Total	**15**	**4**	**12**	**23**

2ndYear - Semester II1

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	MTHS201	Mathematics-III	3	1	0	4
2.	ESCS201	Engineering Mechanics	3	1	0	4
3.	ESCS202	Basic Thermodynamics	3	1	0	4
4.	CHES201	Process Calculations	3	1	0	4
5.	CHES202	Fluid Mechanics & Mechanical Operations	3	1	0	4
6.	EVSS201	Environmental Science	2	0	0	2
7.	SSTS201	Summer Internship - I	0	0	2	2
		Total	**17**	**5**	**2**	**24**

2nd Year - Semester IV

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHES203	Chemical Engineering Thermodynamics	3	1	0	4
2.	CHES204	Heat Transfer	3	1	0	4
3.	CHES205	Chemical Process Industries	4	0	0	4
4.	ESCS203	Introduction to Machine Learning	3	0	2	4
5.	HSSS201	Communication Practicum	1	0	2	3
6.	UHVS201	Universal Human Values -II	3	0	0	3
		Total	**17**	**2**	**4**	**22**

3rd Year - Semester V

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHES301	Mass Transfer-I	3	1	0	4
2.	CHES302	Chemical Reaction Engineering-I (with lab)	3	1	3	5
3.	CHES303	Numerical Methods for Chemical Engineers	3	1	0	4
4.	CHES304	Chemical Engineering Design-I	3	1	0	4
5.	CHES305	Unit Operations Laboratory -I	1	0	4	3
6.	HSSS302	Industrial Management	3	0	0	3
7.	SSTS301	Summer Internship – II	0	0	2	2
		Total	**16**	**4**	**9**	**25**

3rd Year - Semester VI

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHES306	Mass Transfer-II	3	1	0	4
2.	CHES307	Instrumentation & Process Control (with lab)	3	1	3	5
3.	CHES308	Chemical Engineering Design-II	3	1	0	4
4.	CHES309	Chemical Reaction Engineering-II	3	1	0	4
5.	CHES310	Unit Operations Laboratory-II	1	0	4	3
6.	HSSS301	Engineering Economics	3	0	0	3
7.	SSMS301	Seminar	0	0	2	2
		Total	**16**	**4**	**9**	**25**

4th Year - Semester VII

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHE-S401	Transport Phenomena	4	0	0	4
2.	CHE-S402	Process Simulation Lab	1	0	4	3
3.	CHE-S5**	Departmental Elective	3	0	0	3
4.		Open Elective	3	0	0	3
5.	SST-S401	Summer Training	0	0	2	2
6.	PRT-S401	Project -I	0	0	10	5
		Total	**11**	**0**	**16**	**20**

4th Year - Semester VIII

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHE-S5**	Aspen Plus Simulation Software for Chemical Engineers (NPTEL)	2	0	2	3
2.	CHE-S5**	Departmental Elective	3	0	0	3
3.		Open Elective	3	0	0	3
4.		Open Elective	3	0	0	3
5.	PRT-S402	Project -II	0	0	10	5
		Total	**10**	**2**	**10**	**17**

Total Credits – 180

Course Structure for Minor in Chemical Engineering

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHES201M	Process Calculations	3	1	0	4
2.	CHES202M	Fluid Mechanics & Mechanical Operations	3	1	0	4
3.	CHES204M	Heat Transfer	3	1	0	4
4.	CHES301M	Mass Transfer-I	3	1	0	4
5.	CHES302M	Chemical Reaction Engineering-I	3	1	0	4
		Total	**15**	**5**	**0**	**20**

Course Structure for Minor in Energy Engineering

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHES203M	Chemical Engineering Thermodynamics	3	1	0	4
2.	CHES601M	Energy Management	3	1	0	4
3.	CHES602M	Renewable Energy Generation and Storage	3	1	0	4
4.	CHES603M	Energy Resources, Environment, and Economics	3	1	0	4
5.	CHES611M	Solar Energy Technologies	3	1	0	4
	CHES612M	Wind Energy				
	CHES613M	Hydrogen Energy and Fuel Cells				
	CHES614M	Biofuels Engineering				
	CHES615M	Nuclear Reactor Engineering & Fusion Energy				
		Total	**15**	**5**	**0**	**20**

Course Structure for Minor in Green Technology & Sustainability Engineering

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHES602M	Renewable Energy Generation and Storage	3	1	0	4
2.	CHES604M	Green Technology and Sustainable Development	3	1	0	4
3.	CHES605M	Green Technologies and Practices	3	1	0	4
4.	CHES606M	Green Building and Infrastructure Engineering	3	1	0	4
5.	CHES607M	Sustainable Engineering	3	1	0	4
		Total	**15**	**5**	**0**	**20**

Detailed Syllabus

Course Code: MTHS101 **Breakup: 3 –1 – 0 – 4**
Course Name: Mathematics-I

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Test the convergence & divergence of infinite series
CO2	Understand concepts of limit, continuity and differentiability of function of two variables
CO3	Find the maxima and minima of multivariable functions
CO4	Evaluate multiple integrals, concepts of beta & gamma functions
CO5	Apply the concepts of gradient, divergence and curl to formulate chemical engineering problems

Course Details:

Unit-I
Sequences & Series: Definition, Monotonic sequences, Bounded sequences, Convergent and Divergent Sequences Infinite series, Oscillating and Geometric series and their Convergence, n^{th} Term test, Integral test, Comparison Test, Limit Comparison test, Ratio test, Root test, Alternating series, Absolute and Conditional convergence, Leibnitz test.

Unit II
Differential Calculus: Limit Continuity and differentiability of functions of two variables, Euler's theorem for homogeneous equations, Tangent plane and normal. Change of variables, chain rule, Jacobians, Taylor's Theorem for two variables, Extrema of functions of two or more variables, Lagrange's method of undetermined multipliers**.**

Unit III
Integral Calculus: Review of curve tracing, Double and Triple integrals, Change of order of integration. Change of variables. Gamma and Beta functions, Dirichlet's integral; Applications of Multiple integrals such as surface area, volumes

Unit –IV
Vector Calculus: Differentiation of vectors, gradient, divergence, curl and their physical meaning; Identities involving gradient, divergence and curl Line and surface integrals Green's, Gauss and Stroke's theorem and their applications

Unit–V
Probability and Statistics: Concept of probability, random variable and distribution function: discrete and continuous, Binomial, Poisson and Normal Distributions.

Text and Reference Books:

1. G.B.Thomas and R.L.Finney: Calculus and Analytical Geometry, 9th edition, Pearson Education (2010)
2. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, (2005).
3. E. Kreyszig, Advanced Engineering Mathematics, 9th edition, John Wiley and Sons, Inc., U.K. (2011).
4. R.K. Jain and S.R.K. Iyenger, Advanced Engineering Mathematics, 2nd Edition, Narosa Publishing House. (2005).
5. M.D. Weir, J. Hass, F.R. Giordano, Thomas' Calculus, 11th Edition, Pearson Education (2008)

Course Code: PHYS101 **Breakup: 3 –1 – 3 – 5**
Course Name: Physics-I

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the behaviour of global Physical bodies
CO2	Understand the basic concepts related to the motion of all the objects around us in our daily life
CO3	Gain the foundation for applications in various applied fields in science and technology
CO4	Understand the concepts of vectors, laws of motion, momentum, energy, rotational motion, central force field, gravitation, collision and special theory of relativity
CO5	Empower the students to develop the skill of organizing the theoretical knowledge and experimental observations into a coherent understanding

Course Details:(Theory)

Unit 1
Revision of vectors, vector differentiation, ordinary derivatives of vectors, space curves continuity and differentiability, partial derivatives of vectors, gradient, divergence, curl,vector differentiation and their geometrical interpretation, various coordinate systems: polar coordinate, orthogonal curvilinear coordinate system, unit vectors and tangent vectors in curvilinear systems, special orthogonal curvilinear coordinate system, cylindrical coordinate system and spherical polar coordinate systems.

Unit 2
Inertial and non-inertial frames, fictitious force, Coriolis force, Newton's laws of motion and its applications, friction, conservative and non-conservative force, work energy theorem, conservation of linear momentum and energy, variable mass system (Rocket motion), simple harmonic motion, small oscillation, equilibrium, condition for stability of equilibrium, energy diagram, small oscillation in a bound system, working of Teetertoy.

Unit 3
Concept of center of mass and calculation of center of mass for different objects, system of particles and collision, conditions for elastic and inelastic collision, collision in center of mass frame, rigid body kinematics, rotational motion, moment of inertia, theorems on moment of inertia, calculation of moment of inertia of bodies of different shapes.

Unit 4
Central force field, properties of central force field, inverse square law force, gravitational field and potential; Kepler's laws of planetary motion and its application
Wave mechanics, wave particle duality, De-Broglie matter wave, Schrodinger wave equations (time dependent and time independent), uncertainty principle and its applications

Unit 5
Frame of reference, Galilean transformation, Michelson-Morley experiment, postulates of special theory of relativity, Lorentz transformations, Length contraction, time dilation, velocity addition theorem, variation of mass with velocity, Einstein's mass energy relation, relativistic relation between energy and momentum, rest mass of photon.

Text and Reference Books:

1. Vector Analysis by M. R. Spiegel, Schaum's Outlines, (2021)
2. Introduction to Mechanics: R. D. Kleppner and J. Kolenkow, Cambridge University Press,

2nd edition, (2014)
3. A textbook of Mechanics by J. C. Upadhyay,Ram Prasas Publications; 1st Ed (2017)
4. Mechanics by D. S. Mathur, S. Chand; New edition, (2000)
5. Theory & Problems of Theoretical Mechanics by M. R. Spiegel, Schaum's Outline Series, (2017)
6. Introduction to Special Theory of Relativity by Robert Resnick, Wiley, 1st edition (2007)
7. Concept of Physics (Part-I) by H. C. Verma, Bharti Bhawan Publisher, (2019).
8. Quantum Mechanics by L.I. Schiff, McGraw-Hill Education (India) Pvt Limited, (2017)
9. A Textbook of Quantum Mechanics by P.M. Mathews and K. Venkatesan, McGraw-Hill Education (India) Pvt Limited, (2010).
10. Introduction to Quantum Mechanics by D.J.Griffiths, 3E, Cambridge University Press, (2018)

Physics – I Lab:

Course outcomes (CO): At the end of the lab course, the student will be able to:

CO1	Perform basic experiments related to mechanics
CO2	Be familiar with various measuring instruments and also would learn the importance of accuracy of measurements.

Course Details:(Practical)

1. Graphical Analysis (Ref. UIET Laboratory Manual)
2. Trajectory of projectile (Ref. UIET Laboratory Manual) Apparatus Used (Trajectory Apparatus, Metal Balls, Channels, Vernier Callipers, Carbon & Graph Paper)
3. Moment of Inertia of Bicycle wheel (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Bicycle Wheel, Masses, Thread, Stopwatch, Meter Scale, Vernier Callipers)
4. Spring Oscillations (Ref. UIET Laboratory Manual) Apparatus Used (Spring Oscillation Apparatus, Stop Watch, Masses)
5. Coupled Pendulum (Ref. UIET Laboratory Manual) Apparatus Used (Coupled Pendulum Setup, Stop Watch, Scale)
6. Bifilar Suspension System (Ref. UIET Laboratory Manual) Apparatus Used (Bifilar Suspension System Setup, Stop Watch, Masses)
7. Frequency of AC Mains by Melde's Method (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Electrical Vibrator, String, Pulley, Small Pan, Weight Box & Physical Balance)
8. Kater's (Reversible) Pendulum (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Kater's Pendulum, Stop Watch)
9. Inertia Table (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Inertia Table, Stop Watch, Vernier Callipers, Split Disc, Balancing Weights, and Given Body (Disc))
10. Moment of Inertia of Flywheel (Ref. Book by J. C. Upadhyay and UIET Laboratory Manual) Apparatus used (Fly wheel, weight hanger, slotted weights, stop watch, metre scale)

Course Code: TCAS101 **Breakup: 3 –1 – 3 – 5**
Course Name: Engineering Drawing

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the basics of engineering graphics
CO2	Develop skills to prepare basic engineering drawings
CO3	Understand the concept of projection and acquire visualization skills
CO4	Gain imaginative skills to understand section of solids and developments of surfaces

Course Details:

Introduction-Drawing instruments and their uses, global BIS conventions, lettering dimensioning, and free-hand practicing

Orthographic projections: Lines, planes and surfaces of objects, Sectional views, Auxiliary views, Space geometry: lines and planes, True lengths and shapes, Properties of parallelism, Perpendicularity and intersections of lines and planes, Simple intersections of solids and development of lateral simple solids

Isometric Projections: Introduction isometric scale, isometric projection of simple plane figures, isometric projection of tetrahedron, hexahedron(cube), right regular prisms, pyramids, cylinders, cones, spheres, cut spheres and combinations of solids.

Introduction to computer graphics: Some problems on above topics on computer graphics.

Text and Reference Books:

1. K.L. Narayana, & P. Kannaiah, Engg. Graphics, Tata McGraw Hill, New Delhi, (2012)
2. N.D. Bhatt, Elementary Engg. Drawing Charotar Book Stall, Anand (2014)
3. V. Lakshminarayanan & R. S. Vaish Wannar, Engg.Graphics, Jain Brothers, New Delhi (2016)
4. B. Agrawal & C.M. Agrawal, Engineering Graphics, TMH Publication, (2012)
5. M.B. Shah, & B.C. Rana, Engineering Drawing and Computer Graphics, Pearson Education (2008)
6. Narayana, K.L. & P Kannaiah, Text book on Engineering Drawing, Scitech Publishers. (2008)

Course Code: ESCS101 **Breakup: 3 –1 – 3 – 5**
Course Name: Basic Electrical & Electronics Engineering

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Predict the behaviour of any electrical and magnetic circuits
CO2	Formulate and solve complex AC, DC circuits
CO3	Realize the requirement of transformers in transmission and distribution of electric power and other applications
CO4	Have knowledge of some basic electronic components and circuits
CO5	Understand the basics of diode and transistor circuits
CO6	Understand the working of some I C based circuits
CO7	Study logic gates and their usage in digital circuits

Course Details:(Theory)

Unit – I

Sinusoidal steady state circuit analysis, voltage, current, sinusoidal & phaser presentation single phase AC circuit – behavior of resistance, inductance & capacitance & their combination, impedance concept of power, power factor; Series & parallel resonance – band width & quality factor, Three phase circuits – phase voltage & current, line & phase quantities, phasor diagram, balanced & unbalanced loads, Measurement of R, L, and C.

Unit –II

Network Theory: Network theorems – Thevenin's, Norton, maximum power transfer theorem, star delta transformation, circuit theory concept – mesh & nodal analysis.

Unit – III

Magnetic circuit concepts: self-inductance, magnetic coupling analysis of single tuned & double tuned circuit involving mutual inductance, introduction to transformer.

Unit – IV

Basic Instruments, electrical measurement – measurement of voltage, current, power & energy, voltmeters& ammeter, wattmeter, energy meter, three phase power measurement, electronics instrument –multimeter, CRO (analog & digital), an overview of voltage regulator.

Unit – V

Introduction to basic electronics devices – junction diode, BJT, amplifier, op-amps & instrumentation amplifier with mathematical operation

Number System: Introduction to binary, octal, decimal & hexadecimal systems, representation of negative, numbers, 1's, 2's, 9's, 10's complement and their arithmetic.

Text and Reference Books:

1. Edward Hughe Electrical and Electronic Technology, 10th Edition, Pearson Education Asia, (2019)
2. P. Kothari, I J Nagrath, Electric Machines, 5th Edition, Tata McGraw Hill, (2017)
3. P. Malvino, Electronic Principles, 7th Edition, Tata McGraw Hill, (2007)
4. A Textbook of Electrical Technology - Volume I (Basic Electrical Engineering) 23 Rev Ed Edition, S. Chand Publishing. (2020)
5. S. K. Bhattacharya, Basic Electrical and Electronics Engineering, Pearson, (2012)
6. Vincent Del Toro, Electrical Engineering Fundamentals, Prentice Hall of India Private Limited, 2nd Edition, (2003)

7. David Bell, Electronic Devices and Circuits, 5th Edition, Oxford University Press, (2008)
8. Michael Tooley A., Electronic circuits: Fundamentals and Applications, 3rd Edition, Elsevier Limited, (2006)

Course Name: Basic Electrical & Electronics Engineering Lab
Course Details: (Practical)

1. Familiarization with the Electronic Instruments.
2. Familiarization with electronic components and Bread board.
3. To verify the Thevenin theorem.
4. To verify the Superposition theorem.
5. Measurement of voltage and frequency with CRO.
6. To study half wave rectifier.
7. To study full wave bridge rectifier.
8. To study full wave bridge rectifier with filter.
9. To study and verify the truth table of different logic gates using digital IC.
10. To study different type of transformer and their operation.
11. To study basic wiring and design a switchboard/extension board.
12. To study the polarity test of a single phase transformer.
13. To study the open & short circuit test of a transformer and calibration losses.
14. To study the load test and efficiency of a single phase transformer.

Course Code: CHMS101 **Breakup: 3 –1 – 3 – 5**
Course Name: Chemistry - I

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the concept related to atoms and molecules, chemical bonding coordinate compounds and its applications
CO2	Concept of chemical kinetics, electrochemistry, photochemistry and their applications
CO3	Understand the concept of spectroscopy and its applications in various fields
CO4	Understand the basics of stereochemistry, organic reactions, and its mechanism for various types of reactions
CO5	Various experiments help the student to learn the basics of experiments to apply in day today life as well as in industry

Course Details: (Theory)

Unit-I - Atoms and Molecules:
Need for wave mechanical picture of atomic structure [Photoelectric effect, de Broglie concept of matter waves], Derivation of Schrodinger wave equation [as an example particle moving in uni-dimensional potential well]
Chemical Bonding- Orbital concepts in bonding, V.B. and M.O. theory, M.O. diagrams, Intermolecular interactions

Unit-II - Reaction Dynamics:
Order, Molecularity, Rate law, Integrated rate equations, Methods of determining of order of reaction, Complex reaction kinetics- chain reactions and reversible reactions in detail, Catalysis and enzyme catalysis

Unit-III - Electrochemistry:
Arrhenius theory of electrolytic dissociation, Transport number, Kohlrausch's law, Solubility product, Redox reaction, Electrochemical and concentration cells.

Unit-IV- Stereochemistry:
Introduction, Chirality, Enantiomers, Diastereomers, Projection formula of a tetrahedral carbon, Geometrical isomerism, Conformers

Unit- V- Application of Spectroscopic Techniques:
Basic working principle on measurement technique: IR, UV visible spectroscopy and NMR

Unit-VI - Organic Reactions:
Concepts Electron displacement effects, Organic intermediates, Types of reactions [addition, elimination, and substitution reactions]

Unit-VII - Photochemistry:
Principles of photo chemistry, Photo-excitation of organic molecules, Jablonski diagram, Laws of photochemistry and quantum yield, some examples of photochemical reactions, Chemistry of vision and other applications of photochemistry

Unit-VIII - Transition Metal Chemistry:
Structure of coordination compounds corresponding to coordination number up to 6, Types of ligands, chelation, Isomerism [geometrical, optical, ionization, linkage and coordination], Theories of bonding in coordination compounds- crystal field theory, Valence bond theory.

Text and Reference Books:

Physical Chemistry-

1 Physical Chemistry, P. Atkins and j. De Paul, 8th Edition, International Student Edition, Oxford University Press. (2006)
2 Principles of Physical Chemistry B.R Pure, L. R. Sharma, and M. S. Pathania, 37th Edition Shoban Lal Nagin Chand & Co., Jalandhar (2017)

Organic Chemistry-

1. Organic Chemistry, R. T. Morrison and R. N. Boyd, 6th Edition, Prentice-Hall of India (P) Ltd, New Delhi. (2016)
2. A text book of Organic Chemistry, Arun Bahl & B. S. Bahl, S. Chand Publishers, New Delhi (2019)

Inorganic Chemistry-

1. Concise Inorganic Chemistry, J. D. Lee, 5th Edition Chapman & Hall, London, (1997)
2. Inorganic Chemistry, J. E. Huheey, E. A. Keiter and R. L. Keiter (2017)

Engineering Chemistry-

1. Engineering Chemistry, Shashi Chawla, Dhanpat Rai & Co. (2013)
2. Engineering Chemistry, P. C.Jain and Monika Jain. 16th edition, Dhanpat Rai Publishing Company **(**2015)

Course Name: Chemistry Lab- I

Course Details: (Practical)

1. To estimate the strength of the given unknown solution of Mohr's salt (Ferrous ammonium sulphate ($FeSO_4.(NH_4)SO_4.6H_2O$) using $KMnO_4$ solution as an intermediate.
2. To prepare a sample of p-nitroacetanilide.
3. To prepare a sample of Aspirin.
4. Preparation of Tris (Thiourea) Copper (I) sulphate.
5. Preparation of Hexaamine Nickel (II) chloride $[Ni(NH_3)_6]Cl_2$.
6. Estimation of commercial caustic soda: Determination of the amounts of sodium carbonate and sodium hydroxide present together in the given commercial caustic soda.
7. Estimation of calcium ions present in tap water.
8. To determine the partition coefficient of acetic acid between n-butanol and water.
9. To study the photochemical reduction of a ferric salt (Blue printing).
10. To determine the viscosity of a given liquid room temperature using Ostwald's viscometer.
11. To separate Ag(I), Hg (I) and Pb (II) ions by paper chromatography and calculate their RF values.
12. Understanding reaction kinetics and calculating the rate and order of a reaction.
13. To study the kinetics of first order reaction (methyl acetate hydrolysis catalysed by 0.5 N HCl solution).

Course Code: MTHS102 **Breakup: 3 –1 – 0 – 4**
Course Name: Mathematics-II

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Solve the consistent system of linear equations
CO2	Determine the power series expansion of a given function
CO3	Solve arbitrary order linear differential equations with constant coefficients
CO4	Apply Laplace transforms to solve physical problems arising in engineering
CO5	Find eigen values, eigen vectors & diagonalize a matrix
CO6	Understand concept of vector space & linear transformation

Course Details:

Unit–I
Matrix Algebra: Elementary operations and their use in finding Rank, Inverse of a matrix and solution of system of linear equations. Orthogonal, Symmetric, Skew-symmetric, Hermitian, Skew-Hermitian, Normal & Unitary matrices and their elementary properties

Unit–II
Vector Space, Linear transformation, Linear dependent and linear independent, Eigen-values and Eigenvectors of a matrix, Cayley-Hamilton theorem, Diagonalization of a matrix

Unit-III
Ordinary Differential Equations of second order: Solution of linear differential equations with Constant coefficients. Euler-Cauchy equations, Solution of second order differential equations by changing dependent and independent variables; Method of variation of parameters, Introduction to series solution method, Frobenious Methods

Unit- IV
Ordinary differential equations of higher orders: Matrix method

Unit-V
Laplace Transform: Laplace and inverse Laplace transform of some standard functions, Shifting theorems, Laplace transform of derivatives and integrals. Convolution theorem, Initial and final value theorem; Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function. Applications of Laplace transform.

Text and Reference Books:

1. E. Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons, (2005).
2. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, (2005).
3. C. Ray Wylie & Louis C. Barrett, Advanced Engineering Mathematics, Tata McGraw-Hill Publishing Company Ltd. (2003).
4. G.F. Simmons, Differential Equations, Tata McGraw-Hill Publishing Company Ltd. (1981).

Course Code: PHYS102 **Breakup: 3 –1 – 3 – 5**
Course Name: Physics-II

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the vector integration which they can apply in electricity and magnetism
CO2	Understand the concepts of wave optics such as the phenomena of interference, diffraction and polarization of light
CO3	Understand the concepts of electrostatics, magnetostatics, electromagnetic induction, Maxwell's equations and electromagnetic waves
CO4	Apply the concepts of physics in the engineering courses

Course Details:(Theory)

Unit 1
Vector integration, Stokes' theorem, divergence theorem, electrostatics: Coulomb's law, superposition of electric forces, electric flux, Gauss's law, electric field, potential, calculation of electric fields due to different charge distribution, gradient and curl of electric field, electric dipoles and multipoles, potential energy of a dipole placed in external electric field, Laplace's equation, Poisson's equation.

Unit 2
Magnetostatics, motion of charge in electric and magnetic field, Lorentz force, magnetic flux, torque on a current coil in uniform magnetic field, magnetic dipole, potential energy of a magnetic dipole, Biot-Savart law, Ampere's law, calculation of magnetic field due to different current distribution, divergence, and curl of magnetic field.

Unit 3
Electromagnetic induction, Faraday's law, Lenz's law, self-induction, mutual induction, growth and decay of current in L-R circuit, electromagnetic waves, displacement current, Maxwell's equations in free space and matter, verification of Faraday's law of electromagnetic induction and Ampere's law in vacuum by using plane electromagnetic waves and derivation of velocity of light (c) in terms of permittivity and permeability of free space, Poynting vectors, Poynting theorem.

Unit 4
Coherent sources, Interference, Fresnel's biprism, interference in uniform and wedge-shaped thin films, necessity of extended source, Newton's rings and its applications, Fresnel and Fraunhofer diffraction at single slit and double slits, absent spectra, diffraction grating, spectra with grating, dispersive power, resolving power of grating, Rayleigh's criterion of resolution

Unit 5
Dispersion of light, angular dispersion, dispersive power, irrational dispersion, angular and chromatic dispersion, deviation without dispersion, dispersion without deviation, polarization of light, Fresnel's theory of optical activity and polarimeter, fundamental idea of optical fiber, types of fibers.

Text and Reference Books:

1. D.J. Griffiths, Introduction to Electrodynamics, 3E, Prentice-Hall of India Private

Limited, (2002)
2. M. R. Spiegel, Vector Analysis, Schaum's Outlines, (2021)
3. Ajoy Ghatak, Optics, McGraw Hill Education (India) Private Limited,7th Edition, (2020)
4. Subrahmanyam, Brijlal and Avadhanulu, A textbook of Optics by, Schand; 23rd Rev. Edition. (2006).
5. J. D. Jackson, Classical Electrodynamics by,Wiley, 3rd edition, (1998).
6. Aurthur Beiser, Concept of Modern Physics by, McGraw-Hill Education,6th Edition (2021).
7. Ajoy Ghatak and K. Tyagrajan, Introduction to fiber optics by, 1E, Cambridge University Press, (2012)

Course Name: Physics Lab-II

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Gain practical knowledge about electricity and magnetism and measurements such as resistance, voltage, current etc
CO2	Gain experimental knowledge of interference, diffraction and polarization of light and measurement of the wavelengths of the monochromatic light with the help of Newton's ring experiment, Fresnel's biprism experiment, etc.
CO3	Understand the concept of semiconductor physics through the four probe experiment
CO4	Gain knowledge about the various optical devices: prism, grating, spectrometer.
CO5	Understand the basic concept of modern physics through the determination of Planck's constant

Course Details:(Practical)

1. Newton's Ring (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Traveling Microscope, Support for Glass Plate inclined at 450 to the Vertical, Short Focus Convex Lens, Sodium Lamp, Plano Convex Lens, An Optically Plane Glass Plate)
2. Prism Spectrometer (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Spectrometer, Glass Prism, Reading Lens, Mercury Lamp)
3. Plane Transmission Grating (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Spectrometer, Diffraction Grating, Mercury Lamp)
4. Ballistic Galvanometer (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Ballistic Galvanometer, Morse key, Damping key, Condenser, Rheostat, Volt Meter, Storage Battery, Connection Wires)
5. Carey Foster's Bridge (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Carey Foster's Bridge, Laclanche cell, Resistance Box, Galvanometer, Plug Key, Copper Strip)
6. Fresnel's Biprism (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Sodium Lamp, Biprism, Convex Lens, Optical Bench with Four Uprights)
7. Variation of Magnetic Field (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Stewart and Gee type Tangent Galvanometer, Storage Battery, Commutator, Ammeter, Rheostat, One way Plug Key, Connection Wires)

8. Polarimeter (Ref. Book by K. K. Dey, B. N. Dutta) Apparatus Used (Sodium Lamp, Polarimeter, Physical Balance)
9. Planck's Constant (Ref. Book by S.K. Gupta and UIET Laboratory Manual) Apparatus Used (Power supply, photocell, connecting wires)
10. Energy Band Gap by Four Probe Method (Ref. Book by S.K. Gupta and UIET Laboratory Manual) Apparatus Used (An experimental kit)

Course Code: TCAS102 **Breakup: 3 – 0 – 6 – 5**
Course Name: Workshop Practice & IDEA Lab

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the design and applications of different machine tools and their operations based on global standards
CO2	Gain basic knowledge of casting processes and their applications
CO3	Recognize the different types metal forming process and their operations
CO4	Understand and appreciate the basic fabrication processes such as welding
CO5	Have knowledge about modern trends in manufacturing, unconventional machining processes and automation
CO6	Demonstrate the ability to design, prototype, and test electronic systems using measurement instruments, embedded platforms, and fabrication techniques

Course Details: (Theory)

Historical perspectives and Classification of Manufacturing processes

Unit – I Machining: Basic principles of lathe machine & operations performed on it. Basic description of machines & operations of shaper-planer, drilling, milling, grinding Unconventional machining processes, Machine tools.

Unit –II Casting Processes: Pattern & allowances, Moulding sands & its desirable properties. Mould making with the use of a core Gating system, Casting defects & remedies, Cupola furnace, Die-casting & its uses

Unit – III Metal forming: Basic metal forming operations & uses of such as-forging, rolling, wire& tube drawing/making & extrusion, & its products/applications, presswork & die & punch assembly, cutting & forming, its application; Hot working vs Cold working;

Unit – IV Powder metallurgy: Powder metallurgy process &its applications, plastic-products manufacturing, galvanizing & electroplating.

Unit – V Welding: Importance & basic concepts of welding, classification of welding processes, Gas welding, types of flames, Electric arc welding. Resistance welding, Soldering & brazing and its uses, Modern trends in manufacturing, Automation, Introduction to NC/ CNC /DNC, FMS, CAD/CAM, CIM and factory of future

Unit-VI IDEA Lab: Familiarization and use of basic electronic measurement instruments-DSO, Signal and function generator. Bench power supply. Circuit prototyping, 3D printing, Arduino programming

Course Name: Workshop Practice

Course Details: Laboratory Activities

1.	Foundry (1turn)	**4.**	M/C Shop (4 Turns)
2.	Welding (3 turns) i. Gas Welding (1turn) ii. Arc Welding (2 urns)	**5.**	Fitting & Sheet Metal Work (1 turn+1turn)
		6.	Carpentry Shop (1turn)
3.	i. Lap Joint (1 turn), ii. Butt Joint (1 turn)	**7.**	Black-smithy Shop (1turn)

8.	Machining of 3D geometry on soft material such as soft wood or modelling wax.
9.	2D profile cutting on plywood /MDF (6-12 mm) for press fit designs.
10.	Schematic and PCB layout design of a suitable circuit and fabrication.
11.	Embedded programming using Arduino and/or Raspberry Pi.
12.	Discussion and implementation of a mini project.

Text Books:

1. Chapman, W A J & Arnold, E "Workshop Technology,1972; vol. I, II&III" Viva Low Priced Edition 2002.
2. Raghuwanshi,B S "Workshop Technology ,2015; vol. I&II" Dhanpat Rai& Sons.

References:

1. AICTE's Prescribed Textbook: Workshop / Manufacturing Practices (with Lab Manual), Khanna Book Publishing.
2. Chaudhary, Hajra "Elements of Workshop Technology, 2008; vol. I&II" Media Promoters & Publishers.
3. 3D Printing & Design, Dr. Sabrie Soloman, ISBN: 978-9386173768, Khanna Book Publishing Company, New Delhi.
4. Programming Arduino: Getting Started with Sketches. 2nd edition. Simon Monk. McGraw Hill. ISBN-13: 978-1259641633

Course Code: ISCS101 **Breakup: 3 –0 – 3 –5**
Course Name: Programming & Computing (C & UNIX)

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Recollect various programming constructs and to develop C programs
CO2	Understand the fundamentals of C programming
CO3	Choose the right data representation formats based on the requirements of the problem
CO4	Implement different Operations on arrays, functions, pointers, structures, unions and files

Details: (Theory)

Basic concepts of Computers, Basic UNIX Concepts and Vi – Editor

Introduction to C: Basic Programming concepts, Program structure in C, Variables and Constants, Data types, Conditional statements, control statements,

Functions, Arrays, Structures; Introduction to pointers; Introduction to File Systems

Text and Reference Books:

1. Byron S. Gottfried, Programming in C, Schaum Series, 3rd edition, BPB Publication, (2017)
2. Denis Ritchi, The 'C' Programming, Second edition, PHI, (1988)
3. K.R. Venugopal, Mastering C, Second edition, TMH, (2006)
4. Yashavant Kanetkar, Let Us C, 18th Edition, BPB, (2021)
5. E. Balaguruswami, Programming in ANSI C, Eighth Edition, TMH (2019)

Course Name: Computer Programming Lab
Course Details: (Practical)

Learning OS Commands
Practice of all Internal and External DOS Commands, writing simple batch programs, Exposure to Windows environment, Practice of UNIX commands and Vi editor, Writing simple shell script

C Programming:
Practicing programs to get exposure to basic data types, algebraic expressions, Conditional statements, Input Output Formatting, Control structures, arrays, functions, structures, pointers and basic file handling

Course Code: HSSS101 **Breakup: 3 – 1– 0 – 4**
Course Name: Professional Communication

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Enhance their communication skills for tackling the global professional challenges of a diverse workplace
CO2	Learn effective writing skills and be able to write clear global technical reports
CO3	Improve their verbal and non-verbal communication
CO4	Be fluent orally in the use of the nuances of the English language
CO5	Learn good interpersonal skills and be proficient with the soft skills required for national and global placements

Course Details:

Unit -1 Basics of Technical Communication

Technical Communication**:** features; Distinction between global General and Technical communication; Language as a tool of communication; Levels of communication: Interpersonal, Organizational, Mass communication at global level; Flow of Communication: Downward, Upward, Lateral or Horizontal (Peer group); Importance of technical communication; Barriers to Communication.

Unit - II Constituents of Technical Written Communication

Words and Phrases: Word formation. Synonyms and Antonyms; Homophones; Select vocabulary of about 500-1000 New words; Requisites of Sentence Construction: Paragraph Development: Techniques and Methods - Inductive, Deductive, Spatial, Linear, Chronological etc; The Art of Condensation- various steps.

Unit - III Forms of Technical Communication
Business Letters: global and national Sales and Credit letters; Letter of Enquiry; Letter of Quotation, Order, Claim and Adjustment Letters; Job application and Resumes. Reports: Types; Significance; Structure, Style & Writing of Reports; Technical Proposal; Parts; Types; : global and national Writing of Proposal; Significance; Technical Paper, Project based on global standards. Dissertation and Thesis Writing: Features, Methods & Writing.

Unit - IV Presentation Strategies

Defining Purpose; Audience & Locale; Organizing Contents; Preparing Outline; Audio-visual Aids; Nuances of Delivery; local Body Language; Space; Setting Nuances of Voice Dynamics; Time-Dimension.

Unit - V Value- Based Text Readings
Following essays form the suggested text book with emphasis on Mechanics of writing,
The Aims of Science and the Humanities by M.E. Prior
The Language of Literature and Science by A.Huxley
Man and Nature by J.Bronowski
The Mother of the Sciences by A.J.Bahm
Science and Survival by Barry Commoner
Humanistic and Scientific Approaches to Human Activity by Moody E. Prior
The Effect of Scientific Temper on Man by Bertrand Russell.

Text and Reference Books:

1. V.N. Arora and Laxmi Chandra, Improve Your Writing ed. Oxford Univ. Press, New Delhi (2001)
2. Meenakshi Raman & Sangeeta Sharma, Technical Communication – Principles and Practices, OxfordUniv. Press, New Delhi (2007)

3. Barun K. Mitra, Effective Technical Communication, Oxford Univ. Press, New Delhi (2006)
4. R.C. Sharma & Krishna Mohan, Business Correspondence and Report Writing, Tata McGrawHill & Co. Ltd., New Delhi (2020)
5. M.Rosen Blum, How to Build Better Vocabulary, Bloomsbury Pub. London (2011)
6. Norman Lewis, Word Power Made Easy, W.R.Goyal Pub. & Distributors, Delhi (2015)
7. Meera Banerji and Krishna Mohan, Developing Communication Skills -Macmillan India Ltd. Delhi.(2017)
8. L.U.B. Pandey & R.P. Singh, Manual of Practical Communication, A.I.T.B.S. Publications India Ltd., Krishan Nagar, Delhi (2009)

Course Code: MTHS201 **Breakup: 3 –1 – 0 – 4**
Course Name: Mathematics - III

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Obtain the Fourier series expansion of a given function
CO2	Apply Fourier transform for solving Boundary Value Problems
CO3	Determine the solution of linear partial differential equations (PDE) by variable Lagrange's method & some nonlinear PDEs
CO4	Understand and use of complex variable & analyticity
CO5	Expand a function of Laurent series
CO6	Evaluation of real integrals using residues

Course Details:

Unit – I
Function of a Complex variable: Complex numbers- power and roots, limits, continuity and derivative of functions of complex variable, Analytic functions, Cauchy-Reimann equations, Harmonic function, Harmonic conjugate of analytic function and methods of finding it, Complex Exponential, Trigonometric, Hyperbolic and Logarithm function.

Unit – II
Complex Integration: Line integral in complex plane(definite and indefinite), Cauchy's Integral theorem, Cauchy's Integral formula, Derivatives of analytic functions, Cauchy's Inequality, Liouville's theorem, Morera's theorem, Power series representation of analytic function and radius of convergence, Taylor's and Laurent's series, singularities, Residue theorem, Evaluation of real integrals, Improper Integrals of rational functions.

Unit-III
Fourier series: Trigonometric Fourier series and its convergence. Fourier series of even and odd functions, Fourier half-range series; Parseval`s identity, Complex form of Fourier series;

Unit-IV
Fourier Transforms: Fourier integrals, Fourier sine and cosine integrals, Fourier transform, Fourier sine and cosine transforms and their elementary properties, Convolution theorem, Application of Fourier transforms to BVP

Unit-V
Partial Differential Equations: Formation of first and second order partial differential equations. Solution of first order partial differential equations: Lagrange`s equation, Four standard forms of non-linear first order equations.

Text and Reference Books:

1. E. Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons, (2005).
2. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, (2005).

Course Code: ESCS201 **Breakup: 3 –1 – 0 – 4**
Course Name: Engineering Mechanics

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the fundamentals of engineering mechanics and their applications
CO2	Gain knowledge of various types of motion related to body
CO3	Understand the basic concepts of friction and application of friction
CO4	Identify appropriate structural system for studying a given problem and isolate it from its environment
CO5	Carry out kinematic and kinetic analyses for particles and systems of particles
CO6	Apply the principles of mechanics to practical Chemical engineering problems

Course Details:

General Coplanar force systems: Basic concepts, Law of motions, principle of transmissibility of forces, Transfer of a force to parallel position, Resultant of a force system, simplest resultant of two dimensional concurrent & non-concurrent force systems, free body diagrams, equilibrium & its equations, applications

Trusses & Cables: Introductions, simple truss & solutions of simple truss, method of joints & method of sections.

Friction: Introduction, Laws of coulomb friction, equilibrium of bodies involving dry friction, belt friction, applications.

Centre of gravity, centroid, Moment of Inertia: Centroid of plane, curve, area, volume & composite bodies, moment of inertia of plane area, parallel axis theorem, perpendicular axis theorem, principal moment inertia, mass moment of inertia of circulating, disc, cylinder, sphere and cone about their axis of symmetry.

Beams: Introduction, shear force and bending moment, differential equations for equilibrium, shear force & bending moments diagrams for statically determinate beams

Kinematics of rigid body: Introduction, plane motion of rigid bodies, velocity & acceleration under translation & rotational motion, Relative velocity, projectile motion.

Kinetics of rigid bodies: Introduction, force, mass & acceleration, work & energy, impulse & momentum, D'Alembert principles & dynamic equilibrium, Virtual work.

Text and Reference Books:

1. F.P. Beer & F.R. Johnston, Mechanics for Engineers, 11th edition, McGraw Hill, (2017)
2. Shames, I.H., Engineering Mechanics, 4th Edition, P H I (2005)
3. J. L. Meriam, Statics, 7th edition, J. Wiley (2011)
4. J. L. Meriam, Dynamics, 7th edition, J. Wiley, (2011)

Course Code: ESCS202 **Breakup: 3 –1 – 0 – 4**
Course Name: Basic Thermodynamics

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Use thermodynamic terminology correctly and explain fundamental thermodynamic properties
CO2	Derive and discuss the zeroth, first, second, and third laws of thermodynamics
CO3	Apply the first and second laws of thermodynamics to chemical processes and calculate efficiency
CO4	Solve problems using the properties and relationships of thermodynamic fluids.
CO5	Analyze the behaviour of flow and non-flow processes using mass and energy balances
CO6	Analyze basic thermodynamic cycles

Course Details:

Introduction: Definition and scope of thermodynamics, macroscopic and microscopic viewpoint, system, properties, processes and cycles, homogeneous and heterogeneous systems, thermodynamic equilibrium, quasi-static process, phases of a substance, unit systems, specific volume, pressure.

Temperature: Zeroth law of thermodynamics, measurement of temperature, different temperature scales.

Properties of pure substances: Pure substance, p-v diagram, p-T diagram, T-s diagram, h-s diagram or Mollier diagram, quality or dryness fraction, steam table.

Energy and its transfer: Energy, different forms of energy, energy transfer by heat, energy transfer by work, different forms of work transfer - pdV work or displacement work, shaft work, flow work, etc., pdV work in various quasi-static processes, specific heat and latent heat.

First Law of Thermodynamics: Energy balance, energy conversion efficiency, energy analysis of open and closed systems, PMM1.

Second Law of Thermodynamics: Cyclic heat engine, thermal reservoirs, Kelvin-Planck statement, Clausius' statement, refrigerator and heat pump, equivalence of Kelvin-Planck and Clausius' statement, PMM2, conditions for reversibility, Carnot cycle, Carnot's theorem, corollary of Carnot's theorem, absolute thermodynamic temperature scale, efficiency of the reversible heat engine.

Entropy: Clausius' theorem, temperature-entropy plot, Clausius inequality, entropy change in an irreversible process, entropy principle, entropy generation in a closed and open system, entropy and direction, entropy and disorder.

Availability: Available energy, available energy in a cycle, quality of energy, law of degradation of energy, maximum work in a reversible process, second law efficiency.

Thermodynamic relations: Maxwell's equations, TdS equations, Joule-Kelvin effect, Clausius-Clapeyron equation, Gibbs phase rule for non-reactive system.

Power and refrigeration cycles: Simple steam power cycle, Rankine cycle, comparison of Rankine and Carnot cycles, characteristics of an ideal working fluid in vapour power cycles. Carnot gas power cycle, Refrigeration cycle – reversed heat engine cycle, vapour compression refrigeration cycle, components in a vapour compression plant, refrigerants.

Text and Reference Books:

1. P K Nag, Engineering Thermodynamics, Sixth edition, McGraw Hill Education, Delhi (2017).
2. Y A Cengel, M A Boles, M Kanoglu, Thermodynamics An Engineering Approach, Ninth edition, McGraw Hill Education, Delhi (2019).
3. Y V C Rao, An Introduction to Thermodynamics, Universities Press, Hyderabad (2003).

Course Code: CHES201 **Breakup: 3 –1 – 0 – 4**
Course Name: Process Calculations

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Demonstrate comprehensive understanding of material and energy balance equations for open and closed systems
CO2	Select appropriate basis and conduct degree of freedom analysis before solving material and energy balance problems
CO3	Make elementary flow-sheets and perform material and energy balance calculations without and with chemical reactions, and involving concepts like recycle, bypass and purge
CO4	Perform process calculations utilizing psychrometric charts and steam tables
CO5	Apply simultaneous material and energy balance calculations for steady state continuous flow systems and unsteady state systems

Course Details:

Introduction: Units, their dimensions and conversions, Dimensional consistency of equations, Dimensional and dimensionless constants,

Fundamental concept of stoichiometry: Mass and volume relations, Stoichiometric and composition relations, Excess reactants, Degree of completion, Conversion, Selectivity and Yield.

Ideal gases and gas mixture: Gas laws-Ideal gas law, Dalton's Law, Amagat's Law, and Average molecular weight of gaseous mixtures.

Vapour pressure: Effect of temperature on vapour pressure, Vapour pressure plot (Cox chart), Vapour pressures of miscible and immiscible liquids and solutions, Raoult's Law and Henry's Law.

Humidity and Humidity charts: Relative Humidity and percent saturation; Dew point, Dry and Wet bulb temperatures; Use of humidity charts for engineering calculations

Material balances for systems with and without chemical reactions: species and elemental balance. Analysis of systems with by-pass, recycle and purge.

Thermophysics: Heat capacity of gases, liquids and solutions, Heat of fusion and vaporisation;

Thermochemistry: Calculations and application of heat of reaction, combustion, formation, neutralisation and solution; Enthalpy-concentration charts;

Steady state energy balance for systems with and without chemical reactions:

Combustion of solids, liquids and gaseous fuels, calculation of theoretical and actual flame temperatures, Degrees of freedom in steady state processes, solution of simultaneous material and energy balance problems using flow sheeting codes;

Unsteady state material and energy balance

Text and Reference Books:

1. D.M. Himmelblau, Basic Principles and calculations in Chemical Engineering, Printice-Hall (2015)
2. O.A. Hougen, K.M.Watson & R.A.Ragatz, Chemical process principles, John Willey & Sons (2018)

Course Code: CHES202 **Breakup: 3 –1 – 0 – 4**
Course Name: Fluid Mechanics & Mechanical Operations

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand and apply fundamental fluid properties and principles of fluid statics
CO2	Analyze and solve problems related to fluid kinematics and dynamics
CO3	Grasp the concepts of laminar and turbulent flow, boundary layers, and dimensional analysis
CO4	Evaluate and design hydraulic systems, including pipe networks and pumping machinery
CO5	Identify, analyze, and select appropriate mechanical-physical separation techniques and equipment for various solid-fluid systems

Unit 1 Concept of fluid; Distinction between solids and fluids, Fluid Properties, Newton's law of Viscosity, Newtonian & non-Newtonian fluids, vapour pressure, boiling point, compressibility, bulk modulus, surface tension, capillarity, Pascal's law, pressure variation in static fluids, Pressure measuring devices: Barometer, Piezometer, Manometer, Bourdon gauge, Diaphragm gauge. Archimedes' principle, buoyant force, centre of buoyancy, Stability and floating bodies.

Unit 2 Types of flow (1D, 2D, 3D; steady/unsteady; uniform/non-uniform; laminar/turbulent; compressible/incompressible; rotational/irrotational; ideal/real), Lagrangian and Eulerian descriptions, Flow visualization: Pathlines, Streamlines, Streaklines, Timelines, Continuity equation, Euler's equation of motion, Bernoulli's equation and its applications: Venturimeter, Orifice meter, Pitot tube, Rotameter.

Unit 3 Laminar and turbulent flow in pipes, Navier-Stokes equation (introductory concept), Hagen-Poiseuille law, Prandtl's mixing length theory, Boundary layer formation, thickness, laminar vs turbulent boundary layers, Separation and control techniques. Rayleigh's method, Buckingham π-theorem, Similarity and model laws (geometric, kinematic, dynamic), Model types and application.

Unit 4 Hydraulic coefficients, time of emptying tanks (rectangular, conical, horizontal cylindrical), Losses in flow through orifices and mouthpieces (external/internal), Rectangular, triangular (V-notch), trapezoidal, and stepped notches; discharge calculations. Reynolds experiment, energy losses (Darcy-Weisbach, minor losses), Moody's chart, Colebrook equation, Pipe network: Series, parallel, equivalent pipes; flow through nozzles; water hammer, Centrifugal pumps: Components, working, efficiency, specific speed, cavitation, NPSH, Reciprocating pumps: Types, working, discharge, slip, power. Comparison between centrifugal and reciprocating pumps.

Unit 5 Unit operations vs. unit processes, Need and classification of separation processes, Mechanical-physical separation: overview and relevance, Characterization of solid particles: shape, size, mixed particle sizes, average size, Bulk solids: angle of repose, angle of internal friction, Flow and storage: bins, hoppers, flow issues, Mechanisms: compression, impact, attrition, shear, cutting, Laws of comminution (Rittinger, Kick, Bond), Equipment: Coarse crushers, intermediate crushers, grinders, ultra-fine grinders, Criteria for equipment selection, Screening and screening equipment, Magnetic and electrostatic separation, Classification: free and hindered settling, Classifying equipment (mechanical and non-mechanical), Gravity concentration, flotation, and associated equipment

Unit 6 Sedimentation: principles, batch and continuous sedimentation, thickeners, classifiers, Filtration, Principles of cake filtration, filter media, filter aids, Filtration theory: constant and variable pressure filtration, Equipment: filter press, leaf filter, rotary drum filter, Gas-Solid Separation Fundamentals and need for gas cleaning, Gravity settling chamber, inertial separators, fabric filters, wet scrubbers, electrostatic precipitators, cyclone separators, air classifiers, Transportation of Solids : Belt conveyors, screw conveyors, pipe conveyors, bucket elevators, Conveying of powders: flow behavior and handling, Mixing of Solids and Liquids, Auxiliary Operations: Size enlargement, Crystallization, Feeding and weighing, Coagulation and flocculation

Text and Reference Books:

1. C S P Ojha, R Berndtsson, P N Chandramouli, Fluid Mechanics and Machinery, Oxford University Press, New Delhi (2010).
2. P N Modi, S M Seth, Hydraulics and Fluid Mechanics including Hydraulics Machines, Standard Book House, New Delhi (2017).
3. N de Nevers, Fluid Mechanics for Chemical Engineers, Third edition, McGraw Hill, Chennai (2017).

Course Code: EVSS101 **Breakup: 2 –0 – 0 – 2**
Course Name: Environmental Science

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the concepts and definitions associated with ecosystems, environmental pollution and its causes
CO2	Gain knowledge to analyse problems and suggest alternatives and new methods to manage natural resources
CO3	Understand how to Redesign, Recreate & Restore the ecosystems
CO4	Understand the legal aspects and the role of government in environment protection

Course Details:

UNIT-I
Global scope and importance of environmental studies, Need for public awareness, Segments of environment, biodiversities: Genetic diversity, Species diversity, Ecosystem diversity, Landscape diversity, Causes of pollution and detrimental effects.

UNIT-II
Eco systems- Types of systems, energy flow in an ecosystem, Balanced ecosystem,Human activities- Food, shelter, economic and social security, Effects of human activities on environment-Agriculture, housing, Industry, mining and transportation activities, Basics of Environmental Impact Assessment, Sustainable Development.

UNIT-III
Types of natural resources: Water resources-Availability and quality aspects, Water borne diseases, Fluoride problems in portable water, Mineral resources, Food resources, Land resources, Forest Wealth, Material cycles- Carbon, Nitrogen and Sulphur cycle.

UNIT-IV
Energy- Different types of energy (Renewable and Non-renewable), Convectional and non-conventional energy-sources Electromagnetic radiation, Hydro Electric, Fossil fuel based, Nuclear, Solar, Biomass and Bio-gas, Hydrogen as an alternative future source of energyat local and regional level

UNIT-V
Environmental pollution and their effects, Water pollution, Land pollution, Noise pollution, public Health aspects, Air pollution. Current environmental issues of importance and their impact on environmentat local and regional level: Population Growth, Climate change and global warming effect, Urbanization, Automobile pollution, Acid rain, Ozone layer depletion.

UNIT-VI
Preventive measures and control of pollution, Air and Water pollution control, Sold waste management, Case studiesat local and regional level.

UNIT-VII
Role of Government in environment protection, Legal Aspects, Initiatives and protection Acts, public awareness, Initiatives by Non-governmental Organizations (NGOs), Role of IT services, Disaster managementat local and regional level .

UNIT-VIII
Field work/ Activities/ Visit

Text and Reference Books:

1. Benny Joseph, Environmental Studies, Tata McGraw Hill Publication (2017)
   D.L. Manjunath, Environmental Studies, Pearson Education.

2. R. Rajgopalan, Environmental Studies, Oxford Publication (2015)
3. M. Anji Reddy, Textbook of Environmental Science and Technology, BS Publication (2010)
4. P. Venugopala Rao, Principles of Environmental Science and Engineering, Prentice Hall of India (2006)
5. Meenakshi, Environmental Science and Engineering, Prentice Hall of India (2012)

Course Code: SSTS201 **Breakup: 0 –0 – 2 – 2**
Course Name: Summer Internship - I

Course Details:

First-year students are required to undertake a four-week summer internship after completion of two semesters. This internship aims to provide practical experience in the application of engineering principles. Upon completion of the training, students must submit a formal report and their certificate of completion to the department, followed by a professional presentation summarizing their internship experience.

Course Outcomes (CO): Upon successful completion of this seminar, students will be able to:

CO1	Articulate the objectives, activities, and outcomes of their internship experience
CO2	Analyze the relevance of their internship work to their academic curriculum and future career goals
CO3	Develop and deliver a clear, concise, and professional presentation summarizing their internship
CO4	Engage in constructive self-reflection and peer feedback regarding practical industry exposure
CO5	Identify key learning points, challenges, and solutions encountered during the internship period

The seminar will typically involve:

- **Pre-Seminar Preparation:** Students will prepare a detailed report and a presentation.
- **Oral Presentation:** Each student will deliver a presentation to their peers and faculty.
- **Question & Answer Session:** A dedicated time for questions and discussion following each presentation.
- **Feedback:** Constructive feedback will be provided by faculty and peers.

Internship Seminar Topics / Content Guidelines

The seminar presentation should cover the following aspects of the internship:

- Introduction to the Organization:
- Internship Details:
- Project/Work Undertaken:
    - Problem Statement/Objective
    - Methodology/Approach
    - Activities Performed
    - Challenges Faced & Solutions
    - Results/Outcomes
- Learning Outcomes & Impact:
    - Technical Skills Gained/Enhanced
    - Soft Skills Developed
    - Application of Classroom Knowledge
    - Insights into Industry
    - Career Relevance
- Conclusion & Recommendations

Presentation Guidelines

- 8-10 minutes presentation + 2-3 minutes Q&A.

Course Code: CHES10 **Breakup: 3 –1 – 0 – 4**
Course Name: Chemical Engineering Thermodynamics

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Appreciate the scope of the subject as a fundamental subject to calculate thermodynamic properties of substances
CO2	Apply the laws of thermodynamics to closed and open systems and calculate heat effects involved in industrial chemical processes
CO3	Determine thermodynamic properties of ideal and real gaseous mixtures
CO4	Understand and apply the criteria of equilibrium conditions in case of phase equilibria for binary and multi-component systems
CO5	Calculate the important thermodynamic properties of ideal and non-ideal solutions
CO6	Understand reaction equilibrium and determine equilibrium constant and composition of product mixture at given temperature and pressure

Course Details:

Introduction: Macroscopic and microscopic approaches; units; basic concepts of system, property, force, temperature, pressure, work, energy, heat and equilibrium

Review of First and Second law of thermodynamics for closed and open system,

P-v-T behaviour of pure substance: graphical, tabular and mathematical representation Ideal gas, Cubic equations of state; Virial equation of state, laws of corresponding states, compressibility factor, accentric factor, generalized correlation for gases and liquids;

Thermodynamic Potentials and Thermodynamic Property relations: Postulates; Intensive properties; Criteria of equilibrium; Euler relation, Gibbs Duhem relation; Potentials-A,G,H,U; Property relations for homogeneous phases; Maxwell's relation,

Thermodynamic properties of real gases: departure functions; evaluation of departure functions; partial molar properties, fugacity and fugacity coefficient, estimation of fugacity coefficient, thermodynamic properties of real gas mixtures – mixing rules, prediction of P-v-T behaviour, departure functions, fugacity coefficients for real gases; Fugacity of a component in a mixture, Fugacity of liquid and solid,

Thermodynamics of solution: Ideal solution, Raoult's law, phase equilibrium problems; excess properties, activity and activity coefficient, excess Gibbs free energy models; Henry's law, basic equation for vapour liquid equilibrium; VLE at low to moderate pressures and high pressures, excess Gibbs free energy models, azeotropic data, bubble, dew point and flash calculations; dilute solution laws

Chemical reaction equilibrium: standard Gibbs free energy change and equilibrium constant, effect of temperature on equilibrium constant; homogeneous gas and liquid phase reactions

Text and Reference Books:

1. Y.V.C. Rao, Chemical Engineering Thermodynamics, University Press.(1997)
2. Smith & van Ness, Introduction to Chemical Engineering Thermodynamics, McGraw Hill (2019)
3. K. V. Narayanan, Chemical Engineering Thermodynamics, CBS Publication.(2013)

Course Code: CHE-S204 **Breakup: 3 –1 – 0 – 4**
Course Name: Heat Transfer

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the difference between thermodynamics and heat transfer and the general principles of conduction, convection and radiation
CO2	Understand steady state conductive heat transfer through simple geometries
CO3	Understand combined heat transfer mechanisms through composite geometries and extended surfaces
CO4	Able to differentiate types of heat exchangers, their detailed construction, operation and design
CO5	Understand heat transfer with phase change (boiling and condensation)
CO6	Understand the process of evaporation and analyzing the functioning and design of evaporators
CO7	Understand the principles of radiation, the radiation laws and calculation of radiative heat transfer between black and Gray bodies

Course Details:

General Principles of heat transfer by conduction, convection, radiation.

Conduction: Fourier's law of heat conduction; steady state conduction in one dimension with and without heat source through plain wall, cylindrical & spherical surfaces; variable thermal conductivity, combined mechanism of heat transfer (conduction and convection), conduction through composite slab, cylinder and sphere; thermal contact resistance; thermal insulations, properties of insulating materials; critical radius of insulation; extended surfaces: heat transfer from a fin, effectiveness and efficiency

Convection: Natural and forced convection; convective heat transfer coefficient; concept of thermal boundary layer; laminar & turbulent flow heat transfer inside and outside tubes; dimensional analysis, Buckingham pi theorem, dimensionless numbers in heat transfer and their significance; determination of individual & overall heat transfer coefficients and their temperature dependency

Forced convection**:** correlation for heat transfer in laminar and turbulent flow in a circular tube and duct, Reynolds and Colburn analogies between momentum and heat transfer

Natural convection – natural convection from vertical and horizontal surfaces, Grashof and Rayleigh numbers

Heat exchangers: Types of heat exchangers like double pipe, shell & tube, plate type, extended surface, multi-pass exchangers; their detailed construction and operation; calculations on design of heat exchangers; effectiveness of a heat exchanger

Heat transfer with phase change: condensation of pure and mixed vapours; film wise and drop wise condensation, calculations on condensers, heat transfer in boiling liquids, boiling curve, nucleate and film boiling; correlations for pool boiling

Evaporation: elementary principles, boiling point elevation and Duhring's plot; types of evaporators – single, multiple (forward, backward, mixed feed), capacity and economy of evaporators simple calculation on single and multiple effect evaporators

Radiation: Basic concepts of radiation from surface, black body and grey body concepts, Planks Law, Wein's displacement law, Stefan Boltzmann's law, Kirchoff's law, View factor, combined heat transfer coefficients by convection and radiation.

Introduction to unsteady state heat transfer: lumped parameter model, unsteady state heat conduction in various geometries, Heisler charts

Text and Reference Books:

1. B. K. Dutta, Heat Transfer Principles and Applications, PHI (2000)
2. D.Q. Kern, Process Heat Transfer, Mc Graw Hill (2017)
3. J. P. Holman, Heat Transfer, Mc Graw Hill (2017)
4. F.P. Incropera and D. P. Dewitt, Fundamentals of Heat and Mass Transfer, John Wiley (2018)
5. Y. A, Cengel, A. J. Ghajar, Heat and Mass Transfer: Fundamentals & Applications, McGraw Hill (2020)

Course Code: CHES205 **Breakup: 4 –0 – 0 – 4**
Course Name: Chemical Process Industries

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the role of chemical process engineer in chemical industry identify different unit operations and unit processes in a given process flow diagram
CO2	Demonstrate thorough understanding of some important process industries (chloro-alkali, fertilizers, soaps and detergents, sugar manufacture, petroleum, paper and fermentation etc)
CO3	Identify and solve engineering problems during manufacturing of the above-mentioned products
CO4	Identify process industry and make a presentation related to present scenario

Course Details:

Overview: Typical chemical processes: unit operations and unit processes; classification of Indian chemical process industry; study aspects of a CPI- raw materials, process, chemical reactions, process and block flow diagram, major engineering issues and uses;

Common utilities such as electricity, cooling water, steam, hot oil, refrigeration and chilled water at national level.

Chlor-alkali industry: Manufacture of soda ash, caustic soda, chlorine and hydrochloric acid, Sulphur industry: Sulphur, sulphuric acid and oleum

Phosphorus industry: Phosphorus, phosphoric acid and superphosphates
Nitrogen industry: Ammonia, urea, nitric acid and ammonium nitrate.
Cement industry: manufacture by cement rock (limestone) beneficiation and Portland process

Natural product industry: pulp and paper, sugar and alcohol, edible oils and fats

Soap and detergent industry: classification of soap, detergent and surfactants and their manufacture

Polymer industry: general polymerization systems: bulk, solution, suspension and emulsion polymerisation; synthesis of polyethylene, polypropylene, polystyrene and PVC, polyester synthetic fibres

Natural and synthetic fibre industry: manufacture of viscose rayon, nylon 6,6 and nylon 6 fibres and polyester fibres on national level.

Petroleum and petrochemical industry: Petroleum refining: Basic distillation, thermal cracking, alkylation and catalytic cracking, other refining unit processes: reforming, hydrodealkylation, isomerisation, hydrogenation, desulphurisation, polymerisation etc.

Important petrochemicals: C1, C2, C3, C4 etc, benzene, toluene, xylene and other petrochemicals from these basic building blocks

Text and Reference Books:

1. M. Gopala Rao, Dryden's Outlines of Chemical Technology, East West Press (2019)
2. G.T. Austin, Shreve's Chemical Process Industries, Mc Graw Hill (2017)

Course Code: ESCS203 **Breakup: 3 –0 – 2 – 4**
Course Name: Introduction to Machine Learning

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand core ML concepts and implement regression models
CO2	Apply logistic regression and evaluate classification models.
CO3	Explain neural networks and build basic deep learning models.
CO4	Use unsupervised learning and dimensionality reduction techniques
CO5	Execute the ML pipeline with model tuning and deployment basics
CO6	Develop ML models using Python tools with ethical awareness

Course Details:

UNIT I: Introduction to Machine Learning and Supervised Learning
Definition and types of machine learning, applications in engineering, components of ML systems, data characteristics, training and testing concepts, linear regression with single and multiple variables, cost function, gradient descent, normal equation, feature scaling, polynomial regression, underfitting and overfitting, introduction to ML tools.

UNIT II: Classification and Logistic Regression
Classification vs regression, logistic regression, sigmoid function, decision boundaries, cost function, regularization, multiclass classification, model evaluation using confusion matrix, ROC curve, precision, recall, and F1-score.

UNIT III: Neural Networks and Deep Learning
Artificial neurons, neural network architecture, activation functions, forward and backpropagation (conceptual), loss functions, introduction to deep learning, implementation basics using Keras and TensorFlow, ethical concerns.

UNIT IV: Unsupervised Learning and Dimensionality Reduction
Unsupervised learning concepts, k-means clustering, number of clusters, hierarchical clustering, PCA for dimensionality reduction, visualization of data, anomaly detection, association rule learning (introductory).

UNIT V: ML Workflow and Model Optimization
ML workflow stages, EDA, feature engineering, train-validation-test splits, cross-validation, model selection, bias-variance tradeoff, hyperparameter tuning, introduction to ensemble methods, basics of deployment and MLOps.

UNIT VI: Python Tools for Machine Learning
Introduction to Python using Google Colab, basic use of NumPy, Pandas, Matplotlib, Scikit-learn, implementation of regression and classification models, model evaluation, working on a real-world mini project, ethical considerations.

Text and Reference Books:

1. Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, O'Reilly Media.
2. Andreas C. Müller and Sarah Guido, Introduction to Machine Learning with Python, O'Reilly Media.
3. Tom M. Mitchell, Machine Learning, McGraw-Hill Education.
4. Ethem Alpaydin, Introduction to Machine Learning, MIT Press.
5. Trevor Hastie, Robert Tibshirani, and Jerome Friedman, The Elements of Statistical Learning, Springer.

Course Code: HSSS201 **Breakup: 1 –0 – 2 – 3**
Course Name: Communication Practicum

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the nuances of English language for enhancing presentation skills
CO2	Speak in standard English with clarity and fluency and to write business messages professionally
CO3	Speak and communicate clearly in different professional contexts which would improve their chances of employability
CO4	Understand the importance of ethical practices in their professional life

Course Details:

Unit 1- Presentation techniques
Meaning and importance of presentation technique
Presentation skills required for business organization: Negotiation, Persuasion & Time management
Types of business presentations- meetings, seminars, conferences

Unit 2- Oral presentations
Effective oral delivery- Phonetics
Interviews, Group discussions, debates, speeches
Listening skills, Reading skills

Unit 3- Written communication
Style and tone of writing business messages and documents
Persuasive, sales and goodwill messages, delivering bad news
Writing e-mails and short messages, Resume writing

Unit 4 – Non Verbal communication
Nonverbal communication techniques
Business manners, ethics and personality development
Power point presentations

Text and Reference Books:

1. Bove`e, Thill and Schatzman, Business Communication Today, Pearson Education (Singapore), (2003)
2. H. Dan O'Hair, James S. O'Rourke and Mary John O'Hair, Business Communication-a framework of success", South Western College Publishing, (2001)
3. Raymond V. Lesikar, Marie E. Flatley, Basic Business Communication, Tata McGraw Hill Publishing Company Ltd., (2002)

Course Code: UHVS201 **Breakup: 3 –0 – 0 – 3**
Course Name: Universal Human Values - II

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the significance of value inputs in a classroom, distinguish between values and skills, understand the need, basic guidelines, content and process of value education, explore the meaning of happiness and prosperity and do a correct appraisal of the current scenario in the society
CO2	Distinguish between the Self and the Body, understand the meaning of Harmony in the Self the Co-existence of Self and Body
CO3	Understand the value of harmonious relationship based on trust, respect and other naturally acceptable feelings in human-human relationships and explore their role in ensuring a harmonious society
CO4	Understand the harmony in nature and existence, and work out their mutually fulfilling participation in the nature.
CO5	Distinguish between ethical and unethical practices, and start working out the strategy to actualize a harmonious environment wherever they work.

Course Details:

UNIT I: Course Introduction
Need, Basic Guidelines, Content and Process for Value Education Understanding the need, basic guidelines, content and process for Value Education, Self-Exploration–what is it? - its content and process; 'Natural Acceptance' and Experiential Validation- as the mechanism for self exploration, Continuous Happiness and Prosperity- A look at basic Human Aspirations, Right understanding, Relationship and Physical Facilities- the basic requirements for fulfillment of aspirations of every human being with their correct priority, Understanding Happiness and Prosperity correctly- A critical appraisal of the current scenario, Method to fulfill the above human aspirations: understanding and living in harmony at various levels.

UNIT II: Understanding Harmony in the Human Being
Harmony in Myself Understanding human being as a co-existence of the sentient 'I' and the material 'Body', Understanding the needs of Self ('I') and 'Body' - Sukh and Suvidha, Understanding the Body as an instrument of 'I' (I being the doer, seer and enjoyer), Understanding the characteristics and activities of 'I' and harmony in 'I', Understanding the harmony of I with the Body: Sanyam and Swasthya; correct appraisal of Physical needs, meaning of Prosperity in detail, Programs to ensure Sanyam and Swasthya.

UNIT III: Understanding Harmony in the Family and Society
Harmony in Human-Human Relationship Understanding harmony in the Family- the basic unit of human interaction , Understanding values in human-human relationship; meaning of Nyaya and program for its fulfillment to ensure Ubhay-tripti; Trust (Vishwas) and Respect (Samman) as the foundational values of relationship, Understanding the meaning of Vishwas; Difference between intention and competence, Understanding the meaning of Samman, Difference between respect and differentiation; the other salient values in relationship, Understanding the harmony in the society (society being an extension of family): Samadhan, Samridhi, Abhay, Sah-astitva as comprehensive Human Goals, Visualizing a universal harmonious order in societyUndivided Society (AkhandSamaj), Universal Order (SarvabhaumVyawastha)- from family to world family!.

UNIT IV: Understanding Harmony in the Nature and Existence
Whole existence as Co-existence Understanding the harmony in the Nature, Interconnectedness and mutual fulfillment among the four orders of nature- recyclability and self-regulation in nature, Understanding Existence as Co-existence (Sah-astitva) of mutually interacting units in all-pervasive space, Holistic perception of harmony at all levels of existence.

UNIT V: Implications of the above Holistic Understanding of Harmony on Professional Ethics

Natural acceptance of human values, Definitiveness of Ethical Human Conduct, Basis for Humanistic Education, Humanistic Constitution and Humanistic Universal Order, Competence in Professional Ethics: a) Ability to utilize the professional competence for augmenting universal human order, b) Ability to identify the scope and characteristics of people-friendly and eco-friendly production systems, technologies and management models, Case studies of typical holistic technologies, management models and production systems, Strategy for transition from the present state to Universal Human Order: a) At the level of individual: as socially and ecologically responsible engineers, technologists and managers, b) At the level of society: as mutually enriching institutions and organizations.

Text and Reference Books:

1. R R Gaur, R Asthana, G P Bagaria, A Foundation Course in Human Values and Professional Ethics, 2nd Revised Edition, Excel Books, New Delhi, 2019. ISBN 978-93-87034-47-1
2. R R Gaur, R Asthana, G P Bagaria, A Foundation Course in Human Values and Professional Ethics – Teachers Manual, 2nd Revised Edition, Excel Books, New Delhi, 2019
3. http://www.uhv.org.in/) containing: Video of Faculty Development Program (Teachers' Orientation Programme), Presentation (PPTs) material for use in lectures and practice sessions Audio-visual material for use in the practice sessions
4. A Nagaraj, 1999, Jïvana Vidyã Ek Parichaya, Jïvana Vidyã Prakãsåna, Amarkantak.
5. A Nagaraj, 1999, Vyavahãrvãdï. Samãjashãstra, Jïvana Vidyã Prakãsåna, Amarkantak.
6. A Nagaraj, 2001, Ãvartansïla Arthasãstra, Jïvana Vidyã Prakãsåna, Amarkantak.
7. A Nagaraj, 2003, Mãnava Vyavahãra Darsåna, Jïvana Vidyã Prakãsåna, Amarkantak.
8. A Nagaraj, 1998, Samãdhãnãtmak Bhoutikvãd, Jïvana Vidyã Prakãsåna, Amarkantak.
9. A N Tripathy, 2003, Human Values, New Age International Publishers.
10. B L Bajpai, 2004, Indian Ethos and Modern Management, New Royal Class notes Co., Lucknow. Reprinted 2008.
11. B P Banerjee, 2005, Foundations of Ethics and Management, Excel Books.
12. D H Meadows, Dennis L. Meadows, Jorgen Randers, William W. Behrens III, 1972, Limits to Growth – Club of Rome's report, Universe Books.
13. E F Schumacher, 1973, Small is Beautiful: A Study of Economics as if People Mattered, Blond and Briggs, Britain.
14. E G Seebauer and Robert L. Berry, 2000, Fundamentals of Ethics for Scientists and Engineers, Oxford University Press.
15. FAO, 2011, Global Food Losses and Food Waste – Extent, Causes and Prevention, ISBN 978-92-5-107205-9, Rome.
16. M Fukuoka, 1984, The One-straw Revolution: An Introduction to Natural Farming, Published (in India) by Friends Rural Centre, Rasulia.
17. Illich, 1974, Energy and Equity, The Trinity Press, Worcester, and Harper Collins, USA.
18. King Jigme Khesar of Bhutan, 2010, Royal Address at the Kolkata University Convocation, Kolkata (October 5, 2010).
19. M Govindrajran, S Natrajan and V S Senthil Kumar, 2004, Engineering Ethics (including Human Values), Eastern Economy Edition, Prentice Hall of India Ltd.
20. M K Gandhi, 1939, Hind Swaraj, Navjivan Publishing House, Ahmedabad.
21. P L Dhar, R R Gaur, 1990, Science and Humanism, Commonwealth Publishers.
22. S Palekar, 2000, How to Practice Natural Farming, Pracheen (Vaidik) Krishi Tantra Shodh, Amravati.
23. S George, 1976, How the Other Half Dies, Penguin Press. Reprinted 1986, 1991.

Relevant Websites, CDs and Documentaries

1. Universal Human Values website, http://www.uhv.org.in/
2. AKTU Value Education website, http://aktu.uhv.org.in/
3. Story of Stuff website, http://www.storyofstuff.com/
4. Al Gore, An Inconvenient Truth, 2006, Paramount Classics, USA
5. Charlie Chaplin, Modern Times, United Artists, USA
6. IIT Delhi, Modern Technology – The Untold Story
7. Anand Gandhi, Right Here Right Now, 2003, Cyclewala Production

Course Code: CHES301 **Breakup: 3 –1 – 0 – 4**
Course Name: Mass Transfer I

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	To understand the phenomena of mass transfer on macro level
CO2	Understand the concept of equilibrium in all separation operations should be clear
CO3	Able to design Distillation, Extraction, Leaching, Adsorption column by using different methods
CO4	Able to find out optimum conditions for component separation
CO5	To do the design by graphical and analytical method

Course Details:

Distillation: Vapour-liquid equilibria, Relative volatility, Raoult's law, minimum and maximum boiling mixtures, enthalpy-concentration diagrams for binary systems, multicomponent systems – bubble point and dew point calculation, Flash vaporization, Differential distillation, Steam Distillation, Continuous rectification, Azeotropic and Extractive Distillation, Multistage tray towers - Graphical methods of Ponchon-Savarit and McCabe-Thiele, feed-tray location, total reflux, minimum reflux ratio, optimum reflux ratio, open steam, multiple feed and side stream, multi component calculations using short-cut methods.

Liquid Extraction: Introduction, liquid equilibria, equilateral-triangular coordinates systems of three liquids, choice of solvent, single stage and multistage crosscurrent extraction, insoluble liquids, continuous counter current multistage extraction, insoluble liquids.

Leaching: Introduction, lixiviation, decoction, elutriation or elution, preparation of the solid, effect of temperature, types of equilibrium curves, single stage and multistage crosscurrent leaching, multistage counter current leaching.

Adsorption: Introduction, types of adsorption, nature of adsorbents, adsorption equilibria – single gases and vapours, adsorption hysteresis, effect of temperature, heat of adsorption, adsorption of solute from dilute solution, single stage and multistage crosscurrent operation using Freundlich equation, multistage counter current operation using Freundlich equation.

Text and Reference Books:

1. R E Treybal, Mass-Transfer Operations, Third edition, McGraw Hill, New Delhi (2012).
2. K V Narayanan, B Lakshmikutty, Mass Transfer Theory and Applications, CBS Publishers and Distributors, New Delhi (2014).
3. B K Dutta, Principles of Mass Transfer and Separation Processes, Second edition, PHI, New Delhi (2007).
4. A S Foust, Principles of Unit Operations, Second edition, Wiley, New York (1980).
5. W L McCabe, J Smith and P Harriot, Unit Operations of Chemical Engineering, Seventh edition, Tata McGraw Hill, New Delhi (2014).
6. C J Geankoplis, Transport Processes and Unit Operations, Third edition, PHI, New Delhi (1993).

Course Code: CHES302 **Breakup: 3 –1 – 3 – 5**
Course Name: Chemical Reaction Engineering-1

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Estimate the rate expression for various elementary and non-elementary reactions and corresponding the reaction mechanism
CO2	Carry out the kinetic study for various batch and flow reactors for single and multiple reactions
CO3	Determine the best combination of mixed and plug flow reactors on basis of size comparison
CO4	Understand the use of recycle reactors and auto catalytic reactors
CO5	Analyse the effect of temperature and pressure on reaction corresponding to various type of reactors
CO6	Understand the non-ideal flow behaviour inside the reactor and various model to describe this phenomenon

Course Details:

Introduction and overview of chemical reaction engineering

Kinetics of homogeneous reactions, concentration dependent term and temperature dependent term of the rate equation, searching for rate expressions from mechanisms; non elementary homogeneous reactions;

Interpretation of batch reactor data: Constant volume batch reactor; varying volume batch reactor; collection and analysis of batch data – integral and differential method; half-life method, reversible reaction data, temperature and reaction rate;

Introduction to Reactor Design

Single Ideal Reactor: Ideal batch reactor; steady state continuously stirred tank reactor; steady state plug flow reactor; size comparison of single reactions; multiple reactor systems; recycle reactor; autocatalytic reactions;

Design for multiple reactions: parallel reactions-product distribution, fractional yield, reversible and irreversible reaction; series reactions - reversible and irreversible reaction; series-parallel reactions, Denbigh reactions

Non isothermal reactors: temperature and pressure effects on single and multiple reactions, equilibrium conversions, optimum temperature progression, adiabatic and non-adiabatic operations

Non ideal Reactors: Residence time distribution, E, C, F curves, segregation model, dispersion model, chemical reaction and dispersion, tank-in- series model; multiparameter models

Text and Reference Books:

1. O. Levenspiel, Chemical Reaction Engineering, John Willey & Sons (2006)
2. H.S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall (2008)

Chemical Reaction Engineering Lab

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Verify the various theoretical principles of reaction engineering and process control
CO2	Develop experimental skills
CO3	Work in team and develop interpersonal skills at local and regional level
CO4	Develop skills for technical writing

Course Details:

1. Estimation of activation energy of saponification reaction in a batch reactor
2. Estimation of reaction rate constant in a semi-batch reactor
3. Estimation of reaction rate constant in a plug flow reactor
4. Estimation of reaction rate constant in a continuously stirred tank reactor
5. Residence Time Distribution in a plug flow reactor
6. Residence Time Distribution in a continuously stirred tank reactor

Course Code: CHES303 **Breakup: 3 –1 – 0 – 4**
Course Name: Numerical Methods for Chemical Engineers

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Solve problems of algebraic equations
CO2	Solve problems of differential equations and simultaneous equation
CO3	Solve problems of partial differential equations
CO4	Analyze Stirred-tank Reactor System, Distillation in a Plate Column and Unsteady-state operation by solving differential equations
CO5	Assess reasonableness of solutions, and select appropriate levels of solution sophistication

Course Details:

Introduction to Numerical Method: Approximations and errors in computation, commonly used Taylor series, Binomial theorem

Solution of Algebraic and Transcendental equations: bisection methods, Regula-Falsi method, Newton-Raphson methods, Secant method

Solution of simultaneous Algebraic equations:
Gauss elimination method, Gauss Jordan method, Jacobi Iteration method, Gauss-Seidel iteration method

Interpolation and curve- fitting
Graphical method, Least Square method and curve fitting of data, Method of Moments, cubic spline problems, Methods of group averages, approximation of functions interpolation and extrapolation of techniques, Finite differences, forward, backward and central difference,

Numerical differentiation and integration: derivatives from difference tables;Numerical integration – Newton Cotes Integration technique, trapezoidal rule, Simpson's 1/3 rd and 3/8th rule,, Gaussian quadrature; double integration.

Ordinary differential equation: Picard's method, Taylor series method, Euler's method, Euler's modified iteration technique, Runge method, Runge-Kutta 4^{th} order technique, Solutions of ordinary differential equation (initial and boundary value problem)

Linear programming: simplex method, dual simplex, charne penalty method.

Text and Reference Books:

1. S. K. Gupta, Numerical Methods for Chemical Engineers, New Age International (2019)
2. S. Chapra and R. Canale, Numerical Methods for Engineers, McGraw Hill Education (2016)
3. B. S. Grewal, Numerical Methods in Engineering and Science. Khanna Publishers (2013)
4. S. S. Sastry, Introductory Methods of Numerical Analysis, PHI learning (2012)

Course Code: CHES304 **Breakup: 3 –1 – 0 – 4**
Course Name: Chemical Engineering Design-I

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the General overall design considerations, design steps for chemical processes; types of projects
CO2	Have an understanding of development of design database; process creation; types of process design; Feasibility survey; flow sheet presentation – PFD, PID, utility and safety diagrams
CO3	Carry out cost estimation by cash flow for industrial operations, understand factors affecting investment and production costs, capital investment – fixed capital and working capital investment, cost indices
CO4	Understand Taxes and Insurance: cost of capital, corporate tax, insurance Depreciation: depreciable investments
CO5	Find out the optimum solution methodologies – one variable and two variable, optimum production rates in plant operation

Course Details:

Introduction to Chemical Engineering Plant design: Global design considerations, design steps for chemical processes; types of projects; optimum design – optimum economic design, optimum operation design, practical considerations in design; engineering ethics in design at local and regional level

Process design development: development of design global standard database; process creation; types of process design; feasibility survey; flow sheet presentation – PFD, PID, utility and safety diagrams; vessel and piping layout isometrics; flowsheet symbols; utility streams; equipment design and specifications, equipment specification sheet, scale-up of equipment in design, safety factors at local and regional level

Flowsheet synthesis and development: fundamentals of material balance and energy balance for manual flowsheet calculations, general procedure for flowsheet development – hierarchical and algorithmic methods; conceptual design of a chemical process - hierarchy of decisions; computer-aided flow sheeting

General design considerations: Health and safety hazards; Loss prevention; Environmental consideration; Plant location; Plant layout, Plant operation and control
Cost estimation: cash flow for industrial operations, factors affecting investment and production costs, capital investment – fixed capital and working capital investment, cost indices, cost components and methods for estimating capital investment, estimation of revenue, estimation of total product cost, gross and net profit at local and regional level

Interest and investments costs: simple, compound and continuous interest rates, nominal and effective interest rates, time value of money, annuity, cash flow patterns, capitalized cost;
Taxes and Insurance: cost of capital, corporate tax, insurance
Depreciation: depreciable investments, depreciation and taxes, current value, salvage value, methods for calculating depreciation at local and regional level
Profitability, Alternative investments and Replacements: methods of calculating profitability, alternate investment, replacements, practical factors in alternative investment and replacement analysis

Optimum design and Design strategy: optimum solution methodologies – one variable and two variable, optimum production rates in plant operation, optimum conditions in cyclic operations, optimum operating time, optimum cooling water flowrates in exchangers, optimum reflux ratio Project management – network construction, critical path method (CPM), project evaluation and review technique (PERT) at local and regional level

Material selection for equipment: factors contributing to corrosion, combating corrosion, properties of materials, selection of materials,

Text and Reference Books:

1. M.S. Peters, K. D. Timmerhaus, R. E. West, Plant Design and Economics for Chemical Engineers, Mc Graw Hill (2017)
2. R. K. Sinnott, Coulson and Richardson's Chemical Engineering Series, Chemical Engineering Design Vol 6, Elsevier (1999)
3. J. M. Douglas, Conceptual Design of Chemical Processes, McGraw Hill
4. R. Turton, R. C. Bailie, W. B. Whiting, J. A. Shaeiwitz, Analysis, Synthesis, and Design of Chemical Processes, Prentice Hall (2015)
5. K. H. Humphreys, Jelen's Cost and Optimization Engineering, McGraw Hill (1990)
6. V. V. Mahajani and S. M. Mokashi, Chemical Project Economics, Laxmi Publications (2019)
7. W. D. Seider, J. D. Seader, D. R. Lewin, Product and Process Design Principles, Willy & Sons (2015)

Course Code: CHES305 **Breakup: 1 – 0 – 4 – 3**
Course Name: Unit Operation Laboratory -1

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the concepts of different transport processes and unit operations involved in Chemical process industries
CO2	Perform different unit operations safely
CO3	Develop experimental skills, data analysis, and error analysis
CO4	Work in team and develop interpersonal skills
CO5	Develop skills for technical report writing

Course Details:

Screen Analysis; Crushing efficiency for jaw crusher; Crusher rolls; Disintegrater; etc.; Sedimentation and Thickners; Viscosity measurement; Flow through pipes (Reynold'S experiment); Flow-Through Open Channels; Flow Through fitting and Joints; Orifice meter; Venturi meter; Rotameter; Verification of Bernoulli's Theorem; Characteristics of Centrifugal pumps; Fluidized bed; Spouted bed; Plate and Frame filter press; Rotary drum; Vacuum filter; Agitator and mixing.

Course Code: HSSS302 **Breakup: 3 – 0 – 0 – 3**
Course Name: Industrial Management

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the concepts related to business and demonstrate the roles, skills and functions of management
CO2	Understand how the industrial company can be organized and managed
CO3	Understand the complexities associated with management of human resources in the organizations and integrate the learning in handling these complexities
CO4	Express leadership and entrepreneurial attributes through various case studies

Course Details:
UNIT-1
Introduction, Nature and Scope at local and regional level, Evolution of Management, Approaches to Management: Scientific, System and Contingency.

UNIT-2
Taylor's Scientific Management, Fayol's Administrative Management, Contribution of Mayo, Drucker etc., Levels and skills of management

UNIT-3
Organization: Types and structure, Formal-Informal, Line and Staff relationship, Centralization-Decentralization

UNIT-4
Functions of Management Planning: Organization, Staffing, Directing, Controlling, Decision-Making, Management by objectives, Leadership at local and regional level.

UNIT-5
Psychological foundation of Management at local and regional level: Motivation, Personality, Group dynamics, Models of Herzberg, Maslow etc.

UNIT-6
Plant layout, Plant location, Planning and Control, Materials, Management, Inventory control

Text and Reference Books:

1. O.P. Khanna, Industrial Engineering and Management, Dhanpat Rai Publication (2018)
2. T. R. Banga Industrial Engineering and Management, Khanna Publishing (2008)
3. Mahajan : Industrial Engineering and Production Management, Dhanpat Rai & Co (2015)

Course Code: SSTS301 **Breakup: 0 –0 – 2 – 2**
Course Name: Summer Internship - II

Course Details:

First-year students are required to undertake a four-week summer internship after completion of two semesters. This internship aims to provide practical experience in the application of engineering principles. Upon completion of the training, students must submit a formal report and their certificate of completion to the department, followed by a professional presentation summarizing their internship experience.

Course Outcomes (CO): Upon successful completion of this seminar, students will be able to:

CO1	Articulate the objectives, activities, and outcomes of their internship experience
CO2	Analyze the relevance of their internship work to their academic curriculum and future career goals
CO3	Develop and deliver a clear, concise, and professional presentation summarizing their internship
CO4	Engage in constructive self-reflection and peer feedback regarding practical industry exposure
CO5	Identify key learning points, challenges, and solutions encountered during the internship period

The seminar will typically involve:

- **Pre-Seminar Preparation:** Students will prepare a detailed report and a presentation.
- **Oral Presentation:** Each student will deliver a presentation to their peers and faculty.
- **Question & Answer Session:** A dedicated time for questions and discussion following each presentation.
- **Feedback:** Constructive feedback will be provided by faculty and peers.

Internship Seminar Topics / Content Guidelines

The seminar presentation should cover the following aspects of the internship:

- Introduction to the Organization:
- Internship Details:
- Project/Work Undertaken:
    - Problem Statement/Objective
    - Methodology/Approach
    - Activities Performed
    - Challenges Faced & Solutions
    - Results/Outcomes
- Learning Outcomes & Impact:
    - Technical Skills Gained/Enhanced
    - Soft Skills Developed
    - Application of Classroom Knowledge
    - Insights into Industry
    - Career Relevance
- Conclusion & Recommendations

Presentation Guidelines

- 8-10 minutes presentation + 2-3 minutes Q&A.

Course Code: CHES306 **Breakup: 3 –1 – 0 – 4**
Course Name: Mass Transfer II

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	To understand the fundamentals of mass transfer on micro level
CO2	To understand the application of the principles used for diffusion; mass transfer coefficients and inter-phase mass transfer including various theories
CO3	To study the mass transfer between the gas –liquid phase and various equipments used for the mass transfer operation like Absorption and Humidification
CO4	Do analysis of Packed bed equipment to find out HTU, HETP, NTU and height of the column required
CO5	To find the rate of drying, moisture content, time required for drying and various type of drying equipments

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Course Details:

Molecular diffusion in fluids: Introduction; Molecular diffusion; Flux J and N; Steady state molecular diffusion in fluids at rest and in laminar flow; Molecular diffusion in gases through non-diffusing B, equimolal counter diffusion and multi-component mixtures; Factors affecting gas phase diffusion; Experimental determination of the gas phase diffusion coefficient – Twin bulb method, Stefan tube; Pseudo steady state diffusion through a stagnant gas film; Predictive equations for the gas phase diffusivity; Molecular diffusion in liquids; Predictive equations for liquid phase diffusivity; Diffusion through varying cross-sectional area – Spherical geometry, Tapered tube; Types of diffusion – Knudsen, molecular, and transition, surface diffusion.

Mass transfer coefficients: Mass transfer coefficient in different units; Mass transfer from a gas into a falling liquid film; Eddy diffusion; Prandtl mixing length; Theories of mass transfer - Film theory, Penetration theory, Surface renewal theory; Momentum, heat and mass transfer analogies; dimensionless numbers in mass transfer and their analogues in heat transfer; Mass transfer in wetted wall column; Mass transfer for simple situations; j_H and j_D factor.

Diffusion in solids: Fick’s law diffusion; Unsteady state diffusion; Diffusion through polymers; Diffusion through crystalline solids; Diffusion in porous solids.

Interphase mass transfer: Equilibrium; Equilibrium relations; Diffusion between phases; Two-resistance theory; Individual and overall mass transfer coefficients; Material balance in continuous contact equipments - steady state cocurrent and countercurrent processes; Stages - continuous cocurrent processes, batch processes, cascades; Kremser equations.

Humidification and Dehumidification: Psychometric chart; Adiabatic saturation curves; Wet bulb temperature; Adiabatic operations - Water cooling with air, Dehumidification of air-water vapour.

Gas absorption: Equilibrium solubility of gases in liquids; Ideal and non-ideal liquid solutions; Choice of solvent for absorption; Material balance for cocurrent and countercurrent gas absorption and stripping; Absorption factor A; Design of packed towers; Concept of HETP, H_{tG}, N_{tG}, H_{tL}, N_{tL}, H_{tOG}, N_{tOG}, H_{tOL}, N_{tOL}.

Drying: Equilibrium; Definitions; Drying operation; Batch drying - rate of batch drying; Mechanisms of batch drying - cross circulation drying, through-circulation drying.

Adsorption: Continuous countercurrent adsorption of one and two components; Rate of adsorption in fixed beds.

Text and Reference Books:

1. R E Treybal, Mass-Transfer Operations, Third edition, McGraw Hill, New Delhi (2012).
2. K V Narayanan, B Lakshmikutty, Mass Transfer Theory and Applications, CBS Publishers and Distributors, New Delhi (2014).
3. B K Dutta, Principles of Mass Transfer and Separation Processes, Second edition, PHI, New Delhi (2007).
4. A. S. Foust, Principles of Unit Operations, Second edition, Wiley, New York (1980).
5. W L McCabe, J Smith and P Harriot, Unit Operations of Chemical Engineering, Seventh edition, Tata McGraw Hill, New Delhi (2014).
6. C J Geankoplis, Transport Processes and Unit Operations, Third edition, PHI, New Delhi (1993).

Course Code: CHES307 **Breakup: 3 –1 – 0 – 4**
Course Name: Instrumentation and Process Control

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	To estimate the mathematical modelling of the control system
CO2	To calculate the solution of linear differential equation using Laplace transform Transfer function and input–output model, Poles & zeros of system
CO3	Study of interacting & non-interacting response, Inverse response, Multicapacity process, over-damped, critically damped, under-damped response their characteristics
CO4	Able to use different types of controller, on-off, P, PI, PID controller, introduction to measuring sensors
CO5	To study the criteria for stability, characteristic equation, Routh –Hurwitz criteria of stability, Root-Locus analysis, Frequency response analysis of linear processes
CO6	To Design the controllers by Simple performance criteria, Time Integral performance criteria, Ziegler Nichols tuning technique, Cohen –coon tuning technique

Course Details:

Introduction to process control: Needs & control aspects of a chemical plant: stirred tank heater, flow in tank, control of heat exchanger, distillation column and reactor, SISO and MIMO control., Types of controller , on-off, P, PI and PID control modes, introduction to measuring sensors for level, flow, temperature and pressure measurements. Transmission lines, final control elements, Control valves and their characteristics.

Introduction to mathematical modeling: State variables and state equations, dead time, modelling with dead time, degree of freedom, linearization of nonlinear system, deviation variables, multivariable system linearization.

Laplace transform: Laplace transform of step, impulse , pulse ,ramp, trigonometric functions, derivative and integral functions, initial value theorem, Final value theorem, Dirac delta functions, Inverse Laplace transform, solution of linear differential equation using Laplace transform, transfer function and input–output model, Poles & zeros of system.

Dynamic behavior of first order system: Time constant, steady state gain, response of the system

Dynamic behaviors of second order system: study of interacting & non-interacting response, Inverse response, multi-capacity process, over-damped, critically damped, under-gdamped response their characteristics, overshoot ,decay ratio, period of oscillation, rise time, ultimate period, delay time.

Feedback control system: concept of feedback control system, types of controller, on-off, P, PI, PID controller, introduction to measuring sensors, transmission lines, final control elements, block diagram reduction and signal flow graph theory to solve feedback loop,

Stability of Closed-Loop Control Systems: Criteria for stability, characteristic equation, Routh – Hurwitz criteria of stability, Root-Locus analysis, Frequency response analysis of linear processes, Bode stability criteria, Nyquist stability criteria , gain margin, phase margin,

Design of controllers: Simple performance criteria, Time Integral performance criteria, Ziegler Nichols tuning technique, Cohen –coon tuning technique.
Introduction to advance control strategies: ratio, cascade, feed forward, override and valve

positioning (optimizing) control. Microprocessor–based controllers and economic plantwide computer control.

Text and Reference Books:

1. D.R. Coughnour, Process system Analysis & Control, Mc Graw Hill (2017)
2. George Stenphanopolous, An Introduction of Process Dynamics & Control (1985)
3. Curtis D. Johnson, Process Control Instrumentation Technology, international eighth edition, Pearson Education Limited (1993)

Process Control Lab

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Verify the various theoretical principles of reaction engineering and process control
CO2	Operate instrumentation and automation systems in modern chemical plant operation
CO3	Develop experimental skills
CO4	Work in team and develop interpersonal skills at local and regional level
CO5	Develop skills for technical writing

Course Details:

1. Process Control Simulator using electrical analogue
2. Study of Flow Control Trainer
3. Study of Level Control Trainer
4. Study of Temperature Control Trainer
5. Study of Pressure Control Trainer
6. To study the dynamics of two thank interacting and non-interacting system
7. Study of open loop dynamics of first and second order system using MATLAB-SIMULINK

Course Code: CHES308 **Breakup: 3 –1 – 0 – 4**
Course Name: Chemical Engineering Design-II

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Find out the Design information and data – prediction of physical properties, phase equilibrium data
CO2	Understand the characteristics of different types of pumps, theory of compression and equipment; Ejectors and Vacuum systems, Understand the input/output structure of a flowsheet and synthesis a preliminary flowsheet.
CO3	Discuss the detailed design of separation column like multicomponent distillation column; tray hydraulic design
CO4	Discuss the detailed design of heat transfer equipment like shell and tube heat exchanger; condenser and evaporator and understand the concept of heat exchange network
CO5	Estimate the detailed design of pressure vessel and its support

Course Details:

Introduction, nature of design, anatomy of a chemical manufacturing process, organization of a chemical engineering project, project documentation, globally accepted codes and standard, factor of safety, degree of freedom and design variables, optimization Design information and data – prediction of physical properties, phase equilibrium data

Pumps: Theory and characteristics; types of pumps, criterion for selection of pumps; theory of compression, equipment for gas compression; Ejectors and Vacuum systems

Flowsheeting: Introduction, symbols, flowsheet presentation with example, types of flow sheet, synthesis of steady state flow sheet, partitioning and tearing a flowsheet, tearing algorithms based on signal flow graph, algorithms based on reduced graph, comparing various tearing algorithms, principle of method, convergence of flowsheet using different methods – Newton's method, direct substitution, Wegstein's method, dominant Eigenvalue method, quasi Newton method, criteria for acceleration.

Separation columns: Continuous distillation - process description, reflux considerations, feed

point location, selection of column pressure, stage equations, dew point – bubble points, equilibrium flash calculations, design variable in distillation; design method for binary system:

basic equations, McCabe –Thiele method, low product concentrations, Smoker equations Multi-component distillation; Key components, number of columns, short –cut method for stage and reflux requirements, pseudo- binary systems, Smith–Brinkley method, empirical correlations, rigorous solution procedures, batch distillation, plate efficiency, column sizing, plate hydraulic design, Packed columns

Heat transfer equipment: Types of exchangers – double pipe, shell and tube, plate, spiral, finned tube, air cooled, fired heater; Overall heat transfer coefficient, fouling factors, double pipe heat exchangers, shell and tube heat exchangers - tube count, shell type, baffles, support plate and tie rods, tube sheet, shell and header nozzles; mean temperature difference, general design consideration - fluid allocation, shell and tube fluid velocity stream temperature pressure drop, tube side heat transfer coefficient and pressure drop, shell side heat transfer coefficient and pressure drop; design methods - Kern's Method, Bell's method, Condensers –

Single and mixed vapours, Reboilers and Vaporisers Evaporators – boiling point elevation, design of multiple effect evaporators

Heat Exchange Network: minimum heating and cooling requirements, minimum number of exchangers, area estimates, Design of minimum-energy heat exchanger networks, Loops and paths, reducing the number of exchangers.

Pressure vessels: design pressure, design temperature, design stress, welded joint efficiency, minimum practical wall thickness, design of thin walled vessels under internal pressure – head and closures; vessel supports – saddle, skirt, bracket support

Text and Reference Books:

1. R. K. Sinnott, Coulson and Richardson's Chemical Engineering Series, Chemical Engineering Design Vol 6, Elsevier (2006)
2. E. E. Ludwig, Applied Process Design for Chemical and Petrochemical Plants, Elsevier (2001)
3. S. M. Walas, Chemical Process Equipment - Selection and Design, Butterworth Series of Chemical Engineering (2012)
4. R. Smith, Chemical Process Design and Integration, Wiley (2016)
5. V. V. Mahajan and S. B. Umarji, Joshi's Process Equipment Design, Laxmi Publications (2016)
6. S. B. Thakore and B. I. Bhatt, Introduction to Process Engineering and Design, McGraw Hill Education (2017)
7. J. M. Douglas, Conceptual Design of Chemical Process, McGraw Hill Book Company (2017)

Course Code: CHES309 **Breakup: 3 –1 – 0 – 4**
Course Name: Chemical Reaction Engineering -II

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the difference between homogeneous and heterogeneous reactions
CO2	Understand the role of catalysts in chemical reactions and the different types of catalysts used industrially
CO3	Have primary knowledge of catalyst preparation and characterization methods
CO4	Develop rate laws for heterogeneous reactions and kinetic models and design of reactors for heterogeneous catalytic reactions
CO5	Gain knowledge of heat and mass transfer effects (internal and external transport processes) on catalytic reactions
CO6	Understanding the process of deactivation in catalysts, its types and its effect on reaction rate
CO7	Develop kinetic models and design strategy for heterogeneous non-catalytic reactions
CO8	Develop kinetic models and design strategy for heterogeneous fluid-fluid systems with and without chemical reaction

Course Details:

Introduction to heterogeneous reaction; global reaction;

Catalysis: definition, physical properties of catalyst, preparation, testing and characterization of solid catalysts, catalyst selection,

Adsorption: physical and chemical adsorption, isotherms – Langmuir, Freundlich, BET
Rate equation for fluid-solid reaction, surface reaction – dual and single site mechanism, kinetic models (Langmuir-Hinshelwood, Eley-Ridel), heterogeneous data analysis – parameter estimation using regression analysis/Polymath

Internal transport processes: reaction and diffusion with porous catalyst, bulk and Knudsen diffusion, Effectiveness factor, Thiele modulus, Weisz -Prater criterion, falsified kinetics, heat effects during reaction, effect of internal transport on selectivity

External transport processes: overall effectiveness factor, mass transfer coefficient, external temperature gradient, Mear's criterion, effect of external transport on selectivity, non-isothermal condition

Design of solid catalytic reactors: packed bed, mixed flow reactor, bubbling fluidized bed reactor

Deactivation of catalyst: Mechanism of deactivation, rate and performance study of deactivation, effect of pore diffusion on catalysts deactivation, rates for poisoned porous catalyst – uniform poisoning and shell poisoning

Fluid-particle reaction kinetics: Selection of a model, progressive conversion model, shrinking core model for spherical particle of changing and unchanging size, comparison of various model selected, determining controlling resistances and rate equation, fluid particle reactor design

Fluid-fluid reaction kinetics: rate equations for gas -liquid and liquid-liquid systems, Different reaction rates – instantaneous, fast, intermediate, slow; Enhancement factor, Hatta number; fluid-fluid reactor design

Text and Reference Books:

1. H. Scott. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall (2015)
2. J.M. Smith, Chemical Engineering Kinetics, Mc Graw Hill.(2013)
3. O. Levenspiel, Chemical Reaction Engineering, John Willey & Sons (2006)

Course Code: CHES310 **Breakup: 1–0 – 4 – 3**
Course Name: Transport Process & Unit Operations Laboratory -II

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the concepts of different transport processes and unit operations involved in Chemical process industries
CO2	Perform different unit operations safely
CO3	Develop experimental skills, data analysis, and error analysis
CO4	Work in team and develop interpersonal skills
CO5	Develop skills for technical report writing

Course Details:

Heat conduction through rods of different materials; Thermal conductivity of insulating materials; Boiling and Condensation; Double pipe Heat Exchanger; Shell & Tube Heat Exchanger; Long tube evaporator; Distillation; Batch & Continuous column; Absorption with and without chemical reaction; Liquid-liquid extraction/leaching; Adiabatic humidifier, Water cooler; Driers; Tray, Rotary, Spray; Ion exchange, Reverse osmosis.

Course Code: HSSS301 **Breakup: 3 –0 – 0 – 3**
Course Name: Engineering Economics

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Have sufficient knowledge about demand and supply problems
CO2	Understand concepts of production and cost analysis
CO3	Use of microeconomic tools in problem solving
CO4	Utilisation of limited resources in meeting the rising demand in the market

Course Details:

UNIT-1
Meaning, definition and global scope of economics, Basic concepts of demand and supply, Market equilibrium, Ceiling price and floor price.

UNIT-2
Price elasticity of demand: Factors affecting price elasticity of demand, Calculation, Relation between marginal revenue, demand and price elasticity, Income elasticity of demand and Cross elasticity of demand, Indifference curves, Budget Line at local and regional level.

UNIT-3
Production and Cost analysis: Basic concepts, Production in the short- run and long-run, cost analysis
Finding the optimal combination of inputs, Returns to scale.

UNIT-4
Market: Characteristics of perfect completion, Profit maximisation in short-run and long-run
Firms with market power: Measurement and determinants of market power, Profit maximisation under monopoly: output and pricing decisions, Price discrimination, capturing consumer surplus, Strategic decision making in oligopoly markets at local and regional level

UNIT-5
National income: Concepts, Sources, Measurement, Difficulties, circular flow of income
Inflation: Cost-push and Demand-pull inflation, Effects and control of inflation, Business cycle, Functions of RBI, GST at local and regional level.

Text and Reference Books:

1. Paul. A. Samuelson, Economics, Mc Graw Hill, 20th Edition (2019)
2. Managerial Economics by Christopher R. Thomas, S. Charles Maurice, Mc Graw Hill, (2020)
3. J. V. Vaishampayan, Financial Management, NRBC (2015)
4. A. Koutsoyannis, Micro Economics, 2nd Edition (2003)

Course Code: SSMS301 **Breakup: 0 –0 – 2 – 2**
Course Name: Student Seminar

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Articulate the objectives, activities, and outcomes of their internship experience
CO2	Analyze the relevance of their internship work to their academic curriculum and future career goals
CO3	Develop and deliver a clear, concise, and professional presentation summarizing their internship
CO4	Engage in constructive self-reflection and peer feedback regarding practical industry exposure
CO5	Identify key learning points, challenges, and solutions encountered during the internship period

Course Details:

The seminar will typically involve:

- **Pre-Seminar Preparation:** Students will prepare a detailed report and a presentation.
- **Oral Presentation:** Each student will deliver a presentation to their peers and faculty.
- **Question & Answer Session:** A dedicated time for questions and discussion following each presentation.
- **Feedback:** Constructive feedback will be provided by faculty and peers.

Internship Seminar Topics / Content Guidelines

The seminar presentation should cover the following aspects of the internship:

- Introduction to the Organization:
- Internship Details:
- Project/Work Undertaken:
    - Problem Statement/Objective
    - Methodology/Approach
    - Activities Performed
    - Challenges Faced & Solutions
    - Results/Outcomes
- Learning Outcomes & Impact:
    - Technical Skills Gained/Enhanced
    - Soft Skills Developed
    - Application of Classroom Knowledge
    - Insights into Industry
    - Career Relevance
- Conclusion & Recommendations

Presentation Guidelines

- 8-10 minutes presentation + 2-3 minutes Q&A.

Course Code: CHES401 **Breakup: 3 –1 – 0 – 4**
Course Name: Transport Phenomena

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the transport process on macro and micro level for mass, heat and momentum transfer
CO2	Derive the transport equation for various conservative law with boundary conditions
CO3	Solve the transport problem by applying the shell balance approach
CO4	To model the problem by using differential equation
CO5	To use of various mathematical package to solve the equations

Course Details:
Introduction, classification of fluids, Fluid kinematics, rate of rotation, vorticity, Nature of transport Phenomena, The phenomenological law, Analogies between momentum, heat and mass transfer and defining of dimensionless number, Reynolds transport theorem, Eulerian and Lagrangian approach, Navier stokes equation; Introduction of molecular and convective flux.

Momentum Transport Phenomena: Newton's law of Viscosity, science of rheology, Prediction of viscosity and its dependence on temperature, pressure, Non– Newtonian models at steady state for Newton's law of Viscosity, Momentum transport in laminar flow, Boundary conditions and shell momentum balance approach for stress distribution; profiles for flow of a falling film, flow through circular tube, flow through an Annulus, Adjacent flow of two Immiscible fluids, time derivatives. Equation of continuity, motion and mechanical energy their applications in fluid flow problems for isothermal system

Energy Transport Phenomena: Energy transport in laminar flow, Fourier's law of heat conduction, thermal conductivities and its dependence on temperature, pressure, Boundary conditions, Shell balance approach for different types of heat sources such as Electrical, Nuclear, Viscous and Chemical. Heat conduction through composite walls, Principle of extended surfaces as cooling fin, free and forced convection

Equation of change for Non-isothermal systems, The Equations of energy, Equation of motion for free and forced convection in Non-isothermal flow, use of the equation of change to set up steady state heat transfer problems such as tangential flow in an Annulus with viscous heat generation steady flow of a non-isothermal film, Transpiration cooling , free convection from a vertical plate.

Mass Transport Phenomena: Fick's law of diffusion, Prediction of diffusivity and its dependence on temperature and pressure for gas, liquids and solids, Boundary conditions, Shell balance approach for mass transfer problems, Diffusion through stagnant gas film, Diffusion with homogeneous and heterogeneous chemical reaction, Diffusion in to a falling liquid film, Diffusion and chemical reaction in porous catalyst and the effectiveness factor, equation of continuity for binary mixtures, equation of change to set up diffusion problems for simultaneous heat and mass transfer, thermal diffusion, pressure diffusion, forced diffusion.

Text and Reference Books:

1. Transport Phenomena, Bird Stewart & Lightfoot,. John Wiley & Sons (2007)
2. Introduction to Transport Phenomena, William J.Thomson, Pearson Education Asia (1999)
3. Momentum, Heat and Mass transfer, Bennet and Myers, Tata McGraw Hill.(2014)
4. Transport Phenomena: Aunified approach, R S Broadkey, Tata Mcgraw Hill

Course Code: CHES402 **Breakup: 1–0 – 4 – 3**

Course Name: Process Simulation Lab

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the different models for computing thermodynamic and transport properties
CO2	Building a flowsheet for design purposes of flow network consisting of fittings, pumps and piping
CO3	Estimation the performances of pumps, compressors, expanders, valves etc.
CO4	Design and rating of separation processes
CO5	Quantitative and qualitative use to Simulating performance of different reactor models

Course Details:

CHEMCAD Process simulation software used for

1. Comparing different models for computing thermodynamic and transport properties such as K-values, Enthalpy, VLE data etc. for pure substances and mixtures; Flash calculations and VLE of azeotropic mixtures

2. Design of flow network consisting of fittings, pumps and piping (horizontal, vertical & inclined); single and multiple branches

3. Calculations for performances of pumps, compressors, expanders, valves etc.

4. Preparing steady state process flow sheets (equipment selection, numbering, stream designation) and carrying out mass and energy balances with and without recycle for chemical processes

5. Design and rating of heat exchangers (with and without phase changes); double pipe, shell and tube, plate and frame heat exchangers

6. Design and rating of separation processes – simple distillation column with different reflux ratios (short cut design), rigorous column design; multi-component distillation column design, sequencing of distillation columns, absorption and stripping, liquid-liquid extraction

7. Simulating performance of different reactor models for reversible and irreversible reactions

8. Batch reactor rate regression from process of lab data

9. Control of simple unit operations

Course Code: SSTS401 **Breakup: 0 –0 – 0 – 2**
Course Name: Summer Training

Course Details:

Third year students are required to undertake an eight-week summer internship after completion of six semesters in a chemical or allied industry or national level laboratory/institute. This internship aims to provide practical experience in the application of engineering principles. Upon completion of the training, students must submit a formal report and their certificate of completion to the department, followed by a professional presentation summarizing their internship experience.

Course Outcomes (CO): Upon successful completion of this seminar, students will be able to:

CO1	Articulate the objectives, activities, and outcomes of their internship experience
CO2	Analyze the relevance of their internship work to their academic curriculum and future career goals
CO3	Develop and deliver a clear, concise, and professional presentation summarizing their internship
CO4	Engage in constructive self-reflection and peer feedback regarding practical industry exposure
CO5	Identify key learning points, challenges, and solutions encountered during the internship period

The seminar will typically involve:

- **Pre-Seminar Preparation:** Students will prepare a detailed report and a presentation.
- **Oral Presentation:** Each student will deliver a presentation to their peers and faculty.
- **Question & Answer Session:** A dedicated time for questions and discussion following each presentation.
- **Feedback:** Constructive feedback will be provided by faculty and peers.

Internship Seminar Topics / Content Guidelines

The seminar presentation should cover the following aspects of the internship:

- Introduction to the Organization:
- Internship Details:
- Project/Work Undertaken:
  - Problem Statement/Objective
  - Methodology/Approach
  - Activities Performed
  - Challenges Faced & Solutions
  - Results/Outcomes
- Learning Outcomes & Impact:
  - Technical Skills Gained/Enhanced
  - Soft Skills Developed
  - Application of Classroom Knowledge
  - Insights into Industry
  - Career Relevance
- Conclusion & Recommendations

Presentation Guidelines

- 8-10 minutes presentation + 2-3 minutes Q&A.

Course Code: PRTS401 **Breakup: 0 –0 – 10 –5**

Course Name: Project-I

Course Details:

Equipment/Plant design problem related to Chemical engineering at Global, local and regional level to be done by groups of students

Course Code: PRTS402 **Breakup: 0 –0 – 10 – 5**
Course Name: Project-II

Course Details:

Simulation/Experimental/Research/Design Projects based on Global, local and regional level to be done by groups of students.

Department Elective

List of departmental electives (Odd Semester):

Course Code	Course Title
CHES501	Polymer Engineering (Open Elective)
CHES502	Safety in Chemical Process Industries
CHES503	Petroleum Engineering
CHES505	Non-conventional Energy Sources
CHES508	Optimization Techniques (Open Elective)
CHES510	Process Modeling and Simulation
CHES559	Data Science using Python (through NPTEL)
CHE-S560	Introduction to Computational Fluid Dynamics
CHES512	Electrochemical Engineering (Open Elective)
CHES557	Chemical Process Intensification (Open Elective) (through NPTEL)

List of departmental electives (Even Semester):

Course Code	Course Title
CHES504	Environmental Pollution & Control
CHES507	Advanced Separation Processes
CHES509	Biochemical Engineering
CHES511	Fluidization Engineering
CHES513	Piping Engineering
CHES551	Aspen Plus ® Simulation software (through NPTEL)
CHES552	Enhancing Soft Skills and Personality (through NPTEL)
CHES553	Technical Communication for Engineers (through NPTEL)
CHES554	Patent Law for Engineers (through NPTEL)
CHES555	Introduction to MATLAB (through NPTEL)
CHES556	Principle of Packaging Science & Technology

Course Code: CHES44 **Breakup: 3-0-0-3**
Course Name: Polymer Engineering

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Connect properties of polymeric materials to their structures and explain how different material parameters and external factors affect the mechanical properties
CO2	Decide which test methods are suitable for measurement of mechanical properties
CO3	Correlate structure-processing-properties relationships for polymers, blends and composites
CO4	Select a suitable processing and manufacturing technique for a given polymer
CO5	Identify methods for rheological measurements and analysis of the rheological data using models for non-Newtonian fluids

Course Details:

Introduction – defining polymers, classification, molecular weight distributions, conformations

Addition polymerization or chain growth polymerization, radical, ionic and Ziegler-Natta polymer, kinetics, Step growth polymerization, kinetics, Techniques of polymerizations; Characterisation-measurement of molecular weight, thermal behaviour, morphology, viscoelastic behaviour, mechanical properties

Polymer processing; rubbers, plastics and fibres available under local and regional conditions

Text and Reference Books:

1. George Odian, Principles of Polymerization, John Wiley (2007)
2. F. W. Billmeyer, A Textbook of Polymer Science and Engineering, John Wiley (2007)

Course Code: CHES452 **Breakup: 3-0-0-3**

Course Name: Safety in Chemical Process Industries

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the hazards associated with chemical substances, safety related properties of hazardous substances, Classification of dangerous substances
CO2	Understand the hazards associated with chemical plants, Safety in process plant maintenance, Safety considerations in plant site selection and layout planning
CO3	Understand the Hazard identification and assessment for ,various Hazard identification techniques, Hazard and operability studies (HAZOP), Fire and explosion index and toxicity index, Fault tree and event tree analysis
CO4	Understand the Fault tree and event tree analysis, Emission of toxic and flammable gases and vapours, Dispersion of toxic and flammable gases and vapours
CO5	Understand heat radiation from vapour cloud explosions, jet fires, fire balls and pool fires, Probability of accidents and risk calculation

Course Details:

Introduction: Definition of safety, Hazards in common chemical industries, Need and significance of safety in chemical industries, Important global case histories.

Hazards associated with chemical substances: Safety related properties of hazardous substances, Classification of dangerous substances, Hazards of flammable and explosive materials, Hazards of common unit operations, Hazards of common chemical reactions, Safety in bulk storage of hazardous chemicals, Safety in shelf storage of hazardous chemicals, Corrosion in chemical industries at local and regional level.

Hazards associated with chemical plants: Safety in use of pipelines and their fixtures in industries, Safety in use of cross country pipelines, Safety in process control systems and use of instruments, Safety in pressure system design and operation, Safety in process plant maintenance, Safety considerations in plant site selection and layout planning at local and regional level.

Hazard identification and assessment: Hazard identification techniques, Hazard and operability studies (HAZOP), Fire and explosion index and toxicity index, Fault tree and event tree analysis, Emission of toxic and flammable gases and vapours, Dispersion of toxic and flammable gases and vapours, Heat radiation from vapour cloud explosions, jet fires, fire balls and pool fires, Probability of accidents and risk calculation at local and regional level.

Safety management: On site emergency planning, off site emergency planning, Personnel protection and other safety devices, Safety in chemical laboratories, Reliability engineering.

Text and Reference Books:

1. D A Crowl, J F Louvar, Chemical Process Safety Fundamentals With Applications, Third edition, Prentice Hall, Boston (2011).
2. E Sanders, Chemical Process Safety Learning From Case Histories, Third edition, Elsevier, Oxford (2005).
3. R RTatiya, Elements of Industrial Hazards, CRC Press, London (2011).

4. B O Alli, Fundamental Principles of Occupational Health and Safety, Second edition, International Labour Office, Geneva (2008).
5. V Marshall, S Ruhemann, Fundamentals of Process Safety, Institution of Chemical Engineers, Warwickshire (2001).
6. S Mannan (Editor), Lees' Process Safety Essentials: Hazard Identification, Assessment and Control, First edition, Butterworth-Heinemann, Oxford (2014).

Course Code: CHES503 **Breakup: 3-0-0-3**
Course Name: Petroleum Engineering

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understanding the role of petroleum as energy source amidst world energy scenario
CO2	Demonstrate comprehensive understanding of design and operation of petro refineries and petrochemical complexes
CO3	Identify and suggest safe practices in operations of refineries and petrochemical complexes
CO4	Identify challenges, energy security issues and environmental issues
CO5	Perform techno-economic analysis & trouble shooting

Course Details:

Introduction to mineral oils, their origin and mode of occurrence; Oil resources and refineries in India Composition of petroleum, refinery products and their test methods Evaluation of oil stacks introduction to processing of petroleum; general processing & crude distillation, refinery products and their application, natural gas, gasoline, naphtha kerosene, fuel oil and gas oil, petroleum waxes, lubricating oils, tar and asphalts.

Petroleum refining processes and operation: thermal cracking, catalytic cracking, hydro- forming, catalytic reforming, alkylation, polymerization, isomerization and other auxiliary process e.g vis-breaking, de-waxing and de-asphalting operations.
Manufacture of paraffin wax and microcrystalline waxes.

Introduction to lubricants: liquid, solid and gas lubricants and their application.
Lubricating oils: liquids mineral lubricants, synthetic liquids lubricants; Physical properties, additives, manufacture of lubrication oils; Analysis of lubricating oils;

Lubricating Greases: properties, types, ingredients, additives, analysis of lubricating greaser as per BIS test methods; Manufacture of lubricating greases-processes and equipments.

Introduction to petrochemicals; manufacture of alkyl aryl compounds, ethylene oxide; condensation products benzene, toluene, xylene, butadienes, vinyl chloride and styrene etc

Text and Reference Books:

1. W. Nelson, Petroleum Refinery Engineering, McGraw Hill (1958)
2. Dr. Ram Prasad , Petroleum Refining Technology, , Khanna Publishers (1998)
3. O. P. Gupta, Elements of Petroleum Refinery Engineering, Khanna Publishing House (2019)

Course Code: CHES504 **Breakup: 3-0-0-3**
Course Name: Environmental Pollution and Control

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Assess and understand the sources, causes and effects of air, water and land pollution
CO2	Understanding the metrological aspects of air pollutant dispersion, and the dispersion and control of air pollutants at local regional and global level
CO3	Ability to design air pollutant abatement systems for particulate matter and gaseous pollutants at local regional and global level
CO4	Understanding the types of water pollutants and their effect on human and animal life
CO5	Understanding the physical, chemical and biological methods for wastewater treatment and the different unit operations involved in them
CO6	Ability to design wastewater and industrial treatment units at local regional and global level
CO7	Understanding the processes for sludge treatment and solid-waste disposal
CO8	Understanding the process and modelling of treatment wastewater disposal in water bodies

Course Details:

Introduction and importance of Environmental Pollution, case studies;

Air Pollution – Global sources, causes, effects; meteorological and natural purification processes; control of air pollutants – particulates and gases –design aspects ; automobile pollution;

Water Pollution – classification and characterization of water pollutants, Global sources, causes, effects of water pollution; control processes : physical- design of equalization tanks, sedimentation tanks clarifiers etc., chemical- coagulation, disinfection, adsorption etc.,
biological – introduction to bacterial growth and kinetics, BOD estimation, aerobic and anaerobic treatment methods, activated sludge process, trickling filters- design aspects, sludge disposal, clarified water disposal at local and regional level

Solid-waste management, Noise Pollution, Radioactive Pollution at Global local and regional level

Text and Reference Books:

1. Metcalf & Eddy, Waste Water Engineering- Treatment Disposal and Reuse, Tata McGraw Hill (2017)
2. Noel De Nevers, Air Pollution Control Engineering, McGraw Hill (2010)
3. Wark & Werner, Air Pollution
4. C. S. Rao, Environmental Pollution Control Engineering, CBS Publishers (2018)
5. H. S. Peavy & D. R. Rowe, Environmental Engineering, McGraw Hill (2017)

Course Code: CHES505 **Breakup: 3-0-0-3**
Course Name: Non-conventional Energy Sources

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the principles of electricity generation from various non-Conventional sources of energy
CO2	Understand the concept of Solar energy, it's collection and utilization at domestic and industrial level
CO3	Understand the concepts involved in Wind energy, Biomass energy and Geothermal energy
CO4	Understand the concepts of Ocean thermal energy conversion, Tidal energy, and Wave energy
CO5	Understand the concepts of Fuel cells, Batteries, and Hydrogen energy

Course Details:

Introduction: Energy and development; Types of energy resources – Conventional and nonconventional; Indian energy scenario at Global, local and regional level.

Solar energy: Introduction; Fundamentals of solar radiation - Structure of Sun, Solar constant, Extraterrestrial solar radiation, Spectral nature of solar radiation, Terrestrial solar radiation, Solar radiation geometry, Solar radiation measurement at Global, local and regional level.

Solar collectors: Flat plate collectors, Liquid-heating and air-heating flat plate collectors; Solar concentrators - Operating principle, Difference between flat plate collector and concentrating collector, Concentrator parameters, Types of concentrators, Concentrating solar power plants.

Solar thermal energy storage: Introduction, Sensible heat storage, Latent heat storage, Thermo-chemical energy storage, Storage material containers, Solar thermal energy storage for buildings, Solar pond – Non-convecting solar pond, Physics of solar ponds, Design considerations of a solar pond at local and regional level.

Solar photovoltaic power generation: Introduction, Basic structure of a photovoltaic cell, Semiconductor materials, Semiconductor junctions, Photovoltaic cell operation, Types of solar cells.

Wind energy: Introduction, Wind resources, Local winds, Global wind patterns, Jet streams, Theoretical power of the wind, Types of wind turbines - Horizontal axis wind turbines, Vertical axis wind turbines, Offshore wind turbines, Near-shore wind turbines, Selection of wind site, Design of a wind turbine rotor blade, Major components of wind electric system - Wind turbine blades or rotor, Transmission System (Hub, Main shaft, Main bearings, Clamping unit, Gear box, Coupling), Generator, Controller, Towers, Advantages and disadvantages of wind energy, Environmental concerns of wind energy.

Bioenergy: Introduction, Feedstock properties, Chemistry of biomass, Biomass conversion processes - Direct combustion, Thermal conversion, Biochemical conversion; Gasification process - Types of Gasifiers, Properties of Producer gas, Advantages of gasification, Difference between gasification and combustion; Anaerobic digestion process - Types of microorganisms, Anaerobic digestion process, Anaerobic digestion operation modes, Feedstock propertiesat Globallocal and regional level; Biogas plants, Design of biogas plants, Benefits of biogas technology to rural economy; Fuels from biomass – Biogas, Alcohols, Biodiesel, Charcoal.

Geothermal energy: Introduction, Geothermal resources – Hydrothermal, Geopressured, Hot Dry Rock, Magma; Technology and resource type - High temperature resources, Medium temperature resources, Low temperature resources, Advantages and disadvantages of geothermal energy.

Ocean Thermal Energy Conversion: Introduction, Solar energy absorption by water, Cycle types - Closed cycle OTEC, Open cycle OTEC, Hybrid; Selection of working fluids, Potential sites and plant design - Land-based and near-shore facilities, Shelf-mounted facilities, Floating facilities; Advantages and disadvantages of OTEC systems.

Tidal energy: Introduction, Fundamental principles of tides, Creation of tides, Effect of gravity and inertia on tidal bulges, variations in tides due to position and distance of Sun, Moon and Earth, Other factors affecting tidal characteristics, Coriolis forces, Energy of tides, Tidal current velocity, Extraction of tidal energy, Advantages and disadvantages of tidal energy.

Wave energy: Introduction; Formation of waves; Power in waves; Ocean wave energy technologies - Terminator, Attenuator, Point absorber, Overtopping Device; Advantages and disadvantages of wave energyat Global, local and regional level.

Fuel cells: Introduction, Thermodynamics of a fuel cell, Types of fuel cells - Polymer electrolyte membrane fuel cell, Direct methanol fuel cell, Alkaline fuel cell, Phosphoric acid fuel cell, Molten carbonate fuel cell, Solid oxide fuel cell.

Batteries: Introduction; Generation of electricity by a battery; Basic parameters - Free energy, Theoretical voltage, Theoretical capacity (Coulombic), Theoretical energy; Types of batteries - Primary (non-rechargeable) batteries, Secondary (rechargeable) batteries, Reserve batteries; Discussion on some examples of different battery types; Major considerations in selecting a battery; Advantages and limitations of batteries.

Hydrogen energy: Introduction; Production of hydrogen from fossil fuels, water splitting, biomass, and chemical hydrides; Storage of hydrogen in gaseous, liquid, and solid form; Technical issues in hydrogen storage; Pipeline transport of compressed hydrogen gas; Road delivery of hydrogen; Liquid hydrogen transport; Hydrogen fueled vehicular transport.

Energy from waste: Introduction, Definitions of waste, Characteristics of municipal solid wastes, Energy from waste, Incineration of municipal solid waste, Advantages and disadvantages of incineration, Pyrolysis, Other methods.

Text and Reference Books:

1. U C Sharma, Non-conventional Sources of Energy, Studium Press, Texas (2014).
2. T K Ghosh, M A Prelas, Energy Resources and Systems, Vol. 1: Fundamentals and Non-Renewable Resources, Springer (2009).
3. T K Ghosh, M A Prelas, Energy Resources and Systems, Vol. 2: Renewable Resources, Springer (2011).
4. E E Michaelides, Alternative Energy Sources, Springer (2012).
5. J Twidell, T Weir, Renewable Energy Sources, Second edition, Taylor & Francis (2006).
6. V V N Kishore, Renewable Energy Engineering and Technology: Principles and Practice, Fundamentals of Renewable Energy Processes, Earth scan (2009).
7. A V da Rosa, Fundamentals of Renewable Energy Processes, Elsevier (2009).

Course Code: CHES507 **Breakup: 3-0-0-3**
Course Name: Advanced Separation Processes

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand important features, advantages and limitations of advanced separation processes
CO2	Write the governing principle and law of the transport processes involved in membranes separation, electrochemical separations, ion-exchange, chromatographic separations and supercritical extractions
CO3	Classify different membrane separation processes and write their governing principles and areas of application
CO4	Understand the structure of different membrane modules and membrane plant configurations
CO5	Possess introductory knowledge working principle of membrane contactors and membrane reactor

Course Details:

Introduction to membrane separations, advantages and limitations; equilibrium and rate governed processes, separation factor for rate governed separation processes, Film theory, Sherwood number, Classification of membrane separation processes, Membrane type and materials; Membrane Modules; Principles, transport mechanisms, governing equations and applications of the following Membrane Separation Processes - Microfiltration, Ultrafiltration, Nanofiltration, Reverse Osmosis, Dialysis, Gas Separation and Pervaporation;
Similarty parameter (concentration boundary layer); unstirred batch cell; one, two dimensional model of Gel layer; module design (rectangular, spiral and tubular)

Surfactant based separation processes- Liquid Membranes, cloud point extraction, micellar enhanced ultrafiltration; External field induced membrane separations for colloidal particles: electro-osmosis, streaming potential, sedimentation potential, zeta potential, Eelectrophoretic separations; Electrodialysis;

Introduction to membrane contactor and membrane reactor; membrane fouling and concentration polarization; Membrane plant configurations and plant design; Ion-exchange and chromatographic separations, molecular sieve separations; supercritical fluid extraction

Text and Reference Books:

1. J. D. Seader & E. J. Henley, Separation Process Principles and Applications, Wiley & Sons (2015)
2. M. Mulder, Basic Priciples of Membrane Technology, Kluwer Academic Publishers (1996)
3. K. Scott and R. Hughes, Industrial Membrane Separation Technology, Blackie Academic and Professional (1995)

Course Code: CHES508 **Breakup: 3-0-0-3**
Course Name: Optimization Techniques

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Identify different types of optimization problems
CO2	Explain different optimization techniques
CO3	Solve various multivariable optimization problems
CO4	Solve problems by using Linear Programming
CO5	Solve optimization problems of staged and discrete processes, understand the concept of specialized & Non-traditional Algorithms

Course Details:

Introduction of optimization, classification of models, model building, degree of freedom, Analytical method necessary and sufficient conditions for optimum in single and multi-variable unconstrained and constrained problems

Unconstrained one dimensional search, Newton, Quasi-Newton and Secant method for uni-dimensional search, region elimination methods (Golden Section, Fibonacci, Dichotomusetc)

Linear Programming, Graphical simplex method, revised simplex method, duality and transportation problems

Unconstrained multi-variable search, Direct methods, Indirect method, Finite difference approximation

Dynamic Programming, Principle of optimality, Discrete and continuous dynamic programming

Text and Reference Books:

1. T.E. Edger, D.M. Himmelblau, Optimization of Chemical Processes, McGraw Hill (2001)
2. Hameed S. Taha, Operational Research: An Introduction, Pearson (2014)
3. G. C. Onwubolu, B.V. Babu, New Optimization Techniques in Engineering, Springer (2010)
4. S.S. Rao, Engineering Optimization, New Age Publication (2013)

Course Code: CHES509 **Breakup: 3-0-0-3**
Course Name: Biochemical Engineering

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understanding of biological basics and bioprocessing for cell Structure and Cell Types
CO2	Understanding the Kinetics of Enzyme Reactions, Applied Enzyme Catalysis,
CO3	Define the transport Phenomena in Biosystems and Analysis of Biological Reactors
CO4	Design the downstream Product Recovery and Purification system
CO5	Interaction of Mixed Microbial Populations, biological wastewater treatment

Course Details:

Cell Structure and Cell Types, Chemicals of Life (RNA, DNA, enzymes etc.),

Kinetics of Enzyme Reactions, Applied Enzyme Catalysis, Metabolic Stoichiometricand Energetics, Molecular Genetics and Control, Biomass Production,

Transport Phenomena in Biosystems, Design and Analysis of Biological Reactors, Fermentors, Downstream Product Recovery and Purification, Interaction of Mixed Microbial Populations, Biological Wastewater Treatmentat Global, local and regional level.

Text and Reference Books:

1. M.L. Shular, F. Kargi, Bioprocess Engineering: Basic Concepts, Prentice Hall (2015)
2. J.E. Bailey and D.F. Ollis, Biochemical Engineering Fundamentals, Mc Graw Hill (2017)
3. P.M. Doran, Bioprocess Engineering Principles, Academic Press Limited (2012)

Course Code: CHES510 **Breakup: 3-0-0-3**
Course Name: Process Modeling and Simulation

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Model deterministic systems and differentiate between nonlinear and linear models
CO2	Numerically simulate linear and non linear ordinary differential equations for deterministic systems
CO3	Estimate and validate a model based upon input and output data
CO4	Create a model prediction based upon new input and validate the output data
CO5	Develop steady state models for flash vessels, equilibrium staged processes, distillation columns, absorbers, strippers, CSTR, heat exchangers and packed bed reactors
CO6	Demonstrate the knowledge of various simulation packages and available numerical software libraries

Course Details:

Introduction to mathematical modeling; Advantages and limitations of models and applications of process models of stand-alone unit operations and unit processes;

Classification of models – Simple vs. rigorous, Lumped parameter vs. distributed parameter; Steady state vs. dynamic, Transport phenomena based vs. Statistical; Concept of degree of freedom analysis.

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

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

Unsteady state (time dependent) models and their applications; Simple dynamic models of Batch reactors, Adsorption columns, Multistage separation systems; Model reduction through orthogonal collocation; Review of solution techniques and available numerical software libraries.

Introduction to flow sheet simulation; Sequential modular approach; Equation oriented approach; Partitioning and tearing; Recycle convergence methods; Review of thermodynamic procedures and physical property data banks.

Text and Reference Books:

1. W.L. Luyben, Process Modeling, Simulation, and Control for Chemical Engineering, Wiley (2013)
2. A. Hussain, Chemical Process Simulation, Wiley Eastern Ltd., New Delhi,
3. D. C. Holland, Fundamentals of Modelling Separation Processes, Prentice Hall (2016)

Course Code: CHES511 **Breakup: 3-0-0-3**
Course Name: Fluidization Engineering

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the fluidization phenomena, industrial applications of fluidized beds and their operational and design aspects.
CO2	Understand the behaviour of fluidized bed.
CO3	Estimate pressure drop, bubble size, TDH, voidage, heat and mass transfer rates for the fluidized beds
CO4	Write model equations for fluidized beds
CO5	Design a fluidized bed reactor

Course Details:

Introduction: Phenomenon of fluidization, Liquidlike behaviour of a fluidized bed, Comparison with other contacting methods, Advantages and disadvantages of fluidized beds for industrial operations, Selection of a contacting mode for a given application.

Industrial applications: History, Physical operations, Synthesis reactions, Hydrocarbon cracking, Combustion and incineration, Carbonization and gasification, Calcination, Reactions involving solids, Biofluidization.

Fluidization and mapping of regimes: Fixed bed of particles, Fluidization without carryover of particles, Types of gas fluidization without carryover, Fluidization with carryover of particles, Mapping of fluidization regimes.

Dense bed: Distributor types, Gas entry region of a bed, Gas jets in fluidized beds, Pressure drop requirements across distributors, Design of gas distributors, Power consumption.

Bubbles in dense beds: Single rising bubbles, Coalescence and splitting of bubbles, Bubble formation above a distributor, Slug flow.

Bubbling fluidized beds: Experimental findings, Estimation of bed properties, Physical models, scale-up and scale-down, Flow models for bubbling beds.

Entrainment and elutriation from fluidized beds: Freeboard behaviour, Location of the gas outlet of a vessel, Entrainment from tall vessels (H_f> TDH), Entrainment from short vessels (H_f< TDH).

High velocity fluidization: Turbulent fluidized beds, Fast fluidization, Freeboard-entrainment model applied to fast fluidization, Pressure drop in turbulent and fast fluidization.

Solid movement: Vertical movement of solids, Horizontal movement of solids, Segregation of particles, Large solids in beds of smaller particles, Staging of fluidized beds, Leakage of solids through distributor plates.

Gas dispersion and gas interchange in bubbling beds: Dispersion of gas in beds, Gas interchange between bubble and emulsion, Estimation of gas interchange coefficients.

Text and Reference Books:

1. D Kunni, O Levenspiel, Fluidization Engineering, Second edition, Butterworth Heinemann, USA (1991).
2. J R Grace, J M Matsen, Fluidization, Plenum Press, New York (1980).L G Gibilaro, Fluidization Dynamics, Butterworth Heinemann, Oxford (2001).

3. M L Passos, M A S Barrozo, A S Mujumdar, Fluidization Engineering Practice, Second expanded edition, Laval, Canada (2014).
4. W C Yang, Handbook of fluidization and fluid-particle systems, First edition, Marcel Dekker, New York (2003).
5. M Pell, Gas Fluidization, Elsevier, Amsterdam (1990).

Course Code: CHES512 **Breakup: 3-0-0-3**
Course Name: Electrochemical Engineering

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understanding of Faraday's laws, ion-conduction electrode processes, Nernst equation and equilibrium constant, Porbaix diagram
CO2	Estimation of electrochemical potential, Debye-Huckel theory
CO3	Understanding Nernst-Plank equation, mass transport boundary layer
CO4	Determine the experimental methods for Nernst-Plank equation, mass transport boundary layer
CO5	Applications of energy storage and conversion, fuel cells, electrochemical reactions, electric vehicles

Course Details:

Review of fundamental principles of electrochemistry: Faraday's laws and ion-conduction electrode processes, transport number and transference number, Nernst equation and equilibrium constant, Porbaix diagram.

Phase equilibrium: electrochemical potential, Debye-Huckel theory, liquid junction potential

Electrode kinetics: electric double layer, simplified electrode kinetics models

Ionic mass transport: Nernst-Plank equation, mass transport boundary layer, concentration over potential, limiting current density

Experimental methods: potentiometry and galvanometry, impedance methods, scanning probe techniques, electrochemical instrumentation

Applications: energy storage and conversion, fuel cells, electrochemical reactions, electric vehicles, electro-dialysis, ion exchange membrane separations at Global, local and regional level.

Text and Reference Books:

1. Geoffrey Prentice, Electrochemical Engineering Principles, Prentice Hall, (1991)
2. Bard, A. J. And Faulkner, L. R., Electrochemical Methods- Fundamentals and Applications , Wiley India, 2nd ed, (2004)
3. Newman, John and Alea, K. E. Thomas, Electrochemical Systems, John Wiley, 3rd ed. (2004)
4. Strathmann, H., Ion-Exchange Membrane Separation Processes, Elsevier, 1st ed. (2004)

Course Code: CHES513 **Breakup: 3-0-0-3**
Course Name: Piping Engineering

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the basics of Piping Engineering
CO2	Understand the purpose of Piping Engineering
CO3	Learn the responsibilities of piping engineer in a project
CO4	Learn types of calculations involved in piping engineering project.
CO5	Learn requirements of piping modelling and analysis.

Course Details:

Introduction to piping: Pipe, Pipe size, Pipe wall thickness, Piping classification, Basic definitions, Forces, moments, and equilibrium, Work, power, and energy, Heat and temperature, Lengths, areas, surfaces, and volumes.

Piping components: Pipe and tube products; Traps; Strainers; Expansion joints; Threaded joints; Welded and brazed joints; Joining cast-iron pipe; Concrete, cement, and cement-lined pipe.

Piping materials: Material properties of piping materials, Metallic materials, Physical metallurgy of steel, Alloying of steel, Classification of steels, Steel heat treating practices, Degradation of materials in service, Material specifications.

Piping codes and standards: American standards – API, AISI, ANSI, ASME, ASTM, AWS, AWWA, MSS-SP, Unified numbering system (UNS); British standards; German standards; Indian standards.

Bolted joints: Cost of a leak, Flange joint components, Function of gaskets, Function of bolts, Gasket selection, Bolt selection, Flange stress analysis.

Selection and application of valves: Valve terminology, Reference codes and standards, Classification of valves, Valve components, Materials, Valve categories, Valve types, Pressure relief devices, Actuators, Selection and application guidelines.

Piping layout: Piping layout considerations, Specific system considerations, Application of CAD to piping layout.

Stress analysis of piping systems: Theories of failure, Stress categories, Stress limits, Fatigue; Load Classification, Service limits, and code requirements; Local stresses; Types of pipe loading conditions; Methods of analysis.

Piping supports: Introduction, Determination of support locations; Determination of loads and movements; Selection of pipe-supporting devices; Support requirements for specific piping materials; Design detail considerations; other support considerations.

Thermal insulation of piping: Fundamentals of heat transfer, Design parameters, Design conditions, Service considerations, Insulation materials, Accessory materials.

Flow of fluids: Basic fluid properties, Dimensions and units, Viscosity, Pressure variation in a static fluid, Continuity equation, Conservation of energy; Steady single-phase incompressible flow in piping; Steady single-phase compressible flow in piping; Single-phase flow in nozzles, venturi, and orifices; Steady two-phase flow; Transient flow analysis.

Pressure and leak testing of piping systems: Piping codes, Leak testing methods, Selection of a test method and fluid test medium, Pressure testing procedures.

Process systems piping: Introduction, Reference codes and standards, Design conditions, Design loading considerations, Pressure design of piping components, Selection and limitations of piping components, General process piping system considerations, Special design piping systems, System layout considerations, global Case histories.

Nonmetallic piping: Thermoplastics piping - Introduction, Piping materials, Joining methods, Dimensioning systems, Physical and mechanical properties, Chemical resistance, Common design considerations. Fiberglass piping - Typical applications, Resins, Joining systems, Resistant properties, Physical properties, Advantages and limitations of fiberglass piping systems, Pressure ratings, Connection to other equipment and piping material.

Text and Reference Books:

1. M L Nayyar (Editor), Piping Handbook, Seventh edition, McGraw-Hill (2000).
2. M W Kellogg, Design of Piping Systems, Revised Second edition, John-Wiley (1956).
3. P Smith, Process Piping Design Handbook Vol. 1: The Fundamentals of Piping Design, Gulf Publishing Company, Texas (2007).
4. G A Antaki, Piping and Pipeline Engineering, Marcel Dekker, New York (2003).
5. J P Ellenberger, Piping and Pipeline Calculations Manual, Second edition, Butterworth-Heinemann (2014).
6. ITT Grinnel Industrial Piping, Inc., Piping Design and Engineering, Sixth edition (1981).
7. Tube Turns, Inc., Piping Engineering, Sixth edition (1986).

Course Code: CHES556 **Breakup: 3-0-0-3**
Course Name: Principles of Packaging Science and Technology

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	To introduce students to the fundamentals of packaging science and its importance in product safety, quality, sustainability, and logistics
CO2	To understand the materials used in packaging and their properties
CO3	To study packaging processes, machinery, and regulations
CO4	To explore innovations and sustainability practices in packaging

Course Details:

Unit 1: Introduction to Packaging
- Definition, scope, and history of packaging.
- Functions of packaging: containment, protection, communication, convenience, utility.
- Role of packaging in the product life cycle.
- Overview of packaging industries (food, pharma, chemical, consumer goods).

Unit 2: Packaging Materials – Polymers
- Thermoplastics and thermosets: types, properties, selection criteria.
- Common polymers used in packaging (PE, PP, PET, PVC, PS, etc.).
- Barrier properties: oxygen, moisture, light.
- Testing and characterization of polymeric films.

Unit 3: Packaging Materials – Paper, Metal, and Glass
- Types and grades of paper and paperboard; coating and lamination.
- Metal packaging: tinplate, aluminum, cans, foils.
- Glass packaging: types, advantages, design considerations.
- Comparative analysis of materials.

Unit 4: Package Design and Development
- Structural and aesthetic design principles.
- Ergonomics and consumer interaction.
- Prototyping and mockups.
- Product-package compatibility.

Unit 5: Packaging Processes and Machinery
- Form-Fill-Seal (FFS) systems (horizontal and vertical).
- Blow molding, injection molding, thermoforming.
- Labeling, sealing, and capping machinery.
- Quality control in packaging operations.

Unit 6: Environmental and Sustainability Aspects
- Life Cycle Assessment (LCA) of packaging materials.
- Biodegradable and compostable materials.
- Recycling and waste management.
- Sustainable design practices and circular economy in packaging.

Unit 7: Packaging for Transportation and Logistics

- Transport packaging systems and optimization.
- Shock, vibration, and compression resistance.
- Palletization and containerization.
- Distribution simulation and testing.

Unit 8: Packaging Laws, Standards, and Regulations

- National and international packaging standards (BIS, ISO, ASTM).
- Labeling requirements (barcodes, nutrition, safety warnings).
- Legal aspects (recyclability laws, Extended Producer Responsibility, etc.).
- Sectoral compliance (food, pharma, chemicals).

Unit 9: Smart and Active Packaging

- Concepts of smart packaging: RFID, QR codes, sensors.
- Active packaging: oxygen scavengers, antimicrobials, ethylene absorbers.
- Intelligent packaging for supply chain tracking and shelf-life extension.

Unit 10: Emerging Trends and Industry 4.0 in Packaging

- Digital printing and customization.
- Automation, robotics, and IoT in packaging lines.
- AI/ML applications in packaging design and logistics.
- Global packaging trends and market dynamics.

Unit 11: Sectoral Case Studies and Projects

- Packaging in food, pharmaceuticals, cosmetics, and hazardous chemicals.
- Failure analysis and redesign examples.
- Group projects or presentations on packaging innovations or redesigns.
- Industry guest lectures and/or virtual tours.

Suggested Textbooks and References:

1. Yam, K. L., *The Wiley Encyclopedia of Packaging Technology*.
2. Soroka, W., *Fundamentals of Packaging Technology*.
3. Selke, S. E. M., *Plastics Packaging: Properties, Processing, Applications, and Regulations*.
4. Lockhart, H. E., *Packaging: Science and Technology*.
5. Lee, D. S., Yam, K. L., Piergiovanni, L., Food Packaging Science and Technology
6. Packaging journals and current industry reports.

Course Code: CHES560 **Breakup: 3-0-0-3**
Course Name: Introduction to Computaional Fluid Dynamics

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand and classify various types of partial differential equations and the fundamental principles governing their numerical solution.
CO2	Apply finite difference methods to discretize and solve various engineering problems, including those with boundary conditions, variable properties, and interfaces.
CO3	Formulate and implement finite volume and finite element methods for solving convection-diffusion problems and other engineering applications.
CO4	Analyze and implement iterative and direct methods for solving systems of algebraic equations arising from discretized PDEs, and evaluate the stability of time integration schemes.
CO5	Comprehend advanced topics in computational fluid dynamics, including numerical grid generation and various turbulence modeling approaches for Navier-Stokes equations.

Course Details:

Unit 1 Introduction: Conservation equation; mass; momentum and energy equations; convective forms of the equations and general description, Classification and Overview of Numerical Methods, Classification into various types of equation; parabolic elliptic and hyperbolic; boundary and initial conditions; over view of numerical methods.

Unit 2 Finite difference methods; different means for formulating finite difference equation; Taylor series expansion, integration over element, local function method; treatment of boundary conditions; boundary layer treatment; variable property; interface and free surface treatment; accuracy of finite. difference. method.

Unit 3 Finite volume methods; different types of finite volume grids; approximation of surface and volume integrals; interpolation methods; central, upwind and hybrid formulations and comparison for convection-diffusion problem,

Unit 4 Finite element methods; Rayleigh-Ritz, Galerkin and Least square methods; interpolation functions; one and two dimensional elements; applications. Solution of finite difference equations; iterative methods; matrix inversion methods; ADI method; operator splitting; fast Fourier transform. Time integration Methods: Single and multilevel methods; predictor-corrector methods; stability analysis; Applications to transient conduction and advection diffusion problems.

Unit 5 Numerical Grid Generation: Numerical grid generation; basic ideas; transformation and mapping, Navier-Stokes Equations, Explicit and implicit methods; SIMPLE type methods; fractional step methods. Turbulence modelling, Reynolds averaged Navier-Stokes equations, RANS modeling, DNS and LES.

Text & Reference Books:

1. Ferziger, J. H. and Peric, M. (2003). Computational Methods for Fluid Dynamics. Third Edition, Springer Verlag, Berlin.

2. Versteeg, H. K. and Malalasekara, W. (2008). Introduction to Computational Fluid Dynamics: The Finite Volume Method. Second Edition (Indian Reprint) Pearson Education.

3. Anderson, D.A., Tannehill, J.C. and Pletcher, R.H. (1997). Computational Fluid Mechanics and Heat Transfer. Taylor & Francis.

SYLLABUS

Minor Degree Programmes

Offered by

DEPT OF CHEMICAL ENGINEERING

Applicable from 2024-25

Course Structure for Minor in Chemical Engineering

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHES201M	Process Calculations	3	1	0	4
2.	CHES202M	Fluid Mechanics & Mechanical Operations	3	1	0	4
3.	CHES204M	Heat Transfer	3	1	0	4
4.	CHES301M	Mass Transfer-I	3	1	0	4
5.	CHES302M	Chemical Reaction Engineering-I	3	1	0	4
		Total	**15**	**5**	**0**	**20**

Course Code: CHES201M **Breakup: 3 –1 – 0 – 4**
Course Name: Process Calculations

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Demonstrate comprehensive understanding of material and energy balance equations for open and closed systems
CO2	Select appropriate basis and conduct degree of freedom analysis before solving material and energy balance problems
CO3	Make elementary flow-sheets and perform material and energy balance calculations without and with chemical reactions, and involving concepts like recycle, bypass and purge
CO4	Perform process calculations utilizing psychrometric charts and steam tables
CO5	Apply simultaneous material and energy balance calculations for steady state continuous flow systems and unsteady state systems

Course Details:

Introduction: Units, their dimensions and conversions, Dimensional consistency of equations, Dimensional and dimensionless constants,

Fundamental concept of stoichiometry: Mass and volume relations, Stoichiometric and composition relations, Excess reactants, Degree of completion, Conversion, Selectivity and Yield.

Ideal gases and gas mixture: Gas laws-Ideal gas law, Dalton's Law, Amagat's Law, and Average molecular weight of gaseous mixtures.

Vapour pressure: Effect of temperature on vapour pressure, Vapour pressure plot (Cox chart), Vapour pressures of miscible and immiscible liquids and solutions, Raoult's Law and Henry's Law.

Humidity and Humidity charts: Relative Humidity and percent saturation; Dew point, Dry and Wet bulb temperatures; Use of humidity charts for engineering calculations

Material balances for systems with and without chemical reactions: species and elemental balance. Analysis of systems with by-pass, recycle and purge.

Thermophysics: Heat capacity of gases, liquids and solutions, Heat of fusion and vaporisation;

Thermochemistry: Calculations and application of heat of reaction, combustion, formation, neutralisation and solution; Enthalpy-concentration charts;

Steady state energy balance for systems with and without chemical reactions:

Combustion of solids, liquids and gaseous fuels, calculation of theoretical and actual flame temperatures, Degrees of freedom in steady state processes, solution of simultaneous material and energy balance problems using flow sheeting codes;

Unsteady state material and energy balance

Text and Reference Books:

1. D.M. Himmelblau, Basic Principles and calculations in Chemical Engineering, Printice-Hall (2015)
2. O.A. Hougen, K.M.Watson & R.A.Ragatz, Chemical process principles, John Willey & Sons (2018)

Course Code: CHES202M **Breakup: 3 –1 – 0 – 4**
Course Name: Fluid Mechanics & Mechanical Operations

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand and apply fundamental fluid properties and principles of fluid statics
CO2	Analyze and solve problems related to fluid kinematics and dynamics
CO3	Grasp the concepts of laminar and turbulent flow, boundary layers, and dimensional analysis
CO4	Evaluate and design hydraulic systems, including pipe networks and pumping machinery
CO5	Identify, analyze, and select appropriate mechanical-physical separation techniques and equipment for various solid-fluid systems

Course Details:

Unit 1 Concept of fluid; Distinction between solids and fluids, Fluid Properties, Newton's law of Viscosity, Newtonian & non-Newtonian fluids, vapour pressure, boiling point, compressibility, bulk modulus, surface tension, capillarity, Pascal's law, pressure variation in static fluids, Pressure measuring devices: Barometer, Piezometer, Manometer, Bourdon gauge, Diaphragm gauge. Archimedes' principle, buoyant force, centre of buoyancy, Stability and floating bodies.

Unit 2 Types of flow (1D, 2D, 3D; steady/unsteady; uniform/non-uniform; laminar/turbulent; compressible/incompressible; rotational/irrotational; ideal/real), Lagrangian and Eulerian descriptions, Flow visualization: Pathlines, Streamlines, Streaklines, Timelines, Continuity equation, Euler's equation of motion, Bernoulli's equation and its applications: Venturimeter, Orifice meter, Pitot tube, Rotameter.

Unit 3 Laminar and turbulent flow in pipes, Navier-Stokes equation (introductory concept), Hagen-Poiseuille law, Prandtl's mixing length theory, Boundary layer formation, thickness, laminar vs turbulent boundary layers, Separation and control techniques. Rayleigh's method, Buckingham π-theorem, Similarity and model laws (geometric, kinematic, dynamic), Model types and application.

Unit 4 Hydraulic coefficients, time of emptying tanks (rectangular, conical, horizontal cylindrical), Losses in flow through orifices and mouthpieces (external/internal), Rectangular, triangular (V-notch), trapezoidal, and stepped notches; discharge calculations. Reynolds experiment, energy losses (Darcy-Weisbach, minor losses), Moody's chart, Colebrook equation, Pipe network: Series, parallel, equivalent pipes; flow through nozzles; water hammer, Centrifugal pumps: Components, working, efficiency, specific speed, cavitation, NPSH, Reciprocating pumps: Types, working, discharge, slip, power. Comparison between centrifugal and reciprocating pumps.

Unit 5 Unit operations vs. unit processes, Need and classification of separation processes, Mechanical-physical separation: overview and relevance, Characterization of solid particles: shape, size, mixed particle sizes, average size, Bulk solids: angle of repose, angle of internal friction, Flow and storage: bins, hoppers, flow issues, Mechanisms: compression, impact, attrition, shear, cutting, Laws of comminution (Rittinger, Kick, Bond), Equipment: Coarse crushers, intermediate crushers, grinders, ultra-fine grinders, Criteria for equipment selection, Screening and screening equipment, Magnetic and electrostatic separation, Classification: free and hindered settling, Classifying equipment (mechanical and non-mechanical), Gravity concentration, flotation, and associated equipment

Unit 6 Sedimentation: principles, batch and continuous sedimentation, thickeners, classifiers, Filtration, Principles of cake filtration, filter media, filter aids, Filtration theory: constant and variable pressure filtration, Equipment: filter press, leaf filter, rotary drum filter, Gas-Solid Separation Fundamentals and need for gas cleaning, Gravity settling chamber, inertial separators, fabric filters, wet scrubbers, electrostatic precipitators, cyclone separators, air classifiers, Transportation of Solids : Belt conveyors, screw conveyors, pipe conveyors, bucket elevators, Conveying of powders: flow behavior and handling, Mixing of Solids and Liquids, Auxiliary Operations: Size enlargement, Crystallization, Feeding and weighing, Coagulation and flocculation

Text and Reference Books:

1. C S P Ojha, R Berndtsson, P N Chandramouli, Fluid Mechanics and Machinery, Oxford University Press, New Delhi (2010).
2. P N Modi, S M Seth, Hydraulics and Fluid Mechanics including Hydraulics Machines, Standard Book House, New Delhi (2017).
3. N de Nevers, Fluid Mechanics for Chemical Engineers, Third edition, McGraw Hill, Chennai (2017).

Course Code: CHES204M **Breakup: 3 –1 – 0 – 4**
Course Name: Heat Transfer

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the difference between thermodynamics and heat transfer and the general principles of conduction, convection and radiation
CO2	Understand steady state conductive heat transfer through simple geometries
CO3	Understand combined heat transfer mechanisms through composite geometries and extended surfaces
CO4	Able to differentiate types of heat exchangers, their detailed construction, operation and design
CO5	Understand heat transfer with phase change (boiling and condensation)
CO6	Understand the process of evaporation and analyzing the functioning and design of evaporators
CO7	Understand the principles of radiation, the radiation laws and calculation of radiative heat transfer between black and Gray bodies

Course Details:

General Principles of heat transfer by conduction, convection, radiation.

Conduction: Fourier's law of heat conduction; steady state conduction in one dimension with and without heat source through plain wall, cylindrical & spherical surfaces; variable thermal conductivity, combined mechanism of heat transfer (conduction and convection), conduction through composite slab, cylinder and sphere; thermal contact resistance; thermal insulations, properties of insulating materials; critical radius of insulation; extended surfaces: heat transfer from a fin, effectiveness and efficiency

Convection: Natural and forced convection; convective heat transfer coefficient; concept of thermal boundary layer; laminar & turbulent flow heat transfer inside and outside tubes; dimensional analysis, Buckingham pi theorem, dimensionless numbers in heat transfer and their significance; determination of individual & overall heat transfer coefficients and their temperature dependency

Forced convection**:** correlation for heat transfer in laminar and turbulent flow in a circular tube and duct, Reynolds and Colburn analogies between momentum and heat transfer

Natural convection – natural convection from vertical and horizontal surfaces, Grashof and Rayleigh numbers

Heat exchangers: Types of heat exchangers like double pipe, shell & tube, plate type, extended surface, multi-pass exchangers; their detailed construction and operation; calculations on design of heat exchangers; effectiveness of a heat exchanger

Heat transfer with phase change: condensation of pure and mixed vapours; film wise and drop wise condensation, calculations on condensers, heat transfer in boiling liquids, boiling curve, nucleate and film boiling; correlations for pool boiling

Evaporation: elementary principles, boiling point elevation and Duhring's plot; types of evaporators – single, multiple (forward, backward, mixed feed), capacity and economy of evaporators simple calculation on single and multiple effect evaporators

Radiation: Basic concepts of radiation from surface, black body and grey body concepts, Planks Law, Wein's displacement law, Stefan Boltzmann's law, Kirchoff's law, View factor, combined heat transfer coefficients by convection and radiation.

Introduction to unsteady state heat transfer: lumped parameter model, unsteady state heat conduction in various geometries, Heisler charts

Text and Reference Books:

1. B. K. Dutta, Heat Transfer Principles and Applications, PHI (2000)
2. D.Q. Kern, Process Heat Transfer, Mc Graw Hill (2017)
3. J. P. Holman, Heat Transfer, Mc Graw Hill (2017)
4. F.P. Incropera and D. P. Dewitt, Fundamentals of Heat and Mass Transfer, John Wiley (2018)
5. Y. A, Cengel, A. J. Ghajar, Heat and Mass Transfer: Fundamentals & Applications, McGraw Hill (2020)

Course Code: CHES301M **Breakup: 3 –1 – 0 – 4**
Course Name: Mass Transfer I

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	To understand the phenomena of mass transfer on macro level
CO2	Understand the concept of equilibrium in all separation operations should be clear
CO3	Able to design Distillation, Extraction, Leaching, Adsorption column by using different methods
CO4	Able to find out optimum conditions for component separation
CO5	To do the design by graphical and analytical method

Course Details:

Distillation: Vapour-liquid equilibria, Relative volatility, Raoult's law, minimum and maximum boiling mixtures, enthalpy-concentration diagrams for binary systems, multicomponent systems – bubble point and dew point calculation, Flash vaporization, Differential distillation, Steam Distillation, Continuous rectification, Azeotropic and Extractive Distillation, Multistage tray towers - Graphical methods of Ponchon-Savarit and McCabe-Thiele, feed-tray location, total reflux, minimum reflux ratio, optimum reflux ratio, open steam, multiple feed and side stream, multi component calculations using short-cut methods.

Liquid Extraction: Introduction, liquid equilibria, equilateral-triangular coordinates systems of three liquids, choice of solvent, single stage and multistage crosscurrent extraction, insoluble liquids, continuous counter current multistage extraction, insoluble liquids.

Leaching: Introduction, lixiviation, decoction, elutriation or elution, preparation of the solid, effect of temperature, types of equilibrium curves, single stage and multistage crosscurrent leaching, multistage counter current leaching.

Adsorption: Introduction, types of adsorption, nature of adsorbents, adsorption equilibria – single gases and vapours, adsorption hysteresis, effect of temperature, heat of adsorption, adsorption of solute from dilute solution, single stage and multistage crosscurrent operation using Freundlich equation, multistage counter current operation using Freundlich equation.

Text and Reference Books:

7. R E Treybal, Mass-Transfer Operations, Third edition, McGraw Hill, New Delhi (2012).
8. K V Narayanan, B Lakshmikutty, Mass Transfer Theory and Applications, CBS Publishers and Distributors, New Delhi (2014).
9. B K Dutta, Principles of Mass Transfer and Separation Processes, Second edition, PHI, New Delhi (2007).
10. A S Foust, Principles of Unit Operations, Second edition, Wiley, New York (1980).
11. W L McCabe, J Smith and P Harriot, Unit Operations of Chemical Engineering, Seventh edition, Tata McGraw Hill, New Delhi (2014).
12. C J Geankoplis, Transport Processes and Unit Operations, Third edition, PHI, New Delhi (1993).

Course Code: CHES302M **Breakup: 3 –1 – 0– 4**
Course Name: Chemical Reaction Engineering-1

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Estimate the rate expression for various elementary and non-elementary reactions and corresponding the reaction mechanism
CO2	Carry out the kinetic study for various batch and flow reactors for single and multiple reactions
CO3	Determine the best combination of mixed and plug flow reactors on basis of size comparison
CO4	Understand the use of recycle reactors and auto catalytic reactors
CO5	Analyse the effect of temperature and pressure on reaction corresponding to various type of reactors
CO6	Understand the non-ideal flow behaviour inside the reactor and various model to describe this phenomenon

Course Details:

Introduction and overview of chemical reaction engineering

Kinetics of homogeneous reactions, concentration dependent term and temperature dependent term of the rate equation, searching for rate expressions from mechanisms; non elementary homogeneous reactions;

Interpretation of batch reactor data: Constant volume batch reactor; varying volume batch reactor; collection and analysis of batch data – integral and differential method; half-life method, reversible reaction data, temperature and reaction rate;

Introduction to Reactor Design

Single Ideal Reactor: Ideal batch reactor; steady state continuously stirred tank reactor; steady state plug flow reactor; size comparison of single reactions; multiple reactor systems; recycle reactor; autocatalytic reactions;

Design for multiple reactions: parallel reactions-product distribution, fractional yield, reversible and irreversible reaction; series reactions - reversible and irreversible reaction; series-parallel reactions, Denbigh reactions

Non isothermal reactors: temperature and pressure effects on single and multiple reactions, equilibrium conversions, optimum temperature progression, adiabatic and non-adiabatic operations

Non ideal Reactors: Residence time distribution, E, C, F curves, segregation model, dispersion model, chemical reaction and dispersion, tank-in- series model; multiparameter models

Text and Reference Books:

1. O. Levenspiel, Chemical Reaction Engineering, John Willey & Sons (2006)
2. H.S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall (2008)

Course Structure for Minor in Energy Engineering

Sl. No.	Course Code	Course Title	L	T	P	Credits
I. Core Foundational Courses						
1.	CHES203M	Chemical Engineering Thermodynamics	3	1	0	4
2.	CHES601M	Energy Management	3	1	0	4
3.	CHES602M	Renewable Energy Generation and Storage	3	1	0	4
4.	CHES603M	Energy Resources, Environment, and Economics	3	1	0	4
II. Elective Courses (choose any one)						
5.	CHES611M	Solar Energy Technologies	3	1	0	4
	CHES612M	Wind Energy	3	1	0	4
	CHES613M	Hydrogen Energy and Fuel Cells	3	1	0	4
	CHES614M	Biofuels Engineering	3	1	0	4
	CHES615M	Nuclear Reactor Engineering & Fusion Energy	3	1	0	4
		Total	**15**	**5**	**0**	**20**

Course Code: CHES601M **Breakup: 3 –1 – 0 – 4**
Course Name: Energy Management

Course outcomes (CO): Students completing the course will be able to

CO1	Introduction: Objective, scope and energy management of the course includes Energy Basics, Energy Demand Management, Conservation & Resource Development, Energy for Sustainable Development.
CO2	Study about the energy economics, financial evaluation and economic performance indices.
CO3	Study about the need for Energy Management by Sector- Industry, Buildings & Houses, Transport, Electric Power, Energy forecasting techniques; Energy Integration, Energy Matrix.
CO4	Create understanding about the energy conservation for unit operations and equipment majorly used in chemical industries.
CO5	Develop understanding of cogeneration concept for successfully implementation of financial energy conservation in all engineering practices.

Course Details:

Unit 1 General principles of energy management and energy management planning, conducting energy audit (pre-audit, audit and post-audit), energy audit instruments, energy audit report, monitoring, evaluating and following up energy saving measures/ projects, case study. Energy efficiency analysis, management of heating, analysis of past trends plant data, closing the energy balance, laws of thermodynamics, measurements, and portable and on line instruments.

Unit 2 Energy Economics: Time value of money Present-Worth and Future Worth, discount rate, payback period, internal rate of return, life cycle costing. Economic performance indices: Payback – Simple and Discounted, Net Present Value, Internal Rate of Return, Benefit to Cost Ratio, E/D ratio, Life cycle/levelized cost, Financial evaluation of energy projects, evaluation of proposals, profitability index, life cycle costing approach, investment decision and uncertainty.

Unit 3 Electrical Systems: Demand control, power factor correction, load scheduling/shifting, Motor drives- motor efficiency testing, energy efficient motors, motor speed control. Lighting- lighting levels, efficient options, fixtures, daylighting, timers, Energy efficient windows.

Unit 4 Steam Systems: Boiler efficiency testing, excess air control, Steam distribution & use- steam traps, condensate recovery, flash steam utilization, Thermal Insulation. Energy conservation in Pumps, Fans (flow control), Compressed Air Systems, Refrigeration & air conditioning systems. Waste heat recovery: recuperators, heat wheels, heat pipes, heat pumps

Unit 5 Cogeneration- Concept, options (steam/gas turbines/diesel engine based), selection criteria, control strategy. Heat Exchanger Networking: Optimizing Heat Recovery, concept of pinch, target setting, problem table approach, composite curves. Demand side management. Financing energy Conservation

Text & Reference Books

1. Witte, L.C., Schmidt, P.S. and Brown, D.R. "Industrial Energy Management and Utilisation", Hemisphere Publ, Washington, 1988.
2. Turner, W.C. (Editor) "The Efficient Use of Energy", Butterworths, London, 1982.
3. Wayne C. Turner & Steve Doty "Energy Management Handbook", Wiley, New York, 1982.
4. Dryden, I.G.C. (Editor) "Industrial Energy Conservation Manuals", MIT Press, Mass, 1982.
5. National Productivity Council and Center for & Environmental Studies, "Technology Menu for Efficient Energy Use - Motor Drive Systems". Princeton Univ, 1993.

Course Code: CHES602M **Breakup: 3 –1 – 0 – 4**
Course Name: Renewable Energy Generation and Storage

Course outcomes (CO): Students completing the course will be able to

CO1	Understand the different sources of renewable energy and its uses
CO2	Understand the concept of Solar energy, it's collection and utilization at domestic and industrial level
CO3	Understand the concepts involved in Wind energy, and Biomass energy
CO4	Understand the conc5epts of Fuel cells, Batteries, and Hydrogen energy
CO5	Understand the need and modes of Energy Storage, carbon Nano-tubes and Chemical Energy storage (SHS) mediums.

Unit 1 Need of sources of renewable energy: Introduction to different sources of renewable energy, e.g., Solar Energy, Wind Energy, Bio-mass, Geothermal Energy, Ocean energy, Solar Energy and Applications. Basic concepts of radiations: Solar radiation, Direct and Indirect radiation, Radiation measuring instrument, applications etc.

Unit 2 Solar Energy: Basics of solar thermal applications both low and high temperature ranges such as water heating, air heating, steam generation, desalination of water, crop drying and power generation, Principle of photovoltaics including introduction to various components of a photovoltaic systems for standalone/hybrid/grid connected systems. Wind Energy, basic theory of wind, wind power generators both for decentralized applications and grid connected systems, performance characteristics, Augmentation of wind power, Betz criteria

Unit 3 Bioenergy: Types and availability of biomass resources, various methods of biomass utilisation for energy generation: gasification, briquette, palatization, syn-gas, Anaerobic/Aerobic digestion, ethanol and biodiesel production, types of Bio-gas digesters, Combustion characteristics of bio gas and its different utilizations,

Unit 4 Fuel Cells and Hydrogen Energy: Introduction, principle of fuel cells, thermodynamic analysis of fuel cells, types of fuel cells, fuel cell batteries, applications of fuel cells. Hydrogen as a renewable energy source, sources of hydrogen, fuel for vehicles, hydrogen production- direct electrolysis of water, thermal decomposition of water, biological and biochemical methods of hydrogen production.

Unit 5 Need of energy storage; Different modes of Energy Storage. Potential energy: Pumped hydro storage. Kinetic energy and Compressed gas system: Flywheel storage, Compressed air energy storage. Electrical and magnetic energy storage: Capacitors, Electromagnets and Battery storage systems such as primary, secondary, Lithium, Solid-state and Molten solvent batteries. Role of carbon Nano-tubes in electrodes; Chemical Energy storage: Thermo chemical, Photo-chemical, Bio-chemical, Electro-chemical, Fossil fuels and Synthetic fuels and Hydrogen storage, Sensible heat storage (SHS) mediums; Stratified storage systems; Rock-bed storage systems; Thermal storage in buildings.

Text & Reference Books

1. U C Sharma, Non-conventional Sources of Energy, Studium Press, Texas (2014).
2. T K Ghosh, M A Prelas, Energy Resources and Systems, Vol. 1: Fundamentals and Non Renewable Resources, Springer (2009).
3. T K Ghosh, M A Prelas, Energy Resources and Systems, Vol. 2: Renewable Resources, Springer (2011).
4. E E Michaelides, Alternative Energy Sources, Springer (2012).
5. J Twidell, T Weir, Renewable Energy Sources, Second edition, Taylor & Francis (2006).
6. Narayan R, Viswanathan B, Chemical and Electrochemical Energy Systems, University Press (India) Ltd.
7. Sarangpani, S J A Kosek, La Conti A B, Handbook of Solid State Batteries and Capacitors, World Scientific Publications, N J, USA.

Course Code: CHES603M **Breakup: 3 –1 – 0 – 4**
Course Name: Energy Resources, Environment and Economics

Course outcomes (CO): Students completing the course will be able to

CO1	Demonstrate understanding of the different types of renewable and non-renewable energy technologies that are currently available and how they are used to provide energy.
CO2	Identify the availability and distribution of major energy resources and energy consumption patterns across the globe.
CO3	Evaluate Nuclear energy technologies based on efficiency, impacts and other factors.
CO4	Identify Environmental effects of energy extraction, conversion and use
CO5	Evaluate financial and economic feasibility of Energy Systems

Unit I: Classification of energy sources: Renewable vs. Non-renewable, Energy flow diagrams (e.g., to the Earth, within systems). Origin and formation of fossil fuels (coal, oil, natural gas) and their geological timescale. The crucial role of energy in economic development and social transformation. Understanding the "energy crisis" – drivers and implications. Global commercial energy production and final energy consumption patterns. Overview of energy pricing mechanisms and energy sector reforms worldwide, importance of energy conservation, Strategies and technologies for improving energy efficiency.

Unit II: Analysis of energy consumption patterns across various sectors globally, projected global energy consumption trends, Availability and distribution of major energy resources: coal, oil, natural gas, nuclear power, and hydroelectricity, Commercial and non-commercial forms of energy in India, historical and current energy consumption patterns in India (urban vs. rural, sector-wise), Impact of rising energy consumption on the global economy and resource scarcity, future energy options and pathways for sustainable development.

Unit III: Nuclear raw materials (uranium, thorium) and their availability. Principles of nuclear fission and different types of nuclear reactors. Electricity generation from nuclear power, Nuclear installations in India: their capacities, operational aspects, and future plans. Broader socio-economic impacts of energy projects, including positive and negative externalities.

Unit IV: Overview of environmental impacts from energy extraction, conversion, and end-use, Introduction to primary and secondary pollutants. Sources, causes, and effects of air pollution (e.g., SOx, NOx, PM2.5), water pollution (e.g., thermal pollution, chemical effluents), soil pollution and Noise pollution, and their control technologies (e.g., scrubbers, electrostatic precipitators). Pollution due to nuclear power generation, Management and disposal of radioactive waste (low-level, intermediate-level, high-level), Environmental and ecological effects of hydroelectric power stations (e.g., damming, habitat alteration, displacement).

Unit V: Relevance of financial and economic feasibility in energy projects, Energy demand analysis and forecasting methodologies. Energy supply assessment and evaluation, Strategies for balancing energy demand and supply, Software tools for energy planning and analysis, energy-economy interactions, Carbon credits and trading opportunities in carbon markets, Financing mechanisms for large-scale and decentralized energy systems.

Text & Reference Books:

1. Banerjee Bani P, Energy and the Environment in India, Oxford University Press, New Delhi.
2. Rai G D, Non- conventional Sources of Energy, Khanna Publishers, Delhi.
3. Kumar Gopal, Energy Independence Vision of a Hybrid, Unbound Future, Deep and Deep Publications Pvt. Ltd., New Delhi.
4. Asthana D K, Asthana Meera, Environment Problems and Solutions, S Chand and Company Ltd., New Delhi.

5. Mubeen Abdul, Khan M Emran, Hasan M Muzaffarul, Energy and Environment, Anamaya Publishers, New Delhi.
6. Pandel Upender, Poonia M P, Energy Technologies for Sustainable Development, Prime Publishing, Ghaziabad (UP).
7. Ristinen R A, Kraushaar J J, Energy and the Environment, John Willey and Sons. 8. Dass M C, Fundamentals of Ecology, Tata McGraw Hill. 9. Kaushik N D, Kaushik K, Energy, Ecology and Environment, Capital Publishing.

Course Code: CHES611M **Breakup: 3 –1 – 0 – 4**
Course Name: Solar Energy Technologies

Course outcomes (CO): Students completing the course will be able to

CO1	Understanding the solar energy, radiation principles and its measurement.
CO2	Demonstrate the principles, components, and applications of various solar photovoltaic (PV) technologies.
CO3	Analyse the working principles, types, and applications of solar thermal energy conversion systems
CO4	Enables to proficiently design, size, and integrate solar PV systems.
CO5	Evaluate the economic, environmental, and future prospects of solar energy technologies.

Unit I: Introduction to Solar Energy, Global and Indian energy scenarios: current status, challenges, and the role of solar energy, Solar Radiation Physics, Atmospheric effects on solar radiation: absorption, scattering, air mass. Solar Radiation Geometry (Declination angle, hour angle, latitude, zenith angle, azimuth angle) Solar Radiation Measurement and Estimation

Unit II: Fundamentals of Photovoltaic Conversion, Photovoltaic effect, Semiconductor properties for PV, I-V characteristics of a solar cell, Conversion efficiency, Effect of temperature and irradiance on solar cell performance, Types of Photovoltaic Cells, First Generation: Crystalline silicon solar cells, Second Generation (Thin-Film), Third Generation Emerging), Series and parallel connection of solar cells and modules, PV module construction and materials. Performance rating of PV modules.

Unit III: Fundamentals of Solar Thermal Conversion, Heat transfer principles relevant to solar collectors (conduction, convection, radiation), Collector efficiency and performance parameters. Low Temperature Solar Thermal Collectors: Flat Plate Collectors (FPC), Evacuated Tube Collectors (ETC), Concentrating Solar Power (CSP) Technologies, Parabolic Trough Collectors (PTC) Solar Power Towers (SPT)/Central Receiver Systems, Parabolic Dish Systems, Linear Fresnel Reflectors (LFR). Principles of passive solar heating and cooling.

Unit IV: Components of a PV System, PV modules and arrays, Batteries for energy storage: types (Lead-acid, Li-ion), Standalone PV Systems (Off-Grid), Grid-Connected PV Systems, Hybrid PV Systems, PV System Performance parameters: Performance Ratio (PR), Capacity Utilization Factor (CUF), Specific Yield and Monitoring systems for PV plants, Losses in PV systems.

Unit V: Economic Analysis of Solar Projects, Time value of money: NPV, IRR, payback period. Environmental Impacts of solar PV, Life Cycle Assessment (LCA) of solar PV and CSP technologies, Land use implications, water consumption (especially for CSP), Recycling and end-of-life management of solar panels and Carbon footprint. National and international policies promoting solar energy (e.g., India's National Solar Mission, global climate agreements).

Text & Reference books:

1. S.P. Sukhatme and J.K. Nayak, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill Education.
2. C.S. Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications, PHI Learning Private Limited.
3. J.A. Duffie and W.A. Beckman, Solar Engineering of Thermal Processes, John Wiley & Sons.
4. G.N. Tiwari, Solar Energy, Fundamentals, Design, Modeling and Applications, Narosa Publishing House.
5. D.Y. Goswami, F. Kreith, and J.F. Kreider, Principles of Solar Engineering, Taylor and Francis.
6. H.P. Garg and J. Prakash, Solar Energy: Fundamentals and Applications, Tata McGraw Hill.
7. M.A. Green, Third Generation Photovoltaics: Advanced Solar Energy Conversion, Springer.

8. Relevant IS/IEC Standards for Solar PV and Thermal Systems.
9. Reports from IRENA, IEA, MNRE (India), etc.

Course Code: CHES612M **Breakup: 3 –1 – 0 – 4**
Course Name: Wind Energy

Course outcomes (CO): Students completing the course will be able to

CO1	Understand the fundamental principles of wind energy and its atmospheric context.
CO2	Analyze the aerodynamic principles and performance characteristics of wind turbine rotors.
CO3	Evaluate the design, components, and operational aspects of wind electric generators.
CO4	Apply the principles of wind energy for diverse applications, including electricity generation and pumping.
CO5	Assess the socio-economic and environmental implications of wind energy projects, particularly in the Indian context.

Unit I Introduction to wind energy, Atmospheric circulations, Factors influencing wind: variation with height and time, Classification, Wind shear, Turbulence, Wind speed monitoring and maps, Wind energy conversion principles; Types and classification of wind energy conversion systems (WECS), Power, Torque and speed characteristics, Betz limit.

Unit II Aerodynamic design principles; Aerodynamic theories; Axial momentum, blade element and combine theory, Rotor characteristics: Solidity, Tip speed ratio, Tip loss correction, Maximum power coefficient; Dynamic matching, Extension of linear momentum theory, Power extraction by a turbine.

Unit III Wind electric generators: Aerogenerator classification, tower, rotor, gearbox, power regulation, safety mechanisms, Wind turbine design considerations; methodology, Theoretical simulation of wind turbine characteristics; test methods.

Unit IV Wind pumps: Performance analysis, Design concept and standard testing conditions. 14 Principle of wind energy electricity generation; Stand alone, grid connected and hybrid applications of WECS.

Unit V Wind energy in India; Case studies, matching supply and demand, Control option, Environmental benefits and problems of wind energy, Economics of wind energy: Factors influencing the cost of energy generation, Life cycle cost analysis.

Text and Reference Books:
1. Johnson G L, Wind Energy Systems, Prentice Hall Inc, New Jersey, USA.
2. Spera David A Ed, Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, American Society of Mechanical Engineers.
3. Paul Gipe, Karen Perez, Wind Energy Basics: A Guide to Small and Micro Wind Systems, Chelsea Green Publishing Company.
4. Kruger P, Alternative Energy Resources: The Quest for Sustainable Energy, Wiley Publications.
5. Rosa Aldo V, Fundamentals of Renewable Energy Processes, Second Edition, Academic Press.
6. Boyle G, Renewable Energy: Power for a Sustainable Future, Second Edition, Oxford University Press.
7. Mukund R Patel, Wind and Solar Power Systems, CRC Press.
8. John F Walker, Nicholas Jenkins, Wind Energy Technology, John Wiley and Sons.
9. Hau Erich, Wind Turbines: Fundamentals, Technologies, Application and Economics, Springer Verlag.
10. Manwell J F, McGowan J G, Rogers A L, Wind Energy Explained, John Wiley and Sons.
11. Burton Tony, Sharpe David, Jenkins Nick, Bossanyi Ervin, Wind Energy Handbook, John Wiley and Sons.
12. Freris L L, Wind Energy Conversion Systems, Prentice Hall.
13. Sorensen Bent, Renewable Energy, Academic press, New York.

14. Johansson Thomas B Ed, Renewable Energy: Sources for Fuels and Electricity, Earthscan Publishers, London.

Course Code: CHES613M **Breakup: 3 –1 – 0 – 4**
Course Name: Hydrogen Energy and Fuel Cells

Course outcomes (CO): Students completing the course will be able to

CO1	Evaluate various methods for hydrogen production, storage, and transportation, considering their efficiency, environmental impact, and economic feasibility.
CO2	Apply fundamental electrochemical and thermodynamic principles to analyze the working and performance characteristics of different fuel cell types.
CO3	Differentiate between various fuel cell technologies, understand their components, and analyze their suitability for diverse power generation applications
CO4	Design and analyze basic fuel cell systems, considering factors like balance of plant, thermal management, and overall system integration.
CO5	Assess the economic viability, environmental benefits, and safety considerations associated with the development and deployment of hydrogen energy and fuel cell technologies.

Unit I: Introduction to Hydrogen Energy, Overview of Hydrogen Economy: Energy landscape, the role of hydrogen in energy transition, advantages and disadvantages of hydrogen as an energy carrier, current global status and future prospects. Physical and chemical properties, safety considerations, handling, and regulations. Hydrogen Production Methods: Fossil Fuel Based, Water Electrolysis, Thermochemical and Biological Methods, Hydrogen Purification and Separation

Unit II: Hydrogen Storage Methods: Physical Storage: Compressed gas storage (high-pressure tanks), liquid hydrogen storage (cryogenic tanks) – principles, design, and challenges. Material-Based Storage: Metal hydrides, chemical hydrides, carbon-based materials (adsorption), Hydrogen Transportation through Pipelines, road, rail, and ship transport, distribution networks.

Unit III: Introduction to Fuel Cells: History, definition, basic electrochemical principles, comparison with conventional energy conversion devices. Thermodynamics of Fuel Cells, Fuel Cell Kinetics and Losses, Fuel Cell Components: Electrolytes, electrodes (anode, cathode), catalysts, bipolar plates, gas diffusion layers.

Unit IV: Types of Fuel Cells, Low-Temperature Fuel Cells: Proton Exchange Membrane Fuel Cells (PEMFC), Direct Methanol Fuel Cells (DMFC), Alkaline Fuel Cells (AFC), Phosphoric Acid Fuel Cells (PAFC)1 and High-Temperature Fuel Cells: Molten Carbonate Fuel Cells (MCFC), Solid Oxide Fuel Cells (SOFC) – working principles, advantages, disadvantages, and applications. Fuel Cell Applications.

Unit V: Cost analysis of production, storage, and utilization of Hydrogen and Fuel Cells, life cycle cost analysis, factors influencing commercialization, Environmental Impact, potential of greenhouse gas reduction, Hydrogen safety codes and standards, risk assessment, accident prevention. Global and Indian Scenario: National policies and initiatives (e.g., National Hydrogen Energy Mission), case studies of hydrogen and fuel cell projects worldwide and in India.

Text and Reference Books:

1. Larminie, J., & Dicks, A. L. (Latest Edition). Fuel Cell Systems Explained. John Wiley & Sons.
2. Li, Xianguo. (Latest Edition). Principles of Fuel Cells. Taylor & Francis.
3. Sorensen, B., & Spazzafumo, G. (Latest Edition). Hydrogen and Fuel Cells: Emerging Technologies and Applications. Academic Press (Elsevier).
4. Busby, Rebecca L. (Latest Edition). Hydrogen and Fuel Cells: A Comprehensive Guide. PennWell Books.
5. O'Hayre, R., Cha, S., Colella, W., & Prinz, F.B. (Latest Edition). Fuel Cell Fundamentals. John Wiley & Sons.
6. Dincer, I., & Zamfirescu, C. (Latest Edition). Sustainable Hydrogen Production. Elsevier.

7. Hoffmann, Peter. (Revised and Expanded Edition). Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet. MIT Press.
8. Baker BS, Hydrocarbon Fuel Cell Technology, Academic Press, New York

Course Code: CHES614M **Breakup: 3 –1 – 0 – 4**
Course Name: Biofuels Energy

Course outcomes (CO): Students completing the course will be able to

CO1	Characterize diverse biomass resources and explain the principles and applications of various thermochemical conversion technologies for biofuel production.
CO2	Analyze the biochemical pathways and engineering aspects of biological conversion processes for producing biofuels and other valuable bioproducts.
CO3	Evaluate different power generation systems utilizing biomass.
CO4	Assess their integration into existing energy infrastructure.
CO5	Assess the environmental and social impacts of biofuel production and solid waste management systems, proposing mitigation strategies for sustainable development.

Unit I: Origin of biomass, types of biomass resources (agricultural residues, forest biomass, energy crops, industrial waste, municipal solid waste); characteristics (physical, chemical, thermal properties, moisture content, calorific value). methods for biomass estimation, Thermochemical Conversion Processes: Direct Combustion, Incineration, Pyrolysis, Gasification, Liquefaction and Chemical Conversion to produce of bio-crude and bio-diesel; production of various chemicals from biomass (e.g., furfural, levulinic acid).

Unit II: Biodegradation principles, biodegradability of various substrates, microbial metabolism relevant to biofuel production, Biochemistry of anaerobic digestion, process parameters (temperature, pH, C/N ratio); types of biogas digesters (batch, continuous, fixed dome, floating drum, plug flow); design considerations for biogas plants, Applications of biogas, Assessment of environmental and social impacts of biogas plants, mitigation strategies, Methanol and Ethanol Production using Fermentation, Production of organic acids (e.g., lactic acid, citric acid), solvents (e.g., butanol, acetone), amino acids, antibiotics, and other high-value chemicals from biomass.

Unit III: Utilization of industrial waste and agro residues for power generation, briquetting of Biomass, advantages and applications of briquettes as solid fuel, Utilization of producer gas for electricity generation; operation of internal combustion engines (spark ignition and compression ignition) with wood gas, methanol, ethanol, and biogas, Biomass integrated gasification/combined cycle (BIG/CC) systems – principles and advantages.

Unit IV: Biomass integrated gasification/combined cycle (BIG/CC) systems – principles and advantages, Sustainable co-firing of biomass with coal in thermal power plants, Concepts of energy plantations, selection of energy crops, biomass power programs and policies.

Unit V Solid Waste: Definitions, Sources, Types and Compositions; Properties of solid waste; Municipal solid waste: Physical, Chemical and Biological property. Waste minimization and recycling of municipal waste. Waste Treatment and Disposal: Size reduction, Aerobic composting, Furnace type and design; Medical/Pharmaceutical waste incineration. Environmental impacts; Measures of mitigate environmental effects due to incineration; Land fill method of solid waste disposal; Land fill classification; Types, Methods and Siting consideration; Layout and preliminary design of landfills.

Text and Reference Books:
1. D.V.D.C.N. Rao and V.G. Sastry, "Biofuels: A Guide to their Production, Use and Future", CRC Press, 2011.
2. Lee, S., Shah, Y.T., and Bozell, J. "Biofuels: From Biomass to Biofuels", CRC Press, 2012.
3. Twidell, J. and Weir, T. "Renewable Energy Resources", 3rd Edition, Routledge, 2015.
4. Pandey, A., Larroche, C., Ricke, S.C., Dussap, C.-G., and Gnansounou, E. "Biofuels: Alternative Feedstocks and Conversion Processes", Elsevier, 2011.
5. Demirbas, A. "Biofuels: Securing the Planet's Future Energy Needs", Springer, 2009.
6. Klass, D.L. "Biomass for Renewable Energy, Fuels, and Chemicals", Academic Press, 1998.

7. Van Gerpen, J. and Shanks, B. “Biodiesel Production: A Comprehensive Handbook”, AOCS Press, 2004.
8. Balat, M. “Biofuels: Technology, Production, and Advances”, CRC Press, 2011.
9. Mohanty, P. “Biofuels: Production, Properties, and Performance”, IntechOpen, 2019.
10. Gupta, R. and Kumar, P. “Biofuels: Production Technologies and Future Developments”, Springer, 2018.

Course Code: CHES615M **Breakup: 3 –1 – 0 – 4**
Course Name: Nuclear Reactor Engineering and Fusion Energy

Course outcomes (CO): Students completing the course will be able to

CO1	Analyze nuclear phenomena, including decay, reactions, and energy release for fission and fusion.
CO2	Evaluate reactor core performance**,** assessing criticality, reactivity, and fuel burnup.
CO3	Assess reactor thermal-hydraulics and safety**,** including heat transfer, fluid flow, and safety limits**.**
CO4	Compare diverse nuclear reactor technologies**,** covering design, operation, and fuel cycles.
CO5	Explain fusion principles and challenges**,** detailing confinement methods and engineering hurdles.

Unit 1: Fundamentals of Nuclear Physics, Atomic and Nuclear Structure, Nuclear forces, binding energy, mass defect, semi-empirical mass formula, Nuclear stability and radioactive decay, Conservation laws in nuclear reactions, reaction rates, Neutron interactions: elastic scattering, inelastic scattering, absorption (radiative capture, fission), Mechanism of nuclear fission, fission products, energy release, fission yield, neutron multiplication factor, Chain reaction concept.

Unit 2: Neutron Diffusion Theory: Neutron flux, current, and source. Fick's Law of diffusion, Diffusion equation for various geometries (bare and reflected reactors), Reactor Kinetics and Dynamics, Reactivity feedback mechanisms (fuel temperature, moderator temperature, void reactivity), Reactor control methods (control rods, chemical shim), Reactor startup, shutdown, and transient analysis, Homogeneous and Heterogeneous Reactor Cores, Isotopic changes during reactor operation. Fuel depletion and enrichment. Fuel cycle concepts (once-through, reprocessing).

Unit 3: Volumetric heat generation in fuel, Heat transfer mechanisms in reactor core (conduction, convection, boiling), Temperature distribution in fuel elements, Single-phase flow and heat transfer (forced and natural convection), Two-phase flow and heat transfer (boiling regimes, flow patterns, critical heat flux), Pressure drop in reactor channels, Thermodynamic cycles for nuclear power plants (Rankine cycle), Components of a nuclear power plant: reactor, steam generator, turbine, condenser. Efficiency calculations, Thermal design limits and Safety margins.

Unit 4: Properties of fuel (uranium, plutonium), cladding materials (Zircaloy), moderator (water, graphite, heavy water), coolant. Radiation effects on materials (swelling, embrittlement, creep), Reactor Types and Design: Light Water Reactors (LWRs): Pressurized Water Reactors (PWRs), Boiling Water Reactors (BWRs), Heavy Water Reactors (CANDU), Gas-Cooled Reactors (GCRs), Fast Breeder Reactors (FBRs) - design, operation, and safety features. Introduction to Generation IV reactor concepts and Small Modular Reactors (SMRs), Reactor Safety: Defense-in-depth principle, Accident analysis (LOCA, reactivity insertion accidents), Regulatory bodies and licensing processes (e.g., IAEA, national regulations), Nuclear waste management: types of waste, disposal methods.

Unit 5: Introduction to Nuclear Fusion, Fusion reactions (D-T, D-D, D-He3), Conditions for controlled fusion (Lawson criterion), Plasma state of matter: properties, single-particle motion in magnetic fields, Magnetic Confinement Fusion (MCF), Plasma stability and transport, Current fusion research devices (e.g., ITER), Inertial Confinement Fusion (ICF), Fusion Reactor Engineering, Materials for fusion reactors (first wall, blanket, divertor). Safety and environmental aspects of fusion power.

Text and Reference Books:

1. Lamarsh, J.R. and Baratta, A.J. "Introduction to Nuclear Engineering", 3rd Edition, Pearson, 2001 (or latest edition).

2. Glasstone, S. and Sesonske, A. “Nuclear Reactor Engineering”, 4th Edition, Chapman and Hall, 1996.
3. Duderstadt, J.J. and Hamilton, L.J. “Nuclear Reactor Analysis”, John Wiley & Sons, 1976.
4. Stacey, W.M. “Fusion Plasma Physics”, Wiley-VCH, 2005.
5. Freidberg, J.P. “Plasma Physics and Fusion Energy”, Cambridge University Press, 2007.

Course Structure for Minor in Green Technology and Sustainability Engineering

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHES602M	Renewable Energy Generation and Storage	3	1	0	4
2.	CHES604M	Green Technology and Sustainable Development	3	1	0	4
3.	CHES605M	Green Technologies and Practices	3	1	0	4
4.	CHES606M	Green Building and Infrastructure Engineering	3	1	0	4
5.	CHES607M	Sustainable Engineering	3	1	0	4
		Total	**15**	**5**	**0**	**20**

Course Code: CHES602M **Breakup: 3 –1 – 0 – 4**
Course Name: Renewable Energy Generation and Storage

Course outcomes (CO): Students completing the course will be able to

CO1	Understand the different sources of renewable energy and its uses
CO2	Understand the concept of Solar energy, it's collection and utilization at domestic and industrial level
CO3	Understand the concepts involved in Wind energy, and Biomass energy
CO4	Understand the conc5epts of Fuel cells, Batteries, and Hydrogen energy
CO5	Understand the need and modes of Energy Storage, carbon Nano-tubes and Chemical Energy storage (SHS) mediums.

Unit 1 Need of sources of renewable energy: Introduction to different sources of renewable energy, e.g., Solar Energy, Wind Energy, Bio-mass, Geothermal Energy, Ocean energy, Solar Energy and Applications. Basic concepts of radiations: Solar radiation, Direct and Indirect radiation, Radiation measuring instrument, applications etc.

Unit 2 Solar Energy: Basics of solar thermal applications both low and high temperature ranges such as water heating, air heating, steam generation, desalination of water, crop drying and power generation, Principle of photovoltaics including introduction to various components of a photovoltaic systems for standalone/hybrid/grid connected systems. Wind Energy, basic theory of wind, wind power generators both for decentralized applications and grid connected systems, performance characteristics, Augmentation of wind power, Betz criteria

Unit 3 Bioenergy: Types and availability of biomass resources, various methods of biomass utilisation for energy generation: gasification, briquette, palatization, syn-gas, Anaerobic/Aerobic digestion, ethanol and biodiesel production, types of Bio-gas digesters, Combustion characteristics of bio gas and its different utilizations,

Unit 4 Fuel Cells and Hydrogen Energy: Introduction, principle of fuel cells, thermodynamic analysis of fuel cells, types of fuel cells, fuel cell batteries, applications of fuel cells. Hydrogen as a renewable energy source, sources of hydrogen, fuel for vehicles, hydrogen production- direct electrolysis of water, thermal decomposition of water, biological and biochemical methods of hydrogen production.

Unit 5 Need of energy storage; Different modes of Energy Storage. Potential energy: Pumped hydro storage. Kinetic energy and Compressed gas system: Flywheel storage, Compressed air energy storage. Electrical and magnetic energy storage: Capacitors, Electromagnets and Battery storage systems such as primary, secondary, Lithium, Solid-state and Molten solvent batteries. Role of carbon Nano-tubes in electrodes; Chemical Energy storage: Thermo chemical, Photo-chemical, Bio-chemical, Electro-chemical, Fossil fuels and Synthetic fuels and Hydrogen storage, Sensible heat storage (SHS) mediums; Stratified storage systems; Rock-bed storage systems; Thermal storage in buildings.

Text & Reference Books

8. U C Sharma, Non-conventional Sources of Energy, Studium Press, Texas (2014).
9. T K Ghosh, M A Prelas, Energy Resources and Systems, Vol. 1: Fundamentals and Non Renewable Resources, Springer (2009).
10. T K Ghosh, M A Prelas, Energy Resources and Systems, Vol. 2: Renewable Resources, Springer (2011).
11. E E Michaelides, Alternative Energy Sources, Springer (2012).
12. J Twidell, T Weir, Renewable Energy Sources, Second edition, Taylor & Francis (2006).
13. Narayan R, Viswanathan B, Chemical and Electrochemical Energy Systems, University Press (India) Ltd.
14. Sarangpani, S J A Kosek, La Conti A B, Handbook of Solid State Batteries and Capacitors, World Scientific Publications, N J, USA.

Course Code: CHES604M **Breakup: 3 –1 – 0 – 4**
Course Name: Green Technology and Sustainability Development

Course outcomes (CO): Students completing the course will be able to

CO1	Understand the principles of green technology and engineering, including green chemistry, process intensification, and green synthesis methods
CO2	Analyze current industrial pollution and propose greener approaches for sustainable development across various sectors
CO3	Apply concepts of cleaner production, environmental management hierarchies, and analyze relevant industrial case studies
CO4	Evaluate challenges and practical implementation strategies for green technologies and sustainable development in industries
CO5	Comprehend the role of green laws and compliance in promoting environmental sustainability

Course Details:

Unit 1 Principles of Green Technology and Green Engineering: modify the processes and products to make them green safe and economically acceptable to the society, Concepts of green chemistry and Process intensification. Green Synthesis and Catalysis: Green oxidation and photochemical reactions, Microwave and Ultrasound assisted reactions, Synthesis of Green Reagents, Green solvents, Green nanotechnology and Ionic liquids..

Unit 2 Green Industrial Processes: Pollution statistics from various industries like polymer, textile, pharmaceutical, dyes, pesticides and wastewater treatment. A greener approach towards all these industries. Meaning of Sustainable Development, three principal dimensions: the ecological, the economic and the social dimension, including intergenerational justice; use a systems perspective, to describe sustainability challenges and possibilities for major technical systems and for their transformation to meet sustainability requirements.

Unit 3 Concepts of Cleaner Technologies: Cleaner Production (CP), Definition, methodology, Role of CP in Achieving Sustainability, Benefits, Role of Industry, Government and Institutions, Environmental Management Hierarchy, Relation of CP and EMS. CP case studies: Ammonical nitrogen recovery from wastewater, Fluoride removal from wastewater, Reuse of water from sewage treatment plant, Gas quenching process: replacement of oil with nitrogen and Reduction of hydrogen cyanide from process stack. Reuse of liquid industrial waste from several industries.

Unit 4 Challenges and Practical Implementation: Responsibilities and potentials of companies for action. Green Productivity and emerging technologies. Implementation of the practical applications of Green emerging technologies and sustainable development. Case studies in Green Technology. Green laws compliance

Text & Reference Books

1. Chemistry for Environmental Engineering and Science, Sawyer C.N, McCarty P.L and Parkin G.F. 5th ed. McGraw-Hill Professional, 2003.
2. Environmental Chemistry with Green Chemistry, Das A. K. Books and Allied (P) Ltd., Kolkata, India, 2012.
3. Green Chemistry: Environmentally Benign Reactions, Ahluwalia, V.K. Ane Books India, New Delhi, India, 2006.
4. Green Chemistry: An Introductory Text, Lancaster M. Royal Society of Chemistry, Cambridge, 2002.
5. Introduction to Green Chemistry, Matlack A.S. Publisher: Marcel Dekker, Newyork, 2001.

6. Green Chemistry: Theory and Practice, Anastas P.T. and Warner J.C. Oxford University Press, 1998.
7. Pollution Prevention: Fundamentals and Practice, Bishop P. L. McGraw-Hill, Boston, 2000.
8. Cleaner Production Audit Environmental System Reviews, Modak P., Visvanathan C. and Parasnis M. Asian Institute of Technology, Bangkok, 1995.
9. Handbook of Green Chemistry and Technology, Clark J.H. and Macquarrie D.J. Wiley Blackwell Publishers, 2002

Course Code: CHES605M **Breakup: 3 –1 – 0 – 4**
Course Name: Green Technologies and Practices

Course outcomes (CO): Students completing the course will be able to

CO1	Understand the foundational concepts of green technology, its evolution, and the roles of various stakeholders.
CO2	Apply green chemistry principles and waste minimization techniques for effective resource management.
CO3	Develop and implement cleaner production strategies, conducting assessments and applying relevant international standards.
CO4	Analyze environmental impacts using tools like waste audits, carbon accounting, and life cycle assessment.
CO5	Evaluate conventional and non-conventional energy sources, including green fuels and biomass energy, and their implications.

Unit I: Introduction to green technology, importance – Historical Evolution – advantages and disadvantages of green technologies, Factors affecting green technologies, Role of industry, Government and Institutions- Industrial Ecology, Role of Industrial ecology in green technology.

Unit II: Principles of green chemistry, green chemistry metrics- atom economy, E factor, reaction mass efficiency, Waste: Source of waste, different type of waste. Chemical, physical and biochemical methods of waste minimization, clean development Mechanism: reuse, recovery & recycle, Raw Material substitution: Wealth from waste, case studies..

Unit III: Cleaner production project development and implementation Overview of CP Assessment steps and skills, process flow diagram. Material Balance, CP Option Generation: Technical and Environmental Feasibility analysis, Economic valuation of alternatives: Total cost Analysis – CP Financing, Preparing a program plan: Measuring progress - ISO 14000

Unit IV: Pollution Prevention and cleaner production Awareness Plan, Waste audit: Environmental Statement, Carbon Credit, Carbon Trading, Carbon footprint, Carbon Sequestration, Life Cycle Assessment – Elements of LCA, Life cycle Costing, Eco Labeling.

Unit V: Energy Efficacy, Availability and need of conventional energy resource: major environmental problems related to the conventional energy resources, Future possibilities of energy need and availability, Non- conventional energy sources: Solar Energy – solar energy conversion technologies and devices, Solar Energy: Principles, working and application. Green fuels: Definition – benefits and challenges: Comparison of green fuels with conventional fossils fuels with reference to environmental, economic and social impacts – public policies and market driven initiatives, Biomass energy: Concept of biomass energy utilization, types if biomass energy., conversion process, Wind energy, energy conversion technologies, their principles, equipment and suitability in Indian context..

Text & Reference Books:

1. Paul L Bishop, Pollution Prevention: Fundamentals and practice, McGraw Hill Publications, 2000.
2. World Bank group and UNEP, Washington DC, Pollution Prevention and Abatement Handbook
3. Towards Cleaner Production, 1998.
4. Prasad Modak, C. Viswanathan and Mandar Parasnis, Cleaner Production Audit, Environmental System reviews, No 38, Asian Institute of Technology, 1995.
5. Bewik M. W. M., Handbook of organic Waste conversion.
6. Sukhatme P. S., Solar Energy
7. Bokris J. O., Energy, the Solar Hydrogen Alternative.
8. Rai G. D., Non-Conventional Energy Sources.

9. Kiang Y. H., Waste Energy Utilisation Technology.
10. G. D. Rai, Wind, tidal, Geothermal, biomass and Nonconventional Energy Green Fuel.

Course Code: CHES605M **Breakup: 3 –1 – 0 – 4**
Course Name: Green Building and Infrastructure Engineering

Course outcomes (CO): Students completing the course will be able to

CO1	Understand the fundamental concepts, necessity, and various rating systems of green buildings
CO2	Analyze the energy efficiency in buildings, its benefits, and consumption patterns.
CO3	Identify and evaluate green building materials and understand environmentally friendly construction methods.
CO4	Learn about energy conservation measures, waste and water management, HVAC systems, and indoor environmental quality in sustainable facilities.
CO5	Comprehend building energy efficiency standards, codes, and rating systems for commercial buildings, including compliance and documentation.

Unit I: Concept of Green Buildings: Definition of Green Buildings, typical features of green buildings, Necessity, Initiatives, Green buildings in India, Green building Assessment- Green Building Rating Systems (BREEAM, USGBC, LEED, IGBC, TERI-GRIHA, GREEN STAR), Criteria for rating, Energy efficient criteria, environmental benefits economic benefits, health and social benefits, Major energy efficiency areas for building, Contribution of buildings towards Global Warming. Life cycle cost of buildings, Codes and Certification Programs

Unit II: Energy Efficiency, Overview of energy efficiency (EE) in buildings and its benefits, Approach to EE in Buildings, Basics of energy systems in buildings interface of systems and envelope, overview on energy-consuming end uses, energy consumption patterns of different end-use for varying building typologies, energy consumption benchmarks in buildings. Concept of passive building design.

Unit III: Green Building Materials: Sustainably managed Materials, Depleting natural resources of building materials; renewable and recyclable resources; energy efficient materials; Embodied Energy of Materials, Green cement, Biodegradable materials, Smart materials, Manufactured Materials, Volatile Organic Compounds (VOC's), Natural Non-Petroleum Based Materials, Recycled materials, Renewable and Indigenous Building Materials, Engineering evaluation of these materials. Green Building Planning and Specifications: Environment friendly and cost effective Building Technologies, Integrated Life cycle design of Materials and Structures, Green Strategies for Building Systems, Alternative Construction Methods.

Unit IV: Energy Conservation Measures in Buildings, Waste &Water management and Recycling in Sustainable Facilities, Heating, Ventilation and Air Conditioning basics, types of HVAC systems, psychrometric analysis, Thermal comfort basics, Indoor Environment quality. Passive Solar & Daylight, Plumbing and its Effect on Energy Consumption.

Unit V: Building energy efficiency, Standards, codes and rating of buildings (international and national perspective) related to energy efficiency in commercial buildings. Calculation and documentation for compliance and rating. Envelope, HV AC, lighting, controls for code compliance

Text & Reference books:

1. Kubba, S, LEED Practices, Certification, and Accreditation Hand book, 1st ed. Elsevier, 2010.
2. Minsitry of Power, Energy Conservation Building Code 2018, Revised Version, Bureau of Energy Efficiency, 2018,
3. Architectural Energy Corporation, Building Envelope Stringency Analysis, International Institute for Energy Conservation, 2004

4. Indian Building Congress, Practical Handbook on Energy Conservation in Buildings, I st ed. Nabhi Publication, 2008.
5. McQuiston, F.C., and Parker, J.D. Heating, Ventilating, and Air Conditioning, Analysis and De5ign, Fourth Ed. John Wiley & Sons, Inc,1994.
6. Clarke, J.A., Energy Simulation in Building Design, Adam Hilger Ltd. 1985.
7. TERI-Griha's Green Design practices (www.teriin.org/bcsd/griha/griha.html)

Course Code: CHES606M **Breakup: 3 –1 – 0 – 4**
Course Name: Sustainable Engineering

Course outcomes (CO): Students completing the course will be able to

CO1	Understand the relevance and the concept of sustainability and the global initiatives in this direction
CO2	Explain the different types of environmental pollution problems and their sustainable solutions
CO3	Discuss the environmental regulations and standards
CO4	Outline the concepts related to conventional and non-conventional energy
CO5	Demonstrate the broad perspective of sustainable practices by utilizing engineering knowledge and principles

Unit I Sustainability: Introduction, concept, evolution of the concept; Social, environmental and economic sustainability concepts; Sustainable development, Nexus between Technology and Sustainable development; Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs), Clean Development Mechanism (CDM)..

Unit II Environmental Pollution: Air Pollution and its effects, Water pollution and its sources, Zero waste concept and 3 R concepts in solid waste management; Greenhouse effect, Global warming, Climate change, Ozone layer depletion, Carbon credits, carbon trading and carbon foot print, legal provisions for environmental protection

Unit III Environmental management standards: ISO 14001:2015 frame work and benefits, Scope and goal of Life Cycle Analysis (LCA), Circular economy, Bio-mimicking, Environment Impact Assessment (EIA), Industrial ecology and industrial symbiosis.

Unit IV Resources and its utilisation: Basic concepts of Conventional and non-conventional energy, General idea about solar energy, Fuel cells, Wind energy, Small hydro plants, bio-fuels, Energy derived from oceans and Geothermal energy
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Unit V Sustainability practices: Basic concept of sustainable habitat, Methods for increasing energy efficiency in buildings, Green Engineering, Sustainable Urbanisation, Sustainable cities, Sustainable transport.
.

Text and Reference Books:

1. Allen, D. T. and Shonnard, D. R., Sustainability Engineering: Concepts, Design and Case Studies, Prentice Hall.
2. Bradley. A.S; Adebayo, A.O., Maria, P. Engineering applications in sustainable design and development, Cengage learning
3. Environment Impact Assessment Guidelines, Notification of Government of India, 2006
4. Mackenthun, K.M., Basic Concepts in Environmental Management, Lewis Publication, London, 1998
5. ECBC Code 2007, Bureau of Energy Efficiency, New Delhi Bureau of Energy Efficiency Publications-Rating System, TERI Publications - GRIHA Rating System
6. Ni bin Chang, Systems Analysis for Sustainable Engineering: Theory and Applications, McGraw-Hill Professional.
7. Twidell, J. W. and Weir, A. D., Renewable Energy Resources, English Language Book Society (ELBS).
8. Purohit, S. S., Green Technology - An approach for sustainable environment, Agrobios Publication

9. Sorensen Bent, Renewable Energy, Academic press, New York.
10. Johansson Thomas B Ed, Renewable Energy: Sources for Fuels and Electricity, Earthscan Publishers, London.

Course Code: CHES613M **Breakup: 3 –1 – 0 – 4**
Course Name: Hydrogen Energy and Fuel Cells

Course outcomes (CO): Students completing the course will be able to

CO1	Evaluate various methods for hydrogen production, storage, and transportation, considering their efficiency, environmental impact, and economic feasibility.
CO2	Apply fundamental electrochemical and thermodynamic principles to analyze the working and performance characteristics of different fuel cell types.
CO3	Differentiate between various fuel cell technologies, understand their components, and analyze their suitability for diverse power generation applications
CO4	Design and analyze basic fuel cell systems, considering factors like balance of plant, thermal management, and overall system integration.
CO5	Assess the economic viability, environmental benefits, and safety considerations associated with the development and deployment of hydrogen energy and fuel cell technologies.

Unit I: Introduction to Hydrogen Energy, Overview of Hydrogen Economy: Energy landscape, the role of hydrogen in energy transition, advantages and disadvantages of hydrogen as an energy carrier, current global status and future prospects. Physical and chemical properties, safety considerations, handling, and regulations. Hydrogen Production Methods: Fossil Fuel Based, Water Electrolysis, Thermochemical and Biological Methods, Hydrogen Purification and Separation

Unit II: Hydrogen Storage Methods: Physical Storage: Compressed gas storage (high-pressure tanks), liquid hydrogen storage (cryogenic tanks) – principles, design, and challenges. Material-Based Storage: Metal hydrides, chemical hydrides, carbon-based materials (adsorption), Hydrogen Transportation through Pipelines, road, rail, and ship transport, distribution networks.

Unit III: Introduction to Fuel Cells: History, definition, basic electrochemical principles, comparison with conventional energy conversion devices. Thermodynamics of Fuel Cells, Fuel Cell Kinetics and Losses, Fuel Cell Components: Electrolytes, electrodes (anode, cathode), catalysts, bipolar plates, gas diffusion layers.

Unit IV: Types of Fuel Cells, Low-Temperature Fuel Cells: Proton Exchange Membrane Fuel Cells (PEMFC), Direct Methanol Fuel Cells (DMFC), Alkaline Fuel Cells (AFC), Phosphoric Acid Fuel Cells (PAFC)1 and High-Temperature Fuel Cells: Molten Carbonate Fuel Cells (MCFC), Solid Oxide Fuel Cells (SOFC) – working principles, advantages, disadvantages, and applications. Fuel Cell Applications.

Unit V: Cost analysis of production, storage, and utilization of Hydrogen and Fuel Cells, life cycle cost analysis, factors influencing commercialization, Environmental Impact, potential of greenhouse gas reduction, Hydrogen safety codes and standards, risk assessment, accident prevention. Global and Indian Scenario: National policies and initiatives (e.g., National Hydrogen Energy Mission), case studies of hydrogen and fuel cell projects worldwide and in India.

Text and Reference Books:
9. Larminie, J., & Dicks, A. L. (Latest Edition). Fuel Cell Systems Explained. John Wiley & Sons.
10. Li, Xianguo. (Latest Edition). Principles of Fuel Cells. Taylor & Francis.
11. Sorensen, B., & Spazzafumo, G. (Latest Edition). Hydrogen and Fuel Cells: Emerging Technologies and Applications. Academic Press (Elsevier).
12. Busby, Rebecca L. (Latest Edition). Hydrogen and Fuel Cells: A Comprehensive Guide. PennWell Books.
13. O'Hayre, R., Cha, S., Colella, W., & Prinz, F.B. (Latest Edition). Fuel Cell Fundamentals. John Wiley & Sons.
14. Dincer, I., & Zamfirescu, C. (Latest Edition). Sustainable Hydrogen Production. Elsevier.

15. Hoffmann, Peter. (Revised and Expanded Edition). Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet. MIT Press.
16. Baker BS, Hydrocarbon Fuel Cell Technology, Academic Press, New York

Course Code: CHES614M **Breakup: 3 –1 – 0 – 4**
Course Name: Biofuels Energy

Course outcomes (CO): Students completing the course will be able to

CO1	Characterize diverse biomass resources and explain the principles and applications of various thermochemical conversion technologies for biofuel production.
CO2	Analyze the biochemical pathways and engineering aspects of biological conversion processes for producing biofuels and other valuable bioproducts.
CO3	Evaluate different power generation systems utilizing biomass.
CO4	Assess their integration into existing energy infrastructure.
CO5	Assess the environmental and social impacts of biofuel production and solid waste management systems, proposing mitigation strategies for sustainable development.

Unit I: Origin of biomass, types of biomass resources (agricultural residues, forest biomass, energy crops, industrial waste, municipal solid waste); characteristics (physical, chemical, thermal properties, moisture content, calorific value). methods for biomass estimation, Thermochemical Conversion Processes: Direct Combustion, Incineration, Pyrolysis, Gasification, Liquefaction and Chemical Conversion to produce of bio-crude and bio-diesel; production of various chemicals from biomass (e.g., furfural, levulinic acid).

Unit II: Biodegradation principles, biodegradability of various substrates, microbial metabolism relevant to biofuel production, Biochemistry of anaerobic digestion, process parameters (temperature, pH, C/N ratio); types of biogas digesters (batch, continuous, fixed dome, floating drum, plug flow); design considerations for biogas plants, Applications of biogas, Assessment of environmental and social impacts of biogas plants, mitigation strategies, Methanol and Ethanol Production using Fermentation, Production of organic acids (e.g., lactic acid, citric acid), solvents (e.g., butanol, acetone), amino acids, antibiotics, and other high-value chemicals from biomass.

Unit III: Utilization of industrial waste and agro residues for power generation, briquetting of Biomass, advantages and applications of briquettes as solid fuel, Utilization of producer gas for electricity generation; operation of internal combustion engines (spark ignition and compression ignition) with wood gas, methanol, ethanol, and biogas, Biomass integrated gasification/combined cycle (BIG/CC) systems – principles and advantages.

Unit IV: Biomass integrated gasification/combined cycle (BIG/CC) systems – principles and advantages, Sustainable co-firing of biomass with coal in thermal power plants, Concepts of energy plantations, selection of energy crops, biomass power programs and policies.

Unit V Solid Waste: Definitions, Sources, Types and Compositions; Properties of solid waste; Municipal solid waste: Physical, Chemical and Biological property. Waste minimization and recycling of municipal waste. Waste Treatment and Disposal: Size reduction, Aerobic composting, Furnace type and design; Medical/Pharmaceutical waste incineration. Environmental impacts; Measures of mitigate environmental effects due to incineration; Land fill method of solid waste disposal; Land fill classification; Types, Methods and Siting consideration; Layout and preliminary design of landfills.

Text and Reference Books:

11. D.V.D.C.N. Rao and V.G. Sastry, "Biofuels: A Guide to their Production, Use and Future", CRC Press, 2011.
12. Lee, S., Shah, Y.T., and Bozell, J. "Biofuels: From Biomass to Biofuels", CRC Press, 2012.
13. Twidell, J. and Weir, T. "Renewable Energy Resources", 3rd Edition, Routledge, 2015.
14. Pandey, A., Larroche, C., Ricke, S.C., Dussap, C.-G., and Gnansounou, E. "Biofuels: Alternative Feedstocks and Conversion Processes", Elsevier, 2011.
15. Demirbas, A. "Biofuels: Securing the Planet's Future Energy Needs", Springer, 2009.
16. Klass, D.L. "Biomass for Renewable Energy, Fuels, and Chemicals", Academic Press, 1998.

17. Van Gerpen, J. and Shanks, B. “Biodiesel Production: A Comprehensive Handbook”, AOCS Press, 2004.
18. Balat, M. “Biofuels: Technology, Production, and Advances”, CRC Press, 2011.
19. Mohanty, P. “Biofuels: Production, Properties, and Performance”, IntechOpen, 2019.
20. Gupta, R. and Kumar, P. “Biofuels: Production Technologies and Future Developments”, Springer, 2018.

Course Code: CHES615M **Breakup: 3 –1 – 0 – 4**
Course Name: Nuclear Reactor Engineering and Fusion Energy

Course outcomes (CO): Students completing the course will be able to

CO1	Analyze nuclear phenomena, including decay, reactions, and energy release for fission and fusion.
CO2	Evaluate reactor core performance**,** assessing criticality, reactivity, and fuel burnup.
CO3	Assess reactor thermal-hydraulics and safety**,** including heat transfer, fluid flow, and safety limits**.**
CO4	Compare diverse nuclear reactor technologies**,** covering design, operation, and fuel cycles.
CO5	Explain fusion principles and challenges**,** detailing confinement methods and engineering hurdles.

Unit 1: Fundamentals of Nuclear Physics, Atomic and Nuclear Structure, Nuclear forces, binding energy, mass defect, semi-empirical mass formula, Nuclear stability and radioactive decay, Conservation laws in nuclear reactions, reaction rates, Neutron interactions: elastic scattering, inelastic scattering, absorption (radiative capture, fission), Mechanism of nuclear fission, fission products, energy release, fission yield, neutron multiplication factor, Chain reaction concept.

Unit 2: Neutron Diffusion Theory: Neutron flux, current, and source. Fick's Law of diffusion, Diffusion equation for various geometries (bare and reflected reactors), Reactor Kinetics and Dynamics, Reactivity feedback mechanisms (fuel temperature, moderator temperature, void reactivity), Reactor control methods (control rods, chemical shim), Reactor startup, shutdown, and transient analysis, Homogeneous and Heterogeneous Reactor Cores, Isotopic changes during reactor operation. Fuel depletion and enrichment. Fuel cycle concepts (once-through, reprocessing).

Unit 3: Volumetric heat generation in fuel, Heat transfer mechanisms in reactor core (conduction, convection, boiling), Temperature distribution in fuel elements, Single-phase flow and heat transfer (forced and natural convection), Two-phase flow and heat transfer (boiling regimes, flow patterns, critical heat flux), Pressure drop in reactor channels, Thermodynamic cycles for nuclear power plants (Rankine cycle), Components of a nuclear power plant: reactor, steam generator, turbine, condenser. Efficiency calculations, Thermal design limits and Safety margins.

Unit 4: Properties of fuel (uranium, plutonium), cladding materials (Zircaloy), moderator (water, graphite, heavy water), coolant. Radiation effects on materials (swelling, embrittlement, creep), Reactor Types and Design: Light Water Reactors (LWRs): Pressurized Water Reactors (PWRs), Boiling Water Reactors (BWRs), Heavy Water Reactors (CANDU), Gas-Cooled Reactors (GCRs), Fast Breeder Reactors (FBRs) - design, operation, and safety features. Introduction to Generation IV reactor concepts and Small Modular Reactors (SMRs), Reactor Safety: Defense-in-depth principle, Accident analysis (LOCA, reactivity insertion accidents), Regulatory bodies and licensing processes (e.g., IAEA, national regulations), Nuclear waste management: types of waste, disposal methods.

Unit 5: Introduction to Nuclear Fusion, Fusion reactions (D-T, D-D, D-He3), Conditions for controlled fusion (Lawson criterion), Plasma state of matter: properties, single-particle motion in magnetic fields, Magnetic Confinement Fusion (MCF), Plasma stability and transport, Current fusion research devices (e.g., ITER), Inertial Confinement Fusion (ICF), Fusion Reactor Engineering, Materials for fusion reactors (first wall, blanket, divertor). Safety and environmental aspects of fusion power.

Text and Reference Books:

6. Lamarsh, J.R. and Baratta, A.J. “Introduction to Nuclear Engineering”, 3rd Edition, Pearson, 2001 (or latest edition).

7. Glasstone, S. and Sesonske, A. “Nuclear Reactor Engineering”, 4th Edition, Chapman and Hall, 1996.
8. Duderstadt, J.J. and Hamilton, L.J. “Nuclear Reactor Analysis”, John Wiley & Sons, 1976.
9. Stacey, W.M. “Fusion Plasma Physics”, Wiley-VCH, 2005.
10. Freidberg, J.P. “Plasma Physics and Fusion Energy”, Cambridge University Press, 2007.